

**Supplier Embeddedness and Relational Performance in Toyota Buyer Network in  
Uncertain Business Environments**

Buddhika Mannaperuma  
[b.mannaperuma@unimelb.edu.au](mailto:b.mannaperuma@unimelb.edu.au)  
P: +613 8344 1479

Prakash J. Singh  
[pjsingh@unimelb.edu.au](mailto:pjsingh@unimelb.edu.au)  
P: +613 8344 4713

William Ho  
[william.ho@unimelb.edu.au](mailto:william.ho@unimelb.edu.au)  
P: +61 3 9035 7560

Department of Management and Marketing, The University of Melbourne  
Level 10, 198, Berkeley Street Carlton, Victoria, 3010 Australia

(Research Paper)

## **Abstract**

Existing literature offers limited knowledge about the supplier embeddedness and relational performance in global buyer network under business environmental uncertainties. Therefore, this study first develops the empirical context, a part of Toyota's corporate level buyer network that consists of 6,152 suppliers and 14,156 relationships and indicates changes in network patterns. This study invokes the social network theories and environmental uncertainty and supply chain literature. The study applies a hierarchical regression model to validate that environmental uncertainties moderate the positive relationship between supplier embeddedness and relational performance. Supplier firms should strategically position in buyer networks to adapt to environmental uncertainties.

**Keywords:** Supplier Embeddedness, Environmental Uncertainty, Relational Performance, Social Network Analysis

## **Introduction**

A buyer network consists of a focal buyer and suppliers in multiple tiers to deliver a product or service to customers (Kim, 2014). Supplier embeddedness in a buyer network is the value of the supplier's position, by which structural ties are attached to shape its performance (Uzzi, 1996). However, the concept of supplier embeddedness is ambiguous with literature that supports both linear and nonlinear relationship between network embeddedness and performances (Uzzi, 1996; Kim, 2014; Zhao and Peng, 2018). Also, the current literature investigates supplier embeddedness to improve focal buyer's performance but not the suppliers' performance (Choi and Kim, 2008; Kim, 2014).

Current studies in the supply chain use mainly subjective measures of supplier embeddedness, which somewhat impedes proper understanding of its effects on performance (Kim, 2014; Martins et al., 2017; Zhao and Peng, 2018). However, social network analysis (SNA) metrics are now widely available to objectively measure supplier embeddedness in a buyer network through different centralities, such as degree, eigenvector, betweenness, and closeness (Borgatti and Li, 2009; Kim et al., 2011). Since these centralities relate to control and power in the network, they may affect the supplier's relational performance (Borgatti and Li, 2009; Kito et al., 2014; Kim et al., 2015). This study further defines the supplier's relational performance as the ratio of the supplier's relationship value to its sales revenue.

Although both supplier embeddedness and environmental uncertainty influence the supplier's relational performance with the focal buyer, existing literature poorly explains the environmental factor. A supplier's structural position in the buyer network defines its access to potential opportunities in the environment and, hence, the performance (Uzzi, 1996; Borgatti and Li, 2009; Bellamy et al., 2014). The focal buyer supervises supplier embeddedness when structural ties negatively affect the effectiveness and efficiency of the network in uncertain environments (Uzzi, 1996; Kim, 2014; Martins et al., 2017). Therefore, the focal buyer has to adapt to environmental uncertainty dimensions of dynamism, munificence, and complexity that may be intensified by random events, discontinuities, and resource scarcity by altering the relationships with suppliers for its survival. (Choi and Kim, 2008; Nair and Vidal, 2011; Gligor, 2018).

This study uses the automobile manufacturing industry for empirical purposes due to some compelling reasons. The complex nature of products and supply networks of the automobile industry produces a diverse range of centralities of supplier embeddedness, and its geographic dispersion involves significant environmental uncertainty (Choi and Hong, 2002; Kito and Ueda, 2014). This study selects Toyota as the case study network because Toyota's buyer network has undergone substantial reconfiguration due to recent events, such as quality defects, Tsunami disruptions, and concurrent plant closures and openings (Andrews et al., 2011; Matsuo, 2015). The case study analyses the impact of environmental uncertainty and the supplier embeddedness on relational performance. The empirical context involves 284 immediate suppliers and 5868 extended suppliers of Toyota's corporate level buyer network. Among the selected 6152 suppliers, 14,156 relationships exist. This study collected data from the Bloomberg and Marketline databases.

To address the knowledge gaps and industrial issues mentioned earlier, this study first develops a triadic buyer network using empirical data to measure the supplier embeddedness, as informed by eigenvector and closeness centralities with the help of Toyota case study. Eigenvector centrality is how well a supplier connects to other well-connected suppliers, and closeness centrality is how quickly a supplier can reach all of the other suppliers in a network on average (Bonacich, 2007; Borgatti and Li, 2009). Secondly, this study examines the relationships among a supplier's centralities that inform supplier embeddedness, environmental uncertainty dimensions of dynamism, munificence and complexity, and a supplier's relational performance with the focal buyer. In doing so, this study will address the following question:

- How does the supplier embeddedness in a triadic buyer network impact its relational performance in uncertain business environments?

This study makes useful contributions to the literature. This study explains the association between the supplier embeddedness as informed by SNA matrices and the relational performance which differs from the current research where the focus is on the impact of the focal buyer's comprehension of supplier embeddedness on buyer's performance, not the suppliers'. This study further reveals that the environmental uncertainty dimensions moderate the relationships between supplier embeddedness and relational performance. Supplier's eigenvector and closeness centralities improve its relational performance in a buyer network by contradicting the existing beliefs of the nonlinear relationship. Both dynamic and complex environments make these relationships stronger, while only munificence weakens them. This study offers a new definition for the dependent variable, supplier's relational performance. The first-tier network exhibits the characteristics of a scale-free network pattern, while the second-tier shows a multi-tiered diagonal pattern where resource flow connections occur primarily across different tiers.

## **Literature Review and Hypotheses Development**

### **Supplier Embeddedness and Relational Performance**

Buying corporations consider supplier embeddedness as an important factor that decides their performance improvement (Kim, 2014; Bellamy et al., 2014). Kim's (2014) survey-based study confirms that the buyers' understanding of suppliers' structural positions leads to better operational performance, not financial performance. Through the lenses of social network theories and SNA technique, the degree, eigenvector, closeness, and betweenness centralities can be used to measure the concept of supplier embeddedness objectively (Borgatti and Li, 2009; Kim et al., 2011).

Since a supplier's eigenvector and closeness centralities associates with its relative power in a network, this study mainly focuses on them to inform the supplier embeddedness (Borgatti and Li, 2009). Suppliers who connect to other well-connected suppliers get more benefits than suppliers who connect to an equal number of less-connected suppliers, and this property is known as the eigenvector centrality (Bonacich, 2007). Since these suppliers efficiently accumulate diverse resources, they can smoothly supply value-added products to focal buyers with less time and coordination pressures. For instance, the automobile industry employs strategies, such as modularisation and co-competition, to benefit from the structural positions of suppliers in a buyer network (Pathak et al., 2014). Hence, the focal buyer tends to increase the relationship value with such strategic suppliers rather than subdividing resource costs among a pool of suppliers by making direct contracts.

*Hypothesis 1:* A supplier with high eigenvector centrality in a triadic buyer network increases its relational performance.

The suppliers who are shorter distances from other suppliers receive resources and information sooner than suppliers located farther away from most others, and this property is known as the closeness centrality (Borgatti and Li, 2009). In this study, the suppliers with high closeness centrality are closer to other suppliers, and they are likely to perform well in tasks that require resource integration and coordination (Capaldo and Giannoccaro, 2015). Suppliers that have long supply chains may entail greater disruptions and costs when increasing the number of suppliers its resources had to go through to get to the focal buyer (Borgatti and Li, 2009). Hence, a focal buyer would prefer to increase the relationship value of suppliers with shorter supply chain lengths.

*Hypothesis 2:* A supplier with high closeness centrality in a triadic buyer network increases its relational performance.

### ***Environmental Uncertainty: Moderation Effects of Dynamism, Munificence, and Complexity***

Environmental uncertainty is a multidimensional construct, with the most commonly recognised dimensions being munificence, dynamism, and complexity (Pagell and Krause, 2004; Gligor et al., 2018). Although in early times, environmental uncertainty dimensions appear to impact the supply chain strategies directly, scholars recently found that these dimensions actively moderate strategies and performance relationships (Pagell and Krause, 2004; Gligor, 2018). However, the impact of environmental uncertainty on the supplier embeddedness and relational performance remain unexplored in the literature. Supply chain digitalisation practices have significantly advanced the way firms

used to operate, and hence new technologies promote network-level decision making than separate actions which in turn affect the firms' performance in the network (Pagell and Krause, 2004). Therefore, environmental uncertainty is more likely to moderate the supplier embeddedness and relational performance relationship.

Dynamism refers to the unpredictability, which is different from the rate of environmental change (Gligor, 2018). Since focal buyers, such as Proctor and Gamble (P&G), view suppliers as sources of innovation (Bellamy et al., 2014), buyers can increase network resilience by connecting with suppliers of high eigenvector centrality as they can facilitate fast diffusion of innovation and technology within the network (Kim et al., 2015). The focal buyer can assign the gatekeeper role to suppliers with high eigenvector centrality to share and mitigate risks with extended suppliers in dynamic events. Since these suppliers connect with other suppliers who largely contribute to either the focal buyer's actual costs of materials or performance, they are capable of maintaining inventory efficiencies and mitigating network disruptions effectively (Bellamy et al., 2014). Therefore,

*Hypothesis 3:* Higher environmental dynamism leads to a stronger positive relationship between a supplier with high eigenvector centrality in a triadic buyer network, and its relational performance.

Dynamism influences a corporation's diversification strategy while presenting an increased risk for the suppliers (Gligor, 2018). Since a corporation's strategic imperative is to spread the risk of innovation and technologies among the suppliers, it establishes the global supply network revolving around suppliers of high closeness centrality who can easily access other suppliers (Uzzi, 1996; Choi and Hong, 2002). Not surprisingly, the focal buyer would favour high closeness centrality suppliers that are close to all other suppliers within the buyer network and, as a result, they can collectively meet targets by turning rivalry between suppliers into opportunities. Thus,

*Hypothesis 4:* Higher environmental dynamism leads to a stronger positive relationship between a supplier with high closeness centrality in a triadic buyer network, and its relational performance.

Munificence reflects resource abundance and the resulting capacity in the task environment to support the sustained growth of the corporations (Gligor, 2018). A corporation seeks for munificent environments that facilitate growth and stability of the internal business units by enabling resource slack, which could serve as a buffer for times of relative scarcity and innovation efforts. If the buyer corporation realises the risk of remaining in less munificent environments, it expands operations into new markets by reducing its dependence on existing suppliers (Choi and Hong, 2002). The focal buyer assesses the relative importance of a supplier, not by its adjacent suppliers, but by the values of their cumulative material volumes (Bonacich, 2007). So, the gains are limited to high eigenvector centrality suppliers. Hence,

*Hypothesis 5:* Higher environmental munificence leads to a weaker positive relationship between a supplier with high eigenvector centrality in a triadic buyer network, and its relational performance.

Closeness centrality illustrates how suppliers work closely with each other in pursuing mutual strategic goals, such as economies of scale, technology improvements, and innovations (Kim, 2014; Pathak et al., 2014). The focal buyer can effectively organise suppliers' cooperative and competitive behaviours in a buyer network by understanding their resource interdependencies to improve network performance. However, changes of global buyer networks may be locally inefficient, as they commit themselves to sustain the network performance, not that of the suppliers embedded in it (Capaldo and Giannoccaro, 2015). In contrast, suppliers may entertain opportunistic behaviour to maximise their performance, which is detrimental to the interests of the buyer network (Capaldo and Giannoccaro, 2015). Although resource-rich environments increase the economic growth of a buyer network, the focal buyer may encounter unnecessary non-value adding activities, inventories, and material waste along its supply chains. Therefore, the buyer can effectively use the shortest paths in the buyer network, empowering suppliers with high closeness centrality to reduce the wastage in existing operations (Borgatti and Li, 2009; Kim, 2014).

*Hypothesis 6:* Higher environmental munificence leads to a stronger positive relationship between a supplier with high closeness centrality in a triadic buyer network, and its relational performance.

The third business environmental uncertainty dimension, complexity, refers to heterogeneity and concentration of environmental elements (Child, 1972). A supplier reduces its status through hostile connections to high-status suppliers, but the supplier raises its status by connecting to poorly embedded suppliers (Bonacich, 2007). A supplier increases its popularity by being chosen by popular suppliers in the network (Bonacich, 2007). Complex environments are challenging to understand and monitor; hence, the focal buyer tends to delegate coordination and resource integration to suppliers with high eigenvector centralities. In complex environments, poorly embedded suppliers weaken their relationship values with the focal buyer.

*Hypothesis 7:* Higher environmental complexity leads to a stronger positive relationship between a supplier with high eigenvector centrality in a triadic buyer network, and its relational performance.

Since corporations need more information to operate in complex industries, they prefer to have a balance among firms that are similar in size and resources. Global corporations perceive geographic dispersion as an important indicator of environmental complexity because they earn more sales by being a part of different global buyer networks despite the differences in their business and nationalities. With a short average path length, suppliers can communicate and transport materials quickly, thereby they increase the network robustness against disruptions in complex environments (Nair and Vidal, 2011; Kim et al., 2015). If a focal buyer buys more from a few high closeness centrality suppliers, the buyer can manage these suppliers' opportunistic behaviours without difficulty than purchasing from multiple suppliers. In complex environments, a focal buyer undermines the relationships with distant suppliers to deal with government regulations, product diversity, and entry barriers (Kim, 2014; Kim et al., 2015). Hence,

*Hypothesis 8:* Higher environmental complexity leads to a stronger positive relationship between a supplier with high closeness centrality in a triadic buyer network, and its relational performance.

## Conceptual Model

This study aims to explore the impact of supplier embeddedness on relational performance in uncertain environments, as shown in the conceptual model (Figure 1).

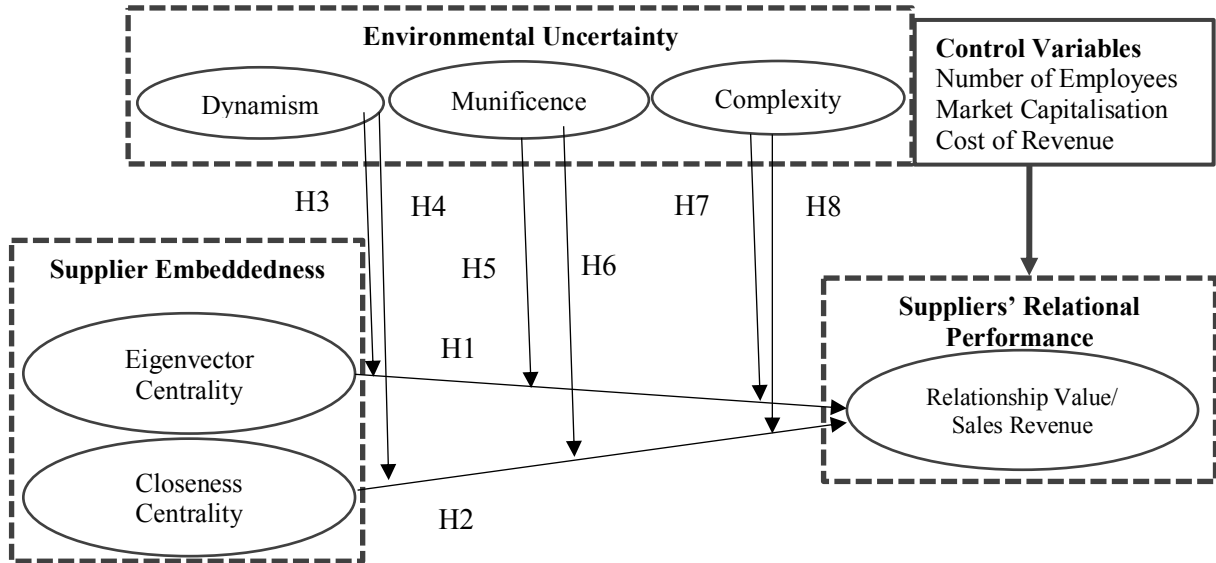


Figure 1: Conceptual model

## Research Methodology

### Data

This study used data from the supply chain module of the Bloomberg database to develop a part of Toyota's corporate level triadic buyer network. Although Toyota connected to 656 supplier corporations in 2016, Bloomberg provided data of relationship value for only 284 immediate suppliers. So, the chosen sub-buyer network of this study consists of 284 immediate suppliers, which account for 65% of Toyota's cost of materials and their 5,867 extended second-tier suppliers. Overall, the subnetwork consists of 6,152 suppliers and 14,156 relationships among them. The unit of analysis is the immediate supplier in Toyota's corporate level sub-buyer network. Further, the study collected data from Marketline reports and industry concentration, and financial analysis reports of the Bloomberg database from 2011 to 2016 within a span of 81 global industries to calculate environmental measures.

### Operational Definitions of Key Variables

*Eigenvector Centrality*: Given an adjacency matrix  $A$ , the centrality of supplier  $i$  (denoted  $c_i$ ), is given by

$$c_i = \alpha \sum A_{ij} c_j \text{ -----(1)}$$

where  $\alpha$  is a parameter (Borgatti et al., 2002; Bonacich, 2007; Borgatti and Li, 2009). This is a percentage measure of the supplier's relative power in a buyer network (Borgatti et al., 2002). This study uses the inverse of the square root of the eigenvector centrality to ensure normal distribution of data.

*Closeness Centrality:* Closeness centrality of a supplier is the reciprocal of farness, and farness is the sum of the magnitudes of supplier's relationships to every other supplier (Borgatti and Li, 2009; Kim et al., 2011). As an alternative to taking the reciprocal after the summation, the reciprocals can be taken before (Borgatti et al., 2002). In this case, closeness is the sum of the reciprocated distances, so that the infinite distances contribute a value of zero (Borgatti et al., 2002). This study calculates the average of in- and out-closeness centralities since the relationships are directed.

*Munificence:* Munificence is the resource generosity that supports sustained growth of a firm (Gligor, 2018). It is objectively measured as the five-year average growth in sales revenue and operating income of the supplier (Heeley et al. 2006; Gligor, 2018). The basic equation followed is

$$y_t = b_0 + b_1 t + a_t \text{ -----(2)}$$

where  $y_t$  = natural logarithms of sales or operating income in year  $t$ ,  $t$  = year, and  $a_t$  = residual.  $b_0$  is the  $y_t$  intercept, and  $b_1$  is the regression coefficient. This study measures munificence as the average of the antilog transformations of the regression coefficients of sales and income. The study uses five-year data points because that period is the length of a typical planning horizon (Gligor, 2018).

*Dynamism:* Dynamism is the unpredictable change in the business environment (Gligor, 2018). The indicators show the five-year patterns of the instability of the environment (Heely et al., 2006). The measure is the average of antilog transformations of the standard error of each regression slope (sales and income) measured for munificence (Heely et al., 2006; Gligor, 2018).

*Complexity:* Complexity is the heterogeneity in products and markets and a measure of industry concentration (Child, 1972; Pagell and Krause, 2004). This study measures complexity as the log transformations of the breadth and variety of a supplier's geographic markets (Gligor, 2018).

*Relational Performance:* This study defines the supplier's relational performance as the ratio of a supplier's relationship value with the focal buyer to the supplier's sales revenue, in light of existing literature (O'Toole and Donaldson, 2002; Choi and Kim, 2008). Log transformations are used for the analysis.

*Control Variables:* Larger supplier corporations might have more market penetration power than smaller firms and, thus, might obtain better relationship values from the buying corporation. Hence, corporate size and value of outstanding market shares are important factors to be controlled. Natural logarithmic transformations of the number of

employees and the market capitalisation are used to control for corporate size. Further, supplier corporations that spend little on the total cost incurred in obtaining sales may secure additional sales from the buyer (O'Toole and Donaldson, 2002). Thus, the log transformation of the supplier's cost of revenue as a third control variable is included in the model.

### ***Descriptive Statistics***

Table 1 provides the mean, standard deviation, and correlations among the variables. Since multicollinearity does not appear in any empirically validated models. Therefore, significant correlations are ignored.

*Table 1: Descriptive statistics and correlations among variables*

Variable	Mean	Standard Deviation	Minimum	Maximum	1	2	3	4	5	6
1.Eigenvector Centrality	7.51	3.06	1.94	15.81	1.00					
2.Closeness Centrality	0.19	0.03	0.13	0.23	-0.40*	1.00				
3.Dynamism	1.03	0.05	1.00	1.52	-0.03	0.05	1.00			
4.Munificence	1.47	0.52	0.37	2.71	-0.05	-0.24*	-0.17*	1.00		
5.Complexity	1.75	0.69	0.00	3.66	-0.12**	0.15*	0.10***	-0.09	1.00	
6.Relational Performance	8.64	1.52	3.30	12.45	0.36*	0.10***	-0.04	-0.21*	0.01	1.00

\* p<0.01, \*\*p<0.05, \*\*\*p<0.01

### **Results**

This study first used UCINET software to develop Toyota's triadic sub-buyer network which consists of 6152 suppliers and 14,156 relationships and obtain the measures of immediate suppliers' eigenvector and closeness centralities (Borgatti et al., 2002). Some of the first-tier suppliers supply directly to both Toyota and its first-tier suppliers. Scholarly articles that focus on automobile supply networks so far have only developed network diagrams for assembly plants (Choi and Hong, 2002; Kim et al., 2011) and Toyota's plant-level network (Kito et al., 2014; Kito and Ueda, 2014). Since the literature has paid less attention to drawing Toyota's very complex corporate level buyer network that consists of endless cycles and hundreds of tiers, this study makes a fair attempt to develop a section of Toyota's triadic buyer network at the corporate-level. Toyota buyer network changes its pattern from scale-free to diagonal, when expanding from first-tier to second-tier. Scale-free network pattern somewhat mirrors Toyota's plant-level 'keiretsu' supply network (Kito and Ueda, 2014; Capaldo and Giannoccaro, 2015; Kim et al., 2015). However, this network consists of some structural holes which are lack of connections between two or more suppliers in a network (Burt, 1992) and network clusters that characterize the modular product network, as well. The diagonal network is

a combination of multi-tiered supply chain networks where the resource flow connections primarily occur across different tiers (Capaldo and Giannoccaro, 2015; Kim et al., 2015).

Second, this study used STATA software to conduct a moderated hierarchical regression analysis. This analysis informs how the environmental uncertainty, the supplier embeddedness, influence the supplier's relational performance in a triadic buyer network. As illustrated in Table 2, the first model accounts for a variance of 16.5% in the dependent variable after controlling for firm size, market capitalisation, and cost of revenue. The second model that includes the centrality dimensions of supplier embeddedness provides an incremental variance of 10.1%. The inclusion of environmental uncertainty dimensions in the third model contributes to 1.1% variance increase in the supplier's relational performance. After adding the interaction terms, the fourth model explains an additional variance of 5.4% with an overall effect of 33.1% of the dependent variable. The interaction terms are the product of mean centred centrality variables and the mean centred environmental uncertainty variables.

*Table 2: Hierarchical moderated regression results for supplier's relational performance in the network shown in Figure 2*

Variables	Relational performance				Hypothesis
	Model 1	Model 2	Model 3	Model 4	
Constant	14.833*	7.809*	11.650*	11.130*	
Number of employees	0.0006	-0.049*	-0.071	-0.052*	
Market Capitalisation	-0.300*	-0.206*	-1.188*	-0.180*	
Cost of Revenue	0.064	0.018	0.024	0.006	
Eigenvector Centrality		0.147*	0.146*	0.168*	H1: Yes
Closeness Centrality		13.818*	12.672*	13.627*	H2: Yes
Dynamism			-1.723***	-1.739	
Munificence			-0.213	-0.338**	
Complexity			0.155	0.178***	
Eigenvector Centrality x Dynamism				0.861*	H3: Yes
Closeness Centrality x Dynamism				66.271***	H4: Yes
Eigenvector Centrality x Munificence				-0.183*	H5: Yes
Closeness Centrality x Munificence				-2.706	H6: No
Eigenvector Centrality x Complexity				0.009	H7: No
Closeness Centrality x Complexity				9.288*	H8: Yes
R-squared	0.165	0.266	0.277	0.331	
R-squared change	0.165	0.101	0.011	0.054	
F test	19.52*	25.62*	20.16*	26.41*	

\* p<0.01, \*\*p<0.05, \*\*\*p<0.01

The results support six out of the eight hypotheses. Hypotheses 1 and 2 are supported, indicating a supplier's eigenvector and closeness centralities increase its relational performance. Only munificence has a significant direct impact on the supplier's relational performance at p<0.05. However, environmental uncertainty dimensions indirectly influence the positive association between the supplier embeddedness and relational

performance. In dynamic environments, a supplier's eigenvector centrality increases its relational performance, while munificence diminishes that positive association. These results support hypotheses 3 and 5. Complexity does not act as a significant moderator of that relationship, thereby not supporting hypothesis 7. Surprisingly, the positive association between a supplier's closeness centrality and its relational performance does not vary significantly in munificent environments, while both dynamism and complexity escalate the positive slope of that relationship. The results contradict hypothesis 6, while supporting hypotheses 4 and 8, respectively.

### ***Normality Tests***

This study performed necessary tests to check the normality conditions of the proposed model. First, multicollinearity does not appear to exist in any model, since the variance inflation factor does not exceed 3.2, with the critical level being 10.0. Second, both the Breusch-Pagan/Cook-Weisberg test and Cameron and Trivedi's decomposition test confirm the nonexistence of heteroscedasticity in the model at  $p > 0.1$ . Third, there are no omitted variables in the proposed model, as the Ramsey reset test is insignificant at  $p > 0.1$ . Also, the link test validates that there are no model specification errors with an insignificant hat square at  $p > 0.1$ . Thus, the proposed model is well-defined.

### ***Robustness***

This study used data from the Bloomberg and Marketline databases to perform a robustness test by using alternative figures of dynamism, munificence and complexity. The results support hypotheses 1 and 2. For moderation effects, the robustness test results support hypotheses 4 and 7. Together, the four separate models provide increasing R-squared values in a sequence with significant F test results. Therefore, the test suggests that the proposed conceptual model is robust.

### ***Endogeneity***

Endogeneity tests attempt to verify whether some explanatory variables are not independent of the residuals. This study used the Two-Stage Least Squares regression analysis, using the instrumental variable procedure to check the endogeneity of the dependent variable. The study used the instrumental variables of the cash conversion cycle and inventory turnover for the supplier's closeness centrality and days of sales outstanding and inventory for the dynamism. Since the robust endogeneity test statistics and over-identification tests are insignificant at  $p > 0.1$ , endogeneity does not exist in the proposed variables, and the instrumental variables are not over-identified.

### **Discussion**

This study aims to understand how environmental uncertainty and supplier embeddedness impact the supplier's relational performance.

### ***Theoretical Contributions***

The literature is yet to explore the effects of supplier embeddedness on its relational performance because scholars mostly examine the comprehension of supplier embeddedness as an antecedent to buyers' performance but not the suppliers' performance within a buyer network (Kim, 2014). Also, the concept of supplier embeddedness creates ambiguity because scholars support both linear and nonlinear effects of embeddedness on performance (Uzzi, 1996; Kim, 2014; Martins et al., 2017; Zhao and Peng, 2018). Hence, this study first investigates what types of associations exist between supplier embeddedness and its relational performance with the focal buyer. Results support for positive associations.

If the monetary value of a supplier's relationship with the focal buyer is high, the supplier is likely to remain longer in the buyer network (O'Toole and Donaldson, 2002). Therefore, this study further defines relational performance as the ratio of the supplier's relationship value to its sales revenue. Current literature mostly informs the supplier embeddedness subjectively and hence relatively neglects the widely available SNA matrices to inform it objectively (Uzzi, 1996; Choi and Kim, 2008; Kim, 2014). Hence, this study uses the eigenvector and closeness centralities that indicate a suppliers' relative power in a network to inform the supplier embeddedness (Borgatti and Li, 2009).

Social network scholars have carried out studies to understand how node level centralities such as eigenvector and closeness deliver better economic outputs for embedded members and the network itself in different social contexts (Burt, 1992; Uzzi, 1996; Borgatti and Li, 2009). However, the literature has paid less attention to understand the influence of environmental uncertainty on the relationships between the centralities of supplier embeddedness and its relational performance. Hence, this study proposed a conceptual model to elucidate how the environmental uncertainty dimensions of dynamism, munificence, and complexity affect those relationships. The underlying conceptual model integrates the social network theories, SNA technique, the literature of environmental uncertainty, supply chain and performance. Results of the moderated regression analysis show that dynamism positively moderates the relationship between a supplier's eigenvector centrality and its relational performance, while munificence negatively moderates that relationship. Dynamism and complexity positively moderate the relationship between a supplier's closeness centrality and its relational performance. Table 3 provides a summary of the hypotheses results.

*Table 3: Summary of the hypotheses*

Independent Variable	Dependent Variable	Direct Effect	Moderating effect		
			Dynamism	Munificence	Complexity
Eigenvector Centrality	Relational Performance	Supported (+)	Supported (+)	Supported (-)	Not Supported
Closeness Centrality	Relational Performance	Supported (+)	Supported (+)	Not Supported	Supported (+)

### ***Managerial Implications***

This study confirms that the focal buyer is likely to increase purchases from a supplier with high eigenvector and closeness centralities in a buyer network. This study proves that non-economic factors, such as supplier embeddedness, cannot alone predict its relational performance in a buyer network. Instead, the environmental uncertainty dimensions control the association between the supplier embeddedness and its relational performance. Suppliers would require understanding the significant interactions between environmental uncertainty and the buyer network to increase the supplier's sales performance.

Most of the quality defects arise, not in Toyota's plants, but those of the other big tier suppliers (Economist, 2010). Usually, first-tier suppliers, such as Bosch, Delphi, and Denso, supply integrated systems directly to Toyota, while second-tier suppliers provide individual parts or assembled components either directly to Toyota or a first-tier supplier (Economist, 2010). Third-tier suppliers often make a single component for several second-tier suppliers. However, over the year, Toyota and its first-tier suppliers managed to reduce the number of second-tier and third-tier suppliers by selecting only the dominant suppliers, possibly the ones with high eigenvector and closeness centralities. However, industrial analysts highlighted that Toyota's sole-sourcing approach had taken it to potentially risky extremes in uncertain business environmental events such as the global quality crisis in 2010 and Japan's 2011 tsunami and earthquake (Matsuo, 2015). Since Toyota is rapidly expanding its operations, it can no longer maintain the same quality control levels or engineering rigour (Economist, 2010). Toyota must realise the vulnerability of dyadic relationships and consequently, the significance of managing suppliers in multiple tiers.

### **Conclusion and Future Research**

Corporate level global buyer networks credibly align with focal buyers' interests. Accordingly, existing literature posits mainly the comprehension of supplier embeddedness in a buyer network as an antecedent of buyer performance by mostly using subjective measures but not the supplier's performance and creates ambiguity between linear and nonlinear relationships among these constructs (Uzzi, 1996; Choi and Kim, 2008; Kim, 2014; Capaldo and Giannoccaro, 2015; Martins et al., 2017; Zhao and Peng, 2018). Hence, this study explores the impact of supplier embeddedness, informed by objective measures of eigenvector and closeness centralities, on supplier's relational performance with the focal buyer. Results confirm the positive associations among them.

Focal buyer has to adapt to the environmental uncertainty by changing structural relationships in the buyer network for its survival, and to access opportunities in the market readily. Consequently, suppliers will be exposed to potential opportunities or threats outside the network that change their relational performance with the focal buyer in response to environmental uncertainty. So, environmental uncertainty is another factor that influences the supplier embeddedness and its effects on relational performance, which remain poorly understood in the literature. This study, thus, offers a conceptual model by integrating the social network theories, SNA technique, and the literature of environmental uncertainty, supply chain and performance. This study reveals that environmental uncertainty dimensions of dynamism, munificence, and complexity,

moderate the relationships between the supplier embeddedness and its relational performance. This study also developed a sub-buyer network of Toyota Motor Corporation.

This study has some limitations, which create opportunities for future research. Future research may develop a full map of a multi-tiered buyer network in order to recognise the essential complexities and centralities involved in it. From a complex adaptive system view, researchers can develop a longitudinal study capturing supplier level and network level transitions. They can further recognise supplier-based adaptation to environmental uncertainty.

## References

- Bellamy, M. A., Ghosh, S. and Hora, M. (2014) 'The influence of supply network structure on firm innovation', *Journal of Operations Management*, 32(6), 357-373.
- Bloomberg, L. P. (2016) Online database, Available: <https://www.bloomberg.com/>
- Bonacich, P. (2007) 'Some unique properties of eigenvector centrality', *Social Networks*, 29(4), 555-564.
- Borgatti, S. P., Everett, M. G. and Freeman, L. C. (2002) 'Ucinet for Windows: Software for social network analysis'.
- Borgatti, S. P. and Li, X. U. N. (2009) 'On social network analysis in a supply chain context', *Journal of Supply Chain Management*, 45(2), 5-22.
- Burt, R. S. (1992) *Structural holes: The social structure of competition*, Harvard University Press.
- Capaldo, A. and Giannoccaro, I. (2015) 'Interdependence and network-level trust in supply chain networks: A computational study', *Industrial Marketing Management*, 44, 180-195.
- Child, J. (1972) 'Organization structure, environment and performance: The role of strategic choice', *Sociology*, 6(1), 1-22.
- Choi, T. Y. and Kim, Y. (2008) 'Structural embeddedness and supplier management: a network perspective', *Journal of Supply Chain Management*, 44(4), 5-13.
- Choi, T. Y. and Hong, Y. (2002) 'Unveiling the structure of supply networks: Case studies in Honda, Acura, and Daimler Chrysler', *Journal of Operations Management*, 20(5), 469-493.
- Economist. (2010, 27 Feb) 'The machine that ran too hot', *The Economist*, Available: <http://www.economist.com/node/15576506>
- Gligor, D. (2018) 'Performance implications of the fit between suppliers' flexibility and their customers' expected flexibility: A dyadic examination', *Journal of Operations Management*, 58(1), 73-85.
- Heeley, M. B., King, D. R. and Covin, J. G. (2006) 'Effects of firm R&D investment and environment on acquisition likelihood', *Journal of Management Studies*, 43(7), 1513-1535.
- Kim, D. Y. (2014) 'Understanding supplier structural embeddedness: A social network perspective', *Journal of Operations Management*, 32(5), 219-231.
- Kim, Y., Chen, Y.S. and Linderman, K. (2015) 'Supply network disruption and resilience: A network structural perspective', *Journal of Operations Management*, 33(1), 43-59.
- Kim, Y., Choi, Y. T., Yan, T. and Dooley, K. (2011) 'Structural investigation of supply networks: A social network analysis approach', *Journal of Operations Management*, 29(3), 194-211.
- Kito, T., Brintrup, A. and New, S. (2014) 'The structure of the Toyota supply network: An empirical analysis', *University of Oxford Report*, Internal Saïd Business School, unpublished.
- Kito, T. and Ueda, K. (2014) 'The implications of automobile parts supply network structures: A complex network approach', *CIRP Annals*, 63(1), 393-396.
- Liker, J. K. and Choi, T. Y. (2004) 'Building deep supplier relationships', *Harvard Business Review*, 82(12), 104-113.
- Martins, G. S., Rossoni, L., Duarte, A. L. and Martins, R. S. (2017) 'Supply chain relationships: Exploring the effects of both relational and structural embeddedness on operational performance', *International Journal of Procurement Management*, 10(5), 639-664.
- Matsuo, H. (2015) Implications of the Tohoku earthquake for Toyota's coordination mechanism: Supply chain disruption of automotive semiconductors. *International Journal of Production Economics*, 161, 217-227.
- Nair, A. and Vidal, J. M. (2011) 'Supply network topology and robustness against disruptions—an investigation using multi-agent model', *International Journal of Production Research*, 49(5), 1391-1404.

- O'Toole, T. and Donaldson, B. (2002) 'Relationship performance dimensions of buyer–supplier exchanges', *European Journal of Purchasing & Supply Management*, 8(4), 197-207.
- Pagell, M. and Krause, D. R. (2004) 'Re-exploring the relationship between flexibility and the external environment.' *Journal of Operations Management*, 21(6), 629-649.
- Pathak, S. D., Wu, Z. and Johnston, D. (2014) 'Toward a structural view of co-opetition in supply networks', *Journal of Operations Management*, 32(5), 254-267.
- Uzzi, B. (1996) 'The Sources and consequences of embeddedness for the economic performance of organizations: The network effect', *American Sociological Review*, 674-698
- Zhao, H. and Peng, X. (2018) 'Exploitation versus exploration: The impact of network embeddedness on the innovation of subsidiary firms', *Chinese Management Studies*, 12(3), 547-574.