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THE EFFECTS OF FLEXIBLE MANUFACTURING CAPABILITIES AND LOGISTICS CAPABILITIES ON FIRM PERFORMANCE: MASS CUSTOMIZATION AS A DUAL MEDIATOR

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ABSTRACT

This study aims to verify the impacts of flexible manufacturing capabilities and logistics capabilities, with mass customization as a dual mediator, on the performances of Taiwan photoelectric companies. Respondents are from department supervisors and managers. Structural equation modeling (SEM) is used to fit the overall pattern of the structural model and measurement mode in this study and followed by applying Sobel Test, Bootstrapping, and Mackinnon PRODCLIN2 method to verify the effect of dual mediator. Results show that: (1) flexible manufacturing capabilities have a significant positive impact on mass customization; (2) mass customization have a significant impact on firm performances; (3) flexible manufacturing capacities also significantly impact on firm performances; (4) logistics capabilities positively impact on mass customization and (5) logistics capabilities have a significant impact on firm performances. Therefore, "mass customization" plays an important role as a dual mediator in the impact pattern of flexible manufacturing capabilities and logistics capabilities on firm performances.

Keywords: Flexible manufacturing capabilities, Logistics capabilities, Firms performance

INTRODUCTION

Some recent incidents, such as the earthquake in Japan in 11 March 2011, caused many companies serious production break-downs. Managers and researchers have realized the importance of green energy and paid a great attention on the photovoltaic application of solar energy. The photovoltaic panel manufacturing has become one of the main industries in Taiwan and created significant GDP

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value. Many empirical researches on electronics industries have been found in the literature. However, little management studies on the green energy industries are investigated to verify the impacts of manufacturing and relevant capabilities on firm performances.Since mass production was first developed on the assembly line technique of Ford Motor Company, production costs have been much reduced by the further development of standardization to achieve economies of scale in industry. However, in the last two decades, mass customization emerged from the customer markets and highlighted the importance of building firm competences not only to reduce product costs but also to satisfy diverse customers' needs. Underlying this trend is a view suggesting that the applicability of flexible manufacturing capabilities and logistics capabilities were necessary for operations management. Our research model argues that flexible manufacturing capabilities and logistics capabilities should enhance the efficiency of a photovoltaic panel manufacturing company. In turn, these improvements should enhance their overall performance. We also propose that the mass customization would mediate the effects of enhancements on performance.

LITERATURE REVIEW

In this section, the existing literature is reviewed to build a theoretical base for proposing comprehensive hypotheses.

Flexible manufacturing capability

Flexible manufacturing capability is the ability of the firm to manage production resources and uncertainty to meet customer requests (Buzacott, 1982). Much of the literature on flexibility is devoted to the study of manufacturing flexibility. Previous research concerning flexibility for assembly lines has only considered a single flexibility type (process), yet numerous types of flexibility have been defined in the literature. In an excellent review, Sethi and Sethi (1990) identified over 50 terms for various flexibility types and classified the flexibility type definitions below. (1) machine flexibility, (2) production flexibility, (3) operation flexibility, (4) process flexibility, (5) product flexibility, (6) routing flexibility, (7) volume flexibility, and (8) expansion flexibility. Empirically measuring flexibility in manufacturing has begun recently in specific industries and their results indicate that manufacturing flexibility can yield significant benefits when configured in the correct way (Upton, 1994). Measures for most of these flexibility types have been attempted and there are varieties of dimensions along which the measures can be developed and compared. Suarez *et al*. (1995) listed the dimensions of manufacturing as: (1) mix flexibility, (2) new product flexibility, (3) volume flexibility, and (4) delivery time flexibility. These dimensions elaborate the conceptual definition of flexible manufacturing capacity for "this new capability has been designed to attain the efficiency of well-balanced, machine-paced transfer lines, while utilizing the flexibility that job shops have to simultaneously machine" (Slack, 1983). Therefore, this study uses the measured dimensions to assess the performance of flexible manufacturing capability.

Logistics capability

Most researchers recognized the time-based and multi-dimensional characteristics from the definition of logistics capability (Daugherty and Pittman, 1995; Wang, 2004). Morash *et al*. (1996) investigated the relationships between logistics capabilities and competitive advantage to achieve successful business results. Their research indicated that two of the dimensions being demand-oriented and supply-oriented constitute the major part of strategic logistics capabilities.Stank and Lackey (1997) further classified logistics capabilities into four dimensions, namely: (1) positioning, (2) agility, (3) integration, and (4) measurement. Liao (1999) explored the relationship of logistics capabilities and organizational performance and classified the dimensions of logistics capabilities by (1) delivery: refers to on-time delivery and prompt delivery, and (2) flexibility: means the delivery treatment that deals with the special customer requirements in a prompt response. Lynch *et al*. (2000) proposed that the logistics capabilities should include: (1) process capabilities, (2) value-added service capabilities. Zhao *et al*. (2001) presented the conceptual focus of logistics capabilities and it indicated: (1) customer focus: refers to the point of view of the market-oriented, with superior skills to understand and meet the customer demand; (2) information focus capacity: refers to the ability to use and integrate information technology. Wang (2004) developed logistics capacity with four dimensions: (1) transportation, (2) elasticity, (3) the degree of information sharing, (4) information technology, and (5) supplier relationships.Based on the above literature review, we defined the logistics capabilities as “the organizational ability that can deal with normal or special customer requirements of prompt delivery” and used Wang’ (2004) dimensions for measurement of logistics capabilities.

Mass customization

Mass customization integrates the manufacturing capabilities of elasticity and agility to provide goods and services that are uniquely tailored to the needs of individual customers (Davis, 1989). Through mass customization, firms can produce individualized products and services in a cost-effective manner. Achieving that ability is much influenced by the operational capabilities of organization (Pine, 1993). Mass customization makes use of information technology system of production and delivery to effectively meet the needs of individual customers at the cost of mass production (Kay, 1993). A flexible process is emphasized to provide customers customized products and services with high yield and reasonable price (Silveira *et al*., 2001). Tu *et al*. (2001) divided mass customization into four types: (1) cost: a customized production process without a substantial increase of cost, (2) yields: to achieve the economies of scale of production, (3) response speed: low delivery time, and (4) customization: deliver the tailored products and services to meet the individual customer needs.In this study, mass customization is defined to make use of highly agile processes, manufacturing flexibility and the integration ability of organization to meet individual customer needs in a low cost, high quality and efficient way. The measures of mass customization, based on the study of Tu *et al*. (2001), are dimensions of cost, yield, responsiveness and customization respectively.

Firm performance

A variety of organizational performance measurement has been found in the literature. Financial performance is one of the most popular metrics. However, in the rapidly changing markets facilitated by information, companies can not only rely on the financial performance as the only one for survival and competition. Only financial performance indicators are impossible to measure the organizational performance adequately.Therefore, Kaplan and Norton (1996) proposed four perspectives of the Balanced Scorecard, namely: (1) financial perspective, (2) customer perspective, (3) internal procedures perspective, and (4) learning growth perspective. Balanced Scorecard links the organization's strategy, structure, vision together with combining traditional, and modern enterprise performance metrics, and helps businesses to achieve the goal of long-term strategy, create customer value, and convert it into the organizational normal activities (Chow and Haddad, 1997).Both the financial and non-financial aspects have been considered in the Balanced Scorecard to adequately measure the organizational performance. Financial performance refers to the real financial output such as EPS, ROS, and other measures of profits. Non-financial performances are measured by organizational innovation performances such as technological innovation that provides new products and services by new techniques, and management innovation that occurred in the organization social system relevant to human resources, management process and organizational structures (Linh and Hong, 2010). Adopted from the studies of Kaplan and Norton (1996) and Linh and Hong (2010), four of the performance dimensions used in this study includes financial performance measure (EPS) and non-financial performance measures (customer dimension, internal procedures dimensions, and learning and growth dimensions).

Flexible manufacturing capability vs. mass customization

Manufacturers can produce diverse products through the flexibility and expertise to meet customer needs for gaining additional profits in niche market without increasing production costs (Pine, 1993).Gooley (1998) proposed that flexible manufacturing capability is one of the essential factors for achieving the ability of mass customization. Chen (2001) pointed out that mass customization must respond to customer needs promptly. Therefore, an infrastructure of modern information technology is essential. The rapid development of the Internet and e-commerce enables enterprises to quickly access the order and flexible manufacturing system make sure the companies can efficiently provide customized products of high quality. Wang (2004) showed that flexible manufacturing capability has a positive impact on mass customization.The perspectives are similar from the literature review on the studies in different industrial sectors. Hence, we can deduce the following hypothesis:

Hypothesis 1: Flexible manufacturing capability can strengthen the ability of mass customization to satisfy diverse customers' needs as well as to reduce product costs.

Mass customization vs. performance

Tai (2008) proposed that the refined production and mass customization could enhance the manufacturing performance to some extent. The implementation of mass customization has a positive impact on manufacturing performance (Lee, 2007). The following hypothesis can be deduced from the above literature review:

Hypothesis 2: Mass customization will enhance the performance of firm.

Flexible manufacturing capability vs. performance

Guo (1998) indicated that the routing planning of the manufacturing system retains good elasticity design, not only can smooth the manufacturing process, but also improve the performance of the system. Chen (2000) showed that the production elasticity morphology makes different and significant contribution to profit margins rate and sales growth rate. For example, production flexibility has a positive contribution to profit margins rate.The following hypotheses are deduced:

Hypothesis 3: Flexible manufacturing capability will enhance the performance of firm.

Logistics capability vs. mass customization

The implementation of mass customization relies on the internal logistics capabilities with high efficiency, the establishment of logistics information system and supply chain coordination. It indicated that logistics capability have a positive impact to mass customization (Wang, 2004).When logistics technology along with the sustained development of information technology becomes the base of e-commerce, logistics will be one of the essential elements of mass customization (Zipkin, 2001). Berman (2002) analyzed three critical success factors for the implementation of mass customization system. They are three capabilities of information extraction, flexible processes and logistics.Base on above literature review, the following hypothesis is deduced:

Hypothesis 4: Logistics capability can strengthen the ability of mass customization to satisfy diverse customers' needs as well as to reduce product costs.

Logistics capability vs. performance

Tsai (2006) showed that the logistics performance has a direct influence on the financial performance and the benchmarking capabilities have the highest impact on financial performance. Shih (2008) indicated that logistics center adopted with services innovation could improve logistics performance.Wang (1998) showed that the logistic automation has a positive impact on the logistics performance. Lin (2010) showed that the higher the level of logistics service innovation, the more competitive advantage and better performance the company could gain.From above literature review, the following hypothesis is deduced:

Hypothesis-5: Logistics capability will enhance the performance of firm.

METHODOLOGY

Research structure

Figure 1 provides an overview of the relationships among flexible manufacturing capability, logistics capability, mass customization, and firm performance.

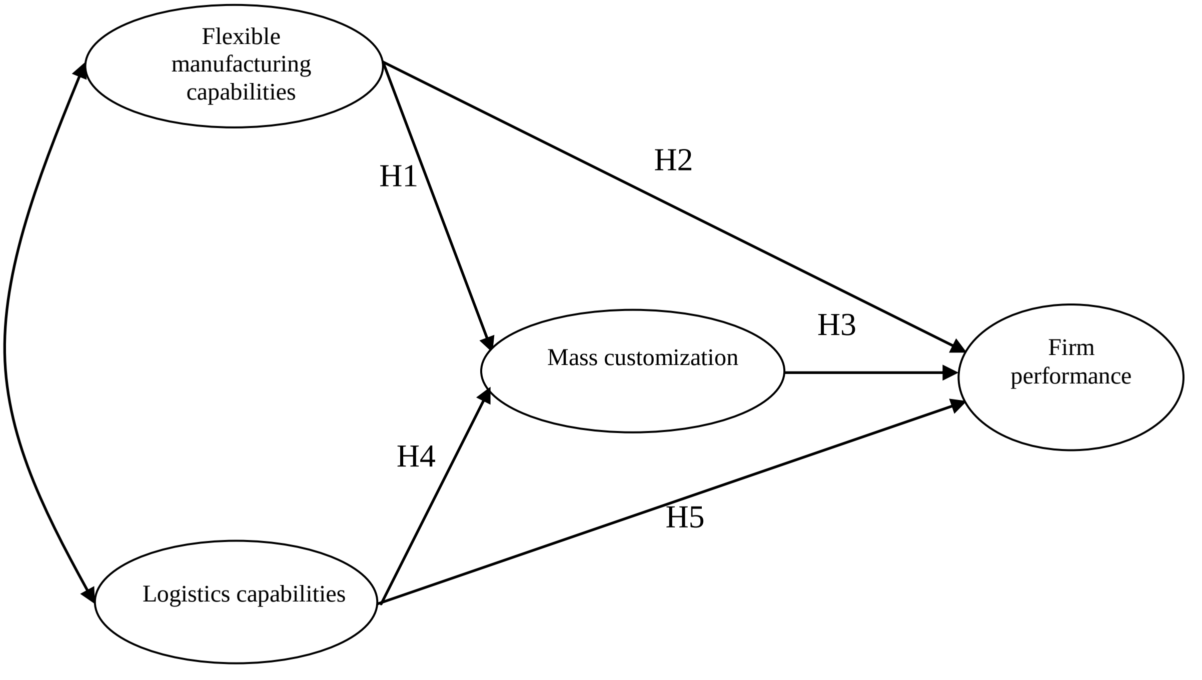

Figure 1: Research structure

Questionnaire design and CMV test

Questionnaire design

The sampling frame of the survey was a nationally representative set of photovoltaic panel manufacturing firms in Taiwan in the year 2010. To increase the content validity and reliability, questionnaire was designed with pilot test and post-test. The questionnaire will be corrected by experts in the pilot test and then the survey was sent to the total 550 respondents of supervisors and managers of the photovoltaic panel manufacturing firms. As a form of post-test, we obtained 208 valid tables (37.8% of sample) from the returned questionnaires. The final scales for all the measurement items were seven-point, Likert-type scales with 1 = extremely disagree, 2 = strongly disagree, 3 = disagree, 4 = neutral, and 5 = agree, 6 = strongly agree, 7 = extremely agree (Fritz and Mackinnon, 2007). The two dimensions of flexible manufacturing capability, including "combination of flexibility" and "competence of new product development", come from Suarez *et al*. (1995) and the total measures contain eight items.The five dimensions of logistics capability, adapted from Wang (2004), are "delivery", "flexibility", "the degree of information sharing", "information technology", and "supplier relationship" and the total measures contain fifteen items.The four dimensions of mass customization, adapted from Tu *et al*. (2001), are "cost", "yield", "responsiveness", and "customization" and the total measures contain eight items.The two dimensions of firm performance, come from Lin and Hong (2010), Kaplan and Norton (1996), are "financial performance", and "non-financial performance" and the total self-designed measures contain eight items.How to reduce common method variance has been taken into account at the beginning of questionnaire survey design. Haman's single-factor test and confirmatory factor analysis were applied to examine the problem of common method variance.In other words, this study uses the difference of value in the chi-square test to examine whether the difference is significant or not. If the difference is significant, it can be claimed that common method variance was not significant (Chang, 2011).

CMV test

The questionnaire was tested common method variance (CMV) problems by CFA comparison method, and the result shows that the difference of between Single Factor and Multi-Factor ($\Delta\chi 2$) has a big value, so it has no CMV problems happened as shown in Table 1.

Table 1: The results of CMV test

Model	χ^2	DF	$\Delta\chi^2$	ΔDF	P
Single Factor	1458.610	209	915.277	27	0.002
Multi-Factor	543.333	182			

SEM and measurement system

Confirmatory Factor Analysis (CFA) was employed to test the construct validity of the capabilities aptitude, mass customization practices and the performance measures in terms of their dimensionality and convergent validity by using Structure Equation Modeling (SEM). The questionnaire is divided by the four latent variables: flexible manufacturing capabilities, logistics capabilities, mass customization, and firm performance. Each latent variable has its sub-variables and each sub-variable contains a number of question items in the survey. The original questionnaire data files are setup after the survey is finished as shown in Table 2. Although the questionnaire design is based on each construct, Dual Measurement method is used to measure the implicit variables and explicit variables (Lee, 2011).

Table 2: Questionnaire structure

ain constructs	Secondary construct or measures	Item number	References
Flexible manufacturing capability	Combination of flexibility	4	Suarez *et al*. (1995), Wang (2004)
	Competence of new product development	4	
Logistics capability	Delivery	3	Wang (2004)
	Flexibility	3	
	Supplier relationship	3	
	Information technology	3	
	The degree of information sharing	3	
Mass customization	Cost	2	Tu *et al* (2001)
	Yield	2	
	Responsiveness	2	
	Customization	2	
Firm performance	Financial performance	4	Lin and Hong (2010), Kaplan and Norton (1996)
	Non-financial performance	4	

Linear SEM model

Confirmatory Factor Analysis (CFA), with respect to exploratory factor analysis (EFA), was employed to test the construct validity of the measures of the four dimensions: flexible manufacturing capabilities, logistics capabilities, mass customization, and performance. Structural equation modeling method, including the structural model and the measurement model, is effective to solve the causal relationship between the latent variables. This study is intended to verify the model in three parts: (1) the overall fit of the structural relationship model, (2) the fit of the measurement model, (3) the fit of the structural model (Lee, 2011).

DATA ANALYSIS AND RESULTS

The overall fitness

The overall framework of the model is verified by the factor analysis of sample data. According to Hair *et al*. (1998), Three types of measurements for the overall fitness of model are measures of absolute fit, incremental fit measures, and parsimonious fit measures (Chen *et al*. 2008).

Table 3: The overall fitness of model

Fitness indices		Assessment criteria	Results
measures of absolute fit	GFI	>0.9	0.921
	AGFI	>0.8	0.901
	RMR	<0.05	0.032
incremental fit measures	NFI	>0.9	0.904
	CFI	>0.9	0.902
parsimonious fit measures	PNFI	>0.5	0.614
	PGFI	>0.5	0.613

Measurement model

Factor loading of the individual items of the latent variables and the explicit variables is a measure of linear strengths. The closer is the factor loading and the more of main dimensions can be explained by the measures of sub-dimensions. The factor loading of sub-dimensions in this study are all larger than 0.7, which indicated a good reliability. Therefore, the sub-dimensions (all explicit variables) are able to measure the main dimensions (all latent variables) in the measurement system of this study. The average variance extracted (AVE) is a measure of degree of explanation on the measurement variances by the latent variables. The higher is AVE value, the higher are the reliability and convergent validity of latent variables. Normally AVE value must be greater than 0.5, so that the dimensions of the cumulative variance is greater than the measurement error (Fornell and Larcker, 1981). In this study, the factor loadings are all greater than 0.7, composite reliability (C. R) and Cronbach'sα are all greater than 0.7, while the AVE are greater than 0.5, this indicates the latent variables have high reliability and convergent validity (See Table 3 and 4).

Table 4: Indicators for the measurement system of model

ain dimensions	measurement indicators	Factor loading	Composite Reliability, C. R.	Cronbach's α	Average Variance Extracted
Flexible manufacturing capability (X)	Combination of flexibility	.851	.843	.841	.671
	Competence of new product development	.832			
Logistics capability (I)	Delivery	.841	.861	.854	.682
	Flexibility	.852			
	Supplier relationship	.861			
	Information technology	.864			
	The degree of information sharing	.861			
Mass customization (Me)	Cost	.881	.881	.874	.693
	Yield	.872			
	Responsiveness	.883			
	Customization	.881			
Firm performance (Y)	Financial performance	.861	.862	.861	.673
	Non-financial performance	.864			

In this study, AVE method is used to determine the discriminant validity of the formative scales. According to the recommendations of Fornell and Larcker (1981), the AVE of each dimension must be greater than the square of the correlation coefficient of the dimensions to ensure the discriminant validity of our measure. The results in Table 5 provide evidence of convergent and discriminated validity among the constructs of Balanced Scorecard, innovation activities, intellectual capital and financial performance.

Table 5: Discriminated validity and vonfidence interval estimators

Parameter	Estimators	Ψ±2σ		Bias-corrected		PercentileMethod	
		Lower	Upper	Lower	Upper	Lower	Upper
X ⟷ Me	.492	.374	.581	.364	.561	.381	.583
Me ⟷ Y	.564	.431	.712	.412	.673	.424	.721
X ⟷ Y	.491	.381	.592	.371	.583	.371	.592
I ⟷ Me	.483	.431	.593	.421	.584	.434	.593
I ⟷ Y	.563	.433	.701	.424	.691	.424	.712

Coefficient of determination

Coefficient of determination is the square of the coefficient of correlation and it provides us with a measure of the strength of the linear relationship of variables, particularly when we want to compare several different models. From the results in Table 6, the latent variables have a moderate degree of interpretation on the dependent variables.

Table 6: Coefficient of determination

Coefficients of Determination	R^2
Flexible manufacturing capability (X) → Mass customization (Me)	.242
Mass customization (Me) → Firm performance (Y)	.318
Flexible manufacturing capability (X) → Firm performance (Y)	.241
Logistics capability (I) → Mass customization (Me)	.233
Logistics capability (I) → Firm performance (Y)	.317

Path Coefficient of Latent Variables

The analysis results of the standardized coefficient and C.R. value are shown in Table 7.

Table 7: Path analysis results of the structural model (Un-standardized)

	Estimate	S.E.	C.R.	P value
Flexible manufacturing capability (X) → Mass customization (Me)	.992	.152	6.526	***
Mass customization (Me) → Firm performance (Y)	1.132	.161	7.031	***
Flexible manufacturing capability (X) → Firm performance (Y)	.863	.152	5.677	***
Logistics capability (I) → Mass customization (Me)	.953	.161	5.919	***
Logistics capability (I) → Firm performance (Y)	1.113	.133	8.368	***

Note: Significance level at: * <0.05, ** <0.01, *** <0.001

Table 8: Standardized Regression Weights: (Group number 1–Default model)

	Estimate
Flexible manufacturing capability (X) → Mass customization (Me)	.431
Mass customization (Me) → Firm performance (Y)	.562
Flexible manufacturing capability (X) → Firm performance (Y)	.582
Logistics capability (I) → Mass customization (Me)	.481
Logistics capability (I) → Firm performance (Y)	.643

Note: Significance level at: * <0.05, ** <0.01, *** <0.001

Path analysis of structural model

Sobel Test, Bootstrapping and Mackinnon PRODCLIN2 methods are used to test the results of path analysis with accumulation of intellectual capital as a dual mediator and the results are shown in Table 9 and 10 (Sobel, 1982; MacKinnon *et al*. 2007).

Table 9: Dual mediator reports (Un-standardized)

Variables	Point of Estimates	Product of Coefficients		Bootstrapping Bias-Corrected 95% CI		Bootstrapping Percentile 95% C		MacKinnon PRODCLIN2 95%CI	
	(Est.)	SE	Z	Lower	Upper	Lower	Upper	Lower	Upper
				Total Effects					
X→Me	.99	.15	6.53	.78	.99	.74	.99		
				Indirect Effects					
Me→Y	1.13	.16	7.03	.36	.95	.32	.93	. 38	.97
				Direct Effects					
X→Y	.86	.15	5.68	.35	.62	.35	.74		

Table 10: Dual mediator reports (Un-standardized)

Variables	Point of Estimates	Product of Coefficients		Bootstrapping Bias-Corrected 95% CI		Bootstrapping Percentile 95% C		MacKinnon PRODCLIN2 95%CI	
	(Est.)	SE	Z	Lower	Upper	Lower	Upper	Lower	Upper
				Total Effects					
I→Me	.95	.16	5.92	.68	.98	.63	.97		
				Indirect Effects					
Me→Y	1.13	.16	7.03	.36	.95	.32	.93	.36	.99
				Direct Effects					
I→Y	1.11	.13	8.37	.35	.88	.31	.83		

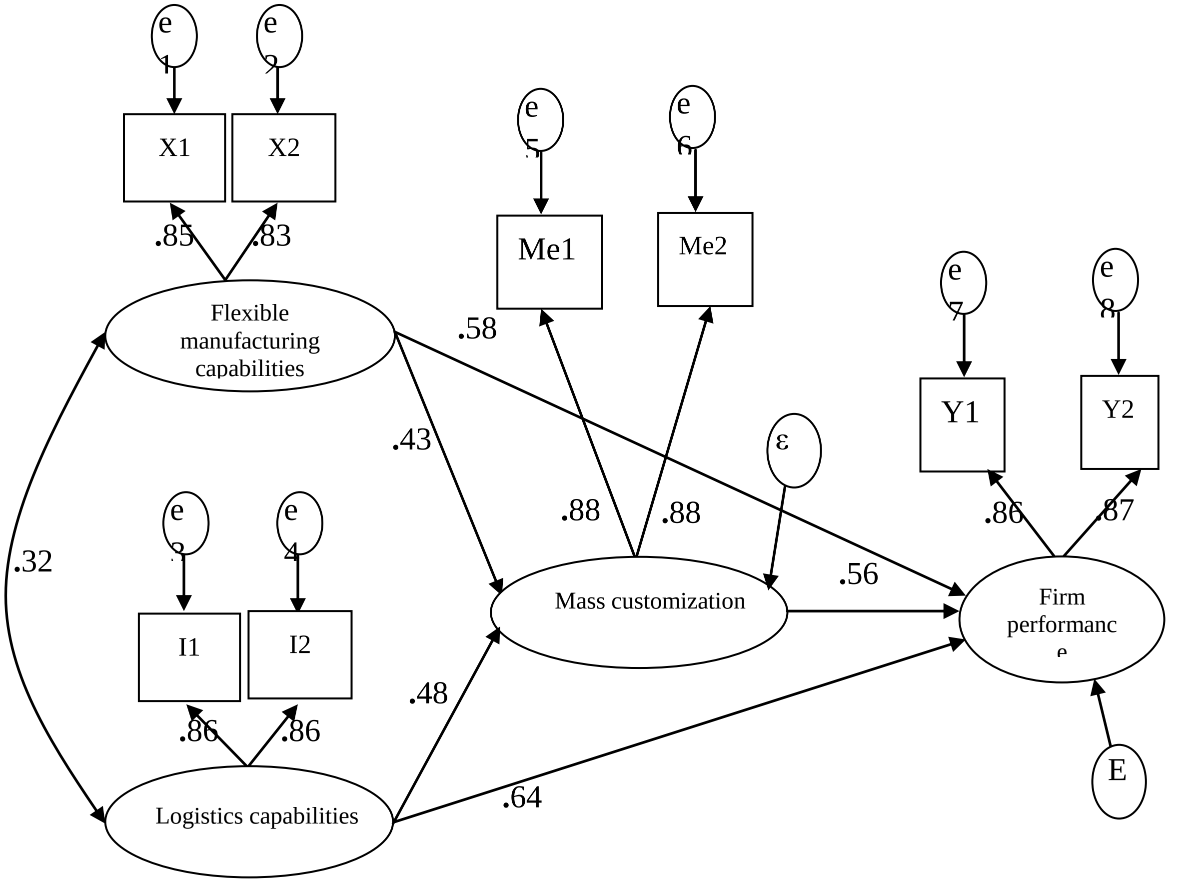

Figure 2: Standardized SEM analysis results

From the results of Table 10, we find that flexible manufacturing capability can strengthen the ability of mass customization to satisfy diverse customers' needs as well as to reduce product costs. The value of standardized estimated parameter was 0.43 and Hypothesis H1 was supported. Mass customization will enhance the performance of firm. The value of standardized estimated parameter was 0.56 and Hypothesis H2 was supported.Flexible manufacturing capability will enhance the performance of firm. The value of standardized estimated parameter was 0.58 and Hypothesis H3 was supported.Logistics capability can strengthen the ability of mass customization to satisfy diverse customers' needs as well as to reduce product costs. The value of standardized estimated parameter was 0.48 and Hypothesis H4 was supported.Logistics capability will enhance the performance of firm. The value of standardized estimated parameter was 0.64 and Hypothesis H5 was supported.Mass customization has a effect of dual partial mediating effect and this implies that mass production plays an important role in the promotion of firm performance.

CONCLUDING REMARKS, RESEARCH LIMITATIONS AND FUTURE DIRECTIONS

The respondent positions are Supervisor and Manager in the photovoltaic panel manufacturing companies in Taiwan. We find that Hypothesis H1 was supported. It indicated that flexible manufacturing capability could strengthen the ability of mass customization to satisfy diverse customers’ needs as well as to reduce product costs for the photovoltaic panel manufacturing companies in Taiwan. The findings are consistent with the studies of Pine (1993), Gooley (1998), and Chen (2001).Hypothesis H2 was supported. It indicated that mass customization would enhance the performance of the photovoltaic panel manufacturing companies in Taiwan. The findings are consistent with the studies of Tai (2008), and Lee (2007).Hypothesis H3 was supported. It indicated that flexible manufacturing capability would enhance the performance of the photovoltaic panel manufacturing companies in Taiwan. The findings are consistent with the studies of Kuo (1998), and Chen (2000).Hypothesis H4 was supported. It indicated that logistics capability could strengthen the ability of mass customization to satisfy diverse customers’ needs as well as to reduce product costs for the photovoltaic panel manufacturing companies in Taiwan. The findings are consistent with the studies of Wang (2004), Zipkin (2001), and Berman (2002). Hypothesis H5 was supported. It indicated that Logistics capability would enhance the performance of the photovoltaic panel manufacturing companies in Taiwan. The findings are consistent with the studies of Shih (2008), Wang (1998), Lin (2010), and Tsai (2006).This study contributes in existing literature by integrating the previous researches to construct a structural equation model with three variables and one dual mediator. The results support the construct validity, as indicated by the fitness indices and measurement error of the model. This study belongs to the important subject of confirmatory factor analysis (CFA) with innovation and is worthy of future study in the related fields.The questionnaire measurements and model dimensions have completed a series of analysis on reliability, validity and CMV. The adopted statistical methods and research methods are innovative.The results of this study can provide the photovoltaic panel manufacturing companies, implementing flexible manufacturing capability, to develop the supply chain manager’s logistics capability when implementing the strategies of mass customization to enhance firm performance. The study used simple random sampling on the population and sent the questionnaire by post mail. It caused a low return percentage of samples and resulted in an inadequate representative of the population. Due to the restrictions of research resources`, the respondents of this survey are limited to the photovoltaic panel manufacturing companies only in the stock market rather than the whole market in Taiwan.The literature exploring the dimensions in the subject of this study is few, particularly the investigations between the dimensions. Therefore, the supporting information becomes inadequate for the inference.Since this study only limited to the supervisors and managers in the photovoltaic panel manufacturing companies in Taiwan, it is suggested to try the same industry but different economics scale, such as small and medium-sized photoelectric companies for innovative breakthroughs.

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