# Predicting the Relationship Between Virtual Enterprises in an Agile Supply Chain Through Structural Equation Modeling

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**Abstract.** Virtual enterprises are formed in response to turbulent market conditions and are influenced by factors such as the changing relationship between customers and suppliers, the spread of agile supply chains and shorter product life cycles. Research suggests that successful virtual co-operation and supply chain agility are best achieved when the core capabilities of the partners are complementary. This paper examines the relationship between virtual enterprises in supply chains and provides further insights into the factors affecting agility. A hypothetical model is developed to examine the factors and a structural equation model tests the hypotheses, based on survey data from virtual enterprises in Mongolia. The model usesa simulation based on exploratory factor analysis, confirmatory factor analysis and path analysis. The results provide empirical evidence of the ability of the model to predict benefits arising from the formation of the virtual enterprise.

**Keywords:** Virtual enterprise, supply chain agility, structural equation modeling.

## 1 Introduction

The business environment today is typified by rapid and unpredictable changes due to political and economic factors [1], disruptive interventions from new entrants to markets and innovative business models [2] and developments that represent a ‘step change’ in enabling technologies [3]. The resulting levels of environmental uncertainty, organizational instability, market turbulence and employment insecurity are making it difficult and expensive for companies to function in isolation. The traditional response of monolithic ‘growth by acquisition’ no longer seems appropriate where downsizing and agility are becoming the normal responses to the business environment. Instead, agile supply chains combining virtual organizations offer the necessary flexibility for supporting lean process improvements and responsive production initiatives to increase market share and sustain growth for all the participants [4]. By combining to form virtual enterprises and aligning themselves in agile supply chains, many companies are now able to develop very flexible logistics systems and supply chain networks, supported by web and mobile technologies that as individual small and medium-sized enterprises (SME) the would not be able to afford [5]. This emerging collaborative strategy is geared to exploiting the temporary windows of opportunities offered by volatile global markets and to sharing risks and optimizing resources based on complementary core competencies and despite geographic locations [6].

To gain a better insight into the phenomenon, it is necessary to explore the factors leading to the collaboration of virtual enterprises in agile supply chains and to study the effects of such collaborations. Therefore, this paper investigates the factors involved in forming virtual enterprises and collaborating in agile supply chains. The aim of the research is the development of a framework that can be used to predict and improve the relationships in a virtual enterprise based on an agile supply chain using the structural equation modeling technique. The rest paper has the following structure; in Section 2 a brief overview of supply chain management, virtual enterprises and supply chain agility is given, and based on this hypotheses are developed. Section 3 explains the research methodology and design by which the hypotheses are tested. Section 4 includes the data analysis using structural equation modeling (SEM), addresses factor measurement and tests the research hypotheses using the results. Section 5 then provides conclusions and makes suggestions for future research.

## 2 Theoretical Basis and Development of Hypotheses

The idea of the virtual enterprise is not new. Davidow and Malone [7] define a virtual enterprise as, '…a number of independent vendors, customers, even competitors, composing a temporary network organization through information technology, in order to share the technology, cost and meet the purpose of the market demand'. Katzy and Schuh [8] state that a virtual enterprise, '…is based on the ability to create temporary co-operations and to realize the value of a short business opportunity that the partners cannot (or can, but only to lesser extent) capture on their own'. A VE is therefore defined in this research as an alliance of separate companies formed temporarily to share costs, to bring together complementary skills and to take advantage of short-term market opportunities. This concept is used to characterize the global supply chain among dynamic organizational networks containing companies with many different relationships [9]. A typical virtual enterprise is ephemeral, as the partners will seek to integrate with others in the supply chain and may take part in different virtual enterprises as opportunities arise [10]. The Internet and mobile technologies are major ingredients in forming virtual enterprises, facilitating value-building functions such as vertical and horizontal integration and flexible collaboration [11].

### 2.1 Definition of Virtual Enterprise

As virtual enterprises are often defined from different perspectives by different researchers, it is difficult to find a suitable definition of the phenomenon, but the literature review suggests that a typical virtual enterprise will exhibit the following properties:

- Affiliation based on the core competencies, resources and skills of selected partners;
- The objective of enhancing a business opportunity which is difficult for a single enterprise to achieve;
- Temporary collaboration until the business opportunity has passed;
- A virtual network based on the Internet and mobile technologies;
- Trusted sharing of information costs, risks and technologies;
- Participating enterprises are geographically dispersed and independent legal entities;
- In most cases, some powerful 'leading' enterprise co-ordinates, organizes and manages the supply chain;
- The virtual enterprise itself owns no resources, assets or plant.

Correspondingly, supply chain agility is the virtual enterprise's ability to react rapidly to changing market forces and to exploit them as business opportunities [12]. Research suggests that supply chain agility can most successfully be arrived at through the integration of enterprise capability factors such as highly skilled and knowledgeable people and information and communication technologies (ICT) such as the rapid and effective adoption of common systems [13]. The research that is the subject of this paper differs from a previous study in that it includes a narrower range of virtual organizations than were examined in [13], focusing on virtual organizations combining in the Mongolian Reserved Meat Program. The data in this paper was used to simulate the relationships between virtual participants in the supply chain to validate the previous study.

Binder and Clegg [14] consider that core competencies and enterprise capability are the main drivers of virtual enterprise collaboration. Yusuf *et al.* [15] consider some early examples of agility and define–agility as, "…a system with exceptional internal capabilities intended to meet the rapidly changing needs of the market place with speed and flexibility. The internal capacities of the firm include 'hard and soft' technologies, human resources, and an educated and highly motivated management". Therefore, enterprise capability has a direct impact on virtual enterprises in agile supply chains. On the other hand, it is suggested that ICT was an essential foundation for the formation and management of many 'real-world' virtual enterprises [16]. Researcher suggests that information sharing can aid the effectiveness and efficiency of supply chains (SC) by streamlining the flow of information, shortening response time to customer needs, enhancing the potential for collaboration and coordination and sharing the risks as well as the benefits of virtual operation [17]. Therefore, the adoption of ICT influences virtual enterprises directly and is therefore one of the major enablers of agility.

### 2.2 Development of Hypotheses

Virtual enterprises seek to combine in a dynamic way the resources and competencies that form the best fit and, "…can be reshaped in different organizational forms to cope with unexpected changes and disruptions, while also seeking to take advantage of new business opportunities" [18]. Based on this and other definitions taken from the literature review (as discussed above) the factors affecting virtual enterprises and agile supply chains were developed into a conceptual model of the relationships (see Fig. 1).

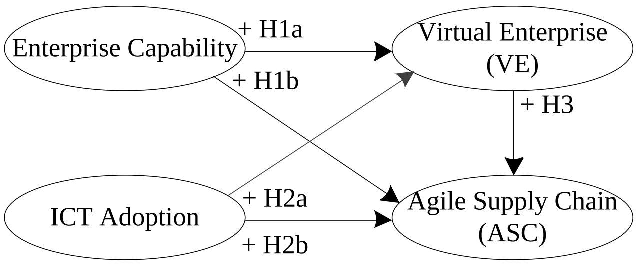


**Fig. 1**. Influences on virtual enterprise and supply chain agility (Samdantsoodol *et al*., 2013)

This enables five hypotheses to be proposed, based on the identified factors of influence (H1 to H3), two of which are linked (H1a and H1b, H2a and H2b) [29]. The hypotheses are as follows:

H1a: Enterprise capabilities positively drive virtual enterprise collaboration;

H1b: Enterprise capabilities positively enable supply chain agility;

H2a: ICT adoption positively enables virtual enterprise collaboration;

H2b: ICT adoption positively influences supply chain agility;

H3: Virtual enterprise formation positively influences supply chain agility.

## 3 Research Methodology and Design

Virtual enterprises in the Mongolian Reserved Meat Program (MRMP) were chosen as the subject for this research as part of a simulation to validate a model of the operation of an agile supply chain. The research was conducted in Mongolia as the MRMP offered a good example of a temporary collaborative network, a phenomenon that has received attention in research [19] and for which frameworks and models have been proposed [20]. To investigate these influencing factors, many groups of measurable indicators needed to be measured in terms of their importance. A questionnaire-based survey was designed to do this and was targeted at companies having a responsibility for logistics, such as the integrated planning and control of all materials, parts and product flows and essential information flows between partners along the whole supply chain.

Five draft questionnaires were initially submitted to a focus group to check the readability of the questionnaire and to detect any unforeseen ambiguities and minor changes were made, based on this pilot survey. Hard and soft copies of the final questionnaire were then distributed to a sample of companies included in a list collected from the Mongolian Yellow Pages site[1]. These organizations are all based in Mongolia and represent a variety of industry types, sizes and levels of turnover. Table 1 presents a breakdown of the number of responding organizations of each type participating in the survey.

[1] Mongolian Yellow Pages available at: www.yp.mn

**Table 1.** Profile of respondents (Samdantsoodol *et al*., 2013)

| **Type of industry/ company profile** | **Number** | **Percentage** |
|---|---|---|
| Total | 65 | 100.0 |
| ***Type of industry*** | | |
| Manufacturing | 20 | 30.7 |
| Transport & Freight Forwarder | 8 | 12.3 |
| Information & Communication | 7 | 10.8 |
| Wholesale & Retail trade | 5 | 7.7 |
| Oils & gas | 1 | 1.5 |
| Others | 5 | 7.7 |
| ***Number of employees*** | | |
| 1-9 | 9 | 13.8 |
| 10-19 | 15 | 23.1 |
| 20-49 | 11 | 16.9 |
| 50-199 | 10 | 15.4 |
| over 200 | 20 | 30.8 |
| ***Company annual turnover (tugrug)*** | | |
| Less than 250 million | 21 | 32.3 |
| Less than 1 billion | 18 | 27.7 |
| Less than 1.5 billion | 3 | 4.6 |
| More than 1.5 billion | 23 | 35.4 |
| ***Designation of respondents*** | | |
| CEO, Director | 21 | 32.3 |
| Manager | 39 | 60 |
| Others | 5 | 7.7 |

The main survey used a three-part research questionnaire; Part One consisted of basic profile information of the participants. Part Two included questions related to the drivers and enablers of the virtual enterprises and the capabilities of agile supply chains. Part Three covered questions related to business successes achieved through supply chain agility. From the literature review, the questions were ranked using a five-point Likert scale (from 'very low' to 'very high') to eliminate skewing the statistics from the second and third parts of the questionnaire. In the first round 50 questionnaires were distributed and 34 responses resulted (a 58% response rate). All the questionnaires were addressed to identified senior officers of the organizations concerned. In the second round, another 50 printed questionnaires were given out, and 36 were subsequently returned. Out of the total of 70 returned questionnaires 65 were usable as five questionnaires were incomplete and did not contain sufficient data for further analysis. This was considered as an acceptable proportion upon which to base a statistical analysis of this type, although it is accepted that this number of responses cannot represent all the firms in the market.

The structural equation modeling technique (SEM) is often used to specify, analyze and test hypothetical models that describe complex relationships between sets of variables [19]. Therefore, the SEM was chosen to analyze the relationship between enterprise capability, ICT adoption, virtual enterprise affiliation and supply chain agility. The SEM was applied in two stages, first developing the measurement model and then the structural model [22]. The measurement model shows how the underlying variables or hypothetical relationships are affected by the observed variables. The exploratory and confirmatory factor analysis models are included in the measurement model which examines the reliability and validity of the modeled relationships between the observed variables. The structural model also identifies the causal relationships between the latent variables, examines the effects of these relationships and indicates the resulting variances, both explained and unexplained, using path diagrams.

# 4 Data Analysis and Discussion

## 4.1 Assessment of Measurement Quality

An analysis of factors was carried out with SPSS 20.0 for Windows (including the AMOS 20.0 software) and principle component analysis (PCA) was used to extract relevant factors. These factors were then subjected to varimax rotation to maximize the squared loading variances on all the variables in the factor matrix, to differentiate clearly the original variables. Some variables that were not correlated strongly were then eliminated from the data set and the remaining variables were then distributed into four factors for analysis. First, exploratory factor analysis (EFA) was carried out to measure the loadings of factors as shown in Table 2. In the same table, the result of reliability testing is demonstrated by Cronbach's alpha analysis, which ranges from .620 to .839, indicating acceptable internal consistency in the data. However, the alpha value of the virtual enterprise was low and although this could create a problem in further analysis, the study continued to include it in the hypothetical model, as it was felt to be so important to the research.

**Table 2**. Reliability and validity of the model (Samdantsoodol *et al*., 2013)

| Latent and measurement variables | Factor loadings | Cronbach's α |
|---|---|---|
| ***Enterprise capability*** | | |
| EC1: Information capability | .876 | .839 |
| EC2: Human related competency | .773 | |
| EC3: Technology competency | .726 | |
| EC4: System integration competency | .670 | |
| EC5: Strategy | .627 | |
| ***ICT adoption*** | | |
| ICT1: Decision support system | .870 | .768 |
| ICT2: Smart technology | .836 | |
| ICT3: Prevent, detect, respond to and recover from a data corruption or security breach | .561 | |
| ***VE*** | | |
| VE1: Usage of information technology | .682 | .620 |
| VE2: Responsiveness | .665 | |
| VE3: Ability to share information and knowledge | .558 | |
| ***Agile SC*** | | |
| ASC1: Quickness/ speed | .833 | .832 |
| ASC2: Cost | .803 | |
| ASC3: Time reduction | .710 | |
| ASC4: Competency | .620 | |

## 4.2 Evaluation and Discussion of Research Hypotheses

In this section the structural model is described as it was established and tested in the present study. The confirmatory factor analysis (CFA) was adopted to examine if the data matched a hypothetical measurement model and whether the measured latent variables correlated with the researchers' understanding of each variable. The maximum likelihood method (MLM) [22] based on covariance matrices between any two variables was employed to calculate the covariances in the structural model.

The AMOS 20.0 software (see Section 3.1) was used to calculate and examine the causal relationships within the hypothetical model, and to analyze the influences upon and between these causal relationships. This analysis confirmed the properties of the structural model by verifying it with the the covariance analysis. Several 'goodness of fit' (GOF) indices of the measurement model are presented in Table 3. As in other studies, the chi-square *per* degree of freedom ($\chi 2/df$), the goodness-of-fit index (GFI), the normed fit index (NFI), the Tucker-Lewis index, the comparative index (CFI), and the root mean square error of approximation (RMSEA) were used to verify the appropriateness of the structural model. The hypothetical model was revised to improve the GOF as shown in Table 3. Two methods were initially considered for refining the model. The first method involves deleting any paths that have exceptionally low causal relationships, and the second method involves identifying additional causal relationships between factors [23]. The second method was chosen and an additional causal relationship was included in the improved hypothetical model. The GOF of the improved model was compared to the original hypothetical model and the GFI and NFI was found to be acceptable. However, both of those indices are sensitive to sample size, underestimating the fit where the number of instances is below 200 [24]. On the other hand, the non-normed fit index (NNFI) is also outside the recommended range for this size of sample [25]. Also, the relatively small sample size and the degrees of freedom have created artificially large values for the RMSEA. The other GOF measures are within in the recommended ranges as shown in Table 3.

**Table 3.** Indices of fit of the structural equation models (Samdantsoodol *et al.,* 2013)

| GOF measure | Threshold | Hypothetical SEM | Moderated SEM |
|---|---|---|---|
| $\chi^2$ | | 152.340 | 124.420 |
| df | | 84.000 | 81.000 |
| $\chi^2$/df | <3.0 | 1.810 | 1.540 |
| GFI | >0.90 | 0.781 | 0.817 |
| Normed fit index (NFI) | >0.90 | 0.711 | 0.764 |
| Tucker–Lewis index | >0.80 | 0.797 | 0.866 |
| Comparative fit index | >0.85 | 0.838 | 0.897 |
| (CFI) | <0.08 | 0.059 | 0.053 |
| RMR | <0.08 | 0.113 | 0.092 |
| RMSEA | | | |
| Lower bound | | 0.084 | 0.058 |
| Upper bound | | 0.141 | 0.122 |

SEM analysis was then used to evaluate the improved hypothetical model (see Fig. 2). The structural model then gives a chi-square value of 138.189 with 82 degrees of freedom (i.e. $p < 0.001$). The ratio of the chi-square value to the degrees of freedom is therefore 1.68, which is below the suggested value of 3.0 [25]. The results shown in Table 4 show that virtual enterprise factors (VE) and agile supply chain (ASC) factors are most influenced (positively and significantly) by enterprise capabilities. ICT adoption factors (ICT) have a significant and positive influence on both sets of factors, but virtual enterprise itself does not strongly influence supply chain agility.

**Table 4.** SEM and path analysis (Samdantsoodol *et al*., 2013)

| **Paths** | **Path coefficient** |
|---|---|
| H1a: Enterprise capability → VE | 0.643** |
| H1b: Enterprise capability → ASC | 0.532** |
| H2a: ICT adoption → VE | 0.324* |
| H2b: ICT adoption → ASC | 0.301* |
| H3: VE → ASC | 0.194* |

*p<0.05; **p<0.01; ***p<0.001.

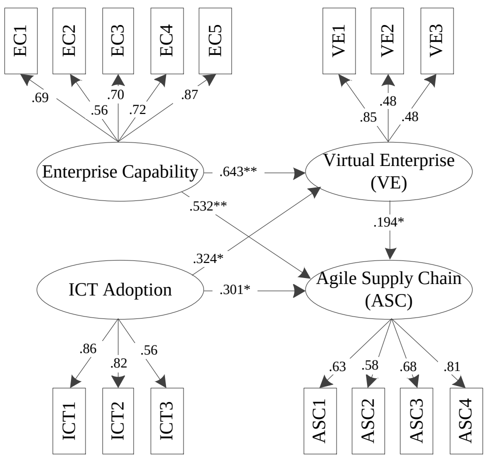


**Fig. 2**: Evaluation of the hypothetical model using SEM (Samdantsoodol et al., 2013)

Table 5 shows the relationships between the factors, the total effect being arrived at by combining the direct and indirect effects [26]. Enterprise capability has the most direct effect on the ASC, as when the value of the enterprise capabilities increases by 1, the agility factor goes up by 0.532. Indirect effects involve one or more intervening (or mediator) variables [27]. Enterprise capabilities have the highest indirect effect, being the most efficient in the short term efficient for the improvement of the agility index. In the longer term, therefore, an improvement to the enterprise capabilities factors implies the achievement of greater agility [28].

**Table 5**. Effects of latent factors on supply chain agility (Samdantsoodol *et al.,* 2013)

| Latent factor | Direct effect | Indirect effect | Total effect |
|---|---|---|---|
| Enterprise capability | 0.532 | 0.125 | 0.657 |
| ICT adoption | 0.301 | 0.063 | 0.364 |
| VE | 0.194 | 0.000 | 0.194 |

To test the hypotheses, the squared multiple correlation ($R^2$) values of the dependent (or endogenous) variables were calculated [29]. Table 4 shows that enterprise capability and ICT adoption have a major positive influence on virtual enterprise collaboration although these contribute 51.8% of the total variance of the VE ($R^2 = 0.518$ as shown in Table 6). These results support the hypotheses H1a and H2a. The analytical results reveal that enterprise capability, ICT adoption and VE have a significant positive effect on supply chain agility. These predictors have 58.2% of variance of the agility factor ($R^2$=0.582 as shown in Table 6). Thus, the results support hypotheses H1b, H2b and H3.

**Table 6.** $R^2$ of endogenous variables (Samdantsoodol *et al*., 2013)

| Dependent variables | $R^2$ |
|---|---|
| VE | 0.518 |
| ASC | 0.582 |

Enterprise capability positively influences five variables: (i) The information capability (standard coefficient = 0.687); (ii) the human-related competency (standard coefficient = 0.559, p<0.001); (iii) the technology competency (standard coefficient = 0.696, p<0.001); (iv) the system integration competency (standard coefficient = 0.721, p<0.001) and (v) the strategy (standard coefficient = 0.871, p<0.001). As party of the measurement component, ICT adoption positively influences three factors: (i) the decision support system (standard coefficient = 0.856); (ii) the smart technology (standard coefficient = 0.816, p<0.001) and (iii) the prevention, detection, response and recovering from a data corruption or security breach (standard coefficient = 0.559, p<0.001). VE also positively influences three other measurement components: (i) the usage of information technology (standard coefficient = 0.854, p = 0.001) and (ii) the responsiveness (standard coefficient = 0.481, p = 0.006) and (iii) the ability to share information (standard coefficient = 0.475). Finally, the results indicate that the ASC positively influences its four key measurement variables: (i) the quickness or speed (standard coefficient = 0.625); (ii) the cost (standard coefficient = 0.583, p<0.001); (iii) time reduction (standard coefficient = 0.685, p<0.001) and (iv) the competency (standard coefficient = 0.809, p<0.001).

It is recognized that this study has the following limitations. Firstly, the relatively small sample size could affect the fit indices. Therefore, more questionnaires should be distributed and collected by the researchers in a fuller study, so that the survey validity will be improved. Secondly, the variable load on a factor could cause an increased bias in the parameter estimates.

## 5 Conclusion

To survive in turbulent and unstable market conditions, SMEs may seek to increase their competitiveness by collaborating to form a virtual enterprise as a supply chain. This study investigated the influence of enterprise capability and ICT adoption on affiliation, and examined causal relationships affecting supply chain agility. First, a conceptual hypothetical model was developed based on a literature review. SEM was applied to improve the relationships between the factors. Analyses were then conducted on the measurement and structural models using exploratory and confirmatory factor analysis respectively, measuring the properties of the observed variables through the reliability and validity of the data. In the second step, the structural model was set up and based on calculated GOF indices, the model was verified and the relevant hypotheses were validated by path analysis and squared multiple correlation. Enterprise capability and ICT adoption are shown to have a strongly positive and significant influence on VE affiliation to build up robust co-operation. additionally, supply chain agility is shown to be influenced positively and significantly by enterprise capabilities and ICT adoption.

The concept of supply chain agility is a complex one and has many factors affecting it, so the entire domain is difficult to cover completely in a single piece of research. Therefore, further research is recommended to expand upon the conceptual model, including additional factors to examine their relationships. In addition, the size of the sample should be increased to improve the quality and reliability of the analysis.

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