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Changing structures of B2B networks in the Japanese textile and apparel industry

Economic relationships between core and peripheralnetworks from the perspective of complex systems

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Abstract

The aim of the present study was to evaluate how the business-to-business (B2B) networks in the Japanese textile and apparel industry changed between 2005 and 2010 using data on 200 companies. Network analysis was used to study the properties of the B2B networks, and how their structures changed was characterized using the USD/JPY exchange rate. The network analysis revealed power-law properties of the B2B networks, and the core networks characterized by the largest degree centrality exhibited positive correlations with the USD/JPY exchange rate. By contrast, the peripheral networks characterized by the network path length exhibited the negative correlations with the exchange rate USD/JPY. Therefore, the changes that occurred in the B2B networks are explained as the complementarity of comparative advantages originating in the USD/JPY exchange rate. Moreover, the USD/JPY exchange rate affected the B2B networks through not only the complementarity of importing and exporting but also by changing the structures.

Keywords: Japanese textile and apparel industry, Business to business (B2B) networks, Complex systems

Introduction

Overview of the present study

Generally, there have been trade frictions between Chinese-U.S. industries involved in information communication technology (ICT) (CNN 2019), and those trade frictions seem to have influenced those various industries. The adaptations to these economic fluctuations are necessary for the industries and the comprised companies in various regions. It is important to understand the state and its changing of the industries influenced by macroeconomy for these necessaries of the companies. However, these phenomena are difficult to analyze because the required datasets cannot be obtained synchronously and spatiotemporally. We require typical cases of trade frictions in order to understand the industries with the companies. Our aim in the present study was to demonstrate the changing of the business-to-business (B2B) networks as the industries caused by the exchange rate as the economic fluctuations. To do this, the present study used datasets on the Japanese textile and apparel industry to show the statistical properties of the B2B networks and the changing relationships with the USD/JPY exchange rate. The method of complex systems was applied to the datasets of the B2B networks. As a result, the analyses revealed an adaptation in the economic changes that took place in the B2B networks. The present study contributed considerations to a method of how the industries with companies should behave with the global economy as complex systems.

Literature review

History and industrial structures of the Japanese textile and apparel industry

Here, this paragraph reviews the history and B2B networks of the Japanese textile and apparel industry from the perspective of the present study. As a typical case, the present study focuses on the Japanese textile and apparel industry the U.S.-Japan trade frictions of which occurred in the 1960s (Yachi 1989). In addition, the economic situation in the 1970s made the Japanese textile and apparel industry more difficult to produce various textile products in Japan (Gereffi 1999). These changes began with the introduction of floating exchange rates in the Japanese economy. Because the production costs (e.g., materials, personnel) rose, the Japanese textile industry, and especially its production departments began to move overseas (Alvstam et al. 2009). At the same time, the commoditization of apparel products and foreign outflows of the industries were encountered. The industry had to reduce its production costs with developing technologies for commoditized markets. As well as the foreign outflows, B2B connections among Asian areas had strengthened through transactions in apparel-related productions (Alvstam et al. 2009). The relationship between the exchange rate and foreign direct investment was investigated in a quantitative economic study (Kiyota et al. 2004). Furthermore, it was also found that international trading companies within these industries had played a role as a connector between companies and countries (Wortzel et al. 1983). Generally, most of the Japanese textile industry had moved from domestic regions to global regions. In other words, companies and its roles in the industries were the keys to clarify the processes of the changes of the B2B connections. Therefore, the present study focused on the relationships between companies and the macroeconomy.

This paragraph focuses on structures and natures of B2B networks. The present study regards the industry as comprising companies and their trading. In other words, an industry was regarded as a network using topological and statistical characteristics. The conceptual industrial network of the Japanese textile and apparel industry has complicated structures that originates in the various companies and their trading. Figure 1 shows the conceptual structure of the Japanese textile and apparel industry (1996). The industry is a heterogeneous and complicated network because the industry comprises various companies and networks. In detail, these industries originated in some manufacturing communities in specific local areas where textile materials could be obtained (Gordon 1985). In Fig. 1, there are materials companies and dyeing companies such as the importing companies and apparel wholesaler which grew into international trading companies that expanded through both international trading and domestic trading (Yamawaki 2002). In recently, old-fashioned communities also continued as traditional manufacturing communities (Yamawaki 2002). However, new communities that do not

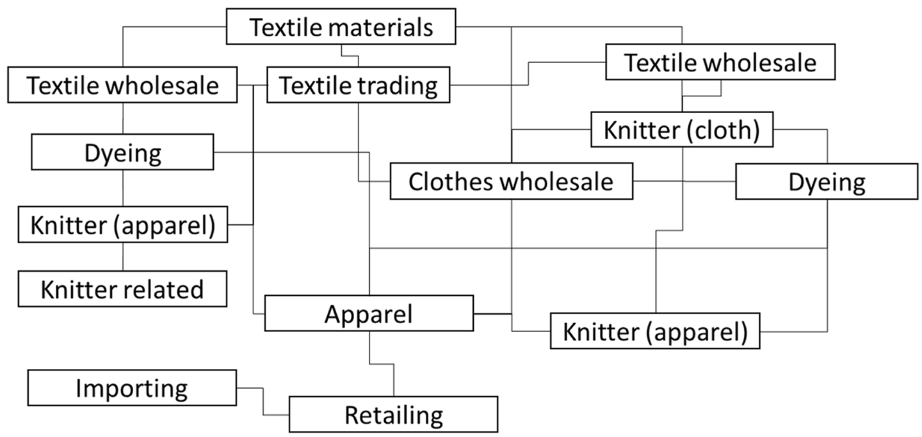

Fig. 1 The conceptual structure of the Japanese textile and apparel industry

depend on the Japanese domestic industry have also grown in this industry (Robertson and Richard 1994).

A problem within industries comes to the instability of ordering and receiving due to the natures of industries as the networks such as the conceptual structure in Fig. 1. Also, industries have tried to solve the problem of instability by utilizing ICT. Based on complex structures of the industries, the bullwhip effect in industries is discussed by applying multi-agent systems (Moyaux and D'Amours 2006). The bullwhip effect demonstrates fluctuations in the number of products due to sharing incomplete information used for regulating orders from companies to companies in B2B networks. A supply-chain management (SCM) system using an ICT related management style has been introduced to solve the bullwhip effect and is also used for sharing information in manufacturing and retailing orders (Turker and Altuntas 2014; Kim 2007). Moreover, a specialty store retailer of private-label apparel (SPA) method uses the processes of manufacturing and retailing apparel products that are self-contained, and the method has become the typical production management style in this industry (Urakami 2010). Generally, SPA is also realized by utilizing ICT. Up to date communities utilizing SCM or SPA manufacturing that do not depend on domestic industries have been at a comparative advantage in the global economy. This is because the Japanese domestic industry had to depend on internal trading despite various costs (e.g., materials, personnel) becoming higher, whereas new communities did not face this situation because their production departments were located in developing Asian areas.

B2B networks as complex systems

The influences of the macroeconomics affected by political powers to the B2B networks consisted of international companies and domestics companies are needed to be considered to analyze based on the mezzo perspective. Social science which comprises metabolic systems at the biological level, individuals at the microscopic level, communities at the mesoscopic level, and global economy at the macroscopic level, is discussed in the context of new economic studies (Martin and Sunley 2007). Given the context of the present study, network analysis can be applied to datasets of B2B networks effected by macroeconomy as mezzo-level analyses (Easley and Kleinberg 2017). To clarify the relationships between macroeconomics and the B2B networks, the present study requires methods of evaluating networks that connect between microscopic and macroscopic behavior.

Social network analyses for quantifying logistic relationships were used and discussed in a related study (Carter et al. 2007). In the studies of network analysis, there are networks of accounts on social networking services (Ahn and Park 2015; Del Vicario et al. 2015), transport networks (Kaluza et al. 2010; Allard et al. 2017), industrial networks of the global transactions (Yu et al. 2013), industrial networks in local regions (Takeda et al. 2008) and so on. A related studies (Rosenkopf and Padula 2008) investigated the evolutionary processes of B2B networks in the mobile communication industry. As one of the most important perspective for the present study, the concepts of core-networks and peripheral-networks have been discussed based on the movie industries (Cattani and Ferriani 2008). In this related study, core-networks are the central structures in networks, while peripheral-networks are the sub-structures around the central structures. Moreover, the properties of scale-free networks can also be seen in various social networks (D'Souza et al. 2007). A complex network that exhibits power-law behavior can be regarded as a scale-free network that comprises many nodes with few connections and a few nodes with many connections.

The properties of scale-free networks have been discussed in the context of actual social networks (D'Souza et al. 2007; Baraba'si and Bonabeay 2003) and the theoretical models such as the Baraba'si-Albert model, which is the best-known computational model that demonstrates the relevancies between power-law in the complex networks and adaptive behaviors of network factors (Albert and Baraba'si 2002). Furthermore, the controllability of complex networks has been discussed based on dynamical-system models (Liu et al. 2011). A related study that used theoretical models noted that network structures are deeply related to adaptiveness for economic changing and environmental changes (Fabrikant et al. 2002).

However, the B2B networks effected by economic fluctuations have not been investigated sufficiently in empirical network analysis, and economic responses of industries based on complex networks are also poorly understood. By using network analysis, we can understand how economic fluctuations affect the B2B networks. The perspective of the core-networks and the peripheral-networks with the responses to the exchange rate was applied to characterize the B2B networks.

Perspectives of evaluating B2B networks and how the macroeconomy changes them

Here, this paragraph gives an economic perspective based on our earlier review ("history and industrial structures of the Japanese textile and apparel industry" section) of the history and industrial structure of the Japanese textile and apparel industry. Overall, based on general macroeconomic theory, the present study interprets from the history and nature of the Japanese textile and apparel industry that the industry has changed with fluctuations in the global economy (Mankiw 2017). The structure of the industry has changed because of the comparative advantages of exporting and importing that were mentioned in the earlier section. There are international companies and domestic companies because the industries had experienced foreign outflows in the economic fluctuations represented as the USD/JPY exchange rate. Generally, the USD/JPY exchange rate is an index of the value valance between the two currencies. The present study regards these industrial structures as B2B networks that comprise various companies and their trading. The present study also focuses on the relationship between international and domestic companies within the B2B networks using the USD/JPY exchange rate. When the USD/JPY exchange rate is higher value, international companies that do not depend on the Japanese economy have an advantage over domestic companies because they trade products in USD. In other words, the international companies can use the stronger USD to increase the trading volumes in various products, and their trading is altered by the USD/JPY exchange rate. Oppositely, when the USD/JPY exchange rate is lower, domestic companies that depend on the Japanese economy have an advantage over international companies because they trade products in JPY. In other words, the domestic companies can use the stronger JPY to increase the trading volumes in various products, and their trading is again altered by the USD/JPY exchange rate. These two natures are typical macroeconomics, and the authors used the macroeconomics of importing and exporting to estimate how the exchange rate influences the B2B networks.

Here, this paragraph gives a topological perspective with economics based on our earlier of reviews ("history and industrial structures of the Japanese textile and apparel industry" section and "B2B networks as complex systems" section) of complex systems. The companies and their trading can be regarded as the networks which are characterized by the method of network analysis. In other words, the changing of trading volumes can be regarded as the changing of the networks. In the present context, adaptive behaviors to economic fluctuations caused by the USD/JPY exchange rate is similar to that in related studies of scale-free structures. As companies within B2B networks try to increase their wealth, they behave adaptively with respect to each region and their natures in the environmental changes as the USD/JPY exchange rate. In the present context, adaptiveness regarding the various companies is regarded as responding to the USD/JPY exchange rate. Considering related studies that proposed the scale-free caused by adaptiveness of the components, the B2B networks of the Japanese textile and apparel industry can be hypothesized to exhibit also scale-free feature as statistical properties. The present study regarded the concepts of scale-free that core-networks correspond to a few central companies with many connections, the peripheral networks correspond to middle or non-central companies with a few connections. Considering the adaptiveness of Japanese companies to the exchange rate, the core networks as represented by indexes of network analysis correspond to international companies, and the peripheral networks represented by indexes of network analysis correspond to domestic companies. Because the industries are affected by the global economy, international companies are more adaptive than the domestic ones. In other words, the international companies as the core networks can be hypothesized that their responses correlated positively with the USD/JPY exchange rate. On the other hand, the domestic companies as the peripheral networks can be hypothesized their responses correlated negatively with the USD/JPY exchange rate. Based on these interpretations, the present study attempted to use the USD/JPY exchange rate to explain the changing structures to the B2B networks. We can explain the fluctuations of social systems based on the methods of evaluating the B2B networks considering the characteristics of the industry.

Hypotheses and conceptual models

Statistical nature and changes in the B2B network structures caused by the USD/JPY exchange rate

The main purpose of the present study is to discuss the changing structures that have occurred in the B2B networks in the Japanese textile and apparel industry. The present study hypothesized that the B2B networks are affected by the USD/JPY exchange rate. As shown in Fig. 2, the conceptual model involves two approaches and three perspectives. In the conceptual model as applied, the explanatory variable is the USD/JPY exchange rate, and the responses variable is the B2B network composing both international companies and domestic companies.

The first approach investigates the statistical properties of the entire networks. This approach is illustrated in the explanatory variable of ① in Fig. 2. This approach reveals whether the trading volumes of the companies within the B2B networks obey power-law.

The second approach focuses on how the internal connectivity of the entire network changes with the USD/JPY exchange rate. This approach are illustrated in the explanatory variable and the responses variable of ② and ③ in Fig. 2. In detail, an economical relationship is hypothesized that ② USD/JPY affects the international companies within the B2B networks as a positive response. Also, international companies can be abstracted by the index of core-networks. Given that economic systems are open to the world, the international companies that are not regionally dependent are more adaptive, and trade in large trading volumes. Oppositely, an economical relationship is hypothesized that ③ USD/JPY affects the domestic companies within the B2B networks as a negative response. Also, domestic companies can be abstracted by the index of peripheral-networks. The domestic companies which depend on the specific regions adapt to the domestic economy, and they have smaller trading.

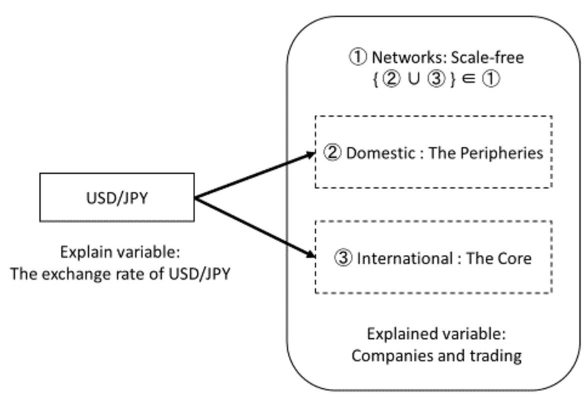

Fig. 2 The conceptual model which consists of three sections

Methods

Subjects: B2B networks of Japanese textile and apparel industry

This section discusses the datasets in detail. The sets of apparel company name with the supplier's company name in men's apparel, women's apparel, total-apparel, children's apparel, innerwear, jeans, and designers are entered into the datasets from Fashion and Bland guide performed by textile and apparel industry newspaper company in Japan (*Senken shimbunsha* (Senken-shimbun company) 2005–2010). The apparel companies trade with supplier companies in the form of textile companies, dyeing companies, knitter companies, fabric companies, trading companies, retailing companies, and so on. Our focus in the present study was on the datasets of total-apparel in (*Senken shimbunsha* (Senken-shimbun company) 2005–2010). In general, total-apparel companies connect with various textile and apparel companies in conceptual structure in Fig. 1. In other words, the datasets of the total apparel companies represent the typical characteristics of the Japanese textile and apparel industry. The trading volumes in the datasets are as follows: 279 companies in 2005, 247 companies in 2006, 279 companies in 2007, 269 companies in 2008, 240 companies in 2009, and 249 companies in 2010. The reason for the time span of the datasets is that the USD/JPY exchange rate underwent two trend fluctuations during that time, namely a stronger USD from 2005 to 2007 and a stronger JPY from 2008 to 2010, therefore using this time span, introduces both USD/JPY perspectives into the analyses. This study applied these datasets to generate networks as the B2B networks.

Definitions for network analysis

This section describes the basic concepts of network analysis. In particular, this section describes the definitions for networks based on Kolaczyk and Csa'rdi (2014), after which the section discusses methods of degree distributions and the indexes for the core-networks and peripheral-networks. First, a network consists of nodes and edges. In this study, a node can be defined as a company name and a supplier name based on the datasets (*Senken shimbunsha* (Senken-shimbun company) 2005–2010) at every year, an edge can be defined as trading between the two companies. The B2B networks are defined based on network analysis Easley and Kleinberg (2017) and Kolaczyk and Csa'rdi (2014); B2B networks: $G(V, E)$, a set of companies: $V = v_1, v_2, ..., v_i$, a set of trading: $E = e_{11}, e_{12}, ..., e_{ij}$. In this study, the network features are given based on the datasets of nodes and edges. A node is denoted by v_i, an edge is denoted by E_{ij}, and these indexes represent a trading relationship between companies. The total number of nodes is denoted by N, the total number of edges is denoted by E, and the degree is denoted by k. The degree k is the number of edges for a node, which in turn represents the number of business partners in a company. Based on these basic definitions, the methods of statistical analysis and the indexes of the networks are denoted as the following sections.

First approach: statistical network analyses

The degree distribution can be calculated using the frequencies of the number of degrees k within the entire networks. Figure 3 shows conceptually the processes of the degree distribution and the complementary cumulative distribution function (CCDF) (Downey 2018). Converting a list of degrees into the frequencies of the degree size generates the

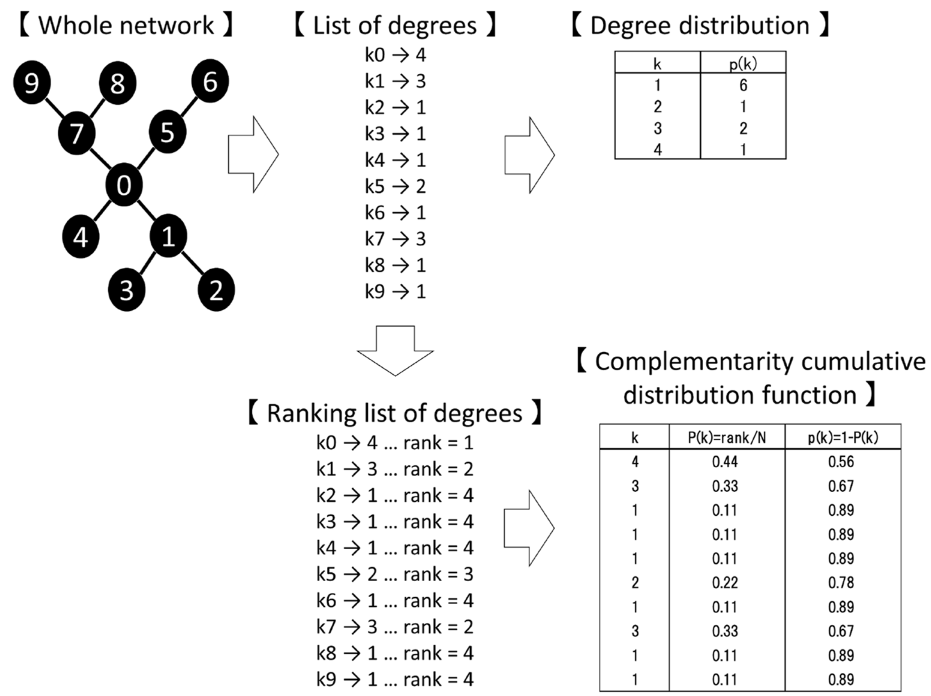

Fig. 3 Conceptual figure of the analysis based on degree distribution and CCDF

degree distributions. As well as the frequencies, a ranking list is also applied for the statistical network analysis. The authors converted the list of degrees as follows: the degrees are ranked by their size k, the list of *Rank* is divided by the number of samples N as the normalized cumulative function $P(k)$, and the CCDF is obtained as $p(k) = 1 - P(k)$. Using this analysis, it is possible to determine the statistical properties of the number of degrees within the entire networks. Comparisons among many networks are also possible because these statistical results are normalized. These CCDF were converted to the log-log scale. The statistical models of the log-log distributions were fitted using a linear model denoted as $p(k) \sim C \cdot k^{\gamma}$ that obeys the rule of power-law on degree distributions as CCDF.

The present study uses the model of power-law to evaluate whether the entire network obeys the scale-free network. If the coefficient γ is in the range of $-3 \leq \gamma \leq -1$, then the networks obey a power-law and is also scale-free (Baraba'si 2009). If the statistical properties of the network obey power-law, then the network comprises a few companies with high degrees and many companies with low degrees. In this statistical modeling of $p(k) \sim C \cdot k^{\gamma}$, the coefficient γ denotes the slopes, whereas the coefficient C denotes the segments. Moreover, linear models based on the least-squared method evaluated on the CCDF were determined based on the best R squared and the significance level of p-value < 0.05. The statistical models were tested using the hypothesis test with the significance level, $H0 : \gamma = 0$, $H1 : \gamma \neq 0$. The slope coefficient, γ, was applied to evaluate the scale-free properties. Some of the statistical properties such as the slopes, the segments, R squared, and p-value were calculated by "igraph" (2019), and "MASS" (2019) in R packages.

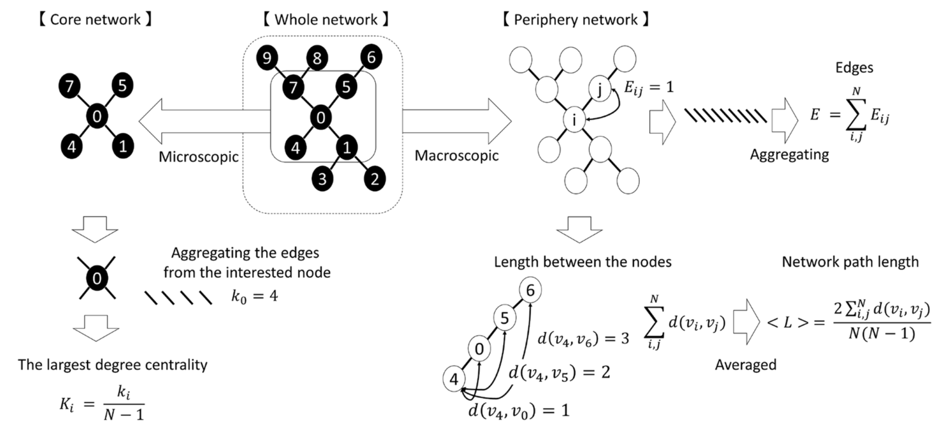

Fig. 4 Illustrations of the set relationships between the indexes and networks with the perspectives

Second approach: changing network structures with the USD/JPY exchange rate

The present study focuses on networks that comprise domestic companies as the peripheral-networks and international companies as the core-networks. Figure 4 shows the set relationships between the two perspectives and the network indexes. The present study defines the peripheral networks using edges (Eq. 1), network path length (Eq. 2), the core networks are defined using degree centrality (Eq. 3). It needs to pay attention that these definitions are not always applied to characterize networks in the context of the complex systems. In Fig. 4, the peripheral networks involve holistic relationships based on a macroscopic perspective, whereas the core networks involve partitive relationships based on a microscopic perspective.

Indexes of the macroscopic characteristics as peripheral networks

This section discusses the indexes of macroscopic properties as domestic companies in the networks. The present study used simple indexes to determine the macroscopic as domestic companies in the entire network, namely the edge number and the network path length. The edge number is denoted as E in Eq. 1 and reflects the trading volumes within the entire network. If there is a link between the nodes v_i and v_j, then the edge is counted as $E_{ij} = 1$. Also, the index is illustrated in the peripheral networks in Fig. 4. The index E is given by:

$$E = \sum_{ij}^{N} E_{ij} \tag{1}$$

The network path length L is the index that describes the average number of intervals between companies within the entire network (Eq. 2). The total number of intervals $d(v_i, v_j)$ between nodes is denoted L, which is divided by the total number of edges within a complete network. In Fig. 4, the interval between nodes v_i and v_j is counted as $d(v_i, v_j) = 1$ if there are no nodes between v_i and v_j. The complete network is defined as a network that the all nodes have the edges to each other. The index can deduce using this index whether the entire network is centralized or decentralized. This index can also describe changes in the peripheral networks, and also characterizes non-hub networks. The index is illustrated in peripheral networks in Fig. 4. The index of $\langle L \rangle$ is given by:

$$\langle L \rangle = \frac{2 \cdot \sum_{ij}^{N} d(v_i, v_j)}{N(N-1)} \tag{2}$$

Index of the microscopic characteristics as core networks

The present study used a simple index to determine the microscopic properties of the entire networks, namely the DC, which describes the number of trading of a company within the entire network (Eq. 3), and is denoted by K_i. The degree is counted as the number of edges from the node in Fig. 4. This index is applied to the core-networks, which have more edges. The number of degree k_i on nodes is divided by the total number of nodes $N-1$ excluding node v_i. This index can be applied to deduce whether the number of trading on a company has increased or decreased. The index of K_i is given by:

$$K_i = \frac{k_i}{N-1} \tag{3}$$

These network indexes for characterizing macroscopic and microscopic features are calculated using "igraph" (2019) in R packages.

Regression analysis between the USD/JPY exchange rate and network indexes

The second approach focuses on the internal connectivities between the entire network and the USD/JPY exchange rate. This section discusses the method of this approach. The network indexes of the macroscopic characteristics and microscopic characteristics are analyzed against the corresponding USD/JPY exchange rate. The present study constructed datasets of the USD/JPY exchange rate by calculating the mean value using the final value and the first value in the years from 2005 to 2010. These controlled datasets are denoted as $\langle USD/JPY \rangle$, and the exchange rate is defined as the explanatory variable for the corresponding network indexes. Oppositely, the network indexes of the edge number E, the network path length $\langle L \rangle$, and the degree centrality K_i are controlled as the response variables. The authors analyzes these indexes using single-factor regression analysis based on the least-squares method. In these cases, the statistical models are as follows: the macroscopic index for domestic companies as $\langle E \rangle = a \cdot \langle USD/JPY \rangle + b$, $\langle L \rangle = a \cdot \langle USD/JPY \rangle + b$, and the microscopic index for international companies as $K_i = a \cdot \langle USD/JPY \rangle + b$. The authors abstracted two of the companies using the list of the number of trading in the datasets of 2010 based on the two tops of the largest number of degree K_i. The companies were named as company A and company B. The present study uses the two largest companies with the largest number of trading to analyze the microscopic behavior of the international companies in the networks. Furthermore, the linear models were determined to assume the relationships between the networks and the USD/JPY exchange rate based on the best R squared and the significance level of p-value < 0.05. The statistical models were determined using the hypothesis test with the significance level, $H0: a = 0$, $H1: a \neq 0$. This hypothesis testing distinguishes whether the correlations between the variables do not exist. These regression analyses were conducted by "MASS" in R packages (2019).

Pretreatments for analyzing B2B networks

The present study analyzed the datasets of the Japanese textile and apparel industry. This section discusses the pretreatments of the datasets for the analyses. The authors generated complex networks using the data of the company name and the supplier company name of the total apparel companies in these datasets (*Senken shimbunsha* (Senken-shimbun company) 2005–2010). In this case, these companies are included in the category of the total-apparel company. Furthermore, the supplier companies of the total-apparel company come from various type of industries and companies. The present study analyzed the datasets to estimate how the B2B networks changed from 2005 to 2010. Therefore, six entire networks were generated. Some isolated nodes and self-looped edges were removed from these datasets. Duplicated edges were replaced as a single edge. These pretreatments were conducted using "igraph" (2019) in R packages.

Results

First approach: statistical network analysis

Figure 5 shows the degree distribution of the entire network converted as the CCDF for (a) 2005, (b) 2006, (c) 2007, (d) 2008, (e) 2009, and (f) 2010. Table 1 presents the linear fitting models of the degree distributions converted as the CCDF of the whole networks. In Table 1, R-squared represented the fitness of statistical models of the actual datasets as follows: $R^2 = 0.954$ in 2005, $R^2 = 0.943$ in 2006, $R^2 = 0.950$ in 2007, $R^2 = 0.941$ in 2008, $R^2 = 0.942$ in 2009, and $R^2 = 0.946$ in 2010. The significance level for the slope coefficient in these years are p-value $< 2.20 \times 10^{-16}$ in 2005, p-value $< 2.20 \times 10^{-16}$ in 2006, p-value $< 2.20 \times 10^{-16}$ in 2007, p-value $< 2.20 \times 10^{-16}$ in 2008, p-value $< 2.20 \times 10^{-16}$ in 2009, and p-value $< 2.20 \times 10^{-16}$ in 2010. The significance level of the slope coefficients γ in these years were p-value < 0.05. In each case, the hypothesis $H1 : \gamma \neq 0$ was satisfied under these conditions. The statistical properties of the degree distributions converted as the CCDF were evaluated as $p(k) \sim C \cdot k^{\gamma}$. In particular, the slope coefficients in these fitting models were represented as follows: $\gamma = -1.45$ in 2005, $\gamma = -1.41$ in 2006, $\gamma = -1.42$ in 2007, $\gamma = -1.36$ in 2008, $\gamma = -1.42$ in 2009, and $\gamma = -1.48$ in 2010. The slope coefficients were in the range of $-3 \leq \gamma \leq -1$, which was fulfilled the requirements of scale-free

Table 1 Estimated linear models on the degree distributions converted as CCDF

Whole network: CCDF	γ: slope	C: segment	R-squared	p-value
2005	− 1.45	− 0.131	0.954	< 2.20E−16
2006	− 1.41	− 0.119	0.943	< 2.20E−16
2007	− 1.42	− 0.120	0.950	< 2.20E−16
2008	− 1.36	− 0.123	0.941	< 2.20E−16
2009	− 1.42	− 0.130	0.942	< 2.20E−16
2010	− 1.48	− 0.136	0.946	< 2.20E−16

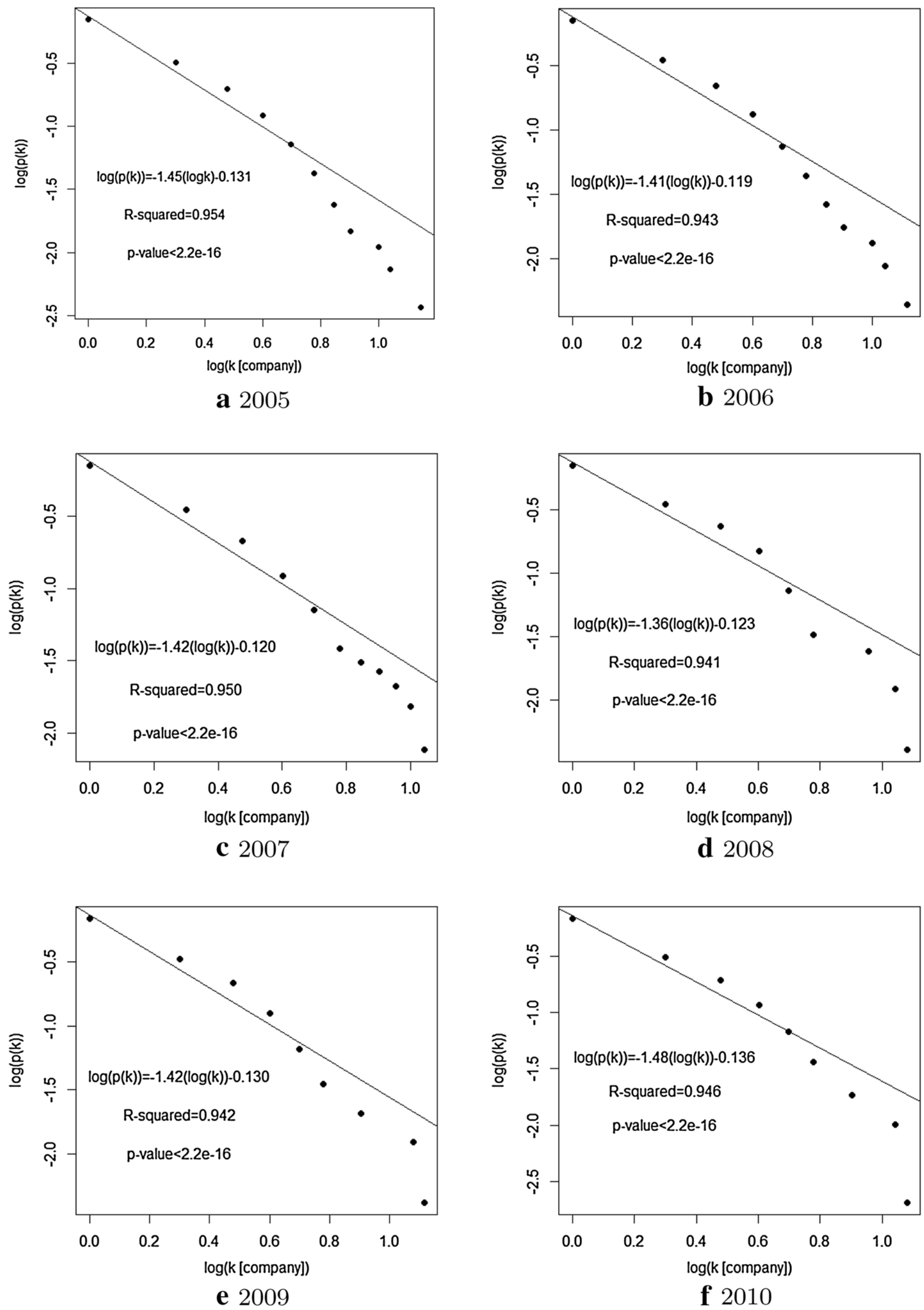

Fig. 5 Degree distributions converted as CCDF from B2B

Table 2 Estimated linear models on the indexes

Explain value	Explained value	a: slope	b: segment	R-squared	p-value
Exchange rate [USD/JPY]	E (company)	0.635	195	0.246	0.317
	L (company)	−2.94E−02	8.42	0.793	1 74E−02
	K_A	5.89E−04	−3.90E-03	0.744	2.70E−02
	K_B	−6.78E−04	0.112	0.528	0.102

networks. The results indicated that the scale-free networks were detected for these years.

Second approach: changing structures of the B2B networks with the USD/JPY exchange rate

Figure 6 shows how the changing network structures are related to the exchange rate of $\langle USD/JPY \rangle$: (a) the edge number E, (b) the network path length $\langle L \rangle$, (c) the degree centrality K_A, and (d) the degree centrality K_B. Table 2 presents the indexes of the edge number, and the network path length with the exchange rate of $\langle USD/JPY \rangle$. Table 2 also presents the indexes of the degree centrality of company A and company B with the exchange rate of $\langle USD/JPY \rangle$.

For E in Table 2, the fitness of its statistical model was given by $R^2 = 0.246$, and the significance level for the coefficient was p-value $= 0.317$. The significance level for the coefficient a was p-value > 0.05, this index was not reached on significance level. In this case, the hypothesis $H0 : a = 0$ was not rejected (Fig. 6).

$\langle L \rangle$ in Table 2, the fitness of its statistical model was given by $R^2 = 0.793$, and the significance level for the coefficient was p-value $= 1.74 \times 10^{-2}$, the significance level for the

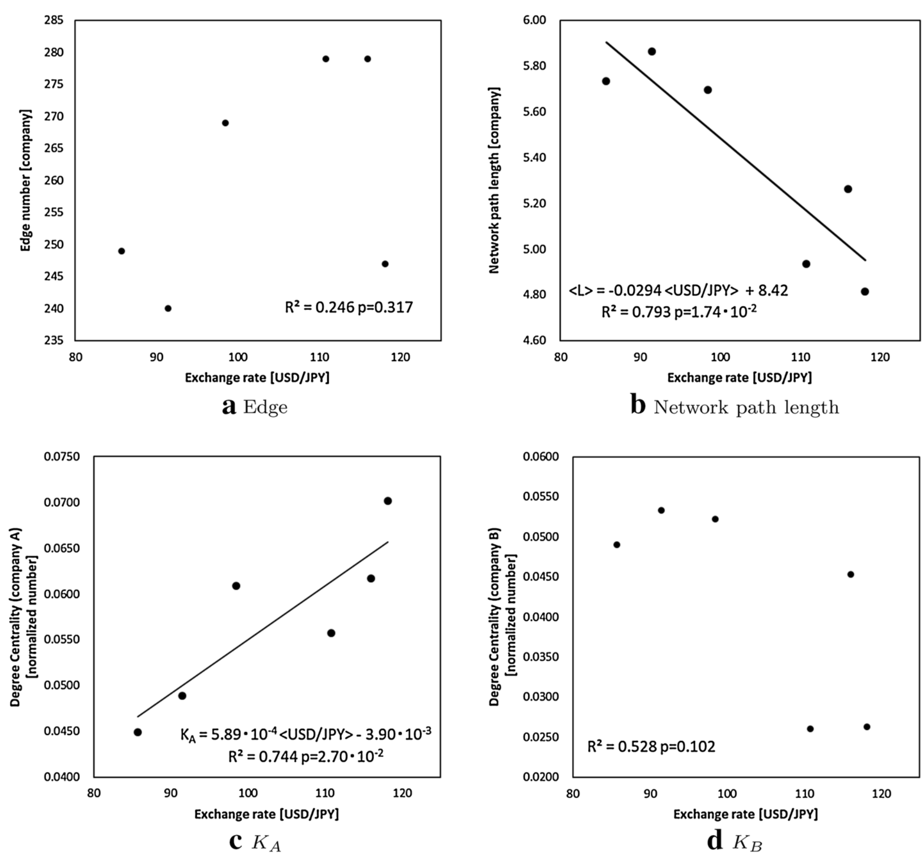

Fig. 6 Two network indexes with the USD/JPY exchange rate: **a** The edge number as the macroscopic index shows no correlation. **b** The network path length as a microscopic index shows a negative correlation. **c** The degree centrality of company A as a microscopic index shows a positive correlations. **d** The degree centrality of company B as a microscopic index shows no correlation

coefficient a was p-value < 0.05. In this case, the hypothesis $H1 : a \neq 0$ was obtained. The slope coefficient was the negative number: $a = -2.94 \times 10^{-2} < 0$. Thus, the network path length showed the negative correlation to the exchange rate of $\langle USD/JPY \rangle$.

K_A in Table 2, the fitness of its statistical model was given by $R^2 = 0.744$, and the significance level for the coefficient was as follow: p-value $= 2.70 \times 10^{-2}$. The significance level for the coefficient a was p-value < 0.05. In this case, the hypothesis $H1 : a \neq 0$ was obtained. The slope coefficient was the positive number: $a = 5.89 \times 10^{-4} > 0$. Thus, the degree centrality showed the positive correlation to the exchange rate of $\langle USD/JPY \rangle$.

K_B in Table 2, the fitness of its statistical model was given by $R^2 = 0.528$, and the significance level for the coefficient was as follow: p-value $= 0.102$. The significance level for the coefficient a was p-value > 0.05, this index was not reached on significance level. In this case, the hypothesis $H0 : a = 0$ was not rejected.

Discussion

First approach: statistical properties of the B2B Networks

This paragraph discusses the statistical properties of the Japanese textile and apparel industry respect to the first approach. The degree distributions converted as the CCDF showed that the networks have scale-free properties, power-law models given by $p(k) \sim C \cdot k^{\gamma}$ were obtained from the hypothesis testing. Furthermore, the slope coefficient γ in the statistical models indicated negative values which fulfilled the requirements for the scale-free networks (Fig. 5, and Table 1). The results of these network analyses indicated that the B2B networks in the Japanese textile and apparel industry have scale-free structures. In other words, the B2B networks comprised a few companies that had large trading volumes, and many companies that had low trading volumes.

Second approach: changing structures of the B2B networks with the USD/JPY exchange rate

In Table 2, the network path length showed that the changing structures of the entire network were correlated negatively with the USD/JPY exchange rate, which is represented as $\langle USD/JPY \rangle$. Furthermore, the degree centrality showed that the changing structures were correlated positively with the USD/JPY exchange rate, which is represented as $\langle USD/JPY \rangle$. These results showed that the changing structures within the entire network obey complementarity between the network path length and the degree centrality. In the context of this study, the complementation showed the relevance of importing and exporting.

The network path length grew when the exchange rate represented as $\langle USD/JPY \rangle$ was lower value. Generally, when USD/JPY is lower value, Japanese domestic companies can decrease the costs of importing materials. In other words, the changing of the networks based on the network path length was typical Japanese domestic industry because most of the Japanese industries are lacking in materials due to their geographical backgrounds. The domestic companies characterized by the network path length can import the materials for textile productions effectively when USD/JPY is a lower value.

Oppositely, the degree centrality of company A grew when the controlled as $\langle USD/JPY \rangle$ was higher value. Generally, when USD/JPY is higher value, international companies can decrease the costs of exporting products from producing areas. In other words, the changing of the networks based on the degree centrality was mass production and international companies because most of the mass production industries with many connections depend on producing foreign areas. The international companies characterized by the degree centrality could export the materials for textile productions effectively when USD/JPY was higher value. These results show that the network structures were also affected by the changing global economy.

Changing networks caused by the USD/JPY exchange rate

This section discusses the implementations of the results. The entire B2B networks obey a power-law on the basis of the results of the statistical models (Fig. 5, Table 1). In the case of a power-law in the complex networks, there are scale-free structures. In addition, these networks comprised core networks and peripheral networks, Fig. 7 shows how the networks changed over time.

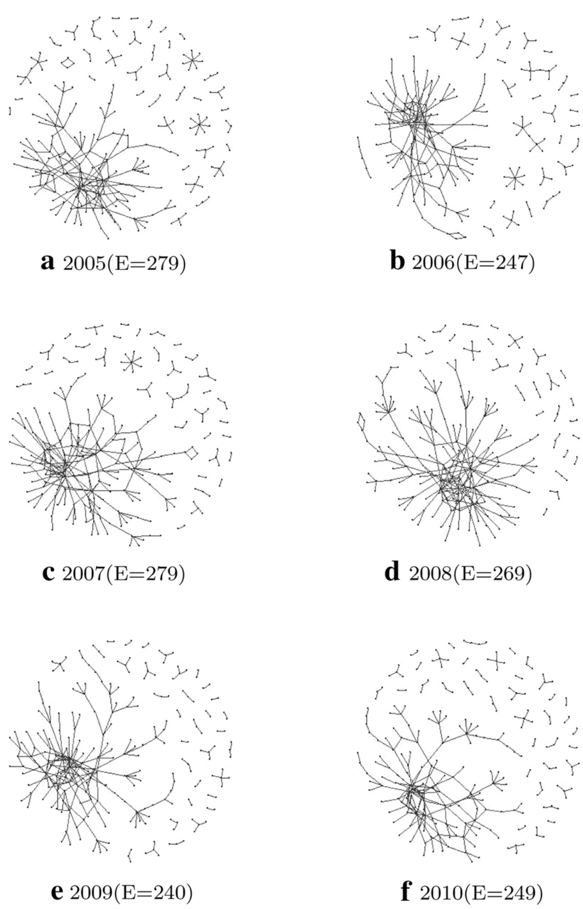

Fig. 7 Changes in B2B networks over time. The networks comprises the core and peripheral structures and show that the edges are aggregated toward the centers of the networks. There are also peripheral-networks around the core-networks

The present study investigated the network path length as the peripheral networks with the exchange rate of $\langle USD/JPY \rangle$. The network path length as the peripheral networks with the exchange rate of $\langle USD/JPY \rangle$ represented the domestic industries in Japan as the negative correlation. In addition, the degree centrality of company A as the core networks are also investigated with the exchange rate of $\langle USD/JPY \rangle$. The degree centrality of company A with the exchange rate of $\langle USD/JPY \rangle$ represented the international companies as the positive correlation. In other words, the peripheral networks behave as domestic industries based on the adaptive trading in the economic fluctuations. The core networks behave as international trading companies based on the adaptive trading in the economic fluctuations. As a result, a complementarity was clarified as the characteristics of the networks (Fig. 6, Table 2).

Figure 8 shows the illustrations of the whole results of this study. From the first approach, the whole networks every year were the scale-free which comprises the core networks and the peripheral networks. From the second approach, complementarity as the B2B networks with the exchange rate of USD/JPY was discussed. The core-networks as trading companies adapted to the fluctuations of the global economy. Because Japanese textile and apparel industries had grown as international industries after the trade friction in the 1960s. Besides, most of the apparel productions had to maintain low-cost manufacturing for commoditized markets. When the USD/JPY exchange rate is lower, which means that USD is stronger than JPY, manufacturing and exporting at low cost is possible by the core networks whose departments of productions are in foreign areas. Oppositely, the peripheral networks are adapted to the internal trading in Japanese domestic industries. To import materials when USD/JPY is higher value, which means that JPY is stronger than USD, requires effective trading and manufacturing for the peripheral networks. These changing structures as the complementarity and the adaptive behavior also made the whole B2B networks the scale-free composed of the core-networks corresponded to the international trading companies and the peripheral-networks corresponded to the domestic industries.

Contributions to complex systems

This section discusses a strategy for adaptations based on complex systems to trade frictions as the environmental changing. Some previous studies that focused on complex

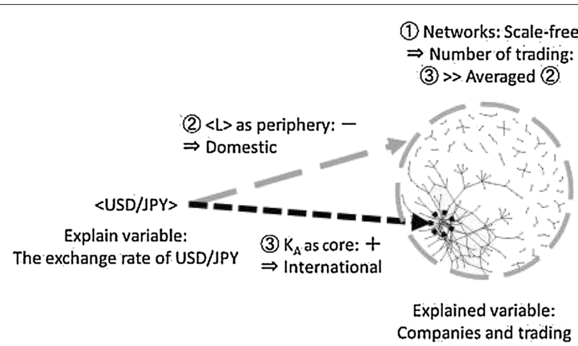

Fig. 8 Illustrations of the results. The USD/JPY exchange rate affected by the peripheral networks and the core networks. The whole networks obeyed the scale-free that comprises the core-networks and the peripheral networks

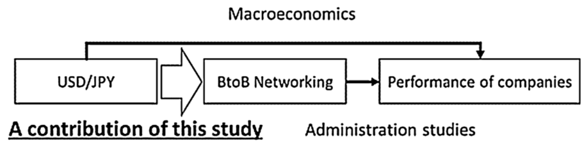

Fig. 9 Contribution of this study

networks have also shown that networks comprise core and peripheral networks. For example, movie industry networks of creators also comprise of core and peripheral networks (Cattani and Ferriani 2008). Besides, various studies of networks of Twitter accounts have also shown that the network structures are the scale-free (Ikegami et al. 2017), and comprise core and peripheral networks (Cattani and Ferriani 2008). These behaviors within core and peripheral have also been discussed regarding the adaptiveness of swarms, and the processes of generating new ideas (Craig 1987). The present study added a case of adaptive behavior in complex networks that comprise of core and peripheral networks in the presence of economic fluctuations.

Generally, that cores of networks are more adaptive to environmental changing is discussed in the context of complex systems. Because the agents of the systems can reach adaptation based on the most adaptive behavior under the same environmental changing. It is easy to reach adaptation for the agents taking the most adaptive behavior. However, adaptive behavior alone cannot create new ideas or methods for adjusting to environmental changes. When the most adaptive communities cannot adjust to environmental changes, peripheries can also introduce new ideas and methods to an entire system. This is why the interactions and networking between core and peripheral are important. In the context of the multi-agent systems, reinforcement learning is implemented with algorithms that are epsilon-greedy methods (Sutton 1990). The algorithm for an agent controlling also comprises the most adaptive attitude and exploratory attitudes. In other words, in the context of this study, the peripheral networks such as domestic industries can survive based on another strategy differentiates from the most adaptive strategies in the fluctuating economy. Besides, the core-networks do not have to only take comparative advantage and the most adaptive strategy under the fluctuating economy. Because there is possibilities that various ideas and interactions on the networks make industries sustainable under the fluctuating economy.

Contributions to economics and business administration studies

Industrial networking has also been discussed thoroughly in the context of business administration studies. For instance, there are *zaibatsu-system* (in Japanese) (Miwa and Ramseyer 2003) and *keiretsu-system* (in Japanese) (McGuire and Dow 2009). Main bank system of the companies which can keep trust relationships between the banks and the companies is also discussed as networking for business strategy as financial arrangements (Aoki and Dore 1994). These systems are in the traditional Japanese management style, which connects within homogeneous communities as an aggregation of sub-communities. Related studies of these systems have also shown that networking between companies affects the performances of companies in industries. Generally, macroeconomics such as international trade theory deals with industries and the exchange rate in various nations (*Senken shimbunsha* (Senken-shimbun company) 2005–2010). Moreover, some business administration studies have shown how the exchange rate affects the performances of Japanese industries (Jorgenson and Kuroda 1992). A related study (Breuer and Clements 2003) investigated how the affects of the yen/dollar exchange rate to the various industries based on the macroeconomic methods focused on the relationships of the U.S., Canada, and Japan. In other words, there are not known well based on numerical methods focused on B2B networks itself. However, the present study focusing on the Japanese textile and apparel industry has shown how currencies as a global economy affect B2B networks as complex structures. Figure 9 shows conceptually how the present contributions compare with those of previous studies. Figure 9 illustrates that the relationships between networking within the companies affects to the performances of the companies are already discussed (Miwa and Ramseyer 2003; Aoki and Dore 1994). Also, the relationships between macroeconomics and company have already been discussed (Mankiw 2017; Jorgenson and Kuroda 1992; Breuer and Clements 2003). The present study contributes to understanding the relationships between macroeconomy and B2B networks that comprise of core-networks as the international companies and peripheral-networks as the domestic companies.

Conclusions

Complex systems of the B2B networks

The changes in related structures of the B2B networks in the Japanese textile and apparel industry were evaluated as a scale-free network within the core and peripheral networks. In the present study, the first approach found the power-law as statistical properties in the entire network. These results showed that the entire network comprised a few companies with high degrees and many companies with low degrees, which also continued on these natures. The second approach found correlations by regression analyses using the network indexes and the USD/JPY exchange rate. This approach showed that the peripheral networks correlated negatively with the USD/JPY exchange rate and that the core networks were correlated positively with the USD/JPY exchange rate. These results were interpreted as the complementarity which was not only economic characteristics of importing and exporting but also the changing of the B2B networks.

As a conclusion of the present study, it was clarified that the changing structures of the B2B networks obeyed complementarity between core and peripheral networks was clarified. The networks comprised core and peripheral networks as a power-law. The core networks, which corresponded to international trading companies, adapted to the global economy. The peripheral networks, which corresponded to domestic industries, adapted to the Japanese domestic economy. These B2B networks that comprise internal connectivities as the peripheral and external connectivities as the cores had been affected by the USD/JPY exchange rate.

Future work

One of the possibilities on the methods which are objective evaluations of B2B networks considering unique characteristics of the industry were shown. The present study conducted analyses using actual datasets, these patterns found can be tested using agent-based modeling which is a simulation tool for social science. In future works, the authors try to demonstrate changing B2B networks using computational models.

Besides, B2B networks are also affected by behavioral interactions between apparel companies and their customers. Nowadays, customers share various informations on social media on a customers-to-customers (C2C) basis, and the authors will propose a mixed study that involves empirical methods and computation based on a B2B–C2C perspective.

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Authors' contributions
The first author analyzed the data, discussed the results, proposed the conclusions for this study. The second author and the third author discussed the validity of the results and the conclusions. All authors read and approved the final manuscript.

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Availability of data and materials
The datasets and material applied in this study are available from the texts.

Competing interests
The authors declare that they have no competing interests.

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References

Ahn, H., & Park, J. H. (2015). The structural effects of sharing function on Twitter networks: Focusing on the retweet function. *Journal of Information Science*, *41*(3), 354–365. https://doi.org/10.1177/0165551515574974.

Albert, R., & Baraba'si, A. L. (2002). Statistical mechanics of complex networks. *Reviews of Modern Physics*, *74*(1), 47–97. https://doi.org/10.1103/RevModPhys.74.47.

Allard, A., Serrano, M. A., Garcia-Perez, G., & Boguna, M. (2017). The geometric nature of weights in real complex networks. *Nature Communications*, *8*(14103), 1–8. https://doi.org/10.1038/ncomms14103.

Alvstam, C. G., Strom, P., & Yoshino, N. (2009). On the economic interdependence between China and Japan: Challenges and possibilities. *Asia Pacific Viewpoint*, *50*(2), 198–214. https://doi.org/10.1111/j.1467-8373.2009.01393.x.

Aoki, M., & Dore, R. (1994). *The Japanese firm sources of competitive strength*. Oxford: Oxford University Press.

Baraba'si, A. L. (2009). Scale-free networks: A decade and beyond. *Science*, *325*(5939), 412–413. https://doi.org/10.1126/science.1173299.

Baraba'si, A. L., & Eric, B. (2003). Scale-free networks. *Scientific American*, *288*(5), 60–69.

Breuer, J. B., & Clements, L. A. (2003). The commodity composition of US-Japanese trade and the yen/dollar real exchange rate. *Japan and the World Economy*, *15*(3), 307–330. https://doi.org/10.1016/S0922-1425(02)00052-X.

Carter, C. R., Ellram, L. M., & Tate, W. (2007). The use of social network analysis in logistics research. *Journal of Business Logistics*, *28*(1), 137–168. https://doi.org/10.1002/j.2158-1592.2007.tb00235.x.

Cattani, G., & Ferriani, S. (2008). A core/periphery perspective on individual creative performance: Social Networks and cinematic achievements in the hollywood film industry. *Organization Science*, *19*(6), 824–844. https://doi.org/10.1287/orsc.1070.0350.

CNN. Trump's trade war with China is starting to get out of hand. Retrieved August 13, 2019, from https://edition.cnn.com/2019/08/05/economy/trade-war-china-yuan/index.html.

Craig, W. (1987). Reynolds, flocks, herds, and schools: A distributed behavioral model. *Computer Graphics*, *21*(4), 25–34. https://doi.org/10.1145/37401.37406.

Del Vicario, M., Zhang, Q., Bessi, A., Zollo, F., Scala, A., Caldarelli, G., et al. (2015). Structural patterns of the occupy movement on facebook. *Association for the Advancement of Artificial Intelligence*, *1501*(07203), 1–8. https://doi.org/10.1007/978-3-319-50901-3_47.

Downey, A. B. (2018). *Think complexity*. Sebastopol: O'REILLY.

D'Souza, R. M., Borgs, C., Chayes, J. T., Berger, N., & Kleinberg, R. D. (2007). Emergence of tempered preferential attachment from optimization. *Proceedings of the National Academy of Sciences of the USA*, *104*, 6112–6117. https://doi.org/10.1073/pnas.0606779104.

Easley, D., & Kleinberg, J. (2017). *Networks, crowds, and markets–reasoning about a highly connected world*. Cambridge: Cambridge University Press.
Fabrikant, A., Koutsoupias, E., & Papadimitriou, C. (2002). *Heuristically optimized trade-offs: a new paradigm for power laws in the internet*. In Proceedings of the 29th international colloquium on automata, languages, and programming (ICALP) (pp. 110–122). https://doi.org/10.1007/3-540-45465-9_11.
Gereffi, G. (1999). International trade and industrial upgrading in the apparel commodity chain. *Cornell International Law Journal*, *47*(1), 37–70. https://doi.org/10.1016/S0022-1996(98)00075-0.
Gordon, A. (1985). *The evolution of labor relations in Japan: heavy industry, 1853–1955*. Cambridge: Harvard University Press.
igraph. Retrieved August 13, 2019, from https://igraph.org/.
Ikegami, T., Mototake, Y., Kobori, S., Oka, M., & Hashimoto, Y. (2017). Life as an emergent phenomenon: Studies from a large-scale boid simulation and web data. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *375*(1), 1–15. https://doi.org/10.1098/rsta.2016.0351.
Jorgenson, D. W., & Kuroda, M. (1992). Productivity and international competitiveness in Japan and the United States, 1960–1985. *The Economic Studies Quarterly*, *43*(4), 313–325. https://doi.org/10.11398/economics1986.43.313.
Kaluza, P., Kolzsch, A., Gastner, M. T., & Blasius, B. (2010). The complex network of global cargo ship movements. *Journal of The Royal Society Interface*, *7*(48), 1093–1103. https://doi.org/10.1098/rsif.2009.0495.
Kim, S. W. (2007). Organizational structures and the performance of supply chain management. *International Journal of Production Economics*, *106*(1), 323–345. https://doi.org/10.1016/j.emj.2014.02.001.
Kiyota, K., & Urata, S. (2004). Exchange rate volatility and foreign direct investment. *The World Economy*, *27*(10), 1501–1536. https://doi.org/10.3386/w4815.
Kolaczyk, E. D., & Csa'rdi, G. (2014). *Statistical analyses of network data with R*. New York: Springer.
Liu, Y. Y., Slotine, J. J., & Baraba'si, A. L. (2011). Controllability of complex networks. *Nature*, *473*(167), 167–173. https://doi.org/10.1038/nature10011.
MASS. Retrieved August 13, 2019, from https://cran.r-project.org/package=MASS.
Mankiw, N. G. (2017). *Principles of economics*. Boston: CENGAGE Learning.
Martin, R., & Sunley, P. (2007). Complexity thinking and evolutionary economic geography. *Journal of Economic Geography*, *7*(1), 573–601. https://doi.org/10.1093/jeg/lbm019.
McGuire, J., & Dow, S. (2009). Japanese *keiretsu*: Past, present future. *Asian Pacific Journal of Management*, *26*(2), 333–351. https://doi.org/10.1007/s10490-009-9160-5.
Miwa, Y., & Ramseyer, J. M. (2003). Does ownership matter? Evidence from the zaibatsu dissolution program. *Journal of Economics & Management Strategy*, *12*(1), 67–89. https://doi.org/10.1111/j.1430-9134.2003.00067.x.
Moyaux, T., & D'Amours, S. (2006). Supply chain management and multi agent systems: an overview. *Studies in Computational Intelligence*,. https://doi.org/10.1007/978-3-540-33876-5_1.
Robertson, P. L., & Richard, N. (1994). Langlois, innovation, networks, and vertical integration. *Forthcoming in Research Policy*, *24*(4), 543–562. https://doi.org/10.1016/S0048-7333(94)00786-1.
Rosenkopf, L., & Padula, G. (2008). Investigating the microstructure of network evolution: Alliance formation in the mobile communications industry. *Organization Science*, *19*(5), 669–687. https://doi.org/10.1287/orsc.1070.0339.
Senisangyo kouzoukaizen jigyoukyoukai (The official institution of Japanese textile and apparel industry). (1996). *Apparel sangyou gairon (The introduction of Japanese apparel industry)*.
Senken shimbunsha (Senken-shimbun company). (2005–2010). *Fashion Brand Guide—FASHION BUSINESS DATA BANK* **(In Japanese)**.
Sutton, RS. (1990). Integrated architectures for learning planning and reacting based on approximating dynamic programing. In Proceedings of the seventh international conference on machine learning (pp. 216–224). https://doi.org/10.1016/B978-1-55860-141-3.50030-4.
Takeda, Y., Kajikawa, Y., Skata, I., & Matsushima, K. (2008). An analysis of geographical agglomeration and modularized industrial networks in a regional cluster: A case study at Yamagata prefecture in Japan. *Technovation*, *28*(1), 531–539. https://doi.org/10.1016/j.technovation.2007.12.006.
Turker, D., & Altuntas, C. (2014). Sustainable supply chain management in the fast fashion industry: An analysis of corporate reports. *European Management Journal*, *32*(1), 837–849. https://doi.org/10.1016/j.emj.2014.02.001.
Urakami, T. (2010). Specialty store strategy within Japanese apparel wholesalers: An empirical analysis. *Journal of Fashion Marketing and Management: An International Journal*, *14*(4), 634–647. https://doi.org/10.1108/13612021011081797.
Wortzel, L. H., & Wortzel, H. V. (1983). Using general trading companies to market manufactured exports from LDCs and NICs. *Management International Review*, *23*(2), 72–77.
Yachi, S. (1989). Beyond trade frictions a new horizon for US-Japan economic relations. *Cornell International Law Journal*, *22*(3), 389–402.
Yamawaki, H. (2002). The evolution and structure of industrial cluster in Japan. *Small Business Economics*, *18*(1), 121–140. https://doi.org/10.1023/A:1015134028.
Yu, C., Davis, C., & Dijkema, G. P. J. (2013). Understanding the evolution of industrial symbiosis research: A bibliometric and network analysis (1997–2012). *Journal of Industrial Ecology*, *18*(2), 280–293. https://doi.org/10.1111/jiec.12073.

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