SBS HDR Student Conference 2010

Oct 1st, 2:00 PM - 2:30 PM

Assessing reliability and validity of a measurement instrument for studying uncertain factors in Thai rice supply chain

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Description

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Location

iC - SBS Teaching Facility

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Abstract
It is widely argued that uncertain factors generate unstable processes along supply chains, which in the end worsen their performance. This research assesses reliability and validity seven uncertain factors (supply, demand, process, planning and control, competitor behavior; government policy and climate uncertainty). Data for the study were collected from rice millers and rice exporters, and the measurement scales were tested on reliability and validity using Partial Least Squares (PLS) and Multicollinearity as there are the formative measurement models. The results support that the formative measures of uncertain factors are reliable and valid. It is expected that this study will provide a useful measurement instrument to assess any effects in agri-supply chains for further research.

Measurement of uncertain factors in Thai rice supply chain

According to the previous studies, uncertain factors in organisations were considered in general and task environment. The general environment refers to political, social, economic, demographic, and technological trend. Meanwhile, the task environment is composed of competitors, suppliers, customers and regulation bodies (Bourgeois, 1980). However, the review of literature analysis indicates that there are seven uncertain factors (supply, demand, process, planning and control, competitor, government policy, and climate) influencing Thai rice supply chain. Additional, each factor can be measured in many dimensions such as quantity, quality and time dimensions. Thus, multi-dimensional measurement are applied in order to increase reliability, and decrease measurement error (Churchill, 1979).

There are three perspectives of environment in organization which are (i) objects, (ii) attributes, and (iii) perceptions (Duncan, 1972, Bourgeois, 1980). To measure uncertain factors in organization, the perceptions of them are considered in this study because managers make decisions on their perceived factors leading that the perceptions of these perceived uncertain factors are more crucial than the objective uncertain factors (Duncan, 1972, Bourgeois, 1980). In addition, two attributes of uncertain factors are (i) degree of change or unpredictability, and (ii) complexity or diversity of environmental factors (Duncan, 1972, Downey et al., 1975). In this study, unpredictability of factors is focused. The reason is that the degree of unpredictable factors reflects more to variability of perceived uncertainty than complexity (Duncan, 1972, Dill, 1958). Moreover, unpredictable factors create more risk and difficulty for managers' decision making and affect to effective strategy making (Bourgeois, 1978). Consequently, the summary of the characteristics of measured uncertain factors in this study is shown in Table 1.

Table 1: The summary of the characteristics of measured uncertain factors

Characteristics of uncertain factors	Measurement in this study
Perspectives	Perception
Attitude	Degree of change or unpredictability

There are three aspects (quality, quantity and time) of supply, demand, process, and planning and control uncertainty to be measured, and these are defined in Table 2 (adapted from van der Vorst 2000).

Table 2 Typology of sources of Rice supply chain uncertainty and the aspects they concern (adopt from van der Vorst, 2000, p.76)

	Quantity aspects	Quality aspects	Time aspects
Supply	Inbound (paddy or milled) rice quantities	Inbound (paddy or milled) rice quality	Inbound (paddy or milled) rice timing to millers
Demand	Customer demand of outbound rice quantities	Customer demand of outbound rice specifications	Timing of customer order
Process	Mill yield, packing yield	Milled rice quality, Milled rice quality after storage	Process throughput times
Planning and control	Information availability	Information accuracy	Information throughput times

Competitor behavior uncertainty is measured under three aspects: their actions, competition in domestic and in international markets, a minor modification of Li's 2002 study. The government policy uncertainty measurement have four aspects: policy affecting rice production, trading, paddy rice mortgage scheme, and any new government regulations (Badri et al., 2000, Javidan, 1984, Bran and Bos, 2005).

Finally, climate uncertainty related to rice production is monitored in three aspects: drought, flooding (both in terms of occurrences and duration), and warmer temperatures (Cruz et al., 2007). Each drought and flood event is characterized by its duration, deficit volume (severity) and time of occurrence, and its occurrence depends on the ratio between water demand and water availability (Tallaksen and Hisdal, 1997, p.142). However, as this measurement instrument is perception, the specific time of occurrence is considered to avoid in the questionnaire because it is too more detail to be recognised by respondents. Thus, to assure that the question delivery a common understanding to respondents, Drought and Flooding occurrences are the simple words to be used. The final list of measurement items ia shown in Table 3.

Formative and Reflective Construct Specification

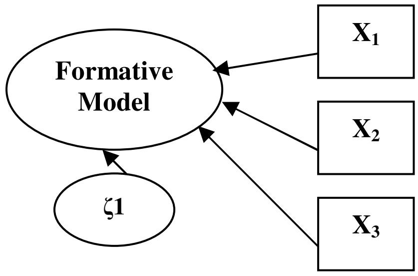
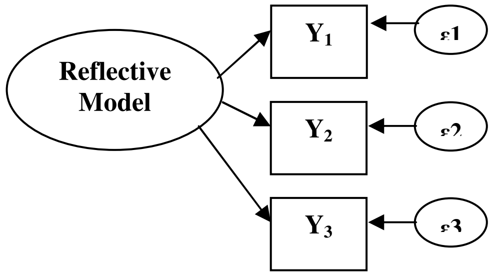
Two basic types of measurement model are reflective and formative indicators (Hulland, 1995). Measurement specification that is deciding whether to use reflective or formative indicator construct is very essential (Bollen and Lennox, 1991). Misspecification of formative and reflective construct indicators can lead to underestimate in theoretical framework testing (Diamantopoulos and Siguaw, 2006, MacKenzie et al., 2005). In addition, these two different measurement models are in conceptual distinctions (MacKenzie et al., 2005) required different statistical analysis procedures such as validity test, reliability test and structural model test (Petter et al., 2007). Moreover, the measurement model misspecification will not be detected with many the most commonly used goodness-of-fit indices (MacKenzie et al., 2005, p.728).

Thus, the summary of differences between formative and reflective measurement model and decision rules for determining whether a construct is formative or reflective is explained in Table 4.

Table 3: The final list of measurement items in Thai rice supply chain.

Uncertain factors	Aspects of measurement	The question in the questionnaire	References
Supply	Quantity	SU1: Rice quantity from rice producers is unpredictable	(van der Vorst, 2000, Li, 2002, Paulraj and Chen, 2007)
	Quality	SU2: Rice quality from rice producers is unpredictable	
	Time	SU3: Rice producers' delivery time is unpredictable	
Demand	Quantity	DU1: The volume of customer demand is difficult to predict	(Li, 2002, Paulraj and Chen, 2007)
	Quality	DU2: Customers' rice preference changes over the year	
	Time	DU3: The lead time[1] of customer order is unpredictable	
Process	Quantity	PU1: Yield of rice processing (e.g. milling, packing) can vary	(van der Vorst, 2000)
	Quality	PU2: The quality of rice after processed (e.g. milled, storied) can be changed	
	Time	PU3: The throughput time of rice processing can vary	
Planning and Control	Quantity	PCU1: Information of stock level of rice and rice production capacity is complete at this moment	(van der Vorst, 2000)
	Quality	PCU2: Information of stock level of rice and rice production capacity is accurate	
	Time	PCU3: Information of stock level of rice and rice production capacity is timely	
Competitor	Actions	CU1: Competitor's actions are unpredictable	(Li, 2002)
	Domestic market	CU2: Competition is intensified in domestic market.	
	International market	CU3: Competition is intensified from different countries	
Government policy	Rice production	GU1: Government policies in rice production directly impacting on your firms are unpredictable	(Badri et al., 2000, Javidan, 1984, Bran and Bos, 2005)
	Rice trading	GU2: Government policies in rice trading (e.g. FTA, tax) directly impacting on your firms are unpredictable	
	Paddy rice mortgage scheme	GU3: The guarantee price from government regulation is unpredictable over the year	
	New government	GU4: The new government regulation is introduced unexpectedly	
Climate	Drought	CMU1: Drought occurrences are unpredictable in each year CMU2: The duration of drought is unpredictable over the year	(Cruz et al., 2007)
	Flooding	CMU3: Flooding occurrences are unpredictable in each year CMU4: The duration of flooding is unpredictable over the year	
	Temperature	CMU5: The temperature is vary unpredictably over the year	

Table 4: Summary of differences between formative and reflective measurement model (Jarvis et al., 2003, p.201)

Composite Latent Variable (Formative) Model	Principle Factor (Reflective) Model
 Direction of causality is from measure to construct	 Direction of causality is from construct to measure
No reason to expect the measures are correlated (Internal consistency is not implied)	Measures expected to be correlation (Measures should posses internal consistency reliability)
Dropping an indicator from the measurement model may alter the meaning of the construct	Dropping an indicator from the measurement model does not alter the meaning of the construct
Takes measurement error into account at the construct level	Takes measurement error into account at the item level
Construct possesses "surplus" meaning	Construct possesses "surplus" meaning
Scale score does not adequately represent the construct.	Scale score does not adequately represent the construct.

In this study, supply, demand, process, planning & control, competitor, and government policy uncertainty is composite in different dimensions such as quantity, quality and time dimensions that differs in monological net. Thus, they are the formative measurement model. Climate uncertainty is composite in drought, floods and temperature dimensions that do totally not share a common theme, while drought and floods dimension are also measured in formative model in terms of duration and frequent aspects. Thus, climate uncertainty construct is the first-order formative, and second-order formative measurement model.

Data Collection Procedure

The final draft of Thai version questionnaire was mailed to 698 rice mill companies and 177 rice export companies (It reduces from 181 to 177 rice export companies because there were found that some of them are the same address) all around Thailand. 46 questionnaires were returned from rice millers, and 36 questionnaires were returned from rice exporters due to, for instance, incomplete address, or business failure within one week. In the first wave of returned questionnaire from rice millers, 89 questionnaires were returned, but 14 of them were abandoned due to incomplete information, resulting in an effective response rate 11.50 percent. After three weeks, the reminder letter was sent to rice millers. 23 questionnaires were returned. The response rate increased to be 15.03 percent with all 98 completed questionnaires returned from 652 completed addresses of rice millers.

Meanwhile, in the first wave from rice exporters, 29 questionnaires were received, but 7 of them were discarded due to incomplete information, resulting in an effective response rate 15.06 percent. After three weeks, the reminder letter was sent to rice exporters by e-mail address. 4 questionnaires were returned. The response rate increased to be 18.43 percent with all 26 completed questionnaires returned from 141 completed addresses of rice exporters.

These response rates are considered generally for survey in developing country (Ahmed et al., 2002). The process of data collection was practiced during April - August, 2009 including process of questionnaire postage until returned questionnaires. However, 26-sample size of rice exporters is too small to process on statistical analysis. With highly cooperation with Thai rice exporters Association, the questionnaires were distributed to 45 meeting members in the annual meeting of the association on December 2009, and received 38 questionnaires back because 6 members used to return the questionnaires in the first wave. Therefore, the respond rate of rice exporter is improved to be 46.10 percent with all 64 completed questionnaires returned from 141 completed addresses of rice exporters.

This considered as the second wave of returned questionnaires. That requires the test of validity of two waves of returned questionnaire that are processed in the next section.

Non Parametric Test

The Mann-Whitney test and the Kolmogorov–Smirnov test are the non parametric tests differences between two independent samples and two conditions which can be applied to these cases:

- No assumptions about the distribution of data, or when data are not normal distribution (Hollander and Wolfe, 1999).
- Data are ranking or ordinal data such as Likert-scale that, by definition, is not normally distributed (Kaplan, 2009).
- All samples from both groups are independent of each other (Hollander and Wolfe, 1999).

The Mann-Whitney test and the Kolmogorov–Smirnov test are applied to compare the question number 18 to 72 in the questionnaire into two procedures:

(1) There is to determine whether the raw data from two wave data collections of rice exporters that were collected in the first wave with (26-sample size and in the second wave with 38-sample size are different or not.

The results show that in both the Mann-Whitney test and the Kolmogorov–Smirnov test, almost variables of the first wave data did not differ significantly from the second wave of data at significant level 0.05, except for SP1 and EF4 (refer to variable code in Table 6-22) that the first wave data did not differ significantly from the second wave of data at significant level 0.01. Therefore, these two groups of data can be pool together represented as rice exporters

(2) There is to determine whether the raw data from rice exporters (64 sample size) and rice millers (98 sample size) are different or not.

The results show that in both the Mann-Whitney test and the Kolmogorov–Smirnov test, almost variables of the rice exporters did not differ significantly from rice millers at significant level 0.05, except for CU1, CU4, LP4, LP6 and EF1 that did differ at significant level 0.05. However, CU1, CU4, LP6 and EF1 did not differ significantly at significant level 0.01, while only LP4 did not differ significantly at significant level 0.001. Therefore, these two groups of data can be pool together in order to be tested in validity and reliability in the next section.

Reliability test for Formative constructs

As formative constructs composited of different aspects of a construct that their indicators are not necessary to correlate with each other (Diamantopoulos and Winklhofer, 2001). Straub, Boudreau et al. (2004, p.400) state that "it is not clear that reliability is a concept that applies well to formative constructs". This statement is also supported by Diamantopoulos and Siguaw (2006, p.270) and Rossiter (2002, p.315) that no dimensionality and reliability test are performed on formative indicators because factorial unity in factor analysis and internal consistency are not relevant. Although, low item-to-total correlation should be dropped from measurement scales to increase internal consistency reliability for reflective measurement model because the scales are from the same content construct, the removal of measurement scales in formative measurement model can lead to change the empirical and conceptual meaning (MacKenzie et al., 2005). Andreev, Heart et al. (2009) conclude that construct reliability of formative should be performed by multicollinearity, test of indicator validity (path coefficients significance), and optionally, if appropriate, test-retest (Petter et al., 2007).

On the other hand, reflective constructs that multicollinearity among items in the same construct is desirable such as high Cronbach's alpha, but reliability of formative construct in term of multicollinearity is not present because if multicollinearity is present, it means that indicators are tapping into the same aspect of the construct (Petter et al., 2007, p.641). Likewise, formative measurement model is based on a multi-regression that multicollinearity should not exist (Diamantopoulos and Winklhofer, 2001). Thus, reliability evaluation for formative constructs is to assess the assumption of no multicollinearity (Diamantopoulos and Siguaw, 2006). Variance Inflation Factor (VIF) is evaluated. There are some guidelines that can be applied:

- VIF is less than 3.3 that shows a excellent value (Diamantopoulos and Siguaw, 2006).
- VIF is less than 10 that no collinearity is commonly accepted (Hair et al., 1995).

As collinearity also can be harmful effects to formative constructs, condition index is the standard diagnostics that measure the relative amount of variance associated with an eigenvalue. Its threshold value should be less than 30 to find no support for the existence of collinearity (Hair et al., 1995). If multicollinearity exists, Petter, Straub et al. (2007, p.642) recommended that at first, the model construct may have both formative and reflective measures. Secondly, the correlated measurement items can be removed, if content validity is not affected. Thirdly, the correlated measurement items can be collapsed into a composite index. Lastly, it can be converted into multidimensional construct.

Thus, in this study there are seven formative measurement models: supply, demand, process, planning & control, competitor, government policy, and climate uncertainty that are evaluated by VIF. Table 5 shows Mean, Standard derivation, and VIF of each formative indicator. The VIF values of all indicators are less than 3.3 except for climate uncertainty, and the condition indices range between 8 and 30, indicating that multicollinearity problem is not concerned.

Table 5: Reliability test of the supply, demand, process, planning & control, competitor, government policy, and climate uncertainty formative constructs.

Construct Name	Code	Mean	S.D.	VIF
Supply *(Condition Index =8.7132)*	SU1	4.5864	1.5550	1.1568
	SU2	4.6049	1.7529	1.3390
	SU3	3.8333	1.7059	1.2019
Demand *(Condition Index =8.9511)*	DU1	4.7716	1.5293	1.1828
	DU2	4.5062	1.7240	1.5834
	DU3	3.5185	1.6006	1.4824
Process *(Condition Index =8.0839)*	PU1	4.2099	1.7318	1.2930
	PU2	4.5494	1.6192	1.2660
	PU3	2.8827	1.4886	1.1227
Planning and Control *(Condition Index =12.6825)*	PCU1	4.9938	1.4382	1.2070
	PCU2	4.7531	1.5566	1.2619
	PCU3	5.1914	1.1718	1.2918
Competitor *(Condition Index =12.2023)*	CU1	4.9506	1.5476	1.0557
	CU2	5.7160	1.3581	1.2708
	CU3	5.3395	1.6500	1.2145
Government policy *(Condition Index =17.1029)*	GU1	4.8075	1.7339	1.7641
	GU2	4.7284	1.7375	1.7254
	GU3	5.6358	1.6522	2.8672
	GU4	5.3889	1.5494	2.6419
Climate Uncertainty *(Condition Index =30.0141)*	CMU1	5.2099	1.6014	5.2147
	CMU2	5.1296	1.7018	5.8479
	CMU3	5.1420	1.6185	7.3547
	CMU4	5.0494	1.6449	6.3717
	CMU5	4.5679	1.7724	2.3008

Validity test for Formative constructs

Validity assessment is the most controversial issues in formative measurement (Diamantopoulos et al., 2008) because there are limitations of the applicability of statistical procedures (Hardin et al., 2008). External validity is recommended by several authors such as estimated error term (Diamantopoulos, 2006), and even individual indicator validity (Diamantopoulos et al., 2008) for testing validity of formative constructs. External validity is to examine "how well the index relates to measures of other variables" (Bagozzi, 1994, p.333). However, the author is unclear to exactly how this should be done.

In formative measurement models, indicator validity refers to the importance of each individual indicator of the related formative construct (Andreev et al., 2009, MacKenzie et al., 2005). It should critically examine whether a particular indicator should enter into the formative index (Henseler et al., 2009, p.302) The estimation of this validity is performed by the Partial Least Square (PLS) approach with a bootstrapping method to calculate item weights (or PLS scores or outer weights), and t-values of each formative indicator whether are significant (Bruhn et al., 2008, Diamantopoulos and Winklhofer, 2001, Chin, 1998). Similarly, indicator relationship with construct antecedents and consequence are also analysed by using PLS with outer item coefficients for first-order formative indicators, and inner path coefficients for second-order formative construct whether have the right signs and adequate t-statistics (Coltman et al., 2008). However, Petter, Straub et al. (2007) suggested that the item weights for indicators that insignificant indicators may be eliminated (Diamantopoulos and Winklhofer, 2001), or remain insignificant indicators to preserve content validity (Bollen and Lennox, 1991). Elimination of formative indicators carries the risk of changing the theoretical perspective of the constructs (Nunnally and Bernstein, 1994). Therefore, any criteria of cut-off value for formative constructs are approached with caution (Diamantopoulos and Winklhofer, 2001, p.272).

In this section, item weight (outer weight) and t-statistics of each item weight should be significant for testing indicator reliability of the formative constructs: supply uncertainty, demand uncertainty, process uncertainty, planning & control uncertainty, competitor uncertainty, government policy, and climate uncertainty with SmartPLS software. PLS algorithm was performed to evaluate item weight and, bootstrapping was performed (Cases: 162 and Sample: 1,000) to evaluate t-statistics (Ringle et al., 2005). A Two- tailed T test is considered with 1.645, 1.96, and 2.576 critical values of t at significant level (p-value) 0.1, 0.05, and 0.01 respectively (Wagner, 1992). Table 6 shows the results of the indicator validity test. T-values of all formative indicators are significantly but even in different p-values. Therefore, the indicator validity test of the formative constructs is accepted.

Table 6: Indicator validity test of the supply, demand, process, planning & control, competitor government policy and climate uncertainty formative constructs.

Construct Name	**Code**	**Item weight**	**T-values**	**Significance at p-value**
Supply	SU1	-0.2014	1.9692	p<0.05
	SU2	0.9552	2.4352	p<0.05
	SU3	0.2064	1.8489	p<0.1
Demand	DU1	0.0830	2.2297	p<0.05
	DU2	1.0201	4.3135	p<0.01
	DU3	-0.1022	1.7716	p<0.1
Process	PU1	-0.3888	1.6788	p<0.1
	PU2	1.0559	4.9259	p<0.01
	PU3	0.1837	1.9843	p<0.05
Planning and Control	PCU1	0.8840	3.1909	p<0.01
	PCU2	0.0266	1.6745	p<0.1
	PCU3	0.2275	2.0363	p<0.05
Competitor	CU1	0.6139	3.8855	p<0.01
	CU2	0.4766	2.4067	p<0.05
	CU3	0.3149	1.8806	p<0.1
Government policy	GU1	0.2973	2.1389	p<0.05
	GU2	0.2315	1.7427	p<0.1
	GU3	0.4714	2.4916	p<0.05
	GU4	0.1986	2.7649	p<0.01
Climate Uncertainty	CMU1	-0.0181	2.0841	p<0.05
	CMU2	1.0159	5.4107	p<0.01
	CMU3	0.8625	3.5450	p<0.01
	CMU4	0.1494	1.5843	-
	CMU5	1.000	-	-

The validity test of the formative second-order construct is inner path coefficients whether have the right signs and adequate t-statistics (Coltman et al., 2008) as presented in Table 7. the results show that t-values of inner path coefficients of Drought and Flooding supports to the second-order formative model (Climate Uncertainty) since t-values is significant at p< 0.01.

Table 7: Inner path coefficient validity test of Climate Uncertainty and Rice quality constructs formative constructs.

Construct Name	Code	Inner path coefficients	T-values	Significance at p-value
Climate Uncertainty	Drought	0.3858	5.3709	p<0.01
	Flooding	0.4116	5.3626	p<0.01

Conclusion

The major contribution of this study is to the development of a set of validated formative measurement instrument of uncertain factors in agri-supply chain for colleting data in further studies. The assessing formative measurement model in reliability and validity test is according to the typical standards of scale development (Henseler et al., 2009, Jarvis et al., 2003, Petter et al., 2007, Coltman et al., 2008, Diamantopoulos and Winklhofer, 2001). We believe that the instrument developed in this study is parsimonious and will be useful for further studies of uncertain factor in supply chain and their relationship with other outcomes such as SCM performance.

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