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Comparative study on the relationship between just-in-time production practices and operational performance in manufacturing plants

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Abstract This study analyzes the differences in approaching JIT production across countries in order to identify alternative paths to high manufacturing performance. We applied ANOVA and regression techniques to the database of High Performance Manufacturing Project to examine the similarities and differences across countries in JIT implementation and the effect of JIT production practices on operational performance. The results indicated that JIT production practices were implemented in different ways across the countries. We found that the relationship between JIT production practices and plant performance is contingent on the national context and infrastructure practices in quality and workforce management. *JIT delivery by suppliers, JIT layout,* and *setup time reduction* were found to be the most effective approaches to improve cost, delivery, and flexibility. This study highlights the important role of shop-floor communication and information sharing, which should be focused for maximizing the benefits of JIT implementation.

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1 Introduction

Since the 1980s, JIT production has been one of the hottest research areas in operations management. It describes the idea of producing the necessary items in the necessary quantities at the necessary time, and eliminating all sources of waste in operations. If such an idea would be realized throughout an organization or a supply chain, the level and cost of inventory could be reduced drastically, and inventory turnover would increase sharply. While many scholars emphasized on the critical role of JIT production, there is still little agreement on what the concept of 'JIT' means, what the components of JIT production are, and how to successfully implement JIT production in manufacturing organizations. For practitioners and researchers, 'JIT' can be defined in either a narrow view (as a set of practices for inventory minimization) or a broad view (as business philosophy aiming to eliminate any source of waste). The relationship between JIT production and performance of manufacturing plants has been intensively investigated in the existing literature with mixed results. While many scholars demonstrated the success of JIT implementation (Mehra and Inman 1992; Sakakibara et al. 1993; McLachlin 1997; Ahmad et al. 2003; Callen et al. 2000; Matsui 2007), others indicated that JIT failed to improve performance (Safayeni and Purdy 1991; Inman and Brandon 1992; Wafa and Yasin 1998). We observed that previous research on JIT production provides very little explanation on why the same set of JIT production practices can produce so much different results in different plants or countries. This paper discusses the difference in approaching JIT production by country in order to identify alternative paths to operational performance. To fill the gap in JIT production literature, we conducted a comparative study on JIT production to answer the following questions:

1. What is the difference and similarity in the implementation of JIT production practices in different countries?
2. What is the linkage between JIT production practices and infrastructure practices in quality and workforce management?

Our study utilizes data collected from 163 manufacturing plants in the United States, Japan, Germany, Italy, and Korea through an extensive questionnaire survey that has been conducted since 2003 in the framework of the High Performance Manufacturing (HPM) Project. Seven measurement scales have been proposed to measure different aspects of JIT (*JIT delivery by suppliers, JIT link to customer, pulls system, leveled master schedule, setup time reduction, JIT layout,* and *multi-functional employee*). Using these scales, we examined the similarities and differences across countries in JIT implementation and the effect of JIT production practices on five dimensions of manufacturing performance: manufacturing unit cost, on-time delivery, volume flexibility, inventory turnover, and cycle time. We further analyzed how JIT production links with the implementation of quality and workforce management practices. We obtained mixed results when using analysis of variance (ANOVA) and regression techniques to test the hypotheses. The results indicated that the JIT production practices are being implemented in different ways across the countries. We found that JIT production practices are aggressively adopted in Korean and US plants while they were not so focused in German and Italian plants. We also found that the linkage between JIT production practices and operational performance in Japanese plants appeared tight, comparing with other countries. Some practices such as *JIT delivery by suppliers*, *JIT layout*, and *setup time reduction* were found to be the most effective approaches to improve cost, delivery, and flexibility. In addition, we observed that the degree of JIT implementation positively relates with infrastructure in quality and workforce management, especially *information feedback, preventive maintenance, small group problem solving*, and *employee suggestions*. We concluded that the relationship between JIT production practices and operational performance is contingent on the national context and infrastructure practices in a plant.

The remains of this paper present the theoretical background and analytical framework, which is followed by the research methodology we adopted for data collection, measurement test and hypothesis testing. The last three sections discuss the important findings and limitations to this research, and give final conclusions.

2 Theoretical background and analytical framework

JIT was originally defined in Toyota Motor Cooperation as having the right part as precisely the right time, and in the right quantity (Ohno 1988). Following Japanese manufacturers, American and European companies adopted JIT production during the 1980's. Scholars recognized JIT production as the practical approach for the elimination of waste through simplifying the production process (Schonberger 1986), implementing the kanban system and set-up time reduction (Monden 1998). Sakakibara et al. (1993) described JIT's dimensions in three categories: (1) management of people and schedules; (2) simplified physical flow; and (3) supplier management. Reviewing the existing JIT production literature, we observed two different approaches to JIT production. The first operationally defined JIT production as a set of practices aimed at reducing inventories in production (Flynn et al. 1995; Ahmad et al. 2003; Matsui 2007). The other, in a broader view, considers JIT as a philosophy of manufacturing related with continuous improvement through elimination of waste in all stages of production process (Sakakibara et al. 2001). In this study, we adopted the eclectic approach and conceptualized JIT production practices along the following dimensions: *JIT delivery by suppliers, JIT link to customer, pull system, leveled master schedule, JIT layout, setup time reduction,* and *multi-functional employees.* Exploring these JIT production perspectives, Sakakibara et al. (2001) was the first to empirically compare JIT practices across the countries and detected the differences on adoption of JIT in the US, Japan, UK, Germany, and Italy during the 1990's. In addition, this indicated that the source of the difference in JIT performance across countries might be attributed to the difference in infrastructure practices in manufacturing strategy, quality and human resource management. This argument has been supported latter by Ahmad et al. (2003), Ayman and Phan (2007), and Bayo-Moriones et al. (2008) which suggested that relationship between JIT practices and plant performance should be contingent on the infrastructure practices in a plant. Continuing these works, we would like to examine the relationship between JIT and operational performance by identifying the similarities and differences in the degree of implementation of JIT production practices and their impact on performance in different contexts. This is important to refine whether relationship between JIT production and performance is contingent upon national context (e.g. country location) and organizational context (e.g. managerial infrastructure).

This study starts by comparing the degree of implementation of JIT practices across the countries. We presume that, with the evolution and spreading of modern technologies, organizations tend to design their operational structures in similar ways in order to be efficient and effective. Thus, as an effective approach to improve manufacturing performance, JIT production is adopted in a similar way across Japanese, US, German, Korean and Italian manufacturing plants. This leads to the first hypothesis, which is stated as follows.

H_1: There is no difference in the degree of implementation of JIT production practices across the countries.

Next is the linkage between JIT production and operational performance. The contribution of JIT to performance of manufacturing plants during 1990's has been empirically provided in existing literature (Mehra and Inman 1992; Sakakibara et al. 1993; McLachlin 1997; Ahmad et al. 2003; Callen et al. 2000; Matsui 2007). It is expected that, in the new context of the manufacturing environment at the beginning of 21st century, JIT production is maintaining its function as key determinant for operational performance as it did during 1980's and 1990's. The second hypothesis is stated as follows.

H_2: JIT production practices positively relate to operational performance of manufacturing plants

The third argument concerns with the impact of JIT production practices on performance across the countries. Learning lessons from Japanese manufacturing where JIT production has been well integrated into a whole production system during the 1970's and 1980's, many countries recognized the power of JIT production and tried to adopt it to improve the efficiency of their production systems. It is assumed that JIT production is effectively explored in other countries as it was in Japan during 1980's and 1990's. The third hypothesis is stated as follows.

H_3: There is no difference on the impact of JIT production practices on operational performance across the countries

The linkages between JIT production and quality management (QM) and workforce management (WM) have been discussed in existing literature. Flynn et al. (1995) indicated the mutual supportive relation between JIT production and QM, which have the same objectives. Although JIT production and QM can be implemented separately, their combination further improves plants performance. QM practices provide JIT production with necessary control of production processes. The improvement of product quality with lower defect rate allows the production flow to be smoother and faster, and leads to less inventory. WM is the second factor affecting JIT implementation, which requires strong focus on task-related training, teamwork, and employee participation. In this study, we suggest that the relationship between JIT production and QM/WM does not exist in one way only (i.e. QM and WM support JIT production) but also in the other way where JIT production pushes QM and WM to higher levels. As indicated in the existing literature, reduction of inventory exposes the quality problem and leads to the development of quality-based supplier relationship. In addition, the implementation of JIT production practices would promote an environment that highly focuses on employee training, employee participation, and cross-functional communication and information sharing. This argument has been empirically supported by Sakakibara et al. (2001), Ahmad et al. (2003), Ayman and Phan (2007), and Bayo-Moriones et al. (2008). The fourth and fifth hypotheses can be stated as follows.

H_4: The degree of implementation of JIT production positively relates with the degree of implementation of QM practices in manufacturing plants

H_5: The degree of implementation of JIT production positively relates with the degree of implementation of WM practices in manufacturing plants

To test the hypotheses, along with the seven JIT production measurement scales as mentioned earlier, we propose ten measurement scales, which intend to measure different quality and human aspects as follows.

QM is characterized in this study by six practices: *Process control (PCTL)*, *Information feedback (IFFB)*, *Housekeeping (CO3S), Preventive maintenance (PVMT)*, *Supplier quality involvement (SQIV)*, and *Customer involvement (CIVM).*

WM is characterized by four practices: *Task-related training for employees (TTEM)*, *Shop-floor contact (SFCT)*, *Employee suggestions (EMSG),* and *Small group problem solving (SGPS).*

Relationship of JIT production on operational performance was tested in this study by examining impact of the above seven JIT practices on five operational indicators: *manufacturing cost, on-time delivery, volume flexibility, inventory turnover*, and *cycle time*.

Because the objective of this study is to identify the impact of JIT production practices on operational performance that can be generalized across countries and industries, the effects of country and industry need to be removed before evaluating the relationship between JIT production practices and operational performance. Therefore, we included the following control variables in the regression analyses. Four country dummy variables, US (US compared to Japan), ITA (Italy compared to Japan), GER (Germany compared to Japan), KOR (Korea compared to Japan), are used to represent the effect of those countries in the regression model. Similarly, two industry dummy variables, MAC (machinery industry compared to electric &electronics industry) and ATM (automobile industry compared to electric & electronics industry), were used to represent the industry effect.

3 Data collection and measurement analysis

This study analyzes the data collected from 163 manufacturing plants in Germany (41 plants), Italy (27 plants), Japan (35 plants), Korea (31 plants), and the United States (29 plants) through an extensive questionnaire survey that has been conducted in 2003 and 2004. The survey was conducted in the framework of the international joint research initiative called High Performance Manufacturing (HPM) project, which was initiated by researchers at the University of Minnesota and Iowa State University. The overall target of this project is to explore "best practices" in manufacturing plants and their impact on plant performance in global competition. The first round of the survey was conducted in 1989, gathering information from forty-six US manufacturing plants. In 1992, the project was expanded to include researchers from Germany, Italy, Japan, and the UK. The second round of the survey gathered data from 146 manufacturing plants from those countries. In 2003, the project was further expanded to include researchers from Austria, Finland, Korea, Spain, and Sweden. Within each country, surveyed are plants with more than 100 employees belonging to one of three industries—electrical & electronics, machinery, and automobile. Each manufacturing company selected one typical plant for participating in the project. The description of survey respondents is summarized in Appendix A.

In each plant, the degree of implementation of JIT production practices were evaluated by five positions including supervisors, production control manager, inventory manager, human resource manager, and plant superintendent as shown in Appendix A. The degree of implementation for each JIT production practice has been evaluated on a seven point Likert scale (1: Strongly disagree, 4: Neither agree nor disagree, 7: Strongly agree). Similar evaluations for QM and WM practices were conducted by seven positions including direct workers, supervisors, process engineer, inventory manager, quality manager, human resource manager, and plant superintendent. Finally, five operational measures of manufacturing plants were subjectively judged by the plant manager. Each plant manager was asked to indicate his/her opinion about how the plant compares to its competitors in the same industry on a global basis on a five-point Likert scale (1=Poor or low end of the industry, 3=Average, 5=Superior or top of the industry).

The first step of analytical process is to test the reliability and validity of seventeen measurement scales. In this study, Cronbach's alpha coefficient was calculated for each measurement scale to evaluate its reliability. We found that the alpha value for all of the seventeen scales exceeded the minimum acceptable value of 0.6 for the pooled sample and country-wise samples. Most of the scales have alpha values above 0.75, indicating that the scales were internally consistent as summarized in Appendix C.

Content validity An extensive review of literature and empirical studies was undertaken about QM and WM practices, JIT production practices to ensure their content validity. This research follows the works of Sakakibara et al. (1993), Schroeder and Flynn (2001), and Matsui (2007), which developed and tested a set of measurement scales of JIT production with the HPM perspective.

Construct validity Construct validity is to ensure that all question items in a scale measure the same construct. Within-scale factor analysis was conducted with the three criteria: uni-dimensionality, a minimum eigenvalue of 1, and item factor loadings in excess of 0.4. The results of measurement analysis prove that all scales have satisfactory construct validity. The factor loadings of most question items range between 0.7 and 0.9 as shown in Appendix B.

4 Data analysis

Firstly, we examine the country effect on the implementation of JIT production. One-way ANOVA was used to identify the similarity and difference in JIT production practices across the countries. Table 1 shows the mean values by country, *F*-statistics and the corresponding significance level for each practice. If we set the significance level at 5%, the ANOVA test suggests that all of the JIT production practices are significantly different across the countries except *Pull system*. In addition, Tukey pairwise comparison tests of mean differences are conducted to identify how JIT practices differ between each pair of countries.

We found that the largest difference across the countries exists in *Leveled master schedule*. German plants showed the lowest score in *Leveled mater schedule* and *JIT link with customers*. Korean plants exhibited higher scores in *JIT delivery by suppliers* and *Setup time reduction* than German, Italian, and Japanese plants. Korean and Japanese plants showed higher scores in *JIT layout* than German plants. German and US plants showed higher scores in *Muti-functional employees* than Japanese plants. Somewhat similar scores were found between Italy and Japan and between Korean and the US (except *Leveled master schedule).* The results also indicated the most focused aspect of JIT production for each country: *Multi-functional employees* (in Germany, Italy, and the US)*, JIT layout* (in Japan), and *Setup time reduction* (in Korea). In contrast, *Pull system* is found to be the least focused among JIT production practices in every country except Germany. In summary, JIT production practices varied widely across countries. Each country evaluated the importance of JIT production in different ways. The competitive environment and the infrastructure in manufacturing management may account for the differences we observed in JIT production

Table 1 JIT production practices across countries

	GER	ITA	JPN	KOR	US	F	Sig.	Pair wise Difference
JIT delivery by suppliers (JDSP)	4.080	4.356	4.578	5.054	4.758	12.368	0.000	(US vs. GER), (JPN vs. GER), (JPN vs. KOR), (KOR vs. GER), (ITA vs. KOR)
JIT link with customers (JLCS)	3.628	4.682	4.418	4.816	4.701	11.417	0.000	(US vs. GER), (JPN vs. GER), (KOR vs. GER), (ITA vs. GER)
Pull system (PULS)	3.834	3.898	3.635	4.133	3.907	1.158	0.332	
Leveled master schedule (LMSC)	3.105	4.253	4.623	5.265	4.085	34.787	0.000	(US vs. GER), (US vs. KOR), (JPN vs. GER), (JPN vs. KOR), (GER vs. KOR), (GER vs. ITA), (KOR vs. ITA)
Setup time reduction (STRD)	4.888	4.817	4.843	5.412	5.313	4.948	0.001	(JPN vs. KOR), (GER vs. KOR), (KOR vs. ITA)
JIT layout (JLYT)	4.630	4.876	5.082	5.082	4.633	3.800	0.006	(JPN vs. GER), (GER vs. KOR)
Multi-functional employees (MFEM)	5.404	5.168	4.957	5.188	5.457	4.174	0.003	(US vs. JPN), (JPN vs. GER)

GER Germany, *ITA* Italy, *JPN* Japan, *KOR* Korea, *US* The United State

practices adopted in different countries. As the result, we would like to reject hypothesis H_1 and state that there is a significant difference in the perception of the implementation of JIT production practices across the countries.

The relationship between seven JIT production practices and five operational performance indicators in each country was tested by analyzing their simple correlation coefficients initially. Table 2 has 35 cells, each corresponding to a pair of one JIT production practice and one performance indicator. Each cell includes the abbreviated name of the countries for which significant correlation was found between the JIT production practice and the performance indicator. We observed that the correlation between JIT production and performance in Japanese plants tends to be high, comparing with other countries. Setting the significant level at 5%, the number of pairs with significant correlation for the Japanese sample is 22 out of 35. This number is 9, 6, 5, and 2 for Korea, Italy, Germany, and the US respectively. Every JIT production practice significantly correlates with at least one of five performance indicators in the Japanese sample. In contrast, we found only two JIT production practices that significantly correlate with *Volume flexibility* in the US sample. *On-time delivery, Volume flexibility,* and *Manufacturing cost* are three performance indicators that are significantly influenced by adopting JIT production for the German, Italian, and Korean samples, while the significant correlation of JIT production practices and *Inventory turnover* and *Cycle time* can be found for the Japanese sample only.

The most effective practices may be attributed to *JIT delivery by suppliers, JIT link to customers, JIT layout*, and *Setup time reduction,* while the effectiveness of *Leveled master schedule* can be found in Japanese and Italian plants only.

To test the second and third hypotheses formally, regression analysis was conducted for the pooled sample with the utilization of six dummy variables representing four countries and two industries. Table 3 shows the results of regression analysis on five performance indicators. If the significance level is set at the 5 % by using two-tailed test, the regression results suggested the contribution of JIT production practices to *On-time delivery*, *Volume flexibility*, and *Inventory turnover*. They also revealed the significant difference in the determinants of operational performance between Japan and other four countries. For example, it is interesting to observe that the impact of *Pull system* on *On-time delivery* was strong in Italy and the impact on *Volume flexibility* was strong in Korea and the US, compared to Japan. The impact of *JIT delivery by suppliers* on *On-time delivery* was strong in Korea, and *Multi-functional employ-*

Table 2 Correlation between JIT production practices and performance indicators

	Manufacturing cost (MFCS)	On-time Delivery (OTDL)	Volume Flexibility (VLFL)	Inventory Turnover (INTO)	Cycle Time (CLTM)
JIT delivery by suppliers (JDSP)	JPN, KOR	GER, ITA	JPN,KOR	JPN	JPN
JIT link with customers (JLCS)	JPN	JPN	JPN, KOR, US	JPN	JPN
Pull system (PULS)	KOR	GER, ITA	KOR	JPN	
Leveled master schedule (LMSC)	JPN		ITA,JPN	JPN	JPN
Setup time reduction (STRD)	GER, JPN, KOR	ITA	JPN, US		JPN
JIT layout (JLYT)	JPN	GER	GER, ITA,JPN, KOR	JPN	JPN
Multi-functional employees (MFEM)	GER	KOR	JPN,KOR		

Table 3 Regression analysis on the effect of JIT production practices on performance with dummy variables for the pooled sample

	Manufacturing cost as Dependent Variable	On-time delivery as Dependent Variable	Volume flexibility as Dependent Variable	Inventory turnover as Dependent Variable	Cycle time as Dependent Variable
R^2	0.356	0.407	0.442	0.384	0.297
Adjusted R^2	0.102	0.177	0.227	0.138	0.018
F and p	1.402 (0.087)	1.774 (0.010)	2.051 (0.002)	1.563 (0.037)	1.064 (0.392)
df.	144	144	144	144	144
(Constant)	−0.274 (0.870)	0.371 (0.811)	−0.635 (0.632)	−0.516 (0.753)	0.309 (0.832)
GER	−0.159 (0.896)	−0.716 (0.532)	1.843 (0.099)	1.117 (0.348)	1.001 (0.428)
ITL	1.668 (0.197)	−0.283 (0.817)	0.526 (0.657)	0.888 (0.485)	0.199 (0.883)
KOR	−0.184 (0.882)	−0.046 (0.969)	−0.684 (0.550)	0.099 (0.936)	0.645 (0.623)
US	0.211 (0.854)	−0.120 (0.912)	2.363 (0.027)	0.180 (0.873)	0.001 (0.999)
ATM	−0.020 (0.881)	0.135 (0.282)	0.144 (0.238)	0.214 (0.101)	0.065 (0.643)
MAC	0.010 (0.929)	0.145 (0.168)	0.048 (0.638)	0.262 (0.017)	0.198 (0.087)
JDSP	0.181 (0.593)	−0.492 (0.130)	0.090 (0.774)	0.236 (0.479)	−0.098 (0.782)
JLCS	0.177 (0.625)	0.745 (0.032)	0.494 (0.142)	0.326 (0.359)	0.432 (0.256)
PULL	−0.309 (0.185)	−0.195 (0.378)	−0.436 (0.044)	−0.204 (0.374)	−0.181 (0.458)
LMSC	0.551 (0.100)	0.086 (0.786)	0.319 (0.301)	0.536 (0.107)	0.492 (0.160)
JLYT	0.318 (0.415)	0.021 (0.954)	0.372 (0.302)	−0.013 (0.973)	0.280 (0.495)
STRD	0.117 (0.813)	0.447 (0.344)	0.029 (0.949)	0.458 (0.347)	0.197 (0.705)
MFEM	−0.226 (0.364)	0.069 (0.772)	0.087 (0.706)	−0.432 (0.084)	−0.196 (0.455)
GER * JDSP	−0.270 (0.806)	1.615 (0.125)	0.043 (0.966)	−0.513 (0.636)	−0.207 (0.857)
GER * JLCS	−0.226 (0.751)	−1.313 (0.055)	−0.763 (0.246)	−1.235 (0.080)	−1.632 (0.030)
GER * PULL	0.486 (0.374)	0.789 (0.131)	0.500 (0.322)	0.639 (0.237)	0.730 (0.204)
GER * LMSC	−0.488 (0.337)	0.234 (0.628)	−0.843 (0.074)	−0.416 (0.408)	−0.361 (0.497)
GER * JLYT	−1.429 (0.267)	0.647 (0.596)	−0.048 (0.968)	0.141 (0.911)	−0.264 (0.844)
GER* STRD	0.247 (0.876)	−2.520 (0.098)	−0.220 (0.881)	−0.291 (0.852)	0.403 (0.809)
GER * MFEM	2.399 (0.126)	1.541 (0.300)	−0.112 (0.938)	1.333 (0.387)	0.824 (0.614)
ITA * JDSP	−1.056 (0.327)	1.157 (0.264)	−0.205 (0.837)	−0.490 (0.643)	0.945 (0.402)
ITA* JLCS	0.289 (0.745)	−1.422 (0.093)	−0.875 (0.285)	−1.076 (0.219)	−1.088 (0.242)
ITA*PULL	0.314 (0.547)	1.085 (0.032)	0.362 (0.455)	0.511 (0.321)	0.249(0.648)
ITA *LMSC	0.150 (0.845)	0.141 (0.847)	0.238 (0.738)	−0.958 (0.207)	−0.588 (0.465)
ITA * JLYT	−0.999 (0.361)	−0.120 (0.909)	−0.070 (0.945)	0.357 (0.740)	−0.395 (0.729)
ITA* STRD	0.131 (0.933)	−1.108 (0.458)	0.162 (0.911)	−1.066 (0.486)	−1.158 (0.479)
ITA*MFEM	−0.259 (0.831)	0.410 (0.721)	−0.223 (0.842)	2.037 (0.092)	1.773 (0.166)
KOR* JDSP	1.321 (0.435)	3.614 (0.026)	1.766 (0.259)	−2.045 (0.215)	−0.652 (0.710)
KOR * JLCS	−0.459 (0.698)	−1.923 (0.089)	0.027 (0.980)	1.655 (0.150)	0.465 (0.703)
KOR * PULL	1.565 (0.107)	0.863 (0.348)	1.778 (0.048)	1.435 (0.137)	1.763 (0.087)
KOR * LMSC	−0.478 (0.659)	−0.977 (0.344)	−1.370 (0.172)	0.047 (0.965)	0.172 (0.880)
KOR* JLYT	−4.022 (0.027)	−0.987 (0.563)	−2.166 (0.192)	−2.230 (0.224)	−1.446 (0.458)
KOR * STRD	1.073 (0.566)	−2.777 (0.120)	−2.014 (0.244)	−2.570 (0.157)	−1.350 (0.485)
KOR * MFEM	1.087 (0.492)	2.350 (0.120)	2.398 (0.102)	3.584 (0.023)	0.230 (0.889)
US * JDSP	0.088 (0.945)	0.324 (0.788)	−0.419 (0.721)	−0.009 (0.994)	0.193 (0.884)
US * JLCS	0.195 (0.847)	0.353 (0.713)	−1.151 (0.218)	−0.766 (0.442)	−0.136 (0.897)
US * PULL	0.000 (1.000)	−0.130 (0.799)	1.067 (0.032)	−0.711 (0.179)	−0.146 (0.791)
US * LMSC	−0.714 (0.266)	−0.057 (0.926)	−0.589 (0.319)	−0.199 (0.752)	−0.545 (0.417)
US * JLYT	−1.833 (0.174)	−0.083 (0.948)	−1.127 (0.363)	0.611 (0.644)	0.441 (0.750)
US * STRD	0.354 (0.804)	−0.101 (0.941)	0.062 (0.962)	−1.615 (0.250)	−0.115 (0.938)
US * MFEM	1.706 (0.117)	−0.036 (0.972)	−0.113 (0.910)	2.905 (0.008)	0.365 (0.745)

ees was influential on *Inventory turnover* in Korea and the US. To confirm this finding on the country effect with more formal statistical evidence, additional regression analysis is required to check whether the coefficients in a particular regression model take the same value for the samples of different countries, after dividing the pooled sample into five sub-samples representing each country. What is required is to compare an estimated regression model including eleven JIT production measurement scales as independent variables for the pooled sample with the corresponding model applied for the five sub-samples. In estimating the regression models for the sub-samples, no restrictions are imposed on the values of regression coefficients so that every coefficient can take different values for different countries.

By an F-test, we can evaluate the improvement in explanatory power by dividing the pooled sample into the five sub-samples and enabling regression coefficients to freely take different values (Chow 1960).

$$\text{F statistic} = \left(\left(\text{RSSR} - \sum \text{SSR}_i\right)/k\right) / \left(\sum \text{SSR}_i / \left(n - i^* k\right)\right) \quad (1)$$

where

RSSR is the sum of squared residuals from a linear regression model for the pooled sample,
SSR_i is the sum of squared residuals from a linear regression model for the i-th sub-sample,
i is the number of subgroups,
k is the number of independent variables, and
n is the number of total observations

The results of five regression models are shown in Appendix D. The results of Chow test are presented at the bottom of each table. We found that, in all of the cases, the determinants of JIT production on operational performance were significantly different across the five countries. In summary, hypothesis H_2 was accepted for the pooled sample if we take *On-time delivery, Volume flexibility,* and *Inventory turnover* as the indicators of operational performance. In addition, because the results from the Chow test show the highly significant level of F-statistics, we should reject hypothesis H_3 and state that the determinants of operational performance were different across the countries.

Finally, we investigated the linkage between JIT production practices and QM/WM practices. An aggregate JIT supper scale was built based on seven individual JIT measurement scales to evaluate overall JIT production implementation of each plant. Based on the score of this overall JIT production we divided 163 plants into three groups. The first group named as "High JIT" consists of 66 plants whose overall JIT production score was no less than 4.75. The second group named as "Medium JIT" consists of 51 plants whose overall JIT production score was between 4.75 and 4.20. The third group named as "Low JIT" consists of the remaining 46 plants whose overall JIT production score was less than 4.20. Then, one- way ANOVA test was conducted to compare the level of six QM practices and four WM practices across three groups and the results are presented in Table 4. We found the significant differences among three groups in six QM practices and three WM practices (except *Task-related training for employees,* which is essential even for non-JIT performers). "High JIT" group generally achieves higher levels of both QM and WM practices. We further conducted Tukey pairwise comparison tests of mean differences to indentify how QM and WM practices differed between each pair of groups. We observed very large differences among three groups in *Preventive maintenance, Information feedback, Small Group problem solving*, and *Employee suggestions*. As the results, we would like to accept Hypotheses H_4 & H_5 and state that the degree of implementation of JIT production positively relate with the degree of implementation of QM and WM practices in manufacturing plants.

5 Discussion

The important findings of this study are the diversification of JIT production implementation across the countries and the close link between JIT production practices and operational performance in Japanese plants. The results of statistical analyses indicate that JIT production practices have been implemented in different ways across countries. We observe that JIT production was aggressively implemented in Korean and US plants while it was not so focused in German and Italian plants. In between those is Japan where JIT production has been adopted earlier than other countries. This finding is in line with the results of previous JIT studies (Lee 1992; Schroeder and Flynn 2001; De Toni et al. 2001). JIT production has been regarded as the key solution for making US manufacturing renewal during the 1980s and 1990s. Learning from Japanese experiences, many US plants have aggressively studied and implemented JIT production to regain the competitiveness. Later, during the 1990s and 2000s, Korean managers have actively adopted Japanese management techniques to enhance the manufacturing capabilities. In contrast, the implementation of JIT practices is difficult and not really worthwhile in Italian manufacturing plants, which are characterized by small and medium size and less repetitive production. The evidence of less concentration on some practices such as *JIT link with customers* and *Leveled master schedule* in German plants suggest further studies on the implementation of JIT production in German manufacturing.

The linkage between JIT production practices and operational performance also appear differently across the countries. Correlation analysis indicates the effectiveness of JIT produc-

Table 4 Quality management and workforce management practices by the degree of JIT implementation

	Low JIT (L)	Medium JIT (M)	High JIT (H)	Pair-wise t-test	F	Sig.
Process control (PCTL)	4.371	4.830	5.118	(M,L), (H,L)	12.412	0.000
Information feedback (INFB)	4.225	4.778	5.388	(M,L), (H,L), (M,H)	31.144	0.000
Housekeeping (CO3S)	5.119	5.320	5.598	(H,L),(H,M)	9.520	0.000
Preventive maintenance (PVMT)	4.178	4.861	5.352	(M,L), (H,L), (M,H)	54.553	0.000
Supplier quality involvement (SQIV)	4.683	4.886	5.236	(H,L),(H,M)	15.594	0.000
Customer involvement (CINV)	5.067	5.162	5.410	(H,L),(H,M)	6.301	0.002
Task-related training for employees (TTEM)	5.093	5.259	5.202		0.691	0.502
Shop-floor contact (SFCT)	4.971	5.058	5.472	(H,L),(H,M)	9.176	0.000
Small group problem solving (SGPS)	4.684	5.127	5.429	(M,L), (H,L), (M,H)	30.944	0.000
Employee suggestions (EMSG)	4.603	4.938	5.412	(M,L), (H,L), (M,H)	25.928	0.000

tion in Japan where high performance plants sharply focused on every JIT production practice. In contrast, JIT production shows limited effect in US plants. In Korean, German, and Italian plants, JIT production is significantly related with manufacturing cost, on-time delivery, and volume flexibility. These indicate that each country should find its own path to high manufacturing performance depending on its specific context and competitive environment. The similarity and difference in the implementation of JIT practices across countries could be explained through the lens of institutional theory that focuses on the movement towards, and maintenance of isomorphic institutional environments. Institutional theorists assert that the institutional environment can strongly influence the development of formal structures in an organization. DiMaggio and Powell (1983) indicates that the net effect of institutional pressures is to increase the homogeneity of organizational structures in an institutional environment. Firms will adopt similar structures as a result of three types of pressures: coercive, mimetic, and normative. Ketokivi and Schroeder (2004) suggests that institutional perspective could be used to explain the variance in the manufacturing practices adopted and implemented by the plants because firms tend to imitate the structure, processes, norms, rule, and practices of a dominant institution. The success of Japanese manufacturing during the 1970s and 1980s leads to the wide adoption and implementation of Japanese management approaches and techniques such as JIT, TQM, and TPM in the US and European plants. The implementation of JIT production in manufacturing plants leads to different results across countries, depending on the fitness with strategic goal of the plants, market requirements, and other institutional factors that shapes the concrete practices in human resource management, quality management, and their organizational infrastructure.

This study provides two implications for the practitioners. Firstly, this study highlights the importance of some JIT production practices such as *JIT link to customers, JIT layout,* and *Setup time reduction* to the achievement of high performance manufacturing. If the managers would like to achieve low cost, *Setup time reduction* should be considered to implement. If the managers would like to improve volume flexibility, *JIT layout* and *JIT link to customers* should be considered to be implemented. One interesting finding is that one particular JIT production practice can simultaneously be associated with several performance indicators. However, this phenomenon, in some cases, can occur in one particular environment only and cannot be generalized in other environments. For example, *Leveled master schedule* has multiple impacts on performance in Japanese plants while we could not find the same evidence in German, Italian, Korean, and the US plants. This leads to the second implication that the significant difference in the impact of JIT production practice on operational performance across countries could be explained by the infrastructure of the plants. To maximize the benefits of JIT production, managers should focus on the implementation of quality management and workforce management practices. While the linkages between JIT production and process control, preventive maintenance, and training have been discussed in the existing literature; we found out that JIT production practices were highly associated with the communication and information sharing on shop-floor level of the plants. The feedback of quality information on shop-floor in a timely and useful manner, the interactions between supervisors and workers, and the participation of employees in small group activities are critical factors in keeping JIT production flow smoothly.

It is important to view this study in the context of its limitations. The utilization of small sample size restricts the scope of the studies and effective deployment of comprehensive analytical techniques. We collected both objective and subjective data on operational performance of the manufacturing plants that participated in the HPM survey. However, the products made by them are so different that only subjective data of performance can be used in this study.

Future JIT studies should be conducted with a larger sample size that would allow researchers to use more comprehensive techniques such as path analysis or structural equation modeling to investigate the relationship between JIT production practices and competitive performance for specific industry. Researchers could explore both objective and subjective performance measures in their studies, particularly when studying the link between the specific JIT production practice (e.g. set up time reduction) and the specific performance indicator (e.g. volume flexibility) in specific industry (e.g. automobile). In addition, the relationship between JIT production and other manufacturing management practices could be studied (e.g. synergy effect between JIT production, TQM, and TPM).

6 Conclusions

This study significantly contributes to the literature by providing new empirical evidence on the impact of JIT production on operational performance. The results of a series of statistical analyses support the contingency perspective, which suggests that the relationship between JIT production practices and plant performance is contingent upon the infrastructure in quality management and workforce management. Both differences and similarities in the implementation of JIT production practices and its impact on operational performance across the countries have been detected. This study finds the linkage between JIT production practices and high performance in Japanese plants where JIT production is intensively used to improve the competitive position. The results of statistical analysis also suggest that manufacturing managers should adopt some JIT production practices such as JIT delivery by suppliers, JIT layout, and setup time reduction to enhance the competitive performance of their plants.

Appendix A: Description of Survey Respondents

Table 5 Characteristics of survey respondents

Industry	Germany	Italy	Japan	Korea	US	Total
Electrical & Electronic	9	10	10	10	9	48
Machinery	13	10	12	10	11	56
Automobile	19	7	13	11	9	59
Total	41	27	35	31	29	163
Plant characteristics						
Average Market Share (%)	30.21	23.38	25.05	31.54	25.50	
Average Sale ($000)	1.736.230	71.209	1.118.492	2.266.962	284.181	
Average of Number of Employee[a]	601	370	1555	1045[b]	583	

[a] Including both salary personnel employee and hourly personnel

[b] Data from 19 plants only

Table 6 Survey respondents

Measurement Scales	DL	HR	PC	IM	PE	PM	QM	SP	PS
JIT Delivery by suppliers (JDSP)			1	1				4	
JIT Link with customers (JLCS)									
Pull system (PULS)			1	1				4	
Leveled master schedule (LMSC)			1	1				4	
Setup time reduction (STRD)			1	1				4	
JIT layout (JLYT)			1	1				4	
Multi-functional employees (MFEM)		1						4	1
Process control (PCTL)	6				1		1		
Information feedback (INFB)	6				1		1		
Housekeeping (CO3S)	6						1	4	
Preventive maintenance (PVMT)					1			4	1
Supplier quality involvement (SQIV)	6			1			1		
Customer involvement (CINV)	6						1	4	
Task-related training for employees (TTEM)		1						4	1
Shop-floor contact (SFCT)									
Small group problem solving (SGPS)	6						1	4	
Employee suggestions (EMSG)	6							4	1
Operational performance						1			

DL Direct Labor, *IM* Inventory Manager, *PM* Plant Manager, *HR* Human Resources Manager, *PE* Process Engineer, *SP* Supervisor, *PC* Production Control Manager, *QM* Quality Manager, *PS* Plant Superintendent

Appendix B: Survey Questionnaire

Question Items of JIT Scales, Quality Management Scales, and Workforce Management Scales (Factor loadings are given in parentheses following each item)

Just-in-Time Delivery by Suppliers

1. Our suppliers deliver to us on a just-in-time basis (.79)
2. We receive daily shipments from most suppliers (.68)
3. We can depend upon on-time delivery from our suppliers (.76)
4. Our suppliers are linked with us by a pull system (.65)
5. Suppliers frequently deliver materials to us (removed)

Just-in-Time Link with Customers

1. Our customers receive just-in-time deliveries from us (.87)
2. Most of our customers receive frequent shipments from us (removed)
3. We always deliver on time to our customers (removed)
4. We can adapt our production schedule to sudden production stoppages by our customers (removed)
5. Our customers have a pull type link with us (.73)
6. Our customers are linked with us via JIT systems (.88)

Leveled Master Schedule

1. Our master schedule repeats the same mix of products, from hour to hour and day to day (.84)
2. The master schedule is level-loaded in our plant, from day to day (.77)
3. A fixed sequence of items is repeated throughout our master schedule (.75)
4. Within our schedule, the mix of items is designed to be similar to the forecasted demand mix (removed)
5. We use a repetitive master schedule from day to day (.81)
6. Our master schedule does not facilitate JIT production (removed)

Pull system

1. Suppliers fill our kanban containers, rather than filling purchase orders (.76)
2. Our suppliers deliver to us in kanban containers, without the use of separate packaging (.76)
3. We use a kanban pull system for production control (.82)
4. We use kanban squares, containers or signals for production control (.82)

Setup Time Reduction

1. We are aggressively working to lower setup times in our plant (.71)
2. We have converted most of our setup time to external time, while the machine is running (.60)
3. We have low setup times of equipment in our plant (removed)
4. Our crews practice setups, in order to reduce the time required (.78)
5. Our workers are trained to reduce setup time (.80)
6. Our setup times seem hopelessly long. (.55)

JIT Layout

1. We have laid out the shop floor so that processes and machines are in close proximity to each other (.73)
2. We have organized our plant floor into manufacturing cells (.57)
3. Our machines are grouped according to the product family to which they are dedicated (.51)
4. The layout of our shop floor facilitates low inventories and fast throughput (79)
5. We have located our machines to support JIT production flow (.79)
6. We have located our machines to support JIT production flow (.66)

Multi-Functional Employees

1. Our employees receive training to perform multiple tasks (.78)
2. Employees at this plant learn how to perform a variety of tasks (.82)
3. The longer an employee has been at this plant, the more tasks they learn to perform (.66)
4. Employees are cross-trained at this plant, so that they can fill in for others, if necessary (.78)
5. At this plant, each employee only learns how to do one job (.66)

Process Control

1. Processes in our plant are designed to be "foolproof" (.75)
2. A large percent of the processes on the shop floor are currently under statistical quality control (.84)
3. We make extensive use of statistical techniques to reduce variance in processes (.81)
4. We use charts to determine whether our manufacturing processes are in control (.70)
5. We monitor our processes using statistical process control (.87)

Information Feedback

1. Charts showing defect rates are posted on the shop floor (.71)
2. Charts showing schedule compliance are posted on the shop floor (.71)

3. Charts plotting the frequency of machine breakdowns are posted on the shop floor (.68)
4. Information on competitive performance is readily available to employees (.81)
5. Information on productivity is readily available to employees (.76)

Housekeeping

1. Our plant emphasizes putting all tools and fixtures in their place (.69)
2. We take pride in keeping our plant neat and clean (.85)
3. Our plant is kept clean at all times (.86)
4. Employees often have trouble finding the tools they need (.57)
5. Our plant is disorganized and dirty (.79)

Preventive Maintenance

1. We upgrade inferior equipment, in order to prevent equipment problems (.71)
2. In order to improve equipment performance, we sometimes redesign equipment (.55)
3. We estimate the lifespan of our equipment, so that repair or replacement can be planned (.74)
4. We use equipment diagnostic techniques to predict equipment lifespan (.75)
5. We do not conduct technical analysis of major breakdowns (.55)

Supplier Quality Involvement

1. We strive to establish long-term relationships with suppliers (.64)
2. Our suppliers are actively involved in our new product development process (.72)
3. Quality is our number one criterion in selecting suppliers (.55)
4. We use mostly suppliers that we have certified (.61)
5. We maintain close communication with suppliers about quality considerations and design changes (.80)
6. We actively engage suppliers in our quality improvement efforts (.77)
7. We would select a quality supplier over one with a lower price (removed)

Customer Involvement

1. We frequently are in close contact with our customers (.69)
2. Our customers seldom visit our plant (removed)
3. Our customers give us feedback on our quality and delivery performance (.70)
4. Our customers are actively involved in our product design process (.58)
5. We strive to be highly responsive to our customers' needs (.72)
6. We regularly survey our customers' needs (.71)

Task-Related Training for Employees

1. Our plant employees receive training and development in workplace skills, on a regular basis (.87)
2. Management at this plant believes that continual training and upgrading of employee skills is important (.76)
3. Employees at this plant have skills that are above average, in this industry (.58)
4. Our employees regularly receive training to improve their skills (.89)
5. Our employees are highly skilled, in this plant (removed)

Shop Floor Contact

1. Managers in this plant believe in using a lot of face-to-face contact with shop floor employees (.68)
2. Engineers are located near the shop floor, to provide quick assistance when production stops (.65)
3. Our plant manager is seen on the shop floor almost every day (.64)
4. Managers are readily available on the shop floor when they are needed (.66)
5. Manufacturing engineers are often on the shop floor to assist with production problems.(.63)

Small Group Problem Solving

1. During problem solving sessions, we make an effort to get all team members' opinions and ideas before making a decision (.64)
2. Our plant forms teams to solve problems (.80)
3. In the past three years, many problems have been solved through small group sessions (.78)
4. Problem solving teams have helped improve manufacturing processes at this plant (.78)
5. Employee teams are encouraged to try to solve their own problems, as much as possible (.65)
6. We don't use problem solving teams much, in this plant (.72)

Employee Suggestions—Implementation and Feedback

1. Management takes all product and process improvement suggestions seriously (.82)
2. We are encouraged to make suggestions for improving performance at this plant (.77)
3. Management tells us why our suggestions are implemented or not used (.76)
4. Many useful suggestions are implemented at this plant (.82)
5. My suggestions are never taken seriously around here (.72)
6. The plant has an informal strategy, which is not very well defined (.67)

Appendix C: Measurement Test

Table 7 Measurement analysis of JIT measurement scales

Measurement Scales	Mean	STD	Cronbach Alpha						Factor analytical results: first eigenvalue (% variance)					
			GER	ITA	JPN	KOR	US	Pooled Sample	GER	ITA	JPN	KOR	US	Pooled Sample
JIT delivery by suppliers (JDSP)	4.538	0.705	0.54	0.76	0.70	0.70	0.68	0.69	1.68 (42)	2.63 (59)	2.15 (54)	2.13 (53)	2.05 (51)	2.09 (52)
JIT link with customers (JLCS)	4.389	0.975	0.79	0.76	0.62	0.83	0.60	0.77	2.14 (72)	2.02 (67)	1.84 (61)	2.24 (75)	1.68 (56)	2.05 (68)
Pull system (PULS)	3.872	0.954	0.70	0.83	0.89	0.74	0.80	0.79	2.12 (53)	2.63 (66)	3.00 (75)	2.26 (56)	2.49 (62)	2.46 (62)
Leveled master schedule (LMSC)	4.206	1.096	0.83	0.68	0.75	0.67	0.64	0.80	2.64 (53)	2.45 (49)	2.40 (48)	2.19 (44)	1.97 (40)	2.50 (63)
Setup time reduction (STRD)	4.854	0.697	0.74	0.71	0.76	0.71	0.74	0.73	2.48 (50)	2.39 (48)	2.65 (53)	2.42 (48)	2.48 (50)	2.44 (49)
JIT layout (JLYT)	5.046	0.684	0.75	0.84	0.73	0.71	0.70	0.76	2.76 (46)	3.36 (56)	2.85 (47)	2.53 (42)	2.57 (42)	2.81 (47)
Multi-functional employees (MFEM)	5.2371	0.595	0.84	0.76	0.82	0.77	0.84	0.79	2.72 (55)	2.60 (52)	2.92 (59)	2.77 (54)	3.05 (61)	2.75 (55)
Process control (PCTL)	4.839	0.857	0.80	0.89	0.85	0.80	0.84	0.82	2.78 (56)	3.67 (69)	3.17 (63)	2.81 (56)	3.12 (62)	2.95 (59)
Information feedback (INFB)	5.362	0.618	0.80	0.88	0.78	0.74	0.76	0.80	2.80 (56)	3.45 (69)	2.71 (54)	2.48 (50)	2.63 (53)	2.79 (56)
Housekeeping (CO3S)	5.224	0.474	0.85	0.79	0.83	0.66	0.81	0.80	3.19 (64)	2.80 (56)	3.08 (62)	2.23 (45)	2.92 (58)	2.82 (56)
Preventive maintenance (PVMT)	4.846	0.685	0.63	0.71	0.77	0.71	0.72	0.68	2.10 (42)	2.37 (47)	2.63 (53)	2.37 (48)	2.43 (49)	2.23 (45)
Customer involvement (CINV)	4.803	0.794	0.66	0.75	0.68	0.71	0.66	0.68	2.10 (53)	2.36 (59)	2.09 (52)	2.17 (54)	2.04 (51)	2.11 (53)
Supplier quality involvement (SQIV)	4.955	0.506	0.70	0.79	0.70	0.62	0.75	0.70	2.29 (46)	2.75 (55)	2.27 (45)	1.89 (47)	2.53 (51)	2.29 (46)
Task-related training for employees (TTEM)	5.189	0.701	0.80	0.76	0.75	0.80	0.82	0.79	2.55 (64)	2.37 (59)	2.29 (57)	2.53 (63)	2.60 (65)	2.28 (57)
Shop-floor contact (SFCT)	5.179	0.628	0.82	0.77	0.78	0.69	0.73	0.74	2.62 (66)	2.31 (60)	2.44 (61)	2.13 (53)	2.20 (55)	2.28 (57)
Small group problem solving (SGPS)	5.007	1.084	0.86	0.84	0.74	0.75	0.85	0.82	3.53 (59)	3.40 (57)	2.63 (44)	2.66 (44)	3.50 (58)	3.14 (52)
Employee suggestions (EMSG)	5.128	1.107	0.87	0.86	0.81	0.69	0.85	0.83	3.33 (67)	3.22 (65)	2.85 (57)	2.37 (47)	3.17 (63)	3.03 (61)

Appendix D: Chow Test Results

Table 8 Impact of JIT production practices on manufacturing cost

	GER	ITA	JPN	KOR	US	Pooled Sample
R^2	0.196	0.324	0.429	0.586	0.269	0.169
Adjusted R^2	0.009	0.062	0.263	0.405	−0.016	0.127
F and p	1.048 (0.420)	1.234 (0.335)	2.577 (0.039)	3.241 (0.024)	0.945 (0.497)	4.000 (0.001)
(Constant)	−0.560 (0.759)	3.585 (0.079)	−0.235 (0.881)	−0.670 (0.682)	0.285 (0.909)	0.265 (0.709)
JDSP	0.062 (0.783)	−0.305 (0.280)	0.178 (0.577)	0.560 (0.082)	0.180 (0.617)	0.102 (0.397)
JLCS	0.054 (0.806)	0.273 (0.219)	0.130 (0.621)	−0.054 (0.842)	0.176 (0.606)	0.041 (0.685)
PULL	−0.031 (0.871)	−0.138 (0.577)	−0.381 (0.150)	0.414 (0.084)	−0.252 (0.331)	−0.090 (0.335)
LMSC	0.160 (0.399)	0.499 (0.053)	0.407 (0.093)	0.161 (0.465)	0.025 (0.913)	0.114 (0.239)
JLYT	−0.189 (0.411)	−0.124 (0.600)	0.298 (0.398)	−0.965 (0.005)	−0.242 (0.360)	−0.106 (0.296)
STRD	0.221 (0.349)	0.167 (0.467)	0.098 (0.792)	0.474 (0.120)	0.227 (0.466)	0.274 (0.007)
MFEM	0.296 (0.230)	−0.305 (0.160)	−0.188 (0.349)	0.115 (0.660)	−0.314 (0.264)	0.159 (0.087)

Chow Test: F=6.188 p=0.000

Table 9 Impact of JIT production practices on on-time delivery

	GER	ITA	JPN	KOR	US	Pooled Sample
R^2	0.369	0.413	0.225	0.454	0.529	0.162
Adjusted R^2	0.221	0.197	0.008	0.215	0.345	0.120
F and p	2.502 (0.038)	1.914 (0.123)	1.036 (0.432)	1.898 (0.137)	2.885 (0.033)	3.868 (.001)
(Constant)	−0.595 (0.705)	−0.554 (0.794)	0.676 (0.722)	0.474 (0.799)	0.064 (0.968)	0.628 (.366)
JDSP	0.157 (0.434)	0.019 (0.940)	−0.424 (0.253)	0.817 (0.031)	−0.366 (0.213)	0.073 (.542)
JLCS	0.055 (0.775)	0.030 (0.877)	0.547 (0.079)	−0.366 (0.251)	0.781 (0.010)	0.065 (.517)
PULL	0.233 (0.181)	0.502 (0.035)	−0.194 (0.512)	0.116 (0.658)	−0.297 (0.159)	0.121 (.192)
LMSC	0.223 (0.188)	0.091 (0.683)	0.080 (0.767)	−0.317 (0.217)	0.096 (0.607)	0.044 (.644)
JLYT	0.279 (0.174)	−0.035 (0.867)	0.003 (0.994)	−0.281 (0.421)	0.010 (0.961)	0.103 (.305)
STRD	−0.495 (0.023)	0.120 (0.571)	0.273 (0.526)	−0.455 (0.190)	0.438 (0.090)	−0.027 (.790)
MFEM	0.317 (0.150)	0.127 (0.521)	0.056 (0.806)	0.770 (0.019)	0.091 (0.682)	0.210 (.025)

Chow Test: F=8.195, p=0.000

Table 10 Impact of JIT production practices on volume flexibility

	GER	ITA	JPN	KOR	US	Pooled Sample
R^2	0.336	0.289	0.477	0.669	0.088	0.223
Adjusted R^2	0.181	0.027	0.331	0.524	−0.267	0.184
F and p	2.166 (0.067)	1.104 (0.400)	3.260 (0.013)	4.623 (0.005)	0.247 (0.967)	5.743 (0.000)
(Constant)	2.644 (0.045)	−0.080 (0.972)	−0.568 (0.668)	−2.006 (0.190)	3.718 (0.025)	1.355 (0.022)
JDSP	0.142 (0.489)	0.052 (0.851)	0.109 (0.718)	0.593 (0.043)	−0.114 (0.776)	0.156 (0.176)
JLCS	0.157 (0.430)	0.062 (0.768)	0.388 (0.126)	0.274 (0.270)	−0.048 (0.899)	0.023 (0.812)
PULL	−0.186 (0.295)	−0.245 (0.326)	−0.444 (0.076)	0.307 (0.146)	0.281 (0.330)	−0.085 (0.342)
LMSC	−0.325 (0.065)	0.235 (0.345)	0.251 (0.261)	−0.215 (0.278)	−0.011 (0.967)	−0.175 (0.061)
JLYT	0.462 (0.032)	0.370 (0.123)	0.337 (0.316)	−0.263 (0.335)	−0.037 (0.899)	0.372 (0.000)
STRD	−0.065 (0.762)	0.108 (0.641)	−0.025 (0.943)	−0.531 (0.057)	0.090 (0.795)	−0.023 (0.809)
MFEM	−0.006 (0.979)	0.010 (0.965)	0.062 (0.742)	0.614 (0.017)	0.099 (0.748)	0.112 (0.209)

Chow Test: F=7.195, p=0.000

Table 11 Impact of JIT production practices on inventory turnover

	GER	ITA	JPN	KOR	US	Pooled Sample
R^2	0.158	0.224	0.564	0.377	.347	0.096
Adjusted R^2	−0.039	−0.078	0.437	0.086	.093	0.050
F and p	0.803(0.592)	0.743 (0.640)	4.439 (0.003)	1.296 (0.317)	1.365 (0.279)	2.077 (0.050)
(Constant)	2.454 (0.204)	0.979 (0.600)	0.055 (0.968)	−0.070 (0.977)	−0.094 (0.968)	0.875 (0.238)
JDSP	0.111 (0.629)	0.124 (0.678)	0.282 (0.312)	−0.234 (0.533)	0.202 (0.554)	0.114 (0.361)
JLCS	−0.377 (0.100)	−0.194 (0.409)	0.272 (0.233)	0.629 (0.080)	−0.091 (0.778)	−0.097 (0.360)
PULL	0.139 (0.484)	0.136 (0.608)	−0.209 (0.345)	0.213 (0.478)	−0.553 (0.032)	0.011 (0.908)
LMSC	0.151 (0.437)	−0.118 (0.651)	0.434 (0.045)	0.260 (0.346)	0.323 (0.153)	0.098 (0.333)
JLYT	0.063 (0.788)	0.172 (0.500)	−0.043 (0.890)	−0.542 (0.172)	0.170 (0.494)	0.099 (0.352)
STRD	0.326 (0.181)	0.279 (0.260)	0.259 (0.431)	−0.286 (0.443)	−0.191 (0.516)	0.054 (0.608)
MFEM	−0.154 (0.538)	0.113 (0.616)	−0.354 (0.053)	0.598 (0.093)	0.478 (0.080)	0.140 (0.151)

Chow Test: $F=7.11$, $p=0.000$

Table 12 Impact of JIT production practices on cycle time

	GER	ITL	JPN	KOR	US	Pooled Sample
R^2	0.344	0.171	0.319	0.127	0.233	0.121
Adjusted R^2	0.191	−0.151	0.129	−0.281	−0.082	0.076
F and p	2.249 (0.058)	0.532 (0.799)	1.674 (0.161)	0.311 (0.938)	0.739 (0.643)	2.683 (0.012)
(Constant)	2.446 (0.076)	0.772 (0.711)	0.692 (0.642)	1.805 (0.477)	0.543 (0.765)	1.879 (0.003)
JDSP	−0.111 (0.584)	0.292 (0.348)	−0.068 (0.843)	−0.159 (0.719)	−0.004 (0.991)	0.068 (0.584)
JLCS	−0.604 (0.004)	−0.113 (0.641)	0.316 (0.269)	0.328 (0.421)	0.211 (0.565)	−0.250 (0.018)
PULL	0.235 (0.186)	−0.009 (0.974)	−0.230 (0.408)	0.393 (0.273)	−0.267 (0.330)	0.080 (0.407)
LMSC	0.150 (0.381)	0.072 (0.789)	0.354 (0.167)	0.239 (0.462)	0.119 (0.628)	0.060 (0.551)
JLYT	0.187 (0.367)	0.102 (0.697)	0.227 (0.551)	−0.198 (0.665)	0.395 (0.164)	0.220 (0.036)
STRD	0.319 (0.139)	−0.107 (0.671)	0.099 (0.805)	−0.164 (0.708)	0.127 (0.698)	0.115 (0.270)
MFEM	−0.013 (0.952)	0.230 (0.331)	−0.141 (0.512)	−0.012 (0.977)	−0.125 (0.669)	0.017 (0.856)

Chow Test: $F=7.43$, $p=0.000$

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