Supply chain management within global manufacturing networks: a contingency flow-based view

Ruggero Golini (ruggero.golini@unibg.it)
Università degli Studi di Bergamo, Department of Management. Information and Production Engineering

Federico Caniato
Politecnico di Milano, Department of Management. Economics and Industrial Engineering

Matteo Kalchschmidt
Università degli Studi di Bergamo, Department of Management. Information and Production Engineering

Abstract

On the base of a large sample of survey data, gathered within the sixth edition of the International Manufacturing Strategy Survey (IMSS 6), we propose an empirical taxonomy of plants by performing a cluster analysis on the level of inflows and outflows between the plant and the rest of the manufacturing network, as opposed to flows with suppliers and customers. In this way we identify 5 clusters, and subsequently we analyse whether there are relationships with the role of the plant, the location advantages and manufacturing and SC integration programmes.

Keywords: Global Manufacturing Networks, Manufacturing Networks Supply Chain Management, IMSS

Introduction

In recent years, multinational companies (MNCs) based in developed and developing economies have continued their expansion in foreign countries thus creating global production networks. Due to this development, they are considered the backbone of the world economy, MNCs and their supply networks account for some 80 per cent of global trade with an increasing impact on value added, jobs and income (UNCTAD, 2013).

MNC networks are made of subsidiaries with different characteristics, Past research on multi-plant organizations focused mainly on localization decisions as the key focus in designing a MNC network (Shi and Gregory, 1998),with the main driving variable being cost (Schmenner, 1979). In the last years however other contributions have extended the set of variables that can be considered to characterize MNC networks (Feldmann and Olhager, 2013; Ferdows, 1997; Vereecke and Van Dierdonck, 2002).

These contributions consider different variables to describe the role of plants, and typically:

- Localization advantage that characterizes the plant (i.e., low cost resources, proximity to market, access to skills and technology);
- Plant-level responsibility, or level of site competence, that can range from just producing the product as mandated by the headquarters to participate to product and process development.

Previous studies demonstrated that these two variables are independent (Feldmann and Olhager, 2013), and their combination provides the identification of different roles (Ferdows, 1997).

Ferdows (1997) developed a classification of plants in global manufacturing networks that distinguishes plants according to six types: offshore, source, server, contributor, outpost, and lead plant. Ferdows' model has been considered as a reference model in different contributions (Cheng et al., 2011; Vereecke and Van Dierdonck, 2002).

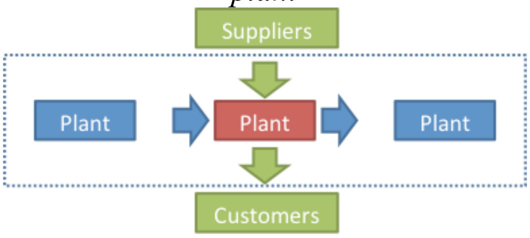
Ferdows classification (and also other models that were derived form this) focuses the attention on the role of the plant mainly looking at the responsibility that each plant has. However, this and other plant-based models fall short in considering that the plant can have internal (i.e., with other plants) and external (i.e., with customers and suppliers) exchanges. In this work in fact we would like to propose a different approach that classifies a plant in a MNC network based on the kind of interactions it has both with the other plants within the manufacturing network and with external suppliers and customers.

Moreover, the role of a plant may not always have a clear relationship with operations and supply chain management practices. Rudberg and Olhager (Rudberg and Olhager, 2003) pointed out that the two perspectives of manufacturing networks and supply chain have never been really integrated. In fact, several studies analyse the different configurations of a manufacturing network (MN) (e.g., horizontal vs. vertical; market vs. process orientation; multinational vs. global; role of the plants) (e.g., Ferdows, 1997; Shi and Gregory, 1998), but the connection with the supply chain (SC) management remains quite unclear.

In this paper, we aim to analyse the relationship between the configuration of a manufacturing network and how the supply chain is configured and managed. As SC management deals with vertical relationships, the two dimensions can interfere (for instance. suppliers can be other plants in the same MN rather than other organizations).

In particular, we propose an innovative view on the issue, i.e. looking at the actual flows of goods entering and exiting from one plant as the connection between the MN structure and SC management. We look at the inflows that can be from either suppliers or other plants and the outflows to either customers or other plants (Figure 1). Based on this conceptual model we may have plants that have mainly exchanges within the manufacturing network (i.e. horizontal exchange thus more focused on the internal manufacturing process) or with external parties (i.e. vertical exchange thus more focused on the specific market or customer) or different combinations of these cases.

Figure 1 – Internal (blue) and external (green) inflows and outflows of goods from one plant



Specifically we aim to achieve three research goals. First of all, we would like to propose a new classification of plants in MN based on the analysis of inflows and outflows. Thus, our baseline hypothesis is related to the framework in Figure 1 at the centre of our framework:

HP0. An emergent taxonomy of plants can be derived from the percentage of internal (i.e. from/to the MN) inflows and outflows of goods?

As a second objective, we aim to relate the proposed taxonomy with existing classification models. To do so, we focused on the antecedents of the different configurations and we aim to verify their association to different MN structures and coordination mechanisms at the plant level.

Literature on the role of the plant has highlighted different variables that influence the role on the plant and specifically (e.g. Ferdows, 1997; Schmenner, 1979) and we tried to associate such drivers with the structure of flows by means of a set of hypotheses.

The first variable is "market scope", that is related to the market/geographic area served by the individual plant. If the plant is serves a local market it can be seen as the local outpost of the manufacturing network, thus *HP1a. Local scope of the market (i.e., the plant serves a specific area) is associated to higher external outflows.*

Next, we considered the "production scope", that is related to the extent to which the plant performs the entire production process. Usually, plants with a small scope are process specialist in a fragmented (vertical) production network, thus *HP1b. Broad scope of the production is associated to lower internal inflows and outflows*.

Furthermore, we considered the level of "control", related to the decisional independence of the plant. Usually, plants that exchange many flows with the rest of the network are less independent, thus *HP1c. Higher control of the plant from the rest of the network is associated to higher internal inflows and outflows.*

"Responsibility" is related to the autonomy in managing internal operations and we followed a similar reasoning as for the control, thus *HP1d. Higher responsibility of the plant is associated to lower internal inflows and outflows.*

Finally we considered the classical two typologies of localization advantage (beside market proximity, already included in the "market scope" variable):

- Low cost advantage: related to whether a specific plant role is to leverage on low costs (for labour, materials. etc.);
- Skill and knowledge advantage: related to whether a specific plant role is to leverage on local presence of high skilled workers, expert suppliers or research centres.

Usually, plants in low cost areas are purchasing or manufacturing outposts for the rest of the network, thus *HP1e. Access to low cost resources is associated to internal outflows.*

Differently, plants that have access to skills and know how will tend to acquire inputs from external sources, thus *HP1c. Access to skills and know how is associated to lower internal inflows.*

As a third objective, we want to verify the connection between the taxonomy and SC management. In our paper, SC management is defined as the integration with suppliers and customers thus as a best practice to improve efficiency and responsiveness (Flynn et al., 2010; Wiengarten et al., 2014). For this reason we consider the following HPs:

HP2a. Higher external inflows are associated to a greater integration with suppliers;

HP2c. Higher external outflows are associated to a greater integration with customers;

HP2c. Lower external inflows and outflows are associated to a greater integration within the company wide network.

Methodology

We test the hypotheses by means of the 2013-2014 International Manufacturing Strategy Survey (IMSS 6) data set (www.manufacturingstrategy.net). This project, originally launched by the London Business School and Chalmers University of Technology, studies manufacturing strategies within the assembly industry (ISIC 25-30 classification) through a common questionnaire administered simultaneously in many countries by local research groups (Lindberg et al., 1998). The main research goal of the project is to investigate the relationships among strategic priorities, manufacturing practices, improvement programs, performance and contingent variables.

Companies are usually selected from local databases and the operations, production or plant manager is contacted regarding the willingness to participate in the research. If the respondent agrees, the link to the online questionnaire is sent out. When necessary, a reminder is sent after a few weeks. Questionnaires that are completed are controlled for missing data, which are handled case by case. Usually by contacting the company again. Finally, all data are grouped into a unique database, which is further controlled by the project coordinator and distributed to all partners.

The first section of the questionnaire is related to the business unit (gathering general information. such as company size. industry. production network configuration. competitive strategy and business performance), whereas the other sections refer to the plant (focusing on manufacturing strategies. practices and performance). Although the structure of the questionnaire has remained the same with every edition, some questions have been updated or removed and new questions have been added by the design team, which is composed of a pool of international researchers, to avoid researchers' country biases (Van de Vijver and Leung, 1997). From the original sample of more than 800 answers, we drew 509 usable answers from companies belonging to 22 different countries. Table 1 shows the distribution of the sample in terms of country, industry and size.

Internal inflows were measured by a question asking in percentage the distribution of value of inputs (materials. components. sub-assemblies products) from other plants/units in the network and double-checked asking the same percentage from external suppliers (sum must be 100%). Internal outflows were measured by a similar question asking in percentage the distribution of value of outputs to other plants/units in the network and double checked asking the same percentage to external customers (sum must be 100%). We applied a hierarchical cluster analysis first, based on squared Euclidean distance and the Ward method, to identify the most suitable number of clusters and the cluster centroids. The analysis of the agglomeration schedule (in

Appendix) suggested five clusters. Next, the K-means clustering algorithm was used to iteratively assign each case to a cluster (Ketchen and Shook, 1996). Figure 1 and Table 2 report the results of the cluster analysis.

Table 1 – Distribution of the sample by country, industry and size

Country	Frequency	Percentage
Belgium	23	4.5
Brazil	22	4.3
Canada	16	3.1
China	49	9.6
Denmark	23	4.5
Finland	14	2.8
Germany	6	1.2
Hungary	29	5.7
India	34	6.7
Italy	26	5.1
Japan	57	11.2
Malaysia	12	2.4
Netherlands	27	5.3
Norway	20	3.9
Portugal	26	5.1
Romania	15	2.9
Slovenia	9	1.8
Spain	16	3.1
Sweden	26	5.1
Switzerland	24	4.7
Taiwan	9	1.8
USA	26	5.1
Total	509	100.0

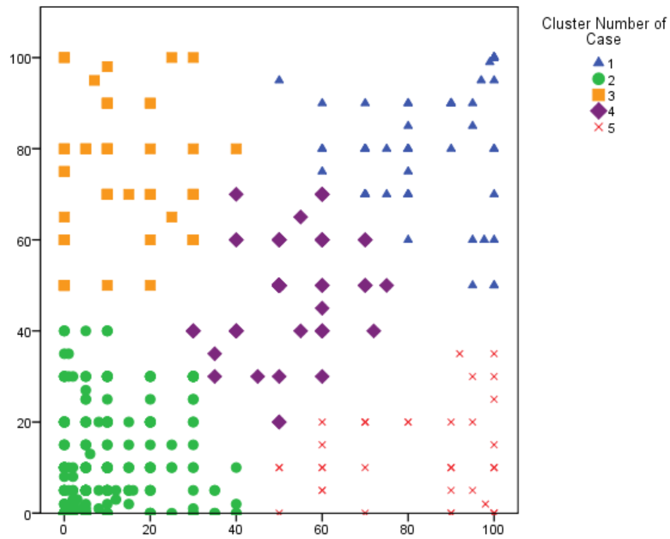
ISIC Code	Frequency	Percentage
25	151	29.7
26	61	12.0
27	90	17.7
28	119	23.4
29	62	12.2
30	26	5.1
Total	509	100.0

Employees	Frequency	Percentage
Small (30-250)	178	35.0
Medium (250-500)	92	18.0
Large (500+)	239	47.0
Total	**509**	**100.0**

ISIC Rev. 4 Code

25: Manufacture of fabricated metal products, except machinery and equipment; 26: Manufacture of computer, electronic and optical products; 27: Manufacture of electrical equipment; 28: Manufacture of machinery and equipment not elsewhere classified; 29: Manufacture of motor vehicles, trailers and semi-trailers; 30: Manufacture of other transport equipment

Figure 1 – Results of the cluster analysis (y-axis: percentage of internal inflows; x-axis: percentage of internal outflows)



First we checked whether differences among clusters exist according to four variables: industry (Table A1), company size and GNI per capita of the country the plant belongs to (Table A2), extent of the manufacturing network (national. regional or global) (Table A3). We found that the clusters are quite evenly distributed by industry and size of the company. On the other side, cluster 1 companies seem to be located in the less developed countries in our sample, while cluster 3 in the wealthier. Finally, companies in cluster 2, 3 and 5 seem to belong to more globalized networks, while cluster 1 and 4 are more evenly distributed.

Table 2 – Average values and number of cases per cluster

	Internal Inflows	**Internal Outflows**	**Number of cases**
1	81.68	85.06	62
2	11.02	8.91	290
3	73.26	13.64	50
4	49.04	51.65	68
5	12.74	81.92	39
Total	**30.95**	**29.96**	509

Next we verified the association between the clusters and a set of variables characterizing the role of the plant in the network and its degree of integration within the network and outside, with customers and suppliers. The constructs and the measures are reported in Table 3. The factor analysis confirmed the independence of the constructs (Table A4).

Table 3 – Constructs used to identify the role of the plant in the network. (The column ID references to Table A4)

Construct	**ID**	**Measure and Scale**
Market Scope	1	Your plant serves just a specified surrounding geographic area/market (1) - Your plant serves the whole world / global market (5)
	2	Your product is tailored to the local needs (1) - The product you produce is the same for all over the world (5)
Production Scope	3	Your plant covers only some specific production steps (the others are performed by other plants in the network) (1) - Your plant covers the full production process (5)
Control	4	You can make your own strategic decisions (1) - The strategy is set by another plant in the network or an international division (5)
	5	This plant is autonomous in defining the production plan (1) - Production plans are coordinated by another plant or an international division (5)
Responsibility	6	No responsibility on Supply Chain (1) - Full responsibility on Supply Chain (5)
	7	No responsibility on Development - Full on Development (5)
Low cost advantage	8	Your current advantage is to access to low cost resources: Strongly disagree (1) Strongly Agree (5)
Skill and knowledge advantage	9	Your current advantage is to access to knowledge and skills: - Strongly disagree (1) Strongly Agree (5)
Implementation of Manufacturing network integration programs (MN Programs)	10	Improve information sharing for the coordination of the flow of goods between your plant and other plants of the network - None (1) – High (5)
	11	Improve joint decision making to define production plans and allocate production in collaboration with other plants in the network - None (1) – High (5)
	12	Improve innovation sharing / joint innovation with other plants - None (1) – High (5)
	13	Improve the use of technology to support communication with other plants of the network - None (1) – High (5)
	14	Developing a comprehensive network performance management system - None (1) – High (5)
Implementation of Supplier Integration programs (SI Programs)	15	Sharing information with key suppliers - None (1) – High (5)
	16	Developing collaborative approaches with key suppliers - None (1) – High (5)
	17	Joint decision making with key suppliers - None (1) – High (5)
	18	System coupling with key suppliers - None (1) – High (5)
Implementation of Customer Integration programs (CI Programs	19	Sharing information with key customers - None (1) – High (5)
	20	Developing collaborative approaches with key customers - None (1) – High (5)
	21	System coupling with key customers - None (1) – High (5)
	22	Joint decision making with key customers - None (1) – High (5)

Results

Table 4 reports the results. First, we performed a MANOVA analysis that tested if significant differences existed among clusters on the plant role variables, but at the same time controlling for: company size (log), geographical extent of the manufacturing network (regional vs. global) and GNI per capita of the country. Next, we confirmed the results by means of an ANOVA analysis. The findings were mainly confirmed, witnessing the marginal role played by the control variables. Finally, we checked for pairwise differences using a LSD test (Table A5). The only critical variable is "production scope" as it appears to be affected by the control variables, but the clusters show interesting differences. As a consequence, we included it in the analysis leaving further analyses for the future developments.

Table 4 – Results of the analysis. Bold and underscored values indicate maximum values that are significantly different by the minimum values in italic and underscored. Non-underscored values indicate average values, not significantly different from the minimum or the maximum.

				Cluster					
Plant role variables	MANOVA Sig.	ANOVA Sig.	Levene Homog.						Total avg.
Market Scope	.020	.005	.030	*3.24*	3.64	*3.24*	3.61	**3.82**	3.56
Production Scope	.213	.093	.011	*3.59*	**3.99**	*3.68*	3.81	3.74	3.87
Control	.000	.000	.122	**2.86**	*2.52*	**3.24**	**3.06**	**3.01**	2.74
Responsibility	.018	.010	.575	*3.72*	**3.98**	*3.69*	*3.73*	*3.54*	3.85
Low cost advantage	.005	.001	.009	3.03	*2.70*	*2.86*	**3.37**	*2.62*	2.84
Skill and knowledge advantage	.995	.866	.465	3.61	3.64	3.64	3.68	3.72	3.65
MN Programs	.008	.001	.685	*3.25*	*3.26*	*3.17*	**3.29**	*3.13*	3.24
SI Programs	.658	.866	.161	3.31	3.10	3.16	3.59	3.18	3.21
CI Programs	.346	.219	.155	3.20	3.01	3.01	3.29	2.90	3.06

Discussion

As a first result we can provide a positive answer to our HP0, since we could indeed find 5 clusters of companies according the their level of internal vs. external inflows and outflows.

Moving to the discussion of the first set of hypotheses:

- HP1a is partially *supported*, since the cluster with the most international market scope is number 5 (that has high internal inflows), but the hypothesis does not hold for cluster 1 (local market scope, high internal inflows).
- HP1b is *supported,* since the cluster with the broadest production scope is number 2, i.e. with low internal inflows and outflows.
- HP1c is *supported,* since the cluster with the lowest control by the rest of the network is number 2, i.e. with low internal inflows and outflows.
- HP1d is *supported,* since the cluster with the highest responsibility is number 2, i.e. with low internal inflows and outflows.
- HP1e is *not supported,* since the cluster with the greatest low cost advantage is number 4, i.e. with intermediate internal inflows and outflows
- HP1f is *not supported,* since there is no significant difference in terms of access to skills and knowledge among the clusters

Finally, moving to the second set of hypotheses:

- HP2a is *not supported,* since there is no significant difference in terms of supplier integration among the clusters
- HP2b is *not supported,* since there is no significant difference in terms of customer integration among the clusters
- HP2c is *not supported,* since the cluster with the highest level of manufacturing network integration is number 4, i.e. with intermediate internal inflows and outflows;

In summary, we propose the following names for the clusters:

1. *Local process specialists*, given the high internal inflows and outflows and the lowest market and production scope.
2. *Independent premium servers*, given the low internal inflows and outflows, the low level of control by the rest of the network, the high production scope and responsibility, the intermediate market scope, and the lack of low cost advantage.
3. *Market outposts*, given the high internal inflow and low internal outflow, associated with low market and production scope, high control by the rest of the network and low responsibility.
4. *Low cost seekers*, given the intermediate internal inflows and outflows, associated with the best low cost advantage, quite high control and high level of integration with the rest of the network.
5. *Sourcing hubs*, given the low internal inflows and high internal outflows, associated with the most international market scope and the lowest level of cost advantage.

Conclusions

In this paper we have bridged together two streams of literature, i.e. manufacturing network and supply chain management, which are seldom investigated together. We have done so starting from an empirical taxonomy based on the level of internal vs. external inbound and outbound flows of a plant within a manufacturing network. In this way we have been able to investigate the relationship between the level of interdependence of the plant with the rest of the network, and a set of variables measuring the role of the plant and its integration with the supply chain. We found several confirmations of our initial hypotheses as far as the role of the plant is concerned, thus supporting the expected relationships. However, we could not find any support for the hypotheses concerning both the location advantages of the plant and the level of integration with the manufacturing network and the supply chain. Therefore the relationships in these latter cases are either non-existing or more complex than expected. Anyway we claim to have provided an innovative perspective to research and therefore opened a new interesting direction for further investigation. Besides, we have also presented some relevant insights for managers of manufacturing networks, who have to face complex decisions considering multiple variables with unclear relationships. We need to further develop the research to better understand whether there is really no clear relationship between the level of interdependence of the plants within the network, the location advantages and the supply chain. A possible development would be the investigation of the relationships between supply chain integration programs and performance, considering the level of internal vs. external flows (i.e. the 5 clusters) as moderating variable.

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Appendix

Table A1 – distribution of the clusters by ISIC Code (Chi-square= 0.23)

		ISIC Code						Total
		25	26	27	28	29	30	
Cluster	1	18	9	13	6	11	5	62
	2	86	32	49	79	32	12	290
	3	19	5	2	16	5	3	50
	4	19	6	18	10	9	6	68
	5	9	9	8	8	5	0	39
Total		151	61	90	119	62	26	509

Table A2 - Kruskal-Wallis non-parametric test for difference in number of employees and GNI per capita of the country

	Cluster Number of Case	N	Mean Rank	Sig.
N. of employees	1	62	262.19	0.357
	2	289	250.11	
	3	50	227.25	
	4	68	279.60	
	5	39	266.00	
	Total	508		
GNI_2013	1	62	170.10	0.000
	2	290	269.94	
	3	50	316.70	
	4	68	220.10	
	5	39	260.58	
	Total	509		

Table A3 – distribution of the clusters by Regional or Global manufacturing network (Chi-square: 0.000)

		National	Regional	Global	Total
Cluster Number of Case	1	29	8	24	61
	2	61	44	184	289
	3	9	7	34	50
	4	24	12	32	68
	5	6	9	24	39
Total		129	80	298	507

Table A4 – Results of the factor analysis

Item	Market Scope	Production Scope	Control	Responsibility	Skill and Knowledge Adv.	Low Cost Adv.	NI Programs	SI Programs	CI Programs
1	0.703								
2	0.866								
3		0.93							
4			0.878						
5			0.827						
6				0.848					
7				0.840					
8					0.929				
9						0.957			
10							0.795		
11							0.74		
12							0.753		
13							0.782		
14							0.789		
15								0.818	
16								0.791	
17								0.742	
18									0.788
19									0.778
20									0.824
Cronbach 's Alpha	.416*		.695	.691			.876	.835	.867

*correlation sig = 0.000

Table A5 - Pairwise LSD test (only p-value is reported)

		1	2	3	4	5
Global_Scope	1		.006	.993	.044	.008
	2	.006		.011	.823	.334
	3	.993	.011		.054	.010
	4	.044	.823	.054		.331
	5	.008	.334	.010	.331	
Control_of_Production	1		.019	.699	.309	.560
	2	.019		.094	.262	.223
	3	.699	.094		.570	.828
	4	.309	.262	.570		.771
	5	.560	.223	.828	.771	
Control	1		.034	.087	.335	.531
	2	.034		.000	.001	.015
	3	.087	.000		.400	.366
	4	.335	.001	.400		.848
	5	.531	.015	.366	.848	
Responsibility	1		.049	.882	.930	.357
	2	.049		.045	.052	.006
	3	.882	.045		.814	.451
	4	.930	.052	.814		.309
	5	.357	.006	.451	.309	
Low_Cost_Adv	1		.053	.460	.120	.097
	2	.053		.391	.000	.690
	3	.460	.391		.027	.351
	4	.120	.000	.027		.002
	5	.097	.690	.351	.002	
MN_Programs	1		.087	.375	.063	.481
	2	.087		.625	.000	.567
	3	.375	.625		.007	.912
	4	.063	.000	.007		.019
	5	.481	.567	.912	.019	