**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 therefore investigates 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 is used to test the hypotheses, based on survey data from virtual enterprises in Mongolia. The structural equation model uses 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.

# 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 forming virtual enterprises and collaborating in agile supply chains, many companies are now able to develop highly flexible logistics processes and supply chain networks, supported by web and mobile technologies that would otherwise be unaffordable to individual small and medium-sized enterprises (SME) [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 for predicting the relationships between virtual enterprises in agile supply chains using the structural equation modeling technique. The rest of paper is organised as follows; Section 2 provides a brief overview of supply chain management, virtual enterprises and supply chain agility and based on this, hypotheses are developed. In Section 3 the research methodology and design are described by which the hypotheses will be tested. Section 4 includes the data analysis using structural equation modeling (SEM), the issues of factor measurement is discussed and the results are used to test the research hypotheses. Section 5 then provides conclusions and suggestions for future research.

# 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 a temporary alliance of companies formed to share costs, combine complementary skills and exploit fast-changing market opportunities. This concept is used to characterize the global supply chain in an environment of dynamic networks of companies that are engaged in many different relationships [9]. The partners in a virtual enterprise integrate their internal systems with the other systems in the supply chain and simultaneously participate in other virtual enterprises to respond to changing opportunities [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, based on the literature review it is considered that a typical virtual enterprise 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 technologies such as the Internet and mobile systems;
* 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 respond to unpredictable market forces and to convert them into business opportunities [12]. Research suggests that supply chain agility can best be achieved through the integration of organizational factors highly skilled and knowledgeable people (both termed enterprise capability) and the rapid and effective adoption of information and communication technologies (ICT) [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 defineagility 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 both virtual enterprises and 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]. Many researchers agree that information sharing is a key driver of effective and efficient supply chains (SC) by speeding up the information flow, shortening the time of response to customer needs, providing enhanced coordination and collaboration and sharing the risks as well as the benefits [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 dynamically the set of competencies and resources that form the best fit, and enterprises, ‘…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**. A conceptual model of the factors influencing virtual enterprises and supply chain agility

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). 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.

# 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 that have a responsibility for logistics, such as the integrated planning and control of all internal and network-wide materials, parts and product flows, including the necessary information flows along the complete supply chain. Five draft questionnaires were initially submitted to a focus group to check the readability and possible ambiguity of the questionnaire and minor changes to the questionnaires were made based on this pilot survey. Hard and soft copies of the questionnaire were distributed to a sample of companies included in a list collected from the Mongolian Yellow Pages site[[1]](#footnote-2). 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.

**Table 1.** Profile of respondents

| Type of industry/ company profile | Number  | Percentage |
| --- | --- | --- |
| Total | 65 | 100.0 |
| Type of industry |  |  |
| ManufacturingTransport & Freight ForwarderInformation & CommunicationWholesale & Retail tradeOils & gasOthers | 2087515 | 30.712.310.87.71.57.7 |
| Number of employees |  |  |
| 1-910-1920-4950-199over 200 | 915111020 | 13.823.116.915.430.8 |
| Company annual turnover (tugrug) |  |  |
| Less than 250 millionLess than 1 billionLess than 1.5 billionMore than 1.5 billion | 2118323 | 32.327.74.635.4 |
| ***Designation of respondents*** |  |  |
| CEO, DirectorManagerOthers | 21395 | 32.3607.7 |

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. Based on the literature review, the questions were ranked by a five-point Likert scale (‘very low’ to ‘very high’) to reduce skewing of the statistics from the second and third parts of the questionnaire. In the first round 50 questionnaires were distributed and 34 responses were received (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 distributed, and 36 questionnaires were returned. Out of 70 responses, 65 were usable, which is an acceptable proportion for statistical analysis, although it is accepted that 65 responses cannot cover all the firms in the market. The five unusable responses did not contain sufficient data for further analysis.

The structural equation modeling technique (SEM) is a useful quantitative technique for specifying, estimating and testing hypothetical models describing the relationships between a set 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 parts, firstly the measurement model and secondly the structural model [22]. The measurement model specifies how the latent variables or hypothetical constructs depend upon or are indicated by the observed variables. The exploratory and confirmatory factor analysis models are included in the measurement model which describes the measurement properties (i.e. reliabilities and validities) of the observed variables. The structural model also specifies the causal relationships among the latent variables, describes the casual effects and assigns the explained and unexplained variances using path diagrams.

# Data Analysis and Discussion

## Assessment of measurement quality

Factor analysis was performed using SPSS 20.0 for Windows (including the AMOS 20.0 software) and principle component analysis (PCA) was used for factor extraction. The factors were rotated using varimax rotation to maximize the variance of the squared loadings of a factor on all the variables in a factor matrix, which has the effect of differentiating the original variables by an extracted factor. Some variables without strong correlation~~s~~ were eliminated from the data set and the remaining variables were then distributed into four factors. First, an exploratory factor analysis (EFA) was conducted to determine the loadings of factors as shown in Table 2. In the same table, the result of reliability is demonstrated by Cronbach’s alpha analysis. The Cronbach’s alpha ranges from .620 to .839 for the factors, indicating acceptable internal consistency in the data. However, the alpha value of the virtual enterprise was low and although this low alpha value could pose a problem in further analysis, the study included the virtual enterprise in the establishment of the hypothetical model, as it was felt to be an important characteristic of the research.

**Table 2**. Reliability and validity of the model

| Latent and measurement variables | Factor loadings | Cronbach’s α |
| --- | --- | --- |
| Enterprise capability |  |  |
| EC1: Information capabilityEC2: Human related competency EC3: Technology competencyEC4: System integration competencyEC5: Strategy | .876.773.726.670.627 | .839 |
| ICT adoption |  |  |
| ICT1: Decision support systemICT2: Smart technologyICT3: Prevent, detect, respond and recover from a contamination/ security event in VE | .870.836.561 | .768 |
| VE |  |  |
| VE1: Usage of information technologyVE2: ResponsivenessVE3: Ability to share information and knowledge | .682.665.558 | .620 |
| ***Agile SC*** |  |  |
| ASC1: Quickness/ speedASC2: Cost ASC3: Time reductionASC4: Competency  | .833.803.710.620 | .832 |

## 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 test whether the data fit a hypothesized measurement model and whether measures of a latent variable are consistent with the researchers’ understanding of the nature of that latent variable. Based on the covariance matrices between two variables, the maximum likelihood method (MLM) [22] was used for calculating the covariance in the structural model.

The AMOS 20.0 software (see Section 3.1) was used to calculate the formation of the causal relationship among the concepts that comprise the hypothetical model, and to analyze the level of influence among the causal relationships. This study confirms the properties of the structural model by verifying its appropriateness from the results of the covariance structural analysis. Several goodness of fit (GOF) indices of the measurement model are presented in Table 3. The chi-square *per* degree of freedom (χ2/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 involved deleting the path that showed a low causal relationship, and the second method involved identifying an additional causal relationship [23]. The second method was chosen by establishing an additional causal relationship in the hypothetical model. The GOF of the improved model was compared to the hypothetical model and the GFI and NFI was still 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.** Fit indices of structural equation models

| GOF measure | Threshold | Hypothetical SEM  | Moderated SEM |
| --- | --- | --- | --- |
| χ2dfχ2/dfGFINormed fit index (NFI) Tucker–Lewis index Comparative fit index (CFI) RMRRMSEALower boundUpper bound | <3.0 >0.90 >0.90 >0.80 >0.85  <0.08 <0.08  | 152.340 84.000 1.810 0.781 0.711 0.797 0.838 0.059 0.113 0.084 0.141 | 124.420 81.000 1.540 0.817 0.764 0.866 0.897 0.053 0.092 0.058 0.122 |

This study conducts SEM analysis to evaluate the hypothetical model (see Fig. 2). The structural model then yields a chi-square value of 138.189 with 82 degrees-of-freedom (p < 0.001). The ratio of chi-square to degrees of-freedom is 1.68, which is below the suggested value of 3.0 [25]. The results shown in Table 4 illustrate that the virtual enterprise factors (VE) and the agile supply chain (ASC) factors are most influenced by the enterprise capabilities (EC), both positively and significantly. On the other hand, the ICT adoption factors (ICT) have a significant and positive influence on both sets of factors, but virtual enterprise itself has a weak influence on supply chain agility.

**Table 4.** SEM and path analysis

| Paths | Path coefficient |
| --- | --- |
| H1a: Enterprise capability → VEH1b: Enterprise capability → ASCH2a: ICT adoption → VEH2b: ICT adoption → ASCH3: VE → ASC | 0.643\*\*0.532\*\*0.324\*0.301\*0.194\* |

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



**Fig. 2**: Evaluation of the hypothetical model using SEM

Table 5 shows the relationships between the factors, the total effect being represented by the sum of the direct and indirect effects [26]. Enterprise capability has the strongest 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**. Standardized effects of latent factors on supply chain agility

| Latent factor | Direct effect | Indirect effect | Total effect |
| --- | --- | --- | --- |
| Enterprise capability ICT adoptionVE | 0.5320.3010.194 | 0.1250.0630.000 | 0.6570.3640.194 |

To test the hypotheses, the squared multiple correlation (R2) values of the dependent (or endogenous) variables are calculated. Table 4 shows that enterprise capability and ICT adoption have a significant positive influence on the virtual enterprise collaboration. However, these contribute 51.8% of the total variance of the VE (R2=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 (R2=0.582 as shown in Table 6). Thus, the results support hypotheses H1b, H2b and H3.

**Table 6.** R2 of endogenous variables

| Dependent variables | R2 |
| --- | --- |
| VEASC | 0.5180.582 |

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). In the measurement component, the 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 contamination/ security event in VE (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 and knowledge (standard coefficient=0.475). Finally, the result indicates that the ASC positively influences its four key measurement variables: (i) The quickness/ speed (standard coefficient=0.625); (ii) The cost (standard coefficient=0.583, p<0.001); (iii) The Time reduction (standard coefficient=0.685, p<0.001); and (iv) The competency (standard coefficient=0.809, p<0.001).

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.

# Conclusion

To survive in turbulent, uncertain and unstable market conditions, SMEs need to increase their competitiveness by collaborating with related SMEs within their supply chains. To exploit fast-changing market opportunities and to increase business performance, SMEs need to affiliate temporarily and to collaborate to achieve agility throughout their supply chains. Therefore, this study investigates the influence of enterprise capability and ICT adoption on VE affiliation, and their causal relationship with supply chain agility.

A conceptual hypothetical model of factors of influence was developed based on a literature review. To test this model, SEM was applied to improve the relationships between the various factors. An analysis was conducted using two models; a measurement model and a structural model using exploratory and confirmatory factor analysis respectively. Factor analysis was performed using SPSS 20.0, and this illustrated the measurement properties of the observed variables through the reliability and validities of the data. In the second step, the structural model was established using the AMOS 20.0 software. Based on calculated specific GOF indices, the model was verified, and the relevant hypotheses were validated through 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. On the other hand, supply chain agility is shown to be influenced positively and significantly by enterprise capabilities and ICT adoption.

The concept of supply chain agility is complex and is influenced by many factors, 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, considering additional factors and their relationships. Also, the sample size should be increased to improve the data quality and reliability of the study.

##### **Acknowledgements.** This work was supported by the European Erasmus-Mundus Sustainable eTourism project 2010-2359 and EU Erasmus Mundus Project-ELINK (EM ECW-ref.149674-EM-1- 2008-1-UK-ERAMUNDUS).

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