Horizon J. Hum. & Soc. Sci. Res. 6 (S): 144 – 155 (2024)

Journal of Humanities and Social Sciences Research
www.horizon-JHSSR.com

CASE STUDY
Open Access

Assessing the Integration of Technology in Operations and Production of Automobile Products in Toyota: A Case Study (2011-2022)

Ribhushankar Anand[1]*, Malavika[2], Bindu Bavadharini[3] and Miriyam Jomy Alias[4]

[1,2,3,4]*CHRIST University, Bengaluru, Karnataka, India*

ARTICLE INFO

Article history
Received: 17-Febuary-24
Revised: 23-April-24
Accepted: 15-May-23
Published: 01-June-24

*Corresponding Author
Ribhushankar Anand
E-mail:
ribhushankar.anand@maeco.christuniversity.in

Co-Author(s):
Author 2: Malavika
E-mail: malavika@maeco.christuniversity.in

Author 3: Bindu Bavadharini
E-mail:
bindu.bavadharini@maeco.christuniversity.in

Author 4: Miriyam Jomy Alias
E-mail: miriyamjomy@gmail.com

Citation: Ribhushankar Anand, Malavika, Bindu Bavadharini and Miriyam Jomy Alias (2024). Assessing the Integration of Technology in Operations and Production of Automobile Products in Toyota: A Case Study (2011-2022). Horizon J. Hum. Soc. Sci. Res. 6 (S), 144–154. https://doi.org/10.37534/bp.jhssr.2024.v6.nS.id1263.p144

ABSTRACT

Firms and industries across various market structures and different economic conditions have undergone a boom of technology over the years in their respective operational activities and production methods. These injections of technology, have mostly improved the levels of production and efficiency levels of both labour and capital elements of a firm, reflecting in their wages and rent. The implementation of technology and business decisions are vital in determining the profits of companies in industries with high levels of competition and differentiation, such as the automobile industry across the world. In this study, various technological integration methods in Toyota's operations and production techniques are vividly analysed in the past 1 decade, in order to understand the effectiveness of technological elements in firms existing in the automobile sector. Variables related to Toyota's worldwide sales, production, exports, prices and technological elements are obtained and analysed with descriptive statistical tools and parametric econometric modelling, supported by a thorough review of literature. The results are interpreted to understand the corresponding impact on the firm's operational, sales-level and pricing decisions aimed for managerial excellence.

Keywords: Technological Integration; Toyota Operations; Automobile Industry; Production Techniques; Operational Efficiency; Descriptive Statistics; Econometric Modelling; Managerial Excellence.

Introduction

The past decade was one that witnessed tremendous change and evolution in terms of both technology and innovation. The patterns of such innovation have been dispersed across industries and sectors. These innovations can be observed in various areas of a firm's activities such as production and operations which add up to a major portion of a firm's activities. These are also areas that offer major cost-cutting opportunities for firms, thereby adding to the relevance of adopting innovative improvements to these processes and using technology to improve the efficiency of the factors employed, be it capital or labour. The effect of technology

 DOI: https://doi.org/10.37534/bp.jhssr.2024.v6.nS.id1263.p144

in both these inputs differ, but can be observed in the resulting rent and wages which are major contributors to the cost of the firm. Thus, the quick adoption of these innovations is necessary to secure profits in highly competitive industries where timing is crucial and the dimensions within which competition exists are multiple (Dosi, 1988).

One such epicentre of innovation and technology is the automobile sector which has not only witnessed an exponential rise in demand but also underwent a redefinition in terms of consumer attitudes and preferences. There was an active shift where the ownership of automobiles which were associated with their usefulness and functionality changed into a more personalised social experience of owning one's own car and further becoming a dimension of one's identity. Modern consumer culture shows how people's values, politics and ideology play into their purchase decisions (F. Coughlin, 2004). This mandated the need to accommodate these requirements into the production and sale of these goods to ensure customer loyalty and effective brand positioning.

In extension to these trends, changes were also observed in the manner in which the automobile industries produced their goods. Rather than just improvements in the final product, the industry itself has improved, evolved and adapted to become more than just competitive. Such observations can be made at the level of individual firms that have extensively absorbed modern technology into their production process and are also constantly undergoing extensive research to exploit maximum efficiency in their operations (Friedlaender et al., 1983). The cutthroat competition in automobile industries where a high degree of differentiation and the potential for extended customisation is present has made it an environment that requires firms to identify all potential areas where they can improve efficiency to better their profit level. Thus, it becomes even more vital for these firms to explore a wide range of profit streams, primarily to retain their position and further their level of competence.

One such example of an automobile company asserting its market position through the adoption of superior technology and innovation in the production process is the case of Toyota. The manufacturer is known for its widespread market presence and efficient production techniques. This has enabled it to level up to the top of the industry competing with world-class automobile manufacturers and establishing itself as a global favourite. The case of Toyota provides a classic example of how the quick absorption of upcoming technology compounded with efforts in bringing about innovative changes to their production activities become a vital element in determining the firm's success in terms of minimizing costs, extending efficiency and thereby improving profits (Corporation, 2023). This not only speaks for the effect of technology in the case of Toyota alone but is an expansive reflection of the significance of technology and innovation in improving profit streams for the automobile industry as a whole. This makes it a relevant model that highlights the potential for untapped profits for other firms in the industry as well.

Literature Review

Phaal, Farrukh, and Probert (2004) on technology road mapping present a comprehensive analysis of the strategic use of roadmaps in navigating the complexities of technological evolution and market disruptions. The study focuses on two main points of view: a multiorganizational perspective that tries to capture the larger environmental landscape, threats, and opportunities for stakeholders in particular technology or application domains, and a company-centric approach that synchronizes technology development with business planning to assess the impact of emerging technologies. The writers stress that roadmaps in their graphical format are an effective means of communication that can effectively convey information that has been compiled. Nonetheless, because roadmaps are brief, they emphasize how crucial it is to provide sufficient documentation to support them. The article also emphasizes how sectoral or multiorganizational road mapping can promote information exchange, make it possible to create group visions and motivate cooperative efforts in response to disruptive technological trends. (Phaal et al., 2004). Similarly, Vickery et al., (2003) delve into the impact of integrated information technologies on supply chain strategy, customer service, and financial performance. Three noteworthy direct relationships are identified by the findings: supply chain coordination and technology integration; coordination and better customer service; and improved customer service and improved financial results. These direct connections weave a coherent story that highlights how integrated technologies are essential in determining supply chain dynamics, which in turn affects customer satisfaction and bottom-line results. The study makes a significant contribution by separating the direct from indirect effects on firm performance and elucidating the intricate interactions between these crucial components. The research offers important insights into the larger framework of organizational success through technology-driven supply chain strategies by methodically assessing and testing these relationships. (Vickery et al.,2003). Voss (1995) explores the development of operations management from more conventional methods such as Taylorism to the more adaptable Toyota model. The need of ongoing development and the search for novel approaches to long-term operations management is emphasized in the article. Operations management can effectively contribute to both existing and emerging interface areas by fortifying its core. Operations management set new goals for the 1990s in response to issues that arose during the 1980s. Within business schools, it is positioned as a guardian and concentrates on managing value-adding processes, which reflects its crucial role in the success of organizations (Voss 1995).

Petersen et al., (2005) focus on the integration of material suppliers into new product development (NPD) processes. It responds to the industry's growing need to shorten development times, improve product quality, save expenses, and guarantee seamless product launches. The study emphasizes how important it is for suppliers to be involved as early as possible in supply chain, product, and process design coordination. The main concerns center on how managerial decisions, taking timeliness and accountability levels into account, affect the efficacy of the NPD team when suppliers are involved. The results highlight the importance of choosing a supplier and placing equal emphasis on cultural fit and skill. In high-responsibility scenarios, in particular, the study emphasizes the significance of supplier input in determining technical metrics and targets. In general, supplier involvement improves decision-making, which leads to better design and, to a lesser extent, better financial performance. However, input on business metrics has a positive impact on decision making in some integration types. The findings highlight the need for more research into the variables influencing project team effectiveness and efficient supplier relationship management techniques, and they encourage businesses to involve suppliers in NPD initiatives. (Petersen et al., 2005).

MacDuffie and Krafcik (1992) study investigates the relationship between technology, production organization, and manufacturing performance in the international auto industry. Their findings support the "integration" hypothesis, emphasizing the importance of a lean production system for effectively utilizing high automation levels. In comparison to MassProd plants, Lean Prod plants exhibit a significantly stronger correlation between technology and performance. With 112% fewer defects per 100 vehicles and 86% fewer hours per vehicle, High-Tech-Lean Prod plants outperform Low-Tech-Mass Prod plants. It's interesting to note that lean production systems are important because High-Tech-Lean Prod plants perform better than High-Tech-Mass Prod plants. Technology is more closely associated with productivity than quality, and the study indicates that lean production methods work best when combined with moderate to high levels of automation to maximize performance gains. The relationship between organizational and technological factors is highlighted by this research as a means of attaining high manufacturing performance. (MacDuffie & Krafcik 1992). Pil and Fujimoto (2007) examines the production models of Toyota and Volvo, traditionally considered extremes in the automotive industry. Toyota prioritized organizational learning and innovation through its Lean Production System, whereas Volvo concentrated on reflective production with the goal of enhancing workers' adaptability and satisfaction. The long-term case study shows how environmental factors like heightened competition and labor shortages have caused practices to converge. Organizational responsiveness, motivation, and flexibility were all integrated by both businesses. Production models evolved and integrated despite differences, such as Volvo's emphasis on individual professionalization and structured relief time, as a result of shared challenges and shifting market conditions. The study emphasizes how the evolution of the production system is influenced by both firm-specific factors and external pressures. (Pil & Fujimoto 2007). J.T. Black (2007), explores the transformation of the mass production system into the renowned Toyota Production System (TPS), now recognized globally as lean production. U-shaped subassembly cells, manufacturing cells, and mixed model final assembly are examples of the strategic adjustments included in the TPS. The system works with the intention of reducing variation and getting rid of waste and delay. In his four design rules for TPS implementation, Black highlights the importance of continuous improvement, leadership commitment, defect prevention, and a simultaneous focus on cost and quality. Strong leadership, zero defects, continuous improvement, and simplicity are all emphasized in the article as critical components of the lean manufacturing process. Black draws attention to the necessity of a cultural shift within businesses to adopt TPS principles, with the ultimate goals of the manufacturing process being perfect quality, on-time delivery, and cost reduction. The lean factory's distinctive design—which emphasizes reducing variation and ongoing system improvement—is highlighted in the article (J.T. Black 2007).

Lander and Liker (2007) explore the applicability of the Toyota Production System (TPS) beyond its traditional use in high-volume, standardized production in the EV segment. The authors contend that rather than being a strict toolkit, TPS should be viewed as a philosophy in overarching principles. To highlight the significance of having a deeper understanding of the system, they present a case study of a low-volume, highly customized artistic clay tile company that successfully applied TPS principles. According to the paper, concentrating only on TPS tools could result in misconceptions and difficulties in a variety of settings. The authors suggest, instead, using a principles-based strategy in which TPS tools can be changed or modified to meet the particular requirements of the company. Reflecting the essence of Toyota's system as a learning organization, the article emphasizes the need of actively participate in the implementation process and stresses that true understanding and improvement come through continuous learning and adaptation. (Lander & Liker 2007). Morgan and Liker (2020) examine the Toyota Product Development System (TPDS) and how it differs from American lean principles. It highlights TPDS's 13 principles, which prioritize customer-defined value, front-loading design processes, and establishing a levelled development flow. Key aspects of TPDS include rigorous standardization, integrating chief engineers, and balancing functional expertise with cross-functional collaboration. TPDS emphasizes technical competence, supplier integration, and a culture of learning and improvement. It also stresses adapting technology to fit processes, using visual communication for alignment, and utilizing powerful tools for standardization and organizational learning. Overall, TPDS is a system that revolves around people and promotes continuous improvement and excellence in product development. (Morgan & Liker, 2020).

The automobile industry in Japan was significantly affected by the Asian Financial Crisis and the collapse of Japan's Bubble, resulting in the industry splitting into two groups - Honda and Toyota, and everyone else. This polarization had an impact on the stock prices and financial performance of auto producers in the 1990s. Weaker companies had to restructure, reduce production, and close plants, leading to the consolidation of their operations and a gradual reduction of Japan's excess production capacity. However, these measures were insufficient to prevent weaker firms from being acquired by international auto groupings such as GM, Ford, Daimler-Chrysler, Renault, and Volkswagen. Toyota's market success and accumulated wealth allowed the company to gain a strategic advantage in Japanese and Asian markets, enabling it to invest in geographic, product, and technology expansions, and develop newer and more profitable products. This helped Toyota to extend its lead in these areas relative to Japanese competitors, while other competitors, except for Honda, found it challenging to respond, putting them under additional competitive pressure. The demand for automobiles in advanced countries is fairly saturated, particularly in the booming U.S. market. Toyota is also working hard to establish a global industry standard for smart cars such as the hybrid car in terms of environmental standards or ITS for driving and transportation systems. Toyota is a customer-focused company, using IT and the Internet to capture ideas from its customers, which is an evolutionary extension of its smart marketing and sales strategy. The production software system is designed to support this demand by producing cars to order. Finally, in terms of using IT in the workplace, there are two approaches - automating existing practices to reduce skills needed to perform a task, "deskilling," and enhancing employees' existing skills, extending capabilities and making them more productive, "upskilling." (Rapp 2000)

China's science and technology have matured, and automation technology has become more widespread, providing many advantages to various manufacturing industries. The use of high-precision automation technology has enabled work to be carried out continuously according to computer programs, reducing the number of errors caused by human work and improving the product's quality. Mechanical manufacturing workers can now use the most suitable automation technology for their needs, combining their experience with the latest automation technology to produce higher-quality work. In the automobile production industry, advanced automation technology can save time in manufacturing parts, allowing staff to handle assembly and processing work more efficiently. This can help the automobile manufacturing industry increase its profits by reducing unnecessary costs. The automobile manufacturing industry has greatly benefited from automation technology. This technology reduces operating costs and improves the quality of production work. By minimizing the probability of work errors, the overall quality of production work is significantly improved. The use of automation technology also benefits automobile companies by helping them to occupy a higher market share, thereby strengthening their competitiveness. While China has made some progress in automation technology, it still needs professionals to continue innovating in all aspects. This is important to promote the smooth development of the automobile machinery manufacturing industry and ensure its bright future. (Wang & Wang, 2021).

The Toyota Production System (TPS) is a highly efficient manufacturing system that aims to achieve excellence in Quality, Cost, and Delivery (QCD) simultaneously, implemented in EV and Lexus segments in 2016. It is a cutting-edge system that integrates hardware and software systems like TMS (Toyota Marketing System), TDS (Toyota Development System), TPS, and Science TQM to optimize business processes across all departments. The TPS system originated from the Toyota Motor Corporation and exemplifies the JIT (Just-in-Time) system. One of the key principles of the TPS is to have all processes function in harmony and to eliminate any wasteful practices. Collaboration between different teams is crucial for success in the TPS system. The white-collar engineers, supervisors, workers, and suppliers are all required to work together in harmony to achieve the desired outcomes. The New JIT concept goes beyond traditional JIT paradigms and addresses management technology issues across different departments. It involves reinforcing TPS with TMS and TDS, focusing on innovation and collaboration to achieve QCD. The TPS manufacturing system has been implemented successfully across different divisions of Toyota Motor Corporation. A case study from Toyota's Plant Motomachi showed how tackling manufacturing bottlenecks facilitates New JIT Production. According to the study, advancing TPS through innovative manufacturing technology and collaboration among stakeholders enhances the production line for automobile rear axle units. The TPS system is a highly efficient and innovative manufacturing system that integrates different hardware and software systems to optimize business processes. The key principles of the TPS system are to achieve QCD simultaneously, eliminate wasteful practices, and encourage collaboration among different divisions (Amasaka, 2009).

The concept of lean production has revolutionized the traditional production system by emphasizing the need for a harmonious integration of human and technological practices. In this regard, (Paez et al., 2004) aims to review the earlier models of lean production that focused on specific aspects of its philosophy, organizational structure, and techniques. The article proposes a new framework of lean production that portrays it as a socio-technological system. This framework offers a holistic view of lean production that takes into account the interactions between human and technological elements. Essentially, the framework sees the lean enterprise as a dynamic process that translates its objectives of zero waste, flow, and pull into a diverse range of techniques that should be implemented throughout the entire organization.

TPS is an innovative manufacturing philosophy that is built on the foundation of "lean" principles, which emphasizes on enhancing customer satisfaction, continuous improvement, quality, waste reduction, and integration of upstream and downstream processes. Since its inception, TPS has become a benchmark for manufacturing companies across the world. The "lean initiative" approach, which is based on TPS, has now extended beyond the shop floor to white-collar offices and service industries. However, most of these efforts have been limited and piecemeal, aimed at quick fixes, rather than creating a culture of learning. (Liker & Morgan, 2006) delve into the management principles of TPS, which can be applied to any technical or service process beyond manufacturing. It is a systems approach that effectively integrates people, processes, and technology and requires a continual and coordinated effort for change and learning across the organization. The philosophy of TPS is not just a set of techniques, but a complete management system that focuses on achieving long-term goals of quality, efficiency, and customer satisfaction by identifying and eliminating waste in all aspects of the business. As technology continues to progress at an accelerated pace, the process of commercializing technological changes, known as industrial innovation, is also evolving. The traditional models of industrial innovation, such as the simple linear 'technology push' and 'need pull' models, have undergone significant changes over time. The 'coupling model' of the 1970s to 1980s and the 'integrated model' of today, which is also known as the 4th Generation innovation process, are now the dominant models (Dosi, 1998).

The most recent model, which is considered the 5th generation model of industrial innovation, represents a significant shift from perceiving innovation as a sequential process to a largely parallel process. This shift was influenced by observing innovation processes in leading Japanese corporations. The proposed 'strategic integration and networking' model suggests that innovation is becoming faster, inter-company networking is increasingly important, and a new electronic toolkit - including expert systems and simulation modelling - is being employed. This model is believed to have great potential in the field of industrial innovation. (Rothwell, 1992). Integrating supply chains has a positive impact on operational performance outcomes.

(Wong et al., 2011) aims to explain the effects of environmental uncertainty on supply chain integration and its impacts on operational performance. It proposes a new theory to explain the connections between environmental uncertainty, supply chain integration, and operational performance. The author examines the impact of supply chain integration on operational performance outcomes under different environmental conditions. The findings have implications for contingency research and managerial practice in operations management. The theories and findings of this paper can help managers identify the appropriate supply chain integration dimension for specific operational performance outcomes under certain environmental conditions. However, further research is needed to explore different means of reducing or mitigating the impacts of environmental uncertainties and to understand other contingency factors. Additionally, more qualitative and quantitative investigations are required to understand the complex interactions and relationships among supply chain integration, environmental uncertainty, operational performance, and other contextual factors.

Objectives

The objectives of the study are as follows:

1. To identify the pattern and trends of sales and production related variables of Toyota inside and outside Japan
2. To understand the effect of technological implementation in the production process on important growth variables of Toyota.

Data and Methodology

The study focuses on analyzing the impact on technology and innovation in production and its subsequent effect on profits of Toyota. In order to facilitate the study, secondary data is sourced from Toyota sales, production and export database which is time series in nature. This data is streamlined to suit the focus of the study, including variables such as worldwide sales, worldwide production, sales in Japan, production in Japan, sales outside Japan and production outside Japan providing insight into the staggering differences within the host and home countries. Furthermore, variables such as production growth rates, export data, sales of electric vehicles and sales of Lexus products are also utilised to provide a more multidimensional understanding of the subject. Descriptive statistics of the said data is availed to understand the basic characteristics of the unified data while graphs are employed to further elucidate the same. Other statistical tools such as correlation matrix is also utilised to establish the underlying relationships between the variables. Further, T test of sales is performed to compare the technological innovation and regression analysis on EV sales volume, done to form conclusive inferences. A simple linear regression model is constructed using production growth explaining EV sales growth rates, analyzing the impact of technological innovation in the production process. Results are represented and analyzed below.

Analysis and Interpretations

In this section, the empirical methodology of the paper is analysed using statistical techniques on the quantitative, time-series dataset of Toyota's sales, production, exports and growth variables, to understand the impact of technology in the production process of automobile products of Toyota. Tables 1 and 2 represent the descriptive statistics of the variables in the dataset.

The average worldwide sales growth stands at 2.8%, which is relatively low for a market leader like Toyota in the past decade. Production and sales growth are both positively skewed and have high range values, indicating a positive trend over the years paired with extreme values. The average electric vehicle sales growth stood high at 16%, potentially due to high technological influences and market penetration. Toyota also innovated the market using Lexus, which is shown by the high growth of Lexus sales worldwide. Similar descriptive statistical indicators are provided in Table 1 and 2 for all the variables. To understand the trends and patterns of these variables, figures 1 to 9 represent the flow of variables of Toyota in the past decade.

We can see that excluding the recession caused by the COVID-19 pandemic, the sales and production of Toyota worldwide, in and outside Japan have been growing steadily. However, a diverging trend has been observed in production inside and outside Japan, as Toyota has invested in manufacturing plants with higher technological access, outside Japan. Growth rates of both sales and production have been unstable, mainly due to dynamic market conditions.

Interestingly, during the pandemic, exports were stable for Toyota, potentially due to its focus on worldwide sales.

Table 1.

	WW Sales	WW Sales growth	SalesJ	SalesOJ	WW Production	WW Production growth	Production J	Production OJ
Mean	10038530.58	2.84	2194665.00	7843865.58	10010886.75	3.15	4082489.83	5928396.92
Standard Error	215202.87	2.48	53874.17	189988.25	227101.28	2.87	88245.08	186491.67
Median	10202754.50	2.00	2256596.50	7962496.00	10165380.00	1.66	4123463.00	6126177.00
Standard Deviation	745484.61	8.23	186625.59	658138.61	786701.90	9.53	305689.92	646026.09
Kurtosis	5.96	3.69	1.03	3.17	5.19	4.01	-0.07	2.50
Skewness	-2.24	1.15	-1.25	-1.58	-2.15	0.99	-0.60	-1.17
Range	2793165	34	628369	2411353	2867108	40	1041591	2582950
Minimum	7948957	-11	1783521	6165436	7858106	-14	3483464	4374642
Maximum	10742122	23	2411890	8576789	10725214	26	4525055	6957592
Count	12	11	12	12	12	11	12	12

(**Source:** *Toyota Database*)

Table 2.

	Exports	WW EV Sales	WW EV sales growth	Lexus Sales	Lexus sales growth
Mean	1889807.33	1615708.58	16.60	629393.75	4.51
Standard Error	41822.30	175106.91	8.37	32603.38	2.99
Median	1872568.50	1461683.00	7.40	660488.00	5.75
Standard Deviation	144876.71	606588.13	27.75	112941.42	9.90
Kurtosis	0.23	0.16	6.99	-0.17	1.51
Skewness	0.56	0.62	2.53	-0.78	-1.12
Range	521926	2097284	99	361395	36
Minimum	1664209	628979	-5	403935	-18
Maximum	2186135	2726263	94	765330	18
Count	12	12	11	12	11

(**Source:** *Toyota Database*)

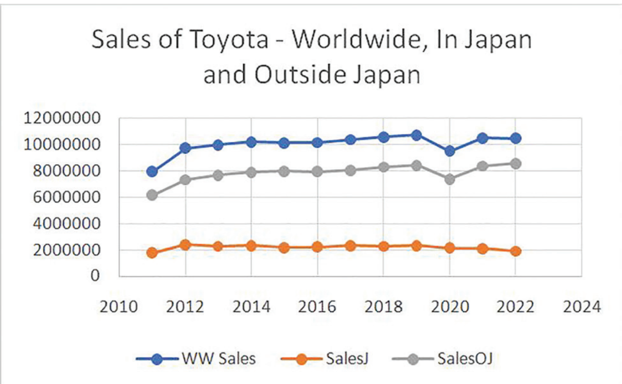


Figure 1. Sales of Toyota

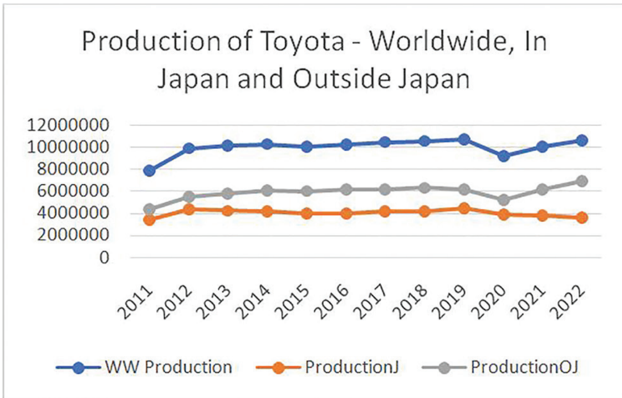
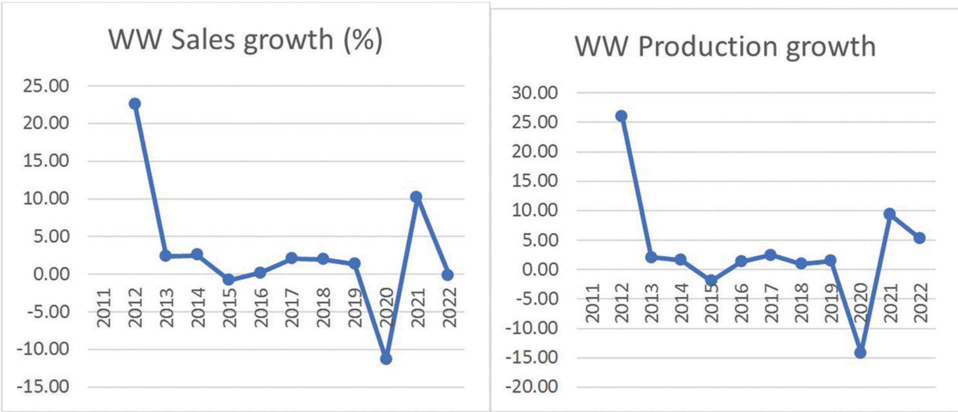


Figure 2. Production of Toyota

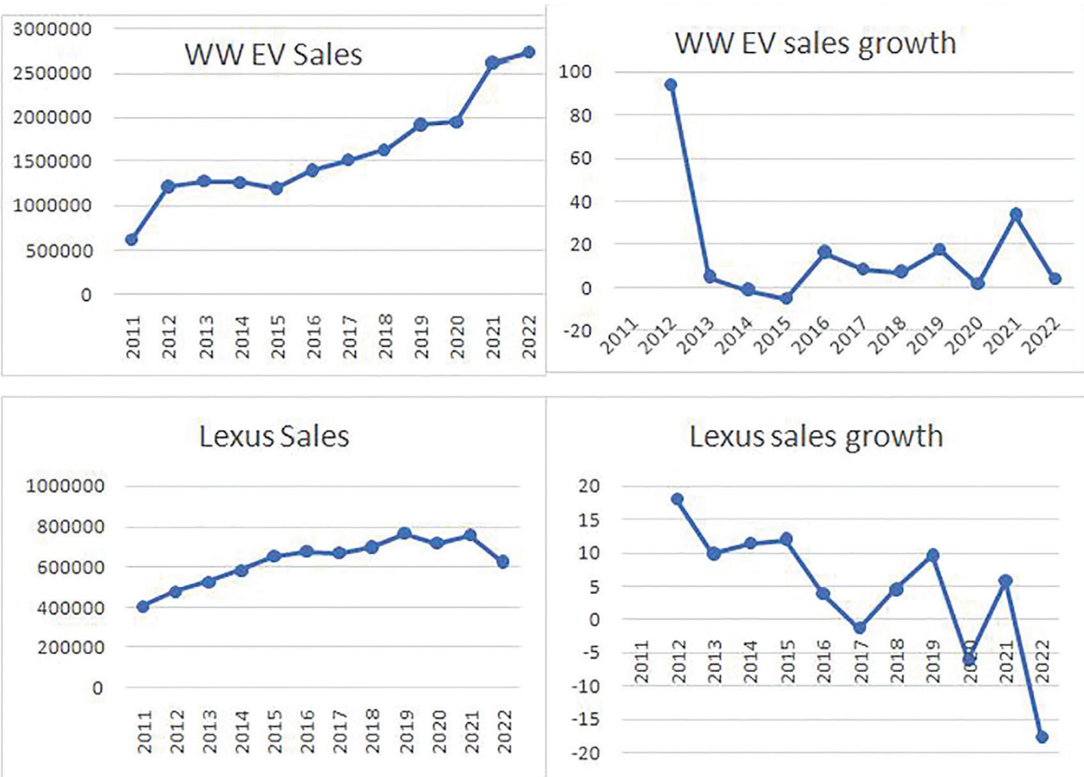
Similarly, their luxury technological innovation through Lexus has also been stable through the years, yielding positive returns for the firm. Their major technological innovation through EV in production, has tremendous sales and high growth rates, though unstable, leaving a lot of future potential for Toyota. To understand the direction and magnitude of the relationship between variables, a correlation matrix represented by table 3, is represented below.



Figures 3 & 4
(**Source:** *Toyota Database*)

Figure 5. Exports

As anticipated, due to technological innovation in the production process through EVs, worldwide EV sales growth has a very high positive correlation with worldwide sales growth and production growth. however, Lexus growth rates are observed to have weak correlations with other variables, followed by domestic production in Japan. Since a major technological breakthrough was observed in 2017 in EV production, this could reflect on sales and production of Toyota. Table 4 represents the Student's t-test results for EV sales



Figures 6, 7, 8 & 9.
(**Source:** *Toyota Database*)

Table 3.

	WW Sales	WW Sales growth	SalesJ	SalesOJ	WW Production	WW Production growth	ProductionJ	ProductionOJ	Exports	WW EV Sales	WW EV sales growth	Lexus Sales	Lexus sales growth
WW Sales	1.00												
WW Sales growth	0.03	1.00											
SalesJ	0.57	0.40	1.00										
SalesOJ	0.97	-0.11	0.36	1.00									
WW Production	0.97	0.15	0.61	**0.93**	1.00								
WW Production growth	0.06	0.98	0.28	-0.04	0.23	1.00							
ProductionJ	0.56	0.37	0.96	0.36	0.61	0.28	1.00						
ProductionOJ	0.92	-0.07	0.28	0.96	0.93	0.06	0.27	1.00					
Exports	0.51	0.40	0.81	0.35	0.56	0.33	0.93	0.24	1.00				
WW EV Sales	0.61	-0.15	-0.11	0.72	0.50	-0.07	-0.11	0.66	-0.02	1.00			
WW EV sales growth	-0.24	**0.88**	0.38	-0.35	-0.16	**0.86**	0.35	-0.35	0.38	-0.08	1.00		
Lexus Sales	0.74	-0.49	0.27	0.76	0.59	-0.53	0.25	0.60	0.21	0.68	-0.39	1.00	
Lexus sales growth	-0.13	0.56	0.77	-0.38	-0.06	0.42	0.73	-0.47	0.64	-0.69	0.44	-0.33	1.00

(**Source:** *Toyota Database*)

Table 4.

t-Test: Two-Sample Assuming Equal Variances		
	EV Sales 2011-16	*EV Sales 2017-22*
Mean	1167177.67	2064239.50
Variance	74410928555.07	252245251305.90
Observations	6.00	6.00
Pooled Variance	163328089930.48	
Hypothesized Mean Di	0.00	
df	10.00	
t Stat	-3.84	
P(T<=t) one-tail	0.00	
t Critical one-tail	1.81	
P(T<=t) two-tail	0.00	
t Critical two-tail	2.23	

(**Source:** *Toyota Database*)

Table 5: SLRM Output

Regression Statistics	
Multiple R	0.86398
R Square	0.746462
Adjusted R Square	0.646462
Standard Error	16.49692
Observations	11

(**Source:** *Toyota Database*)

before and after 2016. With degrees of freedom equal to 10 and level of significance set at 5%, the null hypothesis of 0 mean difference can be rejected as the p-value of the t-test (0.003) is less than 5%. This implies that there is a significant difference in sales of EV Toyota products, after the semiconductor technological breakthrough in 2016.

Table 6.

	Coefficient	Standard Error	t-stat	p-value
Intercept	0.00	NA	NA	NA
WW Production growth	2.81	0.52	5.43	0.00

(**Source:** *Toyota Database*)

Due to a high correlation value identified between worldwide production growth and EV sales growth due to technological intervention in the production process, a simple linear regression is constructed by production growth aiming to explain EV sales growth. results are represented in Tables 5 & 6, followed by figure 10.

Production growth has a positive coefficient value, indicating a positive causal relationship paired with extreme variable significance (0.00). R-square value of 0.74 indicates 75% explanatory power of the model over its residuals. This signals the firm that semiconductor and production improvisations have resulted in tremendous sales for Toyota, especially in the segment of EV products. Figure 10 represents the positive linear relationship between the variables, explained by the SLRM construct in this study. Figure 11 represents the predicted values against the residual values of the model. apart from the outliers caused by the pandemic of 2020 and initial technological changes in 2011, the fitted values and residuals move along in a similar direction.

Figure 10.

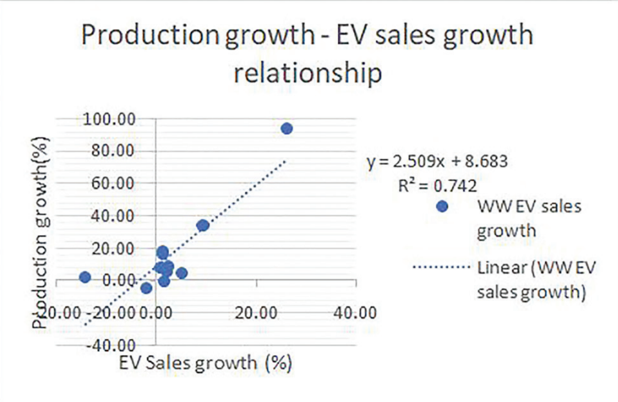
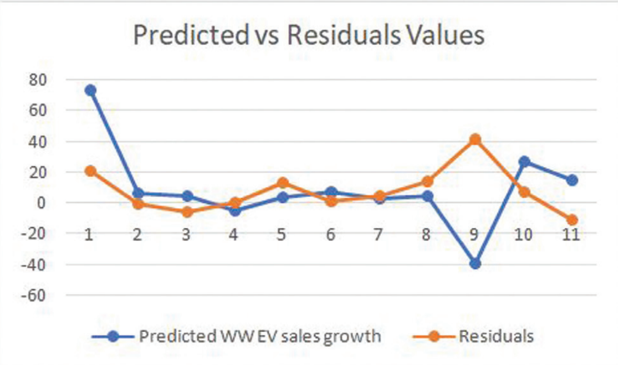


Figure 11.



(**Source:** *Toyota Database*)

Policy Recommendations and Conclusion

From the results obtained in this study, it could be concluded that technological innovation in Toyota's production process has impacted Toyota significantly across the world. Profit margins, revenue and sales growth along with production dynamics have been stabilised substantially by technological production processes. Furthermore, Toyota has to focus on continuing their focus on exports, as it has a global pull which pushes production towards optimal levels and efficient methods. Lexus products could be given more attention, as their luxury technological innovations could potentially yield high returns for the firm. Lastly, Toyota's focus on EV technology and sales maximisation has benefitted the firm significantly, and has better potential in the future if improvised and managed well by Toyota's domestic and worldwide units. Hence, technological innovation in Toyota's production process has significantly improvised the firm's market position and dynamics across the world, leaving room for high potential in the future.

Acknowledgments

The authors wish to express their gratitude to the editors and editorial staff of JHSSR for their assistance during publication period.

Funding

The authors received no financial support for the research, authorship and/or publication of this article.

Declaration of Conflicting Interests

The authors declare that they have no competing interests. This article is the sole work of the authors and has not been presented or published elsewhere.

References

Amasaka, K. (2009). The foundation for advancing the Toyota production system utilizing new JIT. *Journal of Advanced Manufacturing Systems*, *8*(01), 5-26.

Black, J. T. (2007). Design rules for implementing the Toyota Production System. *International Journal of Production Research*, *45*(16), 3639-3664.

Corporation, T. M. (2023, August 2). Toyota Unveils New Technology That Will Change the Future of Cars | Corporate | Global Newsroom | Toyota Motor Corporation Official Global Website. Toyota Motor Corporation Official Global Website.

Dosi. (1988). Sources, Procedures, and Microeconomic Effects of Innovation. Journal of Economic Literature, 26(3), 1120–1171.

Friedlaender, A. F., Winston, C., & Wang, K. (1983). Costs, Technology, and Productivity in the U.S. Automobile Industry. The Bell Journal of Economics, 14(1), 1.

F. Coughlin. (2004). Not Your Father's Auto Industry? Aging, the Automobile, and the Drive for Product Innovation. Journal of the American Society on Aging, 28(4), 38–44.

Lander, E., & Liker, J. K. (2007). The Toyota Production System and art: making highly customized and creative products the Toyota way. *International journal of production research*, *45*(16), 3681-3698.

Liker, J. K., & Morgan, J. M. (2006). The Toyota way in services: the case of lean product development. *Academy of management perspectives*, *20*(2), 5-20.

MacDuffie, J. P., & Krafcik, J. (1992). Integrating technology and human resources for high-performance manufacturing:

Evidence from the international auto industry. *Transforming organizations*, *209226*

Morgan, J., & Liker, J. K. (2020). *The Toyota product development system: integrating people, process, and technology*. CRC Press.

Paez, O., Dewees, J., Genaidy, A., Tuncel, S., Karwowski, W., & Zurada, J. (2004). The lean manufacturing enterprise: An emerging sociotechnological system integration. *Human Factors and Ergonomics in Manufacturing & Service Industries*, *14*(3), 285-306.

Petersen, K. J., Handfield, R. B., & Ragatz, G. L. (2005). Supplier integration into new product development: coordinating product, process and supply chain design. *Journal of operations management*, *23*(3-4), 371-388.

Phaal, R., Farrukh, C. J., & Probert, D. R. (2004). Technology roadmapping—A planning framework for evolution and revolution. *Technological forecasting and social change*, *71*(1-2), 5-26.

Pil, F. K., & Fujimoto, T. (2007). Lean and reflective production: the dynamic nature of production models. *International journal of production research*, *45*(16), 3741-3761.

Rapp, W. V. (2000). Automobiles: Toyota Motor Corporation: gaining and sustaining long-term advantage through information technology.

Rothwell, R. (1992). Successful industrial innovation: critical factors for the 1990s. *R&d Management*, *22*(3), 221-240.

Toyota Corp. Database (2023) – Sales, production and exports.

Vickery, S. K., Jayaram, J., Droge, C., & Calantone, R. (2003). The effects of an integrative supply chain strategy on customer service and financial performance: an analysis of direct versus indirect relationships. *Journal of operations management*, *21*(5), 523-539.

Voss, C. A. (1995). Operations management–from Taylor to Toyota–and beyond?. *British Journal of Management*, *6*, S17-S29.

Wang, X., & Wang, Y. (2021, April). Application of automation technology in automobile machinery manufacturing. In *Journal of Physics: Conference Series* (Vol. 1885, No. 4, p. 042056). IOP Publishing.

Wong, C. Y., Boon-Itt, S., & Wong, C. W. (2011). The contingency effects of environmental uncertainty on the relationship between supply chain integration and operational performance. *Journal of Operations management*, *29*(6), 604-615.

Biographical Statement of Author(s)

Ribhushankar Anand was born in Chennai, TN (India) in 2001. He holds a Bachelor's degree in economics (B.A Economics Honors) from Christ University, Bengaluru and is currently his masters in economics (M.A Applied Economics) from Christ University, Bengaluru. He has worked as a data analyst and associate in firms such as Accenture Solutions and THB Analytics.

His main areas of research interest are monetary economics, macroeconomics and labour economics. He has also presented several research papers at conferences across the nation.

Mr. Ribhushankar Anand
CHRIST University
Bengaluru, Karnataka
India
Email: ribhu2001@gmail.com

Malavika from Kerala, India was born in 2002. She earned a Bachelor's degree in Economics from the University of Calicut in 2023 and is currently pursuing an MA in Applied Economics from Christ University, Bangalore.

Ms. Malavika
CHRIST University
Bengaluru, Karnataka
India
Email: malavika@maeco.christuniversity.in

Bindu Bavadharini is a first-year master of applied economics student in Christ (Deemed to be University), Bengaluru. She received a bachelor's degree in Corporate Economics from Women's Christian College.

Her main areas of research interest are monetary economics, behavioural economics, and Gender & Development Economics.

Ms. Bindu Bavadharini
CHRIST University
Bengaluru, Karnataka
India
Email: bindu.bavadharini@maeco.christuniversity.in

Miriyam Jomy Alias is a postgraduate student of Economics at CHRIST University, Bengaluru. She received her bachelor's degree in Commerce with a specialization in finance and marketing from Mount Carmel College, Bengaluru.

Her ongoing research focuses on social reproduction theory and feminist economics in the Indian context. Her interested areas of study include in political economy, international economics and gender economics.

Ms. Miriyam Jomy Alias
CHRIST University
Bengaluru, Karnataka
India
Email: miriyamjomy@gmail.com