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Inventory trends in emerging market supply chains: Evidence from the Indian automotive industry

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Abstract In the current paper, using a sample data of 58 firms consisting of automakers and auto component suppliers across a 14-year period, we study the factors contributing to efficient inventory management in the Indian automotive Industry. We use fixed effects regression models to document trends in inventory holdings over time and how this varies across inventory types and across tiers in the supply chain. Our results show that inventory holdings have declined differentially across tiers and across different types of inventories. We find tier-1 suppliers reduced all components of their inventories with the help of TQM and lean efforts.

Introduction

In the last decade, emerging economies have attracted large investments from manufacturing industries as a result of which 27 percent of the current manufacturing in the world occurs in the four emerging countries Brazil, Russia, India and China (the BRIC nations) (Marsh, 2011). Given the current downturn in the global economy, especially in developed economies such as the United States and Europe, this focus on emerging markets is likely to continue. Entry of multinational enterprise (MNE) firms often introduces innovative inventory and production management practices to create responsive and efficient supply chains; this is particularly true for the automotive supply chains across the world (Iyer, Saranga & Seshadri, 2013; McDermott & Corredoira, 2010; Vanichchinchai & Igel, 2011). With inventory holdings occupying a strategic and cost-bearing position in any supply chain, their improved management is expected to lead to better performance (Chen, Frank & Wu, 2005; Lieberman & Demeester, 1999). Yet, there is little empirical work to show the extent of operational gains that have been achieved when large investments and entry of MNE firms occur in manufacturing sectors of emerging markets.

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Most empirical studies on inventory holdings have focussed only on average inventories and have failed to capture the behaviour of inventory at the component level within firms and across supply chains. As manufacturing supply chains continue to spread across the globe, the efficiency of a supply chain will increasingly depend on the inventory holdings across the chain and the weakest links in a supply chain tend to be the lower tier suppliers from emerging markets such as India and China. Even though more and more assemblers today mandate just-in-time (JIT) supplies, unless the best practices are adapted by their vendors, the raw material inventory of assemblers simply gets transferred to upstream supply chain and is held in the form of finished goods inventory by the suppliers. Therefore it is important to understand and document the behaviour of various components of inventory, such as raw material (RM), work-in-process (WIP) and finished goods (FG) across the supply chains, and identify the factors driving the inventory management practices of emerging market firms (EMFs).

Literature on transaction costs, operations and supply chain management unearthed a variety of factors that influence the type and level of inventories carried by firms (Cachon & Fisher, 2000; Ellram, 1999; Petersen, Ragatz & Monczka, 2005). For example, transaction cost economics explains the reasons for holding RM stocks (Ellram, Tate, & Billington, 2008; Emery & Marques, 2011), while the WIP inventory levels are typically attributed to operational inefficiency, information asymmetry, poor quality of processes, and long production lead times (Deming, 1982; Womack, Jones & Roos, 1990). Higher levels of FG inventories on the other hand are attributed to the high product variety, product complexity, intensified competition, inflexible production technologies and higher buyer power (Cachon & Fisher, 2000; Cachon & Olivares, 2010; Emery & Marques, 2011). A vast array of process and operational improvement initiatives, such as total quality management (TQM), total productive maintenance (TPM), lean manufacturing, flexible manufacturing systems (FMS) and Six Sigma have been invented and adopted by firms in more advanced economies such as Japan, the United States, and Europe, in order to improve quality of products and reduce the level of inventories in their plants and supply chains.

However, these findings do not investigate if the environment in emerging economies, where institutional and manufacturing networks have historically functioned differently (Gulyani, 2001; Quadros, 2004; Ruamsook, Russel & Thomchick, 2007), is conducive to global best practices that result in operational excellence. Emerging economies are also plagued with delays due to customs clearances, lack of proper road and rail infrastructure, and inadequate enforcement of contractual agreements, and so on, which can create major obstacles to adoption of global best practices to manage emerging market supply chains.

We endeavour to fill this gap by conducting an empirical study on inventory holdings and their driving factors in the Indian automotive industry after the liberalization in 1991. For our empirical analysis, we use secondary data on 58 firms belonging to the Indian automotive industry, which includes automakers and auto component suppliers, during the period 1992 to 2005 to capture long-term trends in inventory holdings. We also carried out a "tierization" exercise to classify our sample firms into automakers (tier-0), their immediate suppliers (tier-1 suppliers) and the suppliers of tier-1 suppliers (tier-2 suppliers), thus identifying the entire supply chain. In addition, we also carried out qualitative studies and case studies of some of the sample firms (by going through industry reports and conducting personal interviews with senior executives at these firms). Our findings indicate that after liberalization of the Indian economy, reduction in transaction costs and adoption of quality and process improvement initiatives have led to important gains in average inventory reduction in the Indian automotive sector.

Our empirical results however also show that these gains tend to vary by the location in the supply chain where the inventory is held (i.e., tier), and the type of inventory being held (i.e., RM, WIP and FG). We, therefore, further analyzed this nuanced evidence obtained from data, through qualitative insights garnered from our expert interviews. The data analysis showed that tier-1 suppliers are the best performers and managed to reduce all components of inventories significantly. Qualitative analysis indicates that quality and process upgrades through adoption of global best practices facilitated by the new MNE entrants have paved the way towards more efficient inventory management in these firms. Automakers (tier-0) have also significantly reduced their RM and WIP inventories but failed to reduce FG inventories. Increased product variety, intensified competition and poor transportation networks are causing the failure in FG reduction, as per the expert opinions. Tier-2 firms on the other hand managed to reduce only RM inventories significantly. Again, our qualitative analysis indicates multiple reasons for failure of these upstream suppliers. While the higher buyer power of tier-1 and tier-0 firms seems to be forcing the tier-2 suppliers to hold higher FG stocks, the batch production practices and lack of exposure to global best practices seem to have hampered tier-2 firms' efforts towards WIP reduction.

Theoretical background and literature review

Role of transaction cost economics on inventory management

It is well-established in the field of supply chain management (SCM) that a firm can reduce its RM and WIP stocks by outsourcing some of their production to suppliers and by making suppliers hold it in the form of their FG inventory. The popularity of JIT supplies can be attributed to this factor. However, for this strategy to work, one needs (a) capable suppliers and (b) outsourcing to be more cost-effective than in-house production. According to transaction cost economics (TCE), vertically integrated firms incur production and governance costs for manufacturing components, while outsourcing firms incur production and transaction costs while buying components (Emery & Marques, 2011). Costs of production for general purpose components of vertically integrated firms are likely to be higher than for firms that outsource to a third party supplier, as suppliers can exploit economies of scale by pooling demand from various customers. However for special purpose components, due to asset specificity, production costs remain the same in both cases (Williamson, 1981).

Firms in protected markets are likely to be more vertically integrated – firstly due to lack of capable supplier networks and secondly due to lack of formal institutional structures, which are essential to ensure that contractual obligations are honoured by the suppliers. When markets are liberalized and institutional structures are put in place, supplier opportunism reduces as market forces and formal institutional mechanisms come into effect (Peng, 2003). While intensified competition forces the incumbent suppliers to develop better capabilities to survive the onslaught of global players, new business opportunities encourage entry of new players and advanced technologies (Kumaraswamy, Mudambi, Saranga, & Tripathy, 2012). This in turn reduces transaction costs for customers and encourages firms to outsource more, which should gradually reduce the level of RM inventories that customers have to stock. The same logic applies across the supply chain as these supplier networks become more capable. The economies of scale from aggregation of various customer demands allow the suppliers to manage higher levels of demands with lower levels of inventories.

We provide quantitative justification for these conjectures using well-established operations and inventory management concepts. Let us consider the case of four automakers that are vertically integrated due to non-availability of appropriate supplier network. Let us suppose that a supplier becomes available to source a specific component (say 'A'), which was manufactured in-house by each of the four automakers, each having a demand say D_A, set-up cost S_A and inventory holding cost h_A. The economic production quantity (EPQ) batch size for each of the firms, for in-house production can be computed as shown in Equation (1) below (Hax & Candea, 1984).

$$Q_A^* = \sqrt{\frac{2S_A D_A}{h_A}} \tag{1}$$

which means that the four firms put together will have to produce a batch size of $4Q_A$* components each time. Now, suppose all four firms decide to procure from the supplier instead of in-house production, the demand on the supplier becomes $4D_A$, resulting in EPQ batch size Q_{AS}* for the supplier, where

$$Q_{AS}^* = \sqrt{\frac{2S_A 4D_A}{h_A}} = 2\sqrt{\frac{2S_A D_A}{h_A}} = 2Q_A^*$$

This means, the supplier has to produce a batch size of only $2Q_A$* components each time, as against the $4Q_A$* components the customers would have to produce if they continued with in-house production. This analysis clearly demonstrates the scale economies available in outsourcing of general purpose components, which reduce the WIP and FG inventory stocks at the supplier's end, and RM and WIP inventories at the customer's end, as well as allow the customer to enjoy JIT deliveries in smaller batches. Even in case of special purpose components, there tends to be some commonality at the part level, which may allow similar benefits to accrue at the supplier's end.

In case of uncertain demand, to ensure that one can still provide some degree of protection against stock-outs, firms maintain safety stocks in addition to the EPQ or economic order quantities (EOQ) described above. Depending upon the level of service that one would like to provide to the end customers, taking into account the demand variability and production (or supply) lead times, the following formula is used to compute the safety stocks (Anupindi, Chopra, Deshmukh, Van Mieghem, & Zemel, 2006, pages:169–194).

$$\text{Safety Inventory}, \quad I_s = z * \sigma_{LTD}, \tag{2}$$

where z is the service level factor that determines the probability of meeting the demand for a given service level, σ_{LTD} represents the variability corresponding to demand as well as lead time uncertainty and is computed using the following equation.

$$\sigma_{LTD} = \sqrt{L\sigma_R^2 + R^2\sigma_L^2}, \tag{3}$$

where L represents lead time, σ_R demand variability and σ_L lead time variability.

Research on buyer–supplier relationships reveals that obligational contracts foster future orientation with joint planning between buyers and suppliers, which subsequently results in better information flow and reduces uncertainties related to demand and supply in the extended supply chain (Ellram, 1999). This collaborative forecasting and planning should subsequently reduce the forecasting errors, and hence σ_R, resulting in lower levels of safety stocks. In addition, adoption of IT systems and advanced information management systems should also lead to information visibility and better forecasting. Similarly, as the supplier capabilities improve and adequate institutional structures are put in place to ensure enforcement of contractual obligations, the supply lead times and lead time uncertainties should reduce, again contributing to lower levels of safety stocks.

Role of MNEs in operational improvement of EMFs

Academic studies provide ample evidence that emerging market firms can improve their productivity and operational effectiveness by supplying to MNE customers (Blalock & Gertler, 2005; Gereffi, Humphrey, & Sturgeon, 2005). Literature on *upgrading* consistently argued that the long-term competitiveness of firms in emerging economies depends on their development of new capabilities that improve on adaptive efficiencies (Moran & Ghoshal, 1999). Automotive firms in most emerging markets typically are the first ones to upgrade their quality, operational efficiency, technological and delivery capabilities, due to the mandatory requirements imposed upon them by the MNE automakers and tier-1 suppliers (Iyer, Saranga & Seshadri, 2013; McDermott & Corredoira, 2010).

The MNE customer's emphasis on efficiency, quality, and productivity improvements drives the emerging market suppliers to adopt waste reduction practices such as lean and total productive maintenance (TPM) and quality improvement initiatives such as ISO and TQM (Iyer, Saranga & Seshadri, 2013; McDermott & Corredoira, 2010; Quadros, 2004). Lean principles emphasize the elimination of wastage through (i) reduction in set-up times and (ii) pull production. Both waste reduction and quality improvement initiatives, if implemented appropriately, should result in reduced inventory stocks. For example, pull production essentially means made-to-order parts/vehicles, and thus minimizes FG inventories. Reduced set-up times allow for smaller lot sizes (lower values of S in Equation (1) result in lower values of Q^*) and hence lower WIP inventory levels. Improved machine maintenance through TPM decreases the need for safety stocks (if machine downtime is reduced, both L and σ_L in Equation (3) reduce and hence the I_S in Equation (2) reduces) and so do TQM efforts which reduce rework and scrap (Lieberman & Demeester, 1999).

Evolution of automotive supply chains in India

As the Indian economy began to relax trade restrictions, partially during the mid-1980s and more comprehensively in the early 1990s, the automotive industry underwent a series of key changes. The most important change occurred in 1983, when the Indian government allowed a joint venture (JV) between a Japanese automaker (Suzuki Motor Corporation) and an Indian public sector company (Maruti Udyog Limited), through partial liberalization of the auto sector. The JV "Maruti Suzuki India Ltd." (MSIL) was allowed complete access to a protected market, by ensuring no other passenger vehicle makers could enter the market, which established MSIL as a dominant player. Since Suzuki was always high on outsourcing in its Japanese market, it wanted to adopt a similar practice in India. Thus, the MSIL partnership began developing an auto component supply chain in India, facilitating partnerships between Indian component suppliers and Suzuki's Japanese suppliers, and sometimes entering into equity partnerships to support small-scale Indian firms (Gulyani, 2001; Okada, 2004). These initiatives and subsequent vendor development efforts by MSIL gradually created a strong auto component supply chain in India by the early 1990s, when the full economic reforms came into effect, and markets were opened for entry of other foreign players.

Taking advantage of these trade reforms in India, majority of the foreign-owned firms and MNE automakers such as General Motors, Ford, Mercedes, Hyundai, Fiat, Toyota, Honda and Nissan made their entry into the Indian auto market. Initially, these MNE automakers began their operations by importing SKUs (semi-knocked-down kits) and CKUs (completely knocked-down kits) from their home countries and simply assembling the finished products in India. However, the government norms stipulated that each MNE has to meet certain local content requirements within 3—5 years of their entry. Simultaneously, the more established auto component firms began to adopt global best practices in shop-floor management to win contracts from the new MNE entrants. These initiatives included ISO quality certification, TQM, Toyota Production System (TPS) and TPM (Iyer, Saranga & Seshadri, 2013; Seth & Tripathi, 2005). As a result of these initiatives, the Indian auto component industry became more robust, with a few firms even winning world class quality awards (such as the Deming award, and Deming's quality medal), customer appreciation awards, and awards in operational excellence (Iyer, Saranga & Seshadri, 2013; Saranga, 2009). Recognizing the improved capabilities of local supply chains, the MNE automakers gradually began to source locally, both to meet the local content requirements as well as to become cost-competitive in a highly price-sensitive market. Even the domestic automakers, who were vertically integrated prior to liberalization, now began to increasingly outsource their component requirements to suppliers (Parhi, 2005). Following the example of MSIL, some of the new MNE entrants and the Indian automakers began to engage in vendor development activities to improve the technological and managerial capabilities of their tier-1 suppliers. The JV partnerships and technology alliances (TAs) with global tier-1 suppliers also helped the Indian suppliers to become competitive in terms of quality, cost and delivery reliability (Kumaraswamy et al. 2012; Saranga, 2009). Gradually, as the immediate supply chain became more robust, automakers in India began moving towards pure assembly operations, delegating most of the production activities to tier-1 suppliers. Thus, there emerged a distinction between tier-1 firms that supply major assemblies and subassemblies to automakers, and the tier-2 firms, who were supplying components to tier-1 firms (Kumaraswamy et al. 2012; Okada, 2004).

Development of hypotheses

As liberalization progresses, due to reduction in TCE, firms opt for higher levels of outsourcing, which should reduce their RM inventories for the reasons listed in the earlier sections. While the automakers tend to reduce their RM inventories by outsourcing most of their component requirement to tier-1 suppliers and demanding JIT deliveries, the tier-1 and tier-2 suppliers can also gradually reduce their RM inventories by taking advantage of scale economies and aggregating demand from multiple customers. Therefore, we posit our first hypothesis as follows:

Hypothesis 1 (H1). In the Indian automotive industry, the raw material inventory **decreased** significantly in tier-0, tier-1, and tier-2 firms after liberalization.

Increased levels of outsourcing coupled with the adoption of best practices such as TQM, TPM, TPS, lean, etc. tend to reduce WIP levels for automakers as well as suppliers, as discussed above. The economies of scale and scope due to pooling of customer demand should also contribute towards reduction of WIP levels for tier-1 and tier-2 suppliers. Hence, we posit our second hypothesis as follows:

Hypothesis 2 (H2). In the Indian automotive industry, the work in process inventory **decreased** significantly in tier-0, tier-1, and tier-2 firms after liberalization.

Increased competition induced by the economic reforms, advanced forecasting and information management systems, and tighter integration with dealerships should enable automakers to reduce their FG inventory levels (Cachon & Olivares, 2010; Holweg, 2003). Up-gradation of shop-floor management systems that enable higher flexibility and JIT production practices coupled with better forecasting systems, should help reduce the FG stocks for tier-1 and tier-2 suppliers. Hence, we posit our third hypothesis as follows:

Hypothesis 3 (H3). In the Indian automotive industry, the finished goods inventory **decreased** significantly in tier-0, tier-1, and tier-2 firms after liberalization.

In addition to the tier-wise and component-wise inventory trends, we also propose a specific hypothesis about the relative size of these effects for WIP inventories. As discussed in the earlier sections, MNE automakers try to establish close relationships with host country suppliers through vendor development activities in a bid to establish a robust supplier network in host countries. Many of the best practices that were transferred through these activities to tier-1 suppliers consisted of ISO certifications, TQM, TPM, Six Sigma and lean manufacturing. Almost all of these are geared towards enabling identification of early defects and hence lower processing times (Corbett, Montes-Sancho & Kirsch, 2005). Systems that ensure identification and elimination of defects at an early stage directly reduce need for maintaining large buffer inventories. The lower processing times result in reduced lead times (*L* in Equation (3)) as well as reduced lead time uncertainty (σ_L in Equation (3)) and hence reduce safety stock levels for WIP inventories. The benefits of TQM are obtained from better process and materials management, fewer defects on the line, less amount of rework, continuous improvement, and incremental innovation (Deming, 1982; Seth & Tripathi, 2005), all of which reduce WIP levels. Similarly lean, TPM and Six Sigma also reduce number of defects and improve productivity through higher yields; ultimately reducing the total WIP required in the process to meet the output targets. Therefore, one would expect the adoption of these best practices to have made a large impact on WIP inventories of those suppliers that had direct dealings with the MNE automakers, i.e. tier-1 suppliers.

However, due to lack of direct interaction between automakers and tier-2 suppliers, vendor development activities and corresponding transfer of best practices take time to reach tier-2 firms. Other factors such as lack of transparency, information asymmetry, and geographical distances between automakers and lower tier suppliers also contribute towards slow diffusion of best practices at the tier-2 suppliers. The inherent nature of production at tier-2, which involves scale economies and requires either batch or mass production (Holweg, 2003), makes significant reductions in WIP difficult to achieve. Automakers (tier-0) on the other hand typically follow a single piece production with fixed cycle times, which again reduces the scope for WIP reduction in automakers in comparison to tier-1. Based on these arguments, we posit our fourth hypothesis:

Hypothesis 4 (H4). Tier-1 suppliers managed to achieve greater reductions in work in process inventory than tier-0 (automakers) and tier-2 suppliers.

Data description and research methodologies

Dataset

We built our dataset on 58 firms in the auto components industry over a 14-year period beginning from 1992 by accessing a detailed India-specific industry database *Prowess*, maintained by the Center for Monitoring Indian Economy (CMIE).[1] *Prowess* is a database of large and medium-sized Indian firms containing detailed information on over 10,000 firms comprising all companies traded on India's major stock exchanges and several others including the central public sector enterprises. The main limitation of the *Prowess* database is that it captures data on publicly traded and listed companies; hence the set of privately owned companies that are not listed in the stock exchanges are not present in our sample. The sample also does not capture firms in the unorganized sector, since they are neither listed nor publicly traded. However, this is not a significant concern in our study since the market share of the unorganized sector in the Indian auto component industry is very small and firms from the unorganized sector are mainly present in the aftermarket segment (Borgave & Chaudhari, 2010). Thus, our sample represents only publicly listed or public traded auto component firms. Note that Fig. 1 below captures the growth in sales in 1992—1993 for the "Transport Equipment" sector in *Prowess* (to which the auto component sector belongs to) and compares it with our sample; our sample captures a similar range of growth experiences and hence is representative of the sector.

Methodology used for supply chain "tierization"

Manufacturing processes that are complicated often have multiple firms working at different points of the supply chain leading to a very natural "tierization" among firms within the industry. However, information on this is neither available with *Prowess* nor in any other publicly available data source. Therefore, we undertook a detailed study to categorize all the firms in the *Prowess* database into three different tiers, viz., tier-0 (automakers), tier-1 and tier-2. It is relatively easier to identify the tier-0 firms from the publicly available data on automakers. However, categorization of component firms into tier-1 and tier-2 is not that straightforward. In the global auto industry, a firm that supplies directly to the automakers is considered as tier-1, while a firm that supplies to tier-1 is considered tier-2 and so on. We too carried out tierization of the Indian auto component firms based on this definition. For tier-1 and tier-2, we carried out the classification in two stages. In the first stage, we collected data on the customer base of all component firms and classified those firms whose major share (60 percent or more) of the customer base constituted tier-0 as tier-1 (since some firms in the Indian context still supply to both automakers as well as tier-1s). On the other hand, if a majority of a firm's customer base constituted tier-1, then it was classified as tier-2. We also asked two industry experts with more than 15 years of experience in the automobile industry to perform the classification based on their knowledge of dealing with vendors. In the second stage, we compared our classification which was based on a firm's customer base with the classification of the two industry experts. Whenever there were discrepancies (we found very few) between the three

[1] http://www.cmie.com.

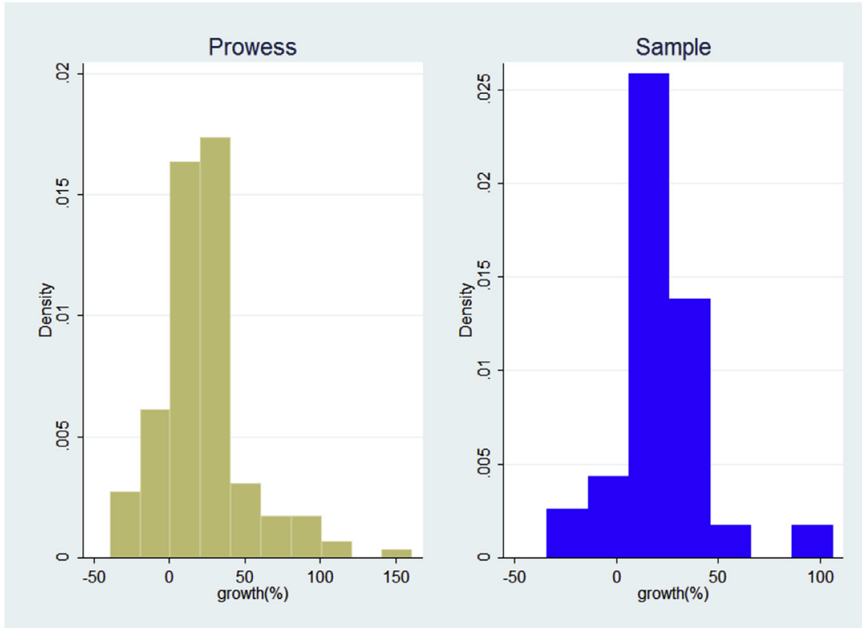

Figure 1 Comparing firm growth rates in *Prowess* database and study sample for 1992—93.

classifications, we selected the classification that matched at least in two cases. This exercise resulted in classification of our sample of 58 firms into 13 tier-0 firms (OEMs); 36 tier-1 and 9 tier-2 firms. Since we are using a panel dataset consisting of a 14-year time period, the size of the each sub-sample is big enough for us to conduct the empirical tests.

Metrics

We use ''inventory days'' as a measure of inventory holdings, which is computed as: Inventory Days (ID) = (Average Inventory/Cost of sales)*365. *Prowess* reports opening stock and closing stock of inventories for all four categories (total inventories, RM, WIP and FG inventories). We first compute average inventories by taking the average of these two stock variables, i.e., (opening stock + closing stock)/2, and then use these averages to calculate the inventory days for each of the four categories across three tiers according to the above description. Finally, we also control for two key macroeconomic variables that are known to affect inventory holding in the auto sector (Chen et al. 2005): (a) GDP growth and (b) rate of interest (ROI). Both of these are obtained from the Central Statistical Organization reports.[2] We report the descriptive statistics of our sample firms in Table 1.

Interviews with industry experts

In addition to procuring the above archival firm-level data, we conducted interviews with senior executives in ten auto components firms (five tier-1 suppliers and five tier-2 suppliers) and four automakers operating in India (two indigenous and two MNE automakers), after conducting the empirical analysis. The tier-1 suppliers had a customer base of indigenous and MNE automakers and the tier-2 suppliers were supplying to indigenous as well as MNE tier-1 suppliers. Our interviewees at these 14 firms were industry veterans, who had spent an average of 20 years in the auto/components industries, and occupied senior positions ranging from assistant general manager to managing director and chief executive officer. The interviews ranged from 1.5 h to 2 h each. We began our interviews with broad, open-ended questions on the changes that had occurred in the Indian automobile industry since market liberalization in 1991, how these changes had affected their firms' behaviours, emerging industry trends, and the potential consequences of these trends for their firms. We gradually shifted to more focussed questions to determine the prevalent supply chain and inventory management practices followed by the interviewee firms and their competitors, and questions on the driving factors behind these practices. Our intention in conducting these interviews was to gain a broad perspective on the Indian auto industry and to validate our empirical results where possible. Thus, we use the information generated by these interviews to provide additional context to our empirical results as well as to explain the results from the data analysis.

Empirical methodology

We investigate trends in inventory holding in our sample during the time period 1992—2005 using parametric panel data analysis methods. Let ID_{it} denote the average number of inventory days for firm i in year t. The vector $\mathbf{X}_{it}$ consists of all independent firm-specific variables that vary over time as well as a linear time trend that captures the change in inventory holding over the 14-year study period.

[2] http://www.rbi.org.in/scripts/AnnualPublications.aspx?head=Handbook%20of%20Statistics%20on%20Indian%20Economy.

Table 1 Summary statistics.

Variables	Full sample			
	Mean	SD	Min	Max
Outcomes:				
Log (Average inventory days)	4.10	0.64	1.56	5.84
Log (Raw material days)	3.85	0.69	0.89	5.86
Log (Work-in-progress days)	2.35	1.10	−0.43	5.05
Log (Finished goods days)	2.17	1.32	−2.81	4.87
Time-varying macro variables:				
Year	1999	4	1992	2005
GDP growth rate (%)	6.36	1.76	4.00	10.00
Rate of interest (%)	12.75	2.29	10.25	17.00
Firm specific time varying variables:				
Accounts receivables	58.11	33.62	2.83	260.29
Accounts payables	65.09	31.24	2.23	209.80
Exports as % sales	6.43	9.94	0.00	82.93
Imports as % sales	8.67	7.63	0.00	61.81
Firm level growth in sales	18.57	33.41	−64.41	718.40

Note: Sample size is 812; SD - Standard deviation.

To test our first three hypotheses (H1 to H3), we use a standard one-way error component model given by Equation (4) that allows us to control for unobserved firm-specific effects that are invariant over time (Baltagi, Matyas & Sevestre, 2008). The key coefficient of interest is the coefficient on time, i.e., π; time (t) is simply a linear counter for each year of observation going from 1 to 14. The coefficient on time gives us the change in the average number of days of inventory for an additional year of being in business after controlling for a number of time-varying covariates as well as all firm-specific time invariant covariates (the μ_is), and helps us test the first three sets of hypotheses.

$$\mathrm{ID}_{it} = \pi t + \beta_1 GDPgrowth_t + \beta_2 ROI_t + \beta_3 receivables_{it} + \beta_4 payables_{it} + \beta_5 X_{it} + \beta_6 M_{it} + \beta_7 Salesgrowth_{it} + \beta_8 \mu_i + \nu_{it} \quad (4)$$

where $GDPgrowth_t$ captures GDP growth for the economy, ROI_t captures the prevailing rate of interest, $receivables_{it}$ captures each firm's average days of debtor in year t, $payables_{it}$ captures each firm's average days of creditor in year t, X_{it} is the exports to sales ratio, M_{it} is the imports to sales ratio, and $Salesgrowth_{it}$ is growth in net sales for each firm in year t. μ_i is a firm-specific unobserved effect for each firm across all years, and ν_{it} is the idiosyncratic unobserved error term that varies by time and year. In Equation (4), π, the coefficient of the time variable (represents the time trend) is the parameter of interest. The interpretation of π critically hinges on the assumption that $E(\nu_{it}|t, \mathbf{X}_{it}, \mu_i) = 0$(where $\mathbf{X}_{it}$ represents the vector of macroeconomic variables and firm-level controls described earlier), i.e., the time-varying covariates are strictly exogenous conditional on the unobserved firm effects. In addition, we use Driscoll and Kraay (1998) corrected standard errors in our panel data models to obtain autocorrelation and heteroskedasticity robust estimates.

In order to test hypothesis 4 on the relative difference in WIP inventory holdings across the three tiers, we modify our regression model (Equation (4)) to include an interaction term between the relevant tier dummy variable and year (t) and estimate the relationship over the two tiers. This allows us to separate the aggregate effect seen in the earlier equation into a component that is common to firms across both tiers and that which is specific to a tier alone. Thus, to look at the difference in the way WIP days have been changing between tier-0 and tier-1 firms for example, we take data for both tiers and estimate a modified version of Equation (4):

$$\mathrm{ID}_{it} = \pi_0 t + \pi_1 t * \mathrm{tier0} + \beta \mathbf{X}_{it} + \mu_i + \nu_{it}, \quad (5)$$

where tier-0 is a dummy variable that takes the value 1 for a firm if it is a tier-0 firm and is zero for all other firms; π_0 captures the linear trend in inventory days; π_1 is the coefficient on the interaction between year and tier-0 indicator and captures how efficient tier-0 firms are relative to tier-1 firms in reducing their WIP inventory: Equation (5) is estimated for a sample of tier-0 and tier-1 firms. To test the relative efficiency of tier-1 and tier-2 firms, we replace tier-0 in Equation (5) with tier-2 and estimate on a sample with tier-1 and tier-2 firms only. $\mathbf{X}_{it}$ is the vector of covariates as defined above, in the description of Equation (4).

Results and discussion

Fig. 2 shows that inventory holding has been declining in the entire Indian automotive industry after liberalization in 1990. The top left quadrant in Fig. 2 provides the average inventory trend across three tiers; this shows that there is wide heterogeneity within the sample even though the overall trend is declining. Although tier-0 and tier-1 firms show a declining trend, the trend for tier-2 is ambiguous. The next three graphs of Fig. 2 depict the inventory trends in RM, WIP and FG holdings across the three tiers.

In order to statistically justify these apparent trends, we use static panel regression models described in the methodology section, controlling for all possible firm-level

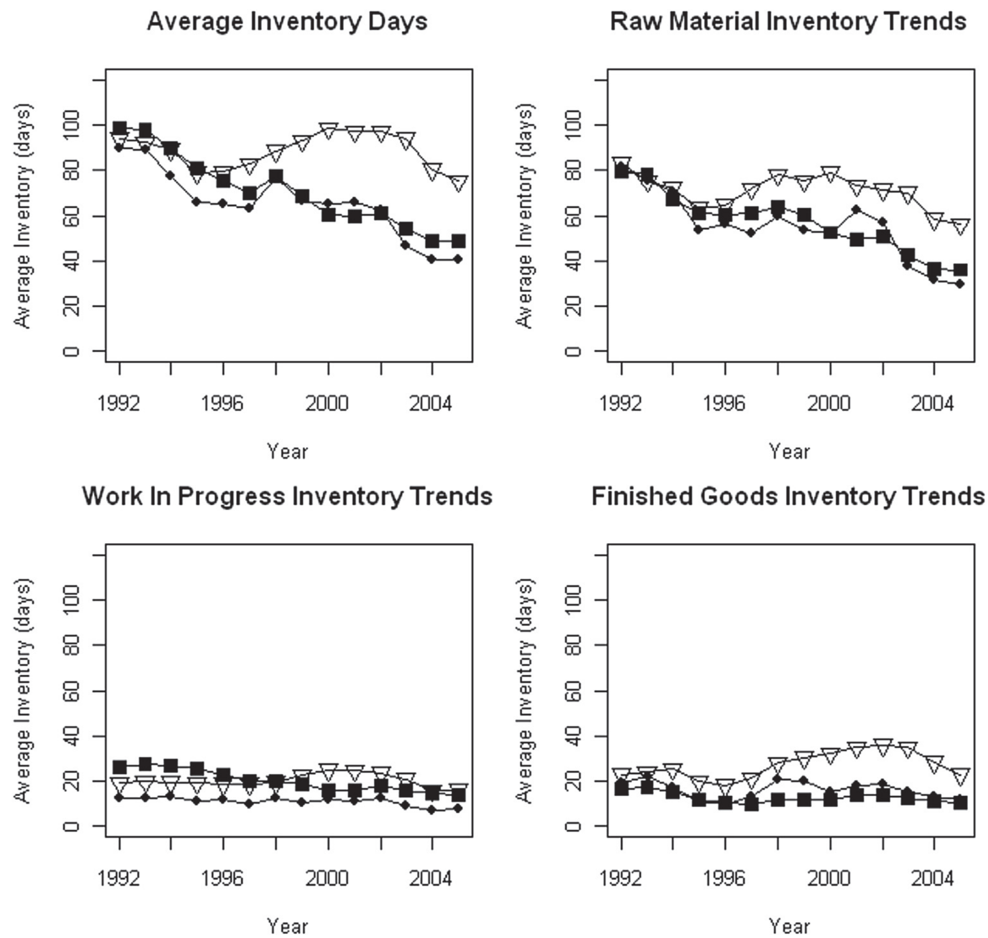

Figure 2 Trends in mean inventory days, RM days, WIP days and FG days, by tier. Note: Each quadrant shows the temporal distribution of different inventory measure across the three tiers. The small dots represent tier-0 or automaker firms, the filled boxes represent tier-1 firms, while the triangles represent tier-2.

differences. We use fixed effects models for our specification because Hausman tests show systematic differences between the fixed effects regression coefficients and the random effects regression coefficients for all the major specifications that we are interested in. The results corresponding to the average inventory days as the dependent variable are reported in Table 2. As one may note from the results listed in the row corresponding to the year variable, we find strong support for our hypotheses corresponding to average inventories. After controlling for all firm-level factors, heteroskedasticity and auto correlation, we find there was a decline of close to 6.5 percent in average inventory per year during the 14-year study period for the full sample at 1 percent level of significance.[3] The tier-wise results show tier-1 mainly contributing to this significant decline with an average inventory reduction of 6.8 percent per year, followed by tier-0 at 4.9 percent and tier-2 at 2.4 percent reduction per year (all three have very strong support at 1 percent level).

Next, we look at results corresponding to component-wise inventory trends in Tables 2 and 3. The results in Table 2, corresponding to the year variable suggest that the decline in average inventory for the full sample is driven by the decline in RM inventory (7.8 percent per year). The results in Table 3 corresponding to the WIP inventory also indicate statistically significant reductions for the full sample, although the size of the reduction is smaller at 4.6 percent per year. We also find that firms in all three tiers have reduced the RM and WIP levels significantly at 1 percent level, except for tier-2 firms, which seem to have failed in reducing their WIP inventories. Finally, we look at the trends in FG levels from Table 3. The FG levels for full sample have also declined (at 1 percent significant level) by 4.4 percent per year. However, the results corresponding to the tiers show that this decline is mainly contributed by tier-1, which managed to reduce FG levels by nearly 4.3 percent per year. FG for tier-0 and tier-2 firms does not show any significant reduction.

Thus, we find strong support for our hypothesis corresponding to RM days (H1) which have declined in all tiers. Our expert interviews suggest that these reductions in case of automakers (tier-0) may be attributed to their shift towards increased outsourcing, mandatory JIT deliveries by tier-1 suppliers and vendor rationalization; the reduction in

[3] We also ran these regressions directly on inventory days and results are similar to log (inventory days). We find there was a decline of close to three days of inventory per year during the 14-year study period for the full sample at 1% level of significance.

Table 2 Fixed effects models for average inventory and raw material (RM) inventory days.

Variables	Average inventory days				Raw material inventory days			
	Full	Tier 0	Tier 1	Tier 2	Full	Tier 0	Tier 1	Tier 2
Year	−0.0653***	−0.0492***	−0.0678***	−0.0240***	−0.0782***	−0.0736***	−0.0677***	−0.0667***
	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01
GDP growth	−0.35	−0.7814*	0.45	−1.5195**	−1.2355***	−0.71	−0.4995*	−1.69
	0.31	0.39	0.31	0.55	0.26	0.59	0.28	0.93
Rate of interest	−0.0200**	−0.02	−0.0127***	−0.0197**	−0.0304**	−0.01	−0.0289***	−0.01
	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01
Average days of debtors	−0.0002**	−0.0003***	−0.0020**	−0.0198***	0.00	0.00	−0.0060***	−0.0063*
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Average days of creditors	−0.0002***	−0.0002***	0.00	0.0178***	−0.0002***	−0.0001**	0.00	0.0280***
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Exports as % sales	0.0084***	0.00	0.0103***	0.00	0.0076***	−0.01	0.0091***	0.0078***
	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Imports as % sales	0.0060*	0.0128*	0.01	0.00	0.0117***	0.01	0.0138***	0.0070***
	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.00
Firm level growth in sales	−0.0021***	−0.0055***	−0.0015***	−0.0035***	−0.0021***	−0.0053***	−0.0014***	−0.0045***
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Constant	134.7700***	102.6928***	139.7268***	52.7309***	160.5389***	151.1926***	139.5341***	137.5068***
	9.47	23.63	5.91	8.81	18.64	17.65	12.49	12.84
Observations	812	182	504	126	812	182	504	126
Number of groups	58	13	36	9	58	13	36	9
R-within	0.445	0.557	0.508	0.292	0.462	0.631	0.491	0.354

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$; Driscoll—Kraay standard errors and these are reported below coefficients. Full is the entire sample; other models are tier-specific.

case of tier-1 and tier-2 may be due to higher outsourcing coupled with restructuring of the component industry into definite tiers and longer supply chains. Thus, we can attribute these reductions in RM inventories of tier-0 and tier-1 firms to reduced transaction costs that allowed firms to outsource more after liberalization. Our interviewees from tier-2 firms revealed that the increasing material costs and year-on-year price reduction expectations by the customers have been forcing them to manage their operations with lower levels of RM stocks. We also find partial support for our hypotheses H2 and H3 corresponding to the remaining two components WIP and FG respectively: while WIP has reduced both in tier-0 and tier-1 firms; only tier-1 has been successful in FG reduction. The efforts of automakers toward streamlining their internal operations, such as technology upgrades, increased levels of automation, and introduction of Kanban seem to have paved the way towards WIP reduction. The tier-1 firms too seemed to have achieved significant reductions in their WIP through adoption of quality and process improvement initiatives. Therefore, the gains in WIP reduction of tier-0 and tier-1 firms can be attributed to the successful implementation of global best practices in shop-floor management.

The results corresponding to FG inventory reveal interesting trends across the supply chain. Our hypothesis (H3) that automakers (tier-0) should have reduced their FG inventories is not supported. Our interviews with the industry experts revealed that given the huge increase in number of models and their variants, coupled with the vast size of Indian subcontinent, it is very difficult to reduce the FG inventory stocks at the automakers. Most interviewees from the tier-0 firms pointed out that the intensified competition, with virtually no difference in technologies or features offered in the low-price segment (which accounts for more than 70 percent of the passenger vehicle market in India) has made availability of vehicles one of the main criteria to garner market share. Long delivery lead times, owing to the huge distances between the plants and dealers combined with poor road infrastructure (less than 2 percent of vehicles are transported by rail in India) are forcing most automakers to follow the built-to-stock (BTS) model and hold sufficient number of finished vehicles, rather than following the pull-based production model. The latter is more popular in developed economies and results in lower levels of FG stocks, but is difficult to implement in developing countries such as India, which still suffer from lower volumes and poor transportation networks.

The FG results corresponding to tier-1 firms show that despite increasing pressures by automakers for JIT deliveries and buffer inventories, tier-1 firms have managed to significantly reduce their FG inventories. This, firstly, indicates a healthy trend of JIT production by tier-1 firms, rather than merely JIT deliveries that require buffer stocks of FG inventories. The popular practice of establishing vendor parks in and around assembly plants and directly connecting tier-1 suppliers to the assembly plants also

Table 3 Fixed effects models for work-in-process (WIP) and finished goods (FG) inventory days.

Variables	Work-in-progress inventory days				Finished goods inventory days			
	Full	Tier 0	Tier 1	Tier 2	Full	Tier 0	Tier 1	Tier 2
Year	−0.0462***	−0.0304***	−0.0526***	−0.0304	−0.0442***	−0.0196	−0.0430***	0.0017
	0.005	0.006	0.004	0.017	0.007	0.017	0.008	0.008
GDP growth	0.0374	0.9144	0.7785	−3.7308***	−1.3997*	−1.7369*	−0.4809	−3.5869**
	0.459	0.526	0.578	0.918	0.789	0.904	0.823	1.161
Rate of interest	0.0113	0.0229**	0.0215***	−0.0402	−0.0710***	−0.0618*	−0.0565***	−0.0692***
	0.009	0.008	0.006	0.036	0.019	0.031	0.014	0.017
Average days of debtors	−0.0001	−0.0001	−0.0009	−0.0115*	−0.0004***	−0.0005***	−0.0025**	−0.0125
	0	0	0.001	0.006	0	0	0.001	0.009
Average days of creditors	−0.0003***	−0.0004***	0.0001	0.0230*	−0.0002***	−0.0003**	−0.0001	−0.0008
	0	0	0	0.01	0	0	0.001	0.007
Exports as % sales	0.0078***	−0.006	0.0105***	−0.0035	0.0143***	0.0193**	0.0162***	0.0041
	0.003	0.007	0.003	0.002	0.003	0.007	0.003	0.004
Imports as % sales	0.0004	0.0025	0.0002	−0.0009	−0.0057	−0.0036	−0.0032	−0.007
	0.002	0.01	0.002	0.002	0.005	0.006	0.008	0.007
Firm level growth in sales	−0.0023***	−0.0052***	−0.0021**	−0.0004	−0.0023*	−0.0082**	−0.0012	−0.0054***
	0.001	0.001	0.001	0.001	0.001	0.003	0.001	0.001
Constant	94.5821***	62.6058***	107.1973***	64.1349*	91.8051***	42.7623	88.8568***	1.0965
	9.471	11.168	7.583	34.418	13.4	35.205	16.002	16.017
Observations	812	182	504	126	812	182	504	126
Number of groups	58	13	36	9	58	13	36	9
R-within	0.27	0.387	0.321	0.125	0.11	0.233	0.105	0.291

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Driscoll–Kraay standard errors and these are reported below coefficients. Full is the entire sample; other models are tier-specific.

enables JIT production at tier-1's end, reducing the need for both FG as well as WIP inventories. Secondly, successful adoption of efficient inventory management systems and accurate forecasting systems by tier-1 suppliers also seem to have contributed to FG reduction at tier-1. This conjecture was corroborated during one of our interviews with a senior executive of a tier-1 supplier, who candidly admitted that, although most of the MNE customers ask them to hold a minimum of 3 days of FG stocks as buffer inventories, they hold only 8 h equivalent of FG inventories. According to this executive, they have their own forecasting system (apart from the forecasts provided by their customers), which gives them more accurate signals about the market demand and have also acquired the flexibility to increase/reduce their production volumes, according to market dynamics. Hence, rather than carry the FG stocks demanded by their customers, they use their own judgment and thus manage to achieve significant reductions in their WIP and FG stocks.

The tier-2 firms on the other hand seem to be bearing the brunt of JIT practices of their customers, as their FG inventories show no significant reduction. The large geographical distances between tier-2 suppliers and their customers (tier-1) also contribute towards higher FG levels at tier-2 as they are forced to maintain higher levels of in-transit and safety inventories and buffer stocks in warehouses close to each customer (Gulyani, 2001). While tier-1 firms managed to establish production operations in automaker's vendor parks and hence can do JIT production, tier-2 firms are located far away and have to hold inventories in the warehouses, in order to do JIT deliveries. The batch production practices involving scale economies at tier-2 (Holweg, 2003) also partly explain their inability to reduce inventories or establish production facilities next to each of their customers. Thus, although there is an overall decline in average inventory levels, we do find some reallocation of inventories across tiers. The various factors that drive the inventory levels across the three tiers of emerging economy automotive supply chains — based on our empirical results and insights gained from expert interviews — are described in Fig. 3.

We also find support for hypothesis H4 from results corresponding to WIP levels in Table 3. As one may note, tier-1 has the highest decline in WIP (5.3 percent per year), while tier-0 and tier-2 have only 3 percent decline. To statistically test this difference, we make use of the regression model (5), which includes a dummy variable for the tier that is interacted to the year to separate the effect of the decline to that which is common to firms across both tiers and that which is specific to a tier alone. Table 4 presents our tier-level disaggregated estimates for the change in WIP days. Column (1) in Table 4 is estimated for firms belonging to both tier-0 and tier-1, and shows that an additional year reduces the WIP inventory of tier-1 firms by 5.5 percent (when clubbed together with tier-0 firms), while the reduction for firms in tier-0 is less at 3 percent ($-0.055 + 0.0251 = -0.0299$).

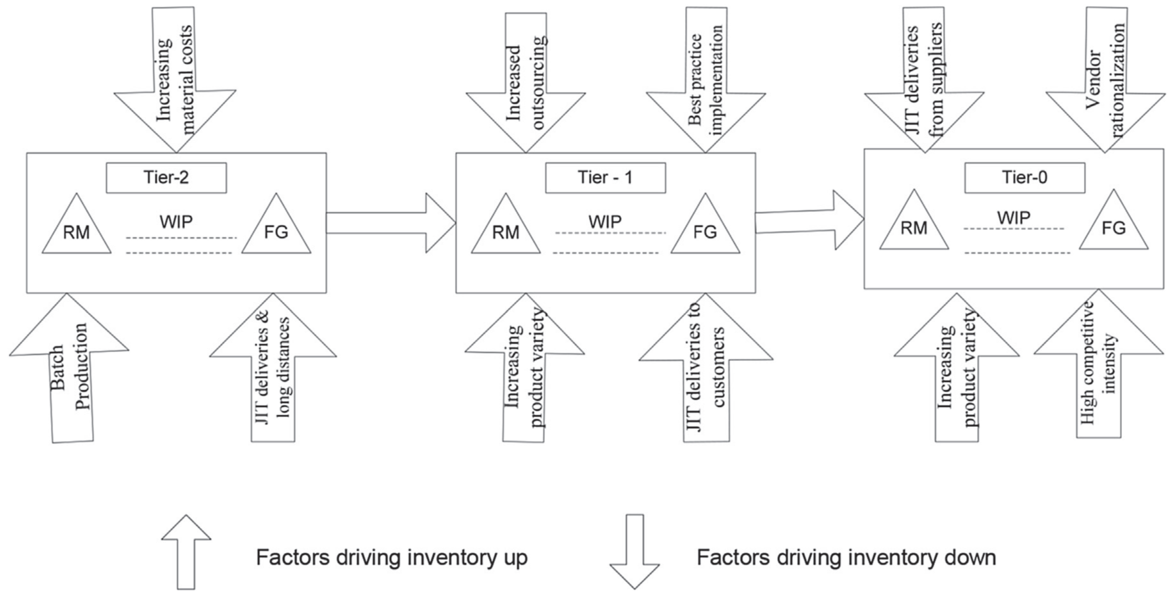

Figure 3 Factors driving inventory levels across the three tiers of auto supply chains in emerging markets.

Similarly, column (2) in Table 4 is estimated for firms belonging to tier-1 and tier-2 and it shows that for an additional year, tier-1 firms experience a decline of 5.84 percent, the decline for firms in tier-2 is only 1.2 percent ($-0.0584 + 0.0463 = -0.012$). Hence, we find strong support for hypothesis 4, that tier-1 firms have become more efficient in managing their internal processes through adoption of lean and other best practices and have reduced their WIP inventories more than both, their customers, i.e., tier-0 firms as well as their suppliers, i.e., tier-2.

Table 4 Decline in work-in-process (WIP) inventories across various tiers.

Variables	Tier 0 + Tier 1	Tier 1 + Tier 2
Year	−0.0550***	−0.0584***
	0.004	0.004
GDP growth	0.5987	0.0328
	0.524	0.485
Rate of interest	0.0181**	0.0114
	0.007	0.009
Average days of debtors	−0.0001	−0.0008
	0	0.001
Average days of creditors	−0.0004***	0.0008*
	0	0
Exports as % sales	0.0098***	0.0064**
	0.003	0.003
Imports as % sales	0.0013	−0.0005
	0.003	0.001
Firm level growth in sales	−0.0024***	−0.0020***
	0.001	0.001
Omitted category: Tier 1 firms		
Tier 0 × Year	0.0251***	
	0.004	
Tier 2 × Year		0.0463***
		0.012
Constant	98.6724***	100.6468***
	7.308	9.629
Observations	686	630
Number of groups	49	45
R-within	0.331	0.271

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Driscoll—Kraay standard errors and these are reported below coefficients.

Conclusions and managerial implications

Supply chains and inventories in emerging economies are organized on very different considerations than cost-minimization and flexibility that are standard for modern supply chains in developed economies with large endowments of physical and financial resources. However, with introduction of latest technology and foreign capital, competitive forces created by the entry of modern manufacturing units can act as a mechanism for positive change as has been seen in the current study. From a vertically integrated structure, Indian automotive firms moved to significant levels of outsourcing, by taking advantage of reduced transaction costs after liberalization. This shift coupled with vendor development and vendor rationalization activities eventually led to a tiered industrial structure and improved inventory management practices. Adoption of global best practices facilitated by MNE customers contributed significantly to efficiency gains in tier-1 firms. However, these best practices do not seem to have diffused uniformly across the supply chains. The lack of significant improvements in tier-2 firms can be attributed partly to the lack of frequent and close interactions with the MNE automakers, as found during our interviews with industry experts; this is similar to the findings in the Argentine automotive sector (McDermott & Corredoira, 2010). Another important factor seems to be the smaller scale and lack of capital resources, which prohibit tier-2 firms from acquiring advanced IT systems and flexible manufacturing technologies that would have helped in inventory reduction. A more detailed study that links impact of various best practices such as TQM, Lean, and TPS directly to the operational efficiencies in upstream supply chains (on similar lines to Vanichchinchai & Igel, 2011) would shed more light in this direction.

Our research findings on inventory trends in the Indian automotive industry provide a number of interesting managerial implications. First of all, across all levels of inventory holding there is substantial variation in the level of inventory held. This variation exists not only between firms but also within the same firm. Thus, managers of firms who are not near the minimum values of inventory holdings can see that other firms are doing better. Further, we find that, over time, firms have consistently been able to innovate and do better by reducing the level of inventory held. Thus, there is significant scope for learning within the sector from competitors and this in turn can shape hiring decisions. Next, much of the gains appear to be located in tier-1 firms where the gains have been across all types of inventories — raw material, work-in progress and finished goods, making them good candidates for benchmarking. From a practice point of view, our results also suggest that with better infrastructure and logistics, there is huge scope for reduction in finished goods inventory of automakers. A key unexplored territory for managing inventory remains tier-2, but change in this tier is also perhaps the hardest in the absence of better integration within the entire automotive supply chain.

Our study results therefore have a number of implications for further research and practice in emerging economies. Firstly, our findings suggest that even in emerging countries, it is possible to create changes across the entire supply chain that lead to firm- and sector-level efficiencies. Secondly, these practices may be improved and upgrades may take shorter time periods if diffusion of best-practices can be systematized and made uniformly accessible. Strategies followed by firms in such reformed supply chains become tier- and product-specific indicating subtle ways in which the auto components sector has adjusted to the changes in the economic and competitive environment in which they operate. Since supply chains are only as strong as the weakest link in the chain, firms operating in emerging markets should take note and exert extra emphasis on improving operational efficiencies of upstream suppliers that may still be suffering from legacy-related problems.

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