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Product modularity influences on firm performance: evidence from bioenergy technology

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1. Introduction

The global climate change and the scarcity of primary energy sources are becoming serious environmental concerns. Distributed, or, in other words, decentralized, biofueled combined heat and power production (CHP) could offer a qualified, sustainable solution for this concern in many countries and regions. Increased use of renewable primary energy sources and improved overall energy efficiency play an important role in future energy production and consumption [1]. Distributed small scale CHP production using biomasses, such as woodchips from logging residue or reed canary grass, is emerging as the used technologies mature and are commercialized. At present, technologies for commercial heat and power production using various biomasses are mainly based on combustion technologies [2]. It is particularly suitable for introducing novel technologies utilizing forest biomasses in the regions that possess adequate natural resources enabling their sustainable exploitation. Further, according to [3] nuclear power phase out and decommissioning of outdated coal plants in many regions will lead to a need for replacement of substantial portion of the current energy generation capacity in the near future. Distributed CHP production has thus an important role in the future energy supply, and it is also expected to provide increased security of energy supply, reduction of greenhouse gas emissions, and saving of electricity grid capacity.

Firms operating in emerging industries such as distributed bio-CHP technology need various resources, capabilities and competences, and they also have to collaborate with other business network players in order to develop new products and services for the novel business environment and to ensure their own competitive advantage [4-6]. Product modularity has been well known for several decades, and its significance as a prerequisite of ensuring firms' competitive advantage in today's dynamic business environments is increasing [7, 8]. The benefits of modularity include, e.g. increased economies of scale, increased product variety, cost savings in inventory, and a shorter product life cycle [7, 9-11]. However, modularity also has confounding effects on firm's competitive advantage: turning to the modular approach may also create, e.g. unplanned and extensive fixed costs [12], and increased variable product costs due to overdesign [10, 11]. In fact, today many firms, including competitors, share their resources and expertise in order to develop new products, achieve economies of scale, and gain access to new markets and technologies, because single firms often lack the necessary resources. The go-it-alone strategy has changed into a strategy of alliance. Strategic alliances can be either intra-industrial or inter-industrial and may include licensing, supplier relations, joint ventures, collaboration, R&D consortia, industry clusters, and innovation networks [13, 14].

The objective of this paper is to analyze the relatively unexplored Finnish heating plant manufacturers capable of supplying power generation units also in the future, and to study, in particular, the effects of product modularity on their financial performance and collaboration within their business networks. The research question of this paper is: "How does product modularity affect Finnish biofuel heating plant manufacturers' and suppliers' financial performance and their business network activities?" Case study research was selected as the research strategy for this paper, and the primary sources of information for the evaluation of the industry were an analysis of the major industry players and key expert interviews. The research data consists of 26 semistructured theme interviews with the heating plant manufacturers' executives and other representatives, and financial and non-financial data of the firms. The results reveal three clusters of heating plant manufacturers and suppliers: network leaders, turnkey suppliers, and distributors. The different players collaborate rather actively within their business networks, which include customers, suppliers and competitors. In general, the network leaders and the turnkey suppliers tend to have higher network activity, and to utilize product modularity more extensively than the distributors. Dividing the firms into two clusters according to their degree of modularity utilization, modularity users and customizers, reveals novel results. This paper contributes to providing evidence that the degree of product modularity exploitation influences the heating plant manufacturers' and suppliers' financial performance and network activities. The study also increases general understanding of the industry's characteristics, which can be considered valuable knowledge for practical managers. The extensive sample consisted of Finnish heating plant manufacturers and suppliers, but the results could probably be generalized to provide valuable knowledge to many other market areas as well.

2. Product modularity

According to [15], for example, product architecture becomes modular, while functional components' interfaces are specified to allow component variations, whereafter the interface specifications are standardized. [16] complements that modular design enables to add new functions to modular units at different hierarchical system levels. Further, modularity can be categorized into six different types: component-sharing, component-swapping, cut-to-fit, mix, bus, and sectional modularity. Component-sharing modularity enables the use of common components in different products, in component-swapping modularity different modules can be alternatively selected for standard products, and in cut-to-fit modularity the modules have unique dimensions such as length, width, or height. Mix modularity is similar to component-swapping modularity, and it appears when a combination of the modules can be selected to standard products. Bus modularity refers to the ability to add one or more modules to an existing base, such as track lightning. Finally, sectional modularity is similar to component-swapping modularity, and it appears when standard modules can be arranged in a unique pattern like Lego bricks [17, 18]. In addition, modularization can be divided into different levels of modularization, such as component level, module level, subsystem level, and system level modularization. Each level of modularization varies in regard to, e.g. opportunities for modularization, product architecture, interface compatibility, component customization, value inputs, and supplier-buyer interdependence [19]. Further, according to [20], modularity can be defined under four key themes: product modularity, including product development modularity; production and process modularity; organizational and supply chain modularity; and modularity of services, including modularity of service product, service development, service production and process, and service organization and supply chain.

Modularity has several advantages which have been widely discussed in previous research. As a matter of fact, the significance of product modularity as a prerequisite for ascertaining firms' competitive advantage in today's dynamic business environments is ever increasing [7, 8]. The benefits of modularity include increased economies of scale, increased product variety, reduced time to market, cost savings in inventory, and shorter product life cycle [7, 9-11, 15]. In addition, it is recognized that modular design decreases product complexity, enables mass customization, and accelerates product innovation cost efficiently [9, 21, 22]. According to [23, 24] modularity also facilitates postponing product differentiation and final delivery until customer requirements are known. This, in turn, improves customer satisfaction, reduces inventory costs, and improves delivery times. [7, 25] argue that product modularity influences supplier relations and integration positively in a number of ways: firstly, modularity improves delivery forecasts' reliability, and thus mutual trust in supplier-customer relationships; secondly, it enhances supplier integration by reducing the communication barrier by creating a common language; thirdly, it helps buyers and suppliers to manage the risks of losing competitive advantage through inadvertent release of intellectual property rights (IPR), and finally, modularity has a positive influence on supplier integration which in turn has a positive effect on firms' performance.

However, modularity also has confounding effects on the firm's competitive advantage: turning to modular approach may create e.g. unplanned and extensive fixed costs [12], and increased variable product costs due to overdesign [10, 11]. According to [26], modular design may also lead to similar products during product development process due to repetitively used common modules. In fact, product innovation is often introduced in a non-modular form, since design engineers have to understand the product architecture before modularization [27, 28]. To sum up, modularity offers a sustainable alternative for permanently fulfilling changing customer requirements such as increased product variety and improved quality [29].

3. Research design and data

The empirical study was carried out as a single case study. In fact, a case study is not a methodology, but rather a research strategy that concentrates on increasing the understanding of the present dynamics within a single setting [30]. [31] argues that a case study is an enquiry that investigates a contemporary phenomenon within its real world context. [32] defines a case study as an exploration of a bounded system that can be defined in terms of time and place, and through detailed, in-depth data collection, involving multiple rich sources of information. Case studies typically combine various data collection methods, such as archives, interviews, questionnaires and observations [30].

The analyses of the firms were based on financial data, a literature review and interviews conducted in order to answer the research question: "How does product modularity affect Finnish biofuel heating plant manufacturers' and suppliers' financial performance and their business network activities?"

The primary source for acquiring the list of companies was a trade magazine [33], and the list was further augmented by experts' knowledge. At present, there are fewer than 40 key players in the small-scale biofuel heating plant manufacturers' and suppliers' branch of business in Finland, and 26 of them agreed to participate in the interview. Those 26 manufacturers and suppliers were also included in the financial analysis. The financial data of the firms was collected from a national information provider [34] whose data base includes financial data on approximately 100 000 national companies including publicly listed companies as well as privately owned small and medium size enterprises (SME). The financial data was based on the financial statements of the firms and included their revenue, net income, return on invested capital (ROIC), equity and quick ratio for the years 2005–2009.

The quantitative analysis was complemented with a literature review of the firms based on their Internet home pages, and interviews with 26 key informants. The interview sessions were conducted in May and June 2010 by two researchers, the interviews were audio recorded and the results were crosschecked by two other researchers. The group of interviewees was composed of top management and company experts including 15 CEOs, two entrepreneurs, and one chairman of the board. The key informants were interviewed using a semi-structured theme questionnaire concentrating on two main issue areas: firm related issues: background information such as market re-

view; offered products and services; modularity utilization; key technologies; CHP potential; human resources; competences; exports, and network related issues: general network structure, network participants; network performance; customer orientation; network benefits to R&D. Finally, the concluding analyses are a synthesis of the firms' financial analysis, literature review, and interviews.

4. Empirical analyses

The majority of the firms manufacture parts and components of the plants, such as boilers, conveyors, automation or firing (combustion) technology based on their core competences, or the product-rights belong to the firm and the manufacturing of the parts may be outsourced. Heating plant building, construction, electrification and plumbing are typically acquired locally. However, end customers usually appreciate turnkey deliveries of the plants, and thus the suppliers have to collaborate with other manufacturers and even competitors in order to carry the full liability of the delivery and meet customer requirements.

The firms were categorized into three generic groups: network leaders, turnkey suppliers, and distributors. Network leaders are larger firms in terms of revenue, balance sheet and number of personnel. Their resources were estimated more significant than those of other firms. The majority of the network leaders also manufacture their core products in-house or own product-rights. Similarly, turnkey suppliers produce a part of their products in their facilities or own the product-rights, but their capabilities are lesser than those of the network leaders. Distributors mostly import their product range.

Further, in a more in-depth study, the firms were distributed into two clusters according to their degree of modularity utilization: modularity users, and customizers. Modularity users are composed of those firms that exploit product modularity from average to full exploitation, whereas customizers' product modularization rate is moderate or they do not exploit modularity at all. Both modularity users and customizers exist among network leaders, turnkey suppliers and distributors.

4.1. General financial analysis

In the analysis, there were altogether 26 firms. Financial data from the national data bank [34] was available for 19 of these firms, and the financial statements of the firms were analysed for the years 2005-2009. Firms with available financial data for less than three years were ignored in the analysis. Based on [35], while evaluating the firms' financial performance ROIC was regarded good, if it was over 15% and satisfactory, if it was below 15%. Negative ROIC was evaluated as weak. Accordingly, over 40% equity ratio was regarded good, 20 to 40% satisfactory and below 20% weak. Quick ratio over 1 was rated good, 0.5 to 1 satisfactory and below 0.5 was regarded weak.

Most of the firms were small and medium size enterprises (SME), whereas two firms belonged to larger groups of companies. The results reveal that the average revenue of all the firms was 6.263 M€, the average revenue of the network leaders was 13.356 M€, the turnkey suppliers' revenue was 2.702 M€, and the distributors' 0.395 M€. The network leaders had the largest net income 0.577 M€ (4.3% of the revenue), and the turnkey suppliers' net income 0.173 M€ (6.4%) was the best comparative one. The distributors' net income was slightly negative (-0.038 M€). The return on invested capital (ROIC) was on good level (i.e. over 15%) in all the groups. The average equity ratio was on satisfactory level (20 to 40%) in all categories, whereas the average quick ratio was on good level. Generally, standard deviation (STDEV) in most of the studied factors and company groups was relatively high, revealing that the firms within the groups were rather heterogeneous. All in all, the network leaders were medium size companies, the turnkey suppliers were small, and the distributors were micro companies. The good ROIC within all the groups could be a consequence of relatively good financial results and modest capital investments. The equity ratios of the firms give support to modest capital investments. The good quick ratios of the firms reveal a generally healthy liquidity of the firms. The financial results of the network leaders, turnkey suppliers and distributors are illustrated in Table 1.

Table 1

Financial results of different clusters

	All Firms (N=19)	Network Leaders	Turnkey Suppliers	Distributors
Revenue average, t€ (STDEV)	6263 (9366)	13356 (12549)	2702 (2827)	395 (390)
Net Income average, t€ (%) (STDEV)	289 (4.6 %) (562)	577 (4.3 %) (840)	173 (6.4 %) (227)	-38 (neg.) (115)
ROIC average, % (STDEV)	30.5 (28.4)	23.9 (23.5)	37.2 (30.2)	26 (39.7)
Equity average, % (STDEV)	31.6 (22)	22.9 (13.9)	39.8 (27.4)	27.3 (14.2)
Quick Ratio average (STDEV)	1.52 (1.16)	1.06 (0.31)	1.70 (1.57)	2.06 (0.75)

Distributing the firms into modularity users, and customizers revealed novel results. The average revenue of the modularity users was 7.572 M€, and the average revenue of the customizers was 1.354 M€. The average net income of the clusters of companies were 0.359 M€ (4.7% of the revenue) and 0.028 M€ (2.1%) respectively. The ROIC of the modularity users (31.5%), and customizers (27%) were on good level, whereas the equity ratios of modularity users (34.9%), and customizers (19%), were on satisfactory and weak level respectively. The average quick ratios of the modularity users (1.48), and customizers (1.69) were on good level. In general, STDEV was high in all factors revealing heterogeneous clusters. As a conclusion, modularity users are larger firms and their financial performance is better than that of the customizers. The financial data of the individual firms is used to further evaluate financial performance in the following chapters. Table 2 summarizes the financial results of the modularity users and customizers.

Table 2

Financial results of modularity users and customizers

	All firms (N = 19)	Modularity users	Customizers
Revenue average, t€ (STDEV)	6263 (9366)	7572 (10169)	1354 (1745)
Net Income average, t€ (%) (STDEV)	289 (4.6%) (562)	359 (4.7%) (618)	28 (2.1%) (19)
ROIC average, % (STDEV)	30.5 (28.4)	31.5 (29.5)	27 (27)
Equity average, % (STDEV)	31.6 (22)	34.9 (22.2)	19 (18.7)
Quick Ratio average (STDEV)	1.52 (1.16)	1.48 (1.23)	1.69 (0.94)

4.2. Modularity and network analysis

The evaluation of the different factors was based on the interviews and supported by the firms' literature, e.g. from their Internet home pages, when applicable. The evaluation of the financial performance was based on the companies' financial statements. The firms' network activities were analyzed by evaluating their overall network performance, customer orientation, and network benefits to R&D. Firm's tendency either to utilize modular products or customize their products were analyzed in a similar manner. The individual factors were scored by numbers one to five so that the best value of the factor was five, an average performance among the firms justified the value three, and the worst value was one. For example, if a firm's financial performance was good the value was five, and if the performance was satisfactory the value was three. Weak financial performance of a firm justified the value one. Correspondingly, in case a firm utilized modular solutions significantly in its offering, the firm's value was five, and if it had very little or no modular solutions at all, the value was one. The average product modularity design within the group justified the value three. The other factors were evaluated accordingly. The evaluation was executed individually by two researchers, and the results were crosschecked by two other researchers.

Finally, the firms' points for overall network performance, network benefits to R&D, and modularity were weighted by a factor 2, whereas financial performance and customer orientation were weighted by a factor 1. The motivation behind that was that financial data was available for only 19 firms, and the worldwide recession that hit industry and commerce in 2008-2009 may have had an influence on these financial figures. Further, firm representatives typically tend to argue that their firm is customer oriented. The general directions for the evaluation were as follows:

- financial performance: financial factors from firm's financial statements;
- overall network performance (a): number and nature of network partners, and network functionality;
- customer orientation (b): scope and functionality of customer relationships, partnerships;
- network benefits to R&D (c): exploitation and functionality of network to company R&D;
- network activity: the average outcome of (a+b+c);
- modularity: exploitation of modular product solutions.

Evaluating the performance of the different clusters, it can be discovered that the network leaders' average score for financial performance is 4, the turnkey suppliers' is 4.22, and the distributors' is 3. It can thus be concluded that the network leaders' and turnkey suppliers' financial performance is comparable, whereas the distributors' performance is less favourable. The network leaders' average modularity score is 7.25, and the network activity score 4.88. The turnkey suppliers' scores, in contrast, are 6.62 and 4.69, and the distributors' 4.8 and 3.4 respectively. The results indicate that network leaders and turnkey suppliers exploit product modularity more, and their general business network activity is more significant than that of

the distributors. The detailed results of individual manufacturers and suppliers as well as different clusters are illustrated in Table 3.

Table 3

Financial performance, network activity and modularity of different clusters

Firms	Financial performance (N = 19)	a) Overall network performance	b) Customer orientation	c) Network benefits to *R&D*	Network activity (N = 26) (average $a+b+c$)	Modularity (N = 26)
Weighting	1	2	1	2		2
Network Leaders, average score (STDEV)	4 (1.0)	6.5	3.13	5	4.88 (1.39)	7.25 (2.12)
M2	4	10	2	6	6	10
M9	3	2	3	2	2.33	6
M13	3	6	3	10	6.33	4
M17	5	8	3	4	5	10
M18	5	6	2	4	4	8
M20		8	3	4	5	6
M22	3	6	5	8	6.33	8
M26	5	6	4	2	4	6
Turnkey Suppliers, average score (STDEV)	4.22 (1.09)	6.31	3.46	4.31	4.69 (1.66)	6.62 (2.99)
M1	5	8	3	8	6.33	10
M3	5	6	4	6	5.33	6
M5		10	4	10	8	10
M8	4	8	5	6	6.33	8
M11		4	4	4	4	2
M12		4	2	2	2.67	4
M14	3	4	2	2	2.67	10
M15		6	4	4	4.67	4
M16	4	8	3	4	5	8
M19	5	4	1	2	2.33	6
M23	2	6	4	2	4	2
M24	5	8	5	4	5.67	10
M25	5	6	4	2	4	6
Distributors, average score (STDEV)	3 (1.73)	5.2	1.8	3.2	3.4 (0.64)	4.8 (3.03)
M4	4	8	3	2	4.33	4
M6		4	1	4	3	4
M7	4	6	1	4	3.67	4
M10		4	2	2	2.67	2
M21	1	4	2	4	3.33	10

By executing a more profound study of the industry by distributing the firms into different clusters according to their degree of modularity utilization, and studying modularity's influences on firms' financial performance and network activity, novel results can be found. Modularity users (N = 17) are composed of those firms that exploit product modularity from average to full exploitation, and their weighted modularity score varies from 6 to 10. Customizers' (N = 9) product modularization rate is moderate or they do not exploit modularity at all, and their weighted modularity score varies from 2 to 4.

While examining modularity's influence on financial performance (19 firms), it is noteworthy that 15 modularity users had financial data available for at least from three years, whereas financial data was available only for four customizers. The results reveal that modularity users' (modularity score 8.13) average financial performance score is 4.13, whereas customizers' (modularity score 3.5) average financial performance score is 3.25. Based on these results, it seems evident that higher modularity exploitation rate improves a firm's financial performance.

Comparing modularity users' and customizers' business network activity (26 firms), the results reveal that modularity users' network activity score is 4.8 in average and customizers' network activity score is 3.93 in average. The results confirm that modularity users operate more

actively within their business network than customizers. Table 4 illustrates in detail modularity's influences on firms' financial performance and network activity.

All in all, the research results indicate that the modularity users are bigger firms, their financial performance is higher, and they collaborate more actively within their business networks than the customizers.

Table 4

Influences of modularity to firm's financial performance and network activity

Modularity vs. Financial performance			Modularity vs. Network activity		
Firms, (N = 19)	Modularity	Financial Performance	Firms, (N = 26)	Modularity	Network Activity
Modularity users, average score (STDEV)	8.13 (1.77)	4.13 (1.19)	Modularity users, average score (STDEV)	8.12 (1.8)	4.8 (1.59)
M1	10	5	M1	10	6.33
M2	10	4	M2	10	6
M3	6	5	M3	6	5.33
M5			M5	10	8
M8	8	4	M8	8	6.33
M9	6	3	M9	6	2.33
M14	10	3	M14	10	2.67
M16	8	4	M16	8	5
M17	10	5	M17	10	5
M18	8	5	M18	8	4
M19	6	5	M19	6	2.33
M20			M20	6	5
M21	10	1	M21	10	3.33
M22	8	3	M22	8	6.33
M24	10	5	M24	10	5.67
M25	6	5	M25	6	4
M26	6	5	M26	6	4
Customizers, average score (STDEV)	3.5 (1.0)	3.25 (0.96)	Customizers, average score (STDEV)	3.33 (1.0)	3.93 (1.15)
M4	4	4	M4	4	4.33
M6			M6	4	3
M7	4	4	M7	4	3.67
M10			M10	2	2.67
M11			M11	2	4
M12			M12	4	2.67
M13	4	3	M13	4	6.33
M15			M15	4	4.67
M23	2	2	M23	2	4

5. Conclusions and discussions

Global warming, mainly due to greenhouse gas emissions, is an increasing environmental concern, and current primary energy sources are gradually becoming exhausted. Increasing use of renewable energy sources together with improved overall energy efficiency is of an ever growing consequence in future sustainable energy policy. Distributed small scale CHP production using biofuels could provide a qualified solution to these environmental issues in many regions. This study increased general understanding of those key heating plant manufacturers and suppliers in Finland that are also capable of providing power generation in the future.

The heating plant manufacturers and suppliers are small and medium size enterprises that can be categorized into three generic groups: network leaders and turnkey suppliers manufacture and supply parts and components, and also complete plants to end customers on turnkey basis. Distributors are micro companies that import their offering. The manufacturers produce their offering based on firm specific capabilities and competences as well as their strategy, and they complement their competences by diversified business networks that include customers, suppliers, other manufacturers, and competitors. Dividing the firms into two more specific clusters: modularity users that utilize product modularity from average to full exploitation, and customizers that mostly tend to customize their product offering, reveals the following vital results: the modularity users are bigger firms whose financial performance is higher than that of the customizers, and the modularity users collaborate more actively within their business networks than the customizers. The results among the heating plant manufacturers and suppliers underpin the results widely discussed in earlier research that firms benefit from product modularization financially, operationally and strategically. Further, high modularization rate enhances firm's collaboration and integration within its business

network.

The research contributes to providing evidence that a higher degree of product modularity exploitation leads to higher financial performance and network collaboration of a firm than low product modularization or pure customization. The study also increases understanding of the key players, networks, and clusters within the industry. These issues can be considered valuable knowledge for practical managers. The sample of the firms can be considered extensive, the interviewees were mostly top managers, and the results of the study were collected by two researchers and crosschecked by two others in order to ensure validity and reliability. The sample consisted of Finnish manufacturers and suppliers, but the results can presumably be generalized to many other regions. The main limitations of the study are the to some extent limited financial data, and the potential influence of the worldwide recession in 2008-2009 on the financial figures of the firms. Bioenergy industry is emerging, and it might be valuable to further study what kind of product modularity issues, and business networks prevail in commercializing small scale CHP plants in the international context.

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GAMINIŲ MODULUMAS DIDINA NAŠUMĄ: ĮRODYMAS TAIKANT BIOENERGETIKOS TECHNOLOGIJĄ

R e z i u m ė

Klimato kaita ir pirminės energijos stoka verčia rimtai susirūpinti. Kartu naudojant biokuro šilumą ir galią galima rasti kvalifikuotą sprendimą. Šio straipsnio tikslas – išanalizuoti Suomijos šilumos gamybos įmonių gaminančių galios generavimo įrenginius patirtį, ypač ištirti, kokią įtaką gaminių modulumui turi finansiniai veiksmai ir bendradarbiavimas. Pirminė informacija remiasi didžiųjų gamintojų dalyvių ir pagrindinių ekspertų vertinimo analize. Rezultatai išryškino dvi gamintojų grupes: modulumo naudotojus ir klientus. Naudojant modulumą, užtikrinami tvirti finansiniai ryšiai ir bendradarbiavimas.

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PRODUCT MODULARITY INFLUENCES TO FIRM PERFORMANCE: EVIDENCE FROM BIOENERGY TECHNOLOGY

S u m m a r y

Climate change and scarcity of primary energy are becoming serious concerns. Distributed biofueled combined heat and power production could offer a qualified solution. The objective of this paper is to analyze Finnish heating plant manufacturers capable of supplying power generation units; in particular, how product modularity affects their financial performance and collaboration. The primary information for the evaluation is based on an analysis of major industry players and on key expert interviews. The results reveal two clusters of manufacturers: modularity users and customizers. Modularity exploitation activity influenced firms' financial performance and collaboration.

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