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Customer-Country diversification and inventory efficiency: Comparative evidence from the manufacturing sector during the pre-pandemic and the COVID-19 pandemic periods

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ARTICLE INFO	ABSTRACT
	This study empirically examines the impact of geographic customer diversification on inventory efficiency and proposes a customer-country diversification strategy as a central element of U.S. manufacturing firms' effort to transform their global supply chains in the aftermath of the COVID-19 pandemic. Using industry-level data during the pre-pandemic period (2003–2018) and the COVID-19 pandemic, this study finds that a geographically diversified customer base significantly reduced inventory efficiency during the pre-pandemic period, but increased inventory efficiency during the COVID-19 pandemic. Our finding suggests that U.S. manufacturing firms may be able to reduce negative impacts on inventory in a global pandemic and achieve greater inventory efficiency if they can target global customer bases with demand characteristics less correlated with U.S. domestic demand.

1. Introduction

Cross-border, cross-firm, and cross-functional global supply chains are subject to longer lead times, greater demand variations, and higher risks of supply chain disruptions. Fragmentation and dispersion of business activities and resources, which have been constantly moved both upstream and downstream across the globe, have further exposed the vulnerabilities of global supply chains (Kano, Tsang, & Yeung, 2020). In responding to political and environmental backlashes against global supply chains, pioneering firms have started to bring production and resources closers to their markets (Clarke & Boersma, 2017). While the strategic significance of onshoring or nearshoring may not have been fully appreciated, the business world has witnessed how the COVID 19 pandemic brought the entire global supply chain to a nearly complete pause. Two years into the pandemic, global supply chains have started to partially resume functioning and it is time for global companies to rethink and transform their global supply chains. In fact, more and more global companies desire to expand into nearby foreign markets with similar customer characteristics for distribution efficiency and easier demand management. Firms are seeking ways to diversify their supply chains by reducing their reliance on a single country, regardless of how attractive that country might be (Wu, 2020).

To mitigate supply chain risks, global companies have sought to manage demand uncertainties by diversifying their customer base and to manage supply uncertainties by diversifying their supply base. According to a Wall Street Journal report (2019), consumer behavior varies significantly across geographic regions due to constant changes in customer demographics. Hence, the heterogeneous consumer base will likely demonstrate a broad and varied set of demand patterns. Market diversification has been considered an effective risk management strategy in domestic markets. In global markets, consumer behavior may differ dramatically from country to country due to a variety of economic conditions, policies, cultures, and many other factors. This can result in low levels of demand correlations between the domestic and foreign markets. For example, in the fourth quarter of 2020 when the pandemic worsened, Apple was still able to generate about 70 percent of its revenues from outside of the Americas, including 17 percent from Europe, 8 percent from China, and 5 percent from Japan (Statista, 2021). Notably, Tesla had its best year in 2020 due to rising sales in China while its sales in 22 U.S. states decreased dramatically (White, 2020). Therefore, for a U.S. manufacturing firm serving multiple foreign markets, it is beneficial to develop a diverse customer-country portfolio where the demand pattern between U.S. domestic market and foreign markets is less, or even negatively, correlated thanks to different economic factors.

However, the supply chain risk management literature primarily focuses on a supply-side diversification strategy without paying adequate attention to the demand-side hedging strategy. In fact, only a few researchers have proposed a demand-side hedging strategy to diversify the global supply chain customer base and enhance supply chain resilience to crises (Manuj and Mentzer, 2008a, 2008b; Kochan and Nowicki, 2018; Pournader et al., 2020). Unfortunately, the benefits and costs of a diversified customer base in global supply chains have not been thoroughly and systematically investigated (Van der Vegt et al., 2015). In particular, the implications of customer-country diversification on inventory efficiency have been overlooked in existing studies. In this research, we employ two competing theoretical lenses (the bargaining power view and the risk pooling theory) to examine the inventory consequences of a customer-country diversification strategy.

Additionally, there is also a theoretical gap in the supply chain risk management literature regarding the impact of a geographically diverse customer base on inventory efficiency. This is due to theoretical ambiguity and a lack of empirical evidence. On the one hand, the bargaining power view argues that a firm with a few major customers may have to keep a higher inventory level due to greater bargaining power exerted by its customers (Cachon and Terwiesch, 2008; Ak and Patatoukas, 2016; Casalin et al., 2017). On the other hand, the operations management view predicts that a concentrated customer base helps a firm implement efficient supply chain management practices and leverage risk pooling to reduce demand variation and to lower inventory holdings (Corbett and Rajaram, 2006; Ben-Zvi and Gerchak, 2012; Çömez-Dolgan and Tanyeri, 2015; Ak and Patatoukas, 2016; Cho et al., 2017; Yang et al., 2021). The risk-pooling theory further argues that the correlation levels of demand among geographic locations may determine the extent of the inventory reduction effect due to aggregating demands (Eppen, 1979; He et al., 2020). This implies that the profile of the geographic customer mix may affect a firm's inventory efficiency. Notably, since the COVID-19 pandemic caused worldwide supply and demand shocks in 2020, the way manufacturers use inventories to cope with supply chain uncertainties and disruptions during the crisis may differ from what they would during non-crisis periods.

Building upon a large dataset of 2,684 industry-year observations during the pre-pandemic period and 259 industry-month observations during the COVID-19 pandemic, this study empirically examines the impact of geographic customer diversification on inventory efficiency. It proposes a customer-country diversification strategy for global manufacturing firms in their effort to transform their global supply chains in the aftermath of a global pandemic. To answer the call for secondary data to test and validate empirical models, and to develop a thorough understanding of the challenges firms face and the solutions that they adopt during the COVID-19 pandemic (Gölgeci, Gligor, Bayraktar and Delen, 2020), we collect data on manufacturing industries to validate our regression models. This research aims to address the following questions:

1) What is the relationship between geographic customer concentration and inventory efficiency?
2) How does the geographic customer profile mix in global supply chains affect inventory efficiency?
3) Does the impact of geographic customer diversification on inventory efficiency differ during the COVID-19 period as compared with the pre-pandemic period?
4) What are the long-term implications of our findings for global supply chain executives in the aftermath of the COVID-19 pandemic?

This study finds that a geographically diversified customer base significantly reduced inventory efficiency, favoring the operations management view. In line with a previous finding that a higher export ratio is associated with higher inventory holdings (Rajagopalan and Malhorta, 2001; Han et al., 2008), this study further indicates that such a relationship is positively moderated by the correlations between domestic and foreign markets. Hence our study confirms that the portfolio of foreign customer bases has a significant impact on inventory efficiency. Essentially, when a firm is entering a foreign country with different demand characteristics from its home country, inventory efficiency will be enhanced. Therefore, a firm needs to carefully target and diversify its customer base when expanding globally. Furthermore, while the findings drawn from data during COVID-19 are largely consistent with what is found during the pre-pandemic period, this study surprisingly finds that the correlations among U.S. domestic sales and foreign sales are largely lower than the correlations during the pre-pandemic period. As a result, U.S. manufacturing firms may be able to mitigate the negative impacts of global expansion on inventory efficiency in the presence of a global pandemic and achieve greater inventory efficiency if they can target global customer bases whose demand characteristics are less correlated with the U.S. domestic market.

This study is among the first empirical efforts that examine the effect of geographic customer diversification on manufacturing inventory efficiency. Our research helps clarify the theoretical ambiguity caused by competing theoretical lenses and fills in the gaps in the existing supply chain risk management literature. For practitioners, this study suggests that a proper portfolio of global customer bases may be developed in managing global supply chain risks, especially in the case of a global pandemic.

The remainder of the paper is organized as follows. In Section 2, the hypotheses are developed based on the survey of the overarching theories and existing supply chain management literature. This is followed by the presentation of data collection and research methodology in Section 3. Then, the pre-pandemic regression results are provided, and the managerial implications are discussed in Section 4. We validate our research model using data collected during the COVID-19 pandemic and discuss the implications in Section 5. We conclude our study in Section 6 with a summary of theoretical and managerial contributions, research limitations, and future research steps.

2. Literature review and hypotheses development

Based on a survey of literature on the relationships between inventory efficiency and global supply chains, exports, and in particular geographical customer concentration, we develop hypotheses on the impact of customer-country diversification on inventory efficiency.

2.1. Export ratio and inventory

Previous studies find that more sales from foreign markets lead to more inventory holdings (Han et al., 2008). Broader geographic coverage in global markets leads to longer lead times, greater demand variation, and higher risks of supply chain disruptions. These factors may have contributed to the amplification of the bullwhip effect, the demand distortion that travels upstream in the supply chain from downstream retailers to wholesalers and upstream manufacturers, due to a large variance of customer orders. This results in more inventories for manufacturers. Previous studies find that a higher ratio of exports over sales is associated with higher inventory levels of finished goods due to less frequent shipments and longer lead time (Levy, 1997; Rajagopalan and Malhorta, 2001; Han et al., 2008). Han et al. (2008) report that a 10 percent increase in export value over sales is associated with a 2.05-day increase in finished goods inventory. Therefore, it is predicted that firms with global customer bases tend to have higher inventory levels and lower inventory efficiency.

2.2. Geographical customer concentration and inventory

Two competing theoretical perspectives have been employed to examine the relationship between geographical customer concentration and inventory efficiency: the bargaining power view and the operations

management view. These two different views result in ambiguity about the impact of global expansion on inventory efficiency. Given that previous studies have shown mixed results, this study aims to reconcile the seemingly conflicting findings on the relationship between customer concentration and inventory holdings from a geographic customer diversification perspective at the industry level. In this study we develop two competing hypotheses.

On the one hand, the bargaining power view predicts that an industry with a higher geographic customer concentration may have a higher inventory level. This view argues that a firm with greater bargaining power either induces or coerces its business partners (including upstream suppliers and downstream customers) to do what they are less willing to do otherwise (Flynn et al., 2010; Cho et al., 2019). The power disparity between a manufacturing firm and its supply chain partners may be caused by unique resources, market share and positioning, and other dependence factors. For example, among the five forces examined by Porter (1979), the bargaining power of suppliers and the bargaining power of customers are critical. A manufacturing firm with a few major customers is likely to lose leverage over its customers and hence its customers are likely to have more bargaining power over the firm. The manufacturing firm's major customers may exercise their power and request higher fill rates and greater product availability (Cachon and Terwiesch, 2008; Ak and Patatoukas, 2016; Casalin et al., 2017). Hence, a firm with a limited number of major customers may need to keep a higher inventory level. Casalin et al. (2017) find that firms with higher customer density retain larger inventories because of the bargaining power exercised by their customers. Therefore, we state our hypothesis as follows:

Hypothesis 1a. Industries with higher geographic customer concentration have lower inventory turnover than industries with lower geographic customer concentration.

On the other hand, from the operations management view, a concentrated customer base leads to reduced demand uncertainties and thus lower inventory holdings. This view is based on two related theoretical building blocks in operations management: the square-root law and the risk-pooling theory.

The square root law suggests that fewer locations of demand lead to lower inventory levels (Maister, 1976; Zinn et al., 1989; Oeser and Romano, 2015). The square-root law formula assesses inventory levels at a variable number of warehouses (i.e., markets), stating that a firm's total safety stock will increase with the addition of new warehouses. The projected total safety stock can be approximated as a multiple of the square root of the ratio of the number of warehouse locations (the increased number over the existing number).

The risk-pooling theory suggests that for the same customer service level, a centralized system carries a lower inventory level than a decentralized system. This is because the sum of safety stock required across separate locations in a decentralized environment exceeds the total safety stock required in a centralized system (Ben-Zvi and Gerchak, 2012; Çömez-Dolgan and Tanyeri, 2015; Cho et al, 2017). Furthermore, a firm with a limited number of major customers can build strong and close relationships and implement advanced supply-chain practices such as collaborative planning, forecasting, and replenishment (CPFR), and vendor-managed inventory (VMI) (Ak and Patatoukas, 2016) to reduce demand uncertainties and increase inventory efficiency. CPFR is the collaborative management of inventory through high visibility and joint replenishment of products, and the continuous updating of existing inventory and upcoming inventory requirements in the supply chain, resulting in greater inventory efficiency. VMI is another inventory management practice where a manufacturer or a supplier directly manages inventory on the customer's warehouse or shelf (i.e., a retailer), leading to greater inventory visibility and efficiency.

Based on the operations management view, a firm with a limited number of major customers may keep a lower inventory level. Ak and Patatoukas (2016) find that manufacturers with more concentrated customer bases hold fewer inventories and are less likely to end up with excess inventories. Yang, Hu and Zhou (2021) compare the benefits of two inventory management systems: a centralized inventory ordering system by a central planner without inventory pooling (for example, the headquarters of a global company) versus a physical or virtual pooling of inventories ordered by each retailer store. They find that centralization benefits the company overall as long as the manager of each individual retail store is more risk-averse and that the benefits of inventory pooling depend on how the additional profit from inventory pooling is shared and allocated among the stores. Examining the value of centralization by a company with multiple retail locations, Corbett and Rajaram (2006) find that aggregate demand uncertainty and inventory costs are both lowered if inventory is centralized and demands from all locations are pooled. Their study has generalized Eppen's original results to situations where demands are nonnormal and positively correlated.

In conclusion, the operations management view predicts that an industry with higher geographic customer concentration may have higher inventory turnover, and hence lower inventory levels. Therefore, our alternative hypothesis is stated as follows:

Hypothesis 1b. Industries with higher geographic customer concentration have higher inventory turnover than industries with lower geographic customer concentration.

2.3. Customer portfolio and inventory

The operations management view on inventory management predicts that higher demand variability leads to higher safety stock and a lower level of customer service. Risk pooling is a technique for reducing demand variability by pooling demand across different individual sources of variation. Equation (1) shows that the variability of aggregated demand (standard deviation of total demand, σ_a) is less than or equal to the sum of the individual variability (sum of standard deviations of demand at the n sources). The standard deviation of total demand σ_a is determined by the disaggregate demand at different sources as well as the covariance between demand sources.

$$\sum_{i=1}^{n} \sigma_i \geq \sigma_a = \sqrt{\sum_{i=1}^{n} (\sigma_i)^2 + 2\sum_{i=1}^{n} \sum_{i<j}^{n} \sigma_i \sigma_j \rho_{ij}} \tag{1}$$

Where σ is the standard deviation of demand, and ρ is the covariance of demand between any two locations.

Eppen (1979) indicates that the benefit from risk pooling decreases as the correlation between two locations increases. If the coefficient is equal to one, the aggregate inventory will be the same as the total of disaggregate inventories. Hence, there may be no cost savings at all from a centralized system when demand across all locations is highly positively correlated (Eppen, 1979; Chen and Lin, 1989).

Risk pooling theory predicts that the correlation between the sales in domestic and foreign markets may have a moderating impact on inventory levels (Eppen, 1979; He et al., 2020). When there is a negative correlation between these two markets, the aggregate inventory level may be lower because the higher demand in one market offsets lower demand in another market, leading to lower aggregate demand variabilities and lower safety stock holdings. Using a product recall setting for a firm with multiple regional markets, He et al. (2020) compare the benefits of two sourcing and distribution strategies: a dedicated strategy, where different suppliers serve dedicated individual markets, and a centralized strategy, where a firm centralizes sourcing decisions and ships products to each regional market. Their study finds that centralization is optimal when recall risk and disruption probability are low and that the positive correlation in recalls improves the performance of the centralized strategy. They also find that the decentralized strategy leads to poorer performance when correlations in recalls are positive.

In this study, we argue that the correlation among geographically diversified customer bases may positively moderate the inventory levels caused by the export ratio. It may explain why a firm that penetrates emerging markets is found to have fewer days of inventory supply and improved financial performance (Han et al., 2013). The correlation of

two markets may be determined by economic ties between two markets during the pre-pandemic period and by the epidemic severity in each market during COVID-19. While previous studies find that a firm with a higher export ratio holds more inventories, this study argues that the relationship between export ratios and inventory levels is positively moderated by the correlations between domestic and foreign markets.

Hypothesis 2

The negative impact of export ratios on inventory turnover is moderated by the correlation between domestic and foreign markets.

3. Methodology and data

To develop the fixed-effect inventory model, this study surveys the literature of empirical studies on inventory management. Previous studies use total inventory value, inventory ratio (average inventory value over the cost of goods sold), inventory days (average inventory value times 365 days over the cost of goods sold), and inventory turnover (cost of goods sold over average inventory value) as dependent variables and measure operational efficiency (Rajagopalan and Malhotra, 2001; Chen et al., 2005, 2007; Gaur et al., 2005; Rumyantsev and Netessine, 2007; Han et al., 2008; Ak and Patatoukas, 2016; Casalin et al., 2017).

In the fixed-effect inventory model, the choice of control variables depends on data availability, which may be limited by the level of data aggregation. Rajagopalan and Malhotra (2001) investigate twenty manufacturing industry sectors from 1961 to 1994 using industry-level inventory data collected from the U.S. Census Bureau while controlling for the growth of output in a sector. Chen et al. (2007) collect both firm-level data from COMPUSTAT and aggregate-level sales and inventory data from the U.S. Census Bureau for the manufacturing, retail, and wholesale sectors. They compare the inventory patterns from these two sources, controlling for interest rates, growth in GDP, inflation, and the optimism expressed by purchasing managers measured by the U.S. manufacturing purchasing managers' index (PMI). Also known as the U.S. manufacturing index, PMI is a monthly indicator of U.S. economic activity based on a survey of purchasing managers at more than 400 U.S. manufacturing companies across 19 primary industries. PMI readings range from 0 to 100. A PMI above 50 represents an expansion when compared with the previous month. A PMI reading under 50 represents a contraction, and a reading at 50 indicates no change. Inventory studies typically include PMI to control for the overall macroeconomic condition. Inventory turns fast when the economy expands while inventory turns slow down when the economy contracts.

Gaur et al. (2005) use firm-level financial data for 311 publicly listed retail firms during the period 1987 to 2000 to examine how gross margin, capital intensity, and the ratio of actual sales to expected sales may have affected inventory turnover. Rumyantsev and Netessine (2007) use the quarterly data of 722 publicly listed U.S. companies to test the hypotheses derived from classical inventory models. With inventory turnover as the dependent variable, they find support for a positive association of inventory turnover with demand uncertainty, length of lead times, and gross margins. They find a negative association of inventory turnover with firm size, and a mixed result with inventory carrying costs. Han et al. (2008) study the effects of import ratios and export ratios on inventory days of raw material and finished goods, respectively, while controlling for cost of capital, sector inflation, sector real growth, and IT investment.

We conduct two separate analyses based on two different datasets collected for the pre-pandemic period and the COVID-19 pandemic. Consisting of 173 five-digit North American Industry Classification System (NAICS) industries over 16 years during the pre-pandemic period (2003-2018), a panel dataset with 2,684 industry-year observations is collected from the USA Trade Online database and the Annual Survey of Manufactures (ASM) published by the U.S. Census Bureau and used for pre-pandemic regression analysis. For the COVID-19 pandemic regression analysis, the industry-level panel data with 273 industry-

month observations, which consist of 39 three-digit industries over a period of seven months during the COVID-19 pandemic period (Jan-July 2020), are collected from the Manufacturers' Shipments, Inventories, & Orders (M3) database of the U.S. Census Bureau. Note that the M3 database is aggregated at the three-digit NAICS industry level.

Building upon the inventory models developed by Gaur et al. (2005), this study uses inventory turnover at the industry level as a dependent variable to measure inventory efficiency. Generally speaking, higher inventory turnover means that lower inventory levels are needed to support the same level of sales and hence higher inventory efficiency. Following the model specifications in previous studies (Rajagopalan and Malhotra, 2001; Chen et al., 2005,2007; Gaur et al., 2005; Rumyantsev and Netessine, 2007; Han et al., 2008; Ak and Patatoukas, 2016; Casalin et al., 2017) and considering data availability at the industry level, we include two primary explanatory variables of research interest in this study: the ratio of export value over total shipment value, and geographic customer concentration. To measure the moderating effect of sales correlations between the U.S. domestic market and foreign markets, an interaction term is created for export ratio and the correlation coefficients between domestic and foreign markets.

Based on the inventory literature discussed above, this study includes industry-level variables that affect inventor efficiency as the control variables, including the yearly growth of shipment value (SG), the capital intensity (CI), the size of the industry sector (SZ), and the average gross margin of an industry sector (GM). The regression model is displayed in Equation (2).

$$INV = \beta_0 + \beta_1\ ER + \beta_2\ GC + \beta_3\ ER\ x\ CORR + \beta_4\ SG + \beta_5\ CI + \beta_6\ SZ + \beta_7\ GM + \varepsilon \tag{2}$$

Definitions and measures for all variables included in the regression model are described below.

- **INV** is inventory turnover measured by the cost of goods sold over the average value of total inventory. The inventory data are collected from the ASM.
- **ER** is the export ratio measured by the export value over shipment value. A higher export ratio is expected to increase inventory holdings. Data on export value and shipment value are collected from USA Trade Online and the ASM, respectively.
- **GC** is geographic customer concentration which is an application of the Herfindahl-Hirschman index (HHI). Following prior studies (Patatoukas, 2012; Ak and Patatoukas 2016), we measure geographic customer concentration as shown in Equation (3):

$$GC_{it} = \sum_{j=1}^{J}\left(Export_{ijt}/Export_{it}\right)^2 \tag{3}$$

where $Export_{ijt}$ is industry i's export value from the U.S. to country j in year t, and $Export_{it}$ represents industry i's total U.S. exports in year t. The data on export value are collected from USA Trade Online.

- **CORR** is measured by the 16-year correlation coefficient between an industry's U.S. domestic sales, which is derived by subtracting export value from this industry's total value of shipments, and its export value for a foreign destination country during 2003-2018. Underlying data are collected from USA Trade Online and the ASM.
- **ER x CORR** is an interaction term used to capture the moderating effect of sales correlations between the U.S. domestic market and foreign markets on inventory turnover.
- **SG** is the yearly growth of an industry's total value of shipments collected from the ASM.
- **CI** is capital intensity, measured by the shipment value per employee ratio collected from the ASM. A higher shipment value per employee ratio implies higher labor efficiency and higher capital intensity.
- **SZ** is the size measured by the logarithm of the number of employees of an industry, collected from the ASM.

- **GM** is the gross margin ratio, calculated by the equation: (total shipment value – costs of goods sold) / total shipment value. All related data are also collected from the ASM.

4. Pre-pandemic regression results and discussion

Tables 1 and 2 report descriptive statistics and correlation coefficients among all variables used in the regression models, respectively. Overall, inventory turnover averages 5.57 days ranging from 1.62 days to 43.10 days. About 28 percent of the total value of shipments is exported to foreign markets. The higher the export ratio for an industry, the lower the correlation is between the sales from the U.S. domestic market and foreign markets. Geographic customer concentration is positively correlated to inventory turnover, a relationship consistent with the operations management view. The relationships between various control variables and inventory turnover are generally consistent with the findings reported by previous studies. Higher inventory turnover is observed to be associated with higher capital intensity, higher sales growth, larger industry size, but lower gross margin ratio. According to Table 2, correlations among all independent variables are reasonably low without causing concerns of multicollinearity.

Table 3 reports descriptive statistics of industries at the three-digit NAICS level due to space limitations. Industries like computer and electronic product manufacturing, miscellaneous manufacturing, leather and allied product manufacturing, apparel manufacturing, and textile mills appear to have high percentages of sales generated from foreign markets, displaying low geographic concentration and negative correlations between U.S. domestic and foreign markets.

The regression results of the fixed-effect inventory model, which is used to test our research hypotheses, are reported in Table 4. Column 1 of Table 4 shows the results of the baseline model. The export ratio (ER) displays a negative impact on inventory turnover at a significance level of 0.01, implying that more sales from foreign markets lead to higher inventory levels. A one-percent point increase in the export ratio is, *ceteris paribus,* associated with a 0.6-percent point decrease in inventory turnover. This finding is consistent with those reported in previous studies (Rajagopalan and Malhortra, 2001; Han et al., 2008).

To test Hypotheses 1a and 1b, Geographic Customer Concentration (GC) is included in the regression model as presented in Column 2 of Table 3. The results show that GC has a positive impact on inventory turnover at a significance level of 0.05, lending support for Hypothesis 1b and rejection of Hypothesis 1a. This study finds evidence in favor of the operations management view that higher geographical customer concentration in foreign markets leads to lower inventory levels and higher inventory efficiency. Based on our models, a 10-percent point increase in geographic concentration measured by the HHI is associated with a 13.76-percent point increase in inventory turnover.

To test Hypothesis 2, the interaction term between export ratios (ER) and market correlations (CORR) is included in the inventory model as presented in Column 3 of Table 3. The interaction term is found to be significant in moderating the relationship between ER and inventory turnover (INV) at a significance level of 0.01, lending support for Hypothesis 2. These results provide evidence that the negative impact of the export ratios on inventory turnover can be enhanced when the

correlations between the U.S. domestic market and foreign markets are negative. As the results have suggested, when an industry expands its customer base to a country whose demand characteristics are very different from its home country, this strategic move may help the industry generate higher levels of sales with relatively lower inventory levels. In contrast, when an industry penetrates a foreign market whose economy has a close tie to its home country, the inventory turnover is expected to worsen due to positive correlations between sales locations and loss of risk pooling effects.

These findings may have a profound impact on a firm's global geographic diversification strategy in the context of global supply chains. As firms are increasing their sales to global markets, more complex supply chains have caused higher risks of supply chain disruption, longer lead times, and eventually more inventory holdings. To mitigate the supply chain risk, firms have adopted different supply chain risk management strategies such as diversified customer bases. While previous studies (Rajagopalan and Malhortra, 2001; Han et al., 2008) argue that a higher export ratio leads to more inventory holdings, this study finds that a geographically concentrated customer base can significantly reduce inventories while achieving the same level of sales. This finding provides important insights to global supply chain executives. While researchers have been advocating resilient supply chains by diversifying their customer base, this strategy comes with high costs. When its customers are dispersed across more countries, a firm needs to keep more inventories in the warehouses near its customers. As a result, a firm will face a greater need for working capital and inventory holdings, resulting in a longer cash conversion cycle.

Furthermore, this study indicates that the right mix of foreign customer bases has a significant impact on inventory efficiency. A firm needs to carefully diversify its customer base when expanding globally. When expanding to a country whose economy is highly correlated to that of its home country, a firm should expect its inventory turnover to decrease. In contrast, when a firm is penetrating a country where economic trends tend to move in a direction opposite to its home country, the aggregate demand variation will be reduced, and inventory turnover will be improved. Therefore, a firm needs to take into consideration the correlations of market demands between its domestic market and the foreign markets it plans to enter.

To provide more insights for U.S. firms to diversify their global customer bases, Table 5 summarizes the 16-year correlation coefficients between the U.S. domestic market and major foreign markets across 173 industries. Because the coefficients may not be normally distributed, Table 5 reports both the median and means of correlation coefficients. The results show that the U.S. domestic market has a higher correlation with its neighbors such as Canada and the countries in South America, followed by Australia and Europe. The correlation is lower for countries in Asia and Africa. This finding has significant managerial implications and is consistent with the study of Han et al. (2013), who find that a firm's sales penetration into emerging markets is associated with fewer inventory days. While many U.S. firms may prefer neighborhood countries and developed economies when penetrating foreign markets, this study suggests that a U.S. firm should include more Asian or African countries in its customer portfolio for the benefits of improved inventory turnovers. The benefits are heightened in case of global supply disruptions such as the COVID-19 pandemic.

5. Model validation under the COVID-19 pandemic

Since the first case of COVID-19 was officially reported in China in December 2019, the coronavirus has quickly spread around the world, bringing global supply chains to a nearly complete pause. In the first three months of 2020, the economies of G20 countries fell 3.4 percent on a year-over-year basis (OECD, 2020). Between April and June 2020, the International Labor Organization estimated that an equivalent of 400 million full-time jobs were lost across the world (McKeever, 2020). In the first half of 2020, U.S. exports were down 15.7 percent compared to

Table 1
Descriptive Statistics.

Variable	Observations	Mean	Std. Dev.	Min	Max
INV	2,684	5.57	4.12	−1.62	43.10
ER	2,684	0.28	0.43	0.00	4.55
CORR	2,684	0.24	0.63	−1.00	0.98
GC	2,684	0.20	0.13	0.03	0.88
SG	2,684	0.02	0.15	−0.67	2.67
CI	2,684	549.74	939.28	87.13	13,068.74
SZ	2,684	10.57	1.03	7.68	13.34
GM	2,684	0.40	0.11	0.09	0.87

Table 2
Correlation Table.

	INV	ER	CORR	GC	SG	CI	SZ	GM
INV	1.00							
ER	−0.19	1.00						
CORR	0.19	−0.38	1.00					
GC	0.22	−0.19	−0.07	1.00				
SG	0.09	−0.09	0.14	0.00	1.00			
CI	0.35	−0.07	0.15	−0.07	0.09	1.00		
SZ	0.12	−0.21	0.26	−0.09	0.06	−0.10	1.00	
GM	−0.41	0.02	−0.04	−0.19	−0.02	−0.08	−0.06	1.00

Table 3
Descriptive Statistics by Industry.

NAICS	Industry	INV	ER	CORR	GC	SG	CI	SZ	GM
311	Food Manufacturing	8.07	0.07	0.63	0.19	4.1%	693.17	10.52	0.40
312	Beverage and Tobacco Product Manufacturing	6.74	0.07	0.68	0.22	4.0%	1163.27	10.08	0.59
313	Textile Mills	5.14	0.43	−0.17	0.22	−2.4%	256.15	9.62	0.32
314	Textile Product Mills	4.44	0.11	−0.41	0.25	−1.2%	204.94	10.32	0.36
315	Apparel Manufacturing	2.86	0.47	−0.06	0.15	−6.9%	152.45	9.41	0.38
316	Leather and Allied Product Manufacturing	4.27	0.77	−0.72	0.16	−0.7%	225.98	9.07	0.33
321	Wood Product Manufacturing	5.46	0.06	0.19	0.23	2.5%	220.68	11.28	0.30
322	Paper Manufacturing	6.12	0.22	0.38	0.25	1.4%	516.07	10.56	0.38
323	Printing and Related Support Activities	5.40	0.05	−0.40	0.19	−2.0%	150.18	11.74	0.49
324	Petroleum and Coal Products Manufacturing	10.25	0.05	0.83	0.25	6.3%	4224.95	10.42	0.26
325	Chemical Manufacturing	5.58	0.23	0.47	0.11	3.8%	1168.42	10.16	0.45
326	Plastics and Rubber Products Manufacturing	5.42	0.18	0.60	0.22	3.9%	313.06	10.99	0.36
327	Nonmetallic Mineral Product Manufacturing	4.75	0.13	0.25	0.29	4.1%	326.55	10.06	0.47
331	Primary Metal Manufacturing	4.99	0.26	0.50	0.20	4.3%	641.59	10.54	0.29
332	Fabricated Metal Product Manufacturing	3.68	0.17	0.33	0.19	3.7%	276.30	11.07	0.40
333	Machinery Manufacturing	3.31	0.38	0.29	0.10	4.2%	350.69	11.39	0.40
334	Computer and Electronic Product Manufacturing	4.00	0.85	−0.15	0.10	−3.1%	388.58	10.83	0.48
335	Electrical Equipment, Appliance, and Component Manufacturing	4.43	0.43	−0.16	0.17	3.7%	332.86	10.27	0.41
336	Transportation Equipment Manufacturing	9.51	0.25	0.20	0.31	4.7%	516.82	11.11	0.29
337	Furniture and Related Product Manufacturing	5.91	0.05	0.16	0.35	1.7%	206.59	10.88	0.41
339	Miscellaneous Manufacturing	2.84	0.78	−0.16	0.15	−0.2%	244.79	10.71	0.48
Total		5.57	0.28	0.24	0.20	2.5%	549.47	10.57	0.40

Table 4
Regression Results for the Pre-pandemic Period (2003–2018).

VARIABLES	(1) INV	(2) INV	(3) INV
ER	−0.601***	−0.588***	−0.650***
	(0.129)	(0.129)	(0.131)
GC		1.376**	1.345**
		(0.554)	(0.553)
ER × CORR			−2.13x10⁻¹¹***
			(0.721x10⁻¹¹)
SG	0.532***	0.530***	0.508***
	(0.160)	(0.160)	(0.160)
CI	0.000766***	0.000766***	0.000882***
	(0.0000820)	(0.0000819)	(0.0000907)
SZ	0.541***	0.570***	0.606***
	(0.129)	(0.130)	(0.130)
GM	−6.842***	−6.873***	−6.932***
	(0.627)	(0.626)	(0.626)
Constant	2.303*	1.723	1.376
	(1.379)	(1.397)	(1.400)
Observations	2,684	2,684	2,684
R-squared	0.105	0.107	0.110
Number of industries	173	173	173

Standard errors in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 5
Correlations between U.S. Domestic Market and Foreign Markets during 2003–2018.

Variable	Median	Mean	Std. Dev.	Min	Max
Overall	**0.42**	**0.24**	**0.63**	**−1.00**	**0.98**
US Domestic and Canada	0.54	0.28	0.63	−0.99	0.98
US Domestic and South America	0.44	0.27	0.60	−0.99	0.99
US Domestic and Australia and Oceania	0.31	0.18	0.54	−0.97	0.99
US Domestic and Europe	0.30	0.20	0.55	−0.99	0.93
US Domestic and Asia	0.28	0.18	0.60	−1.00	0.97
US Domestic and East and South East Asia	0.28	0.19	0.57	−0.97	0.96
US Domestic and Middle East	0.28	0.13	0.58	−0.96	0.98
US Domestic and China	0.27	0.17	0.56	−0.99	0.93
US Domestic and Africa	0.21	0.12	0.49	−0.97	0.97
US Domestic and South Asia	0.19	0.12	0.53	−0.98	0.94

still hold during the pandemic. Hopefully, our findings will offer first-hand insights into the behavior of firms during the pandemic and draw inferences about transformations needed to the long-term global strategy in the aftermath of the pandemic.

Given that the impacts of COVID-19 were not felt globally until January 2020, this study collected monthly data during January-July in 2020 from the M3 survey published by the U.S. Census Bureau to validate our inventory model. The M3 survey adopts an industry categorization that is partially comparable to the four-digit NAICS categorization. As a result, the monthly data collected from the M3 survey have fewer observations as compared with the five-digit NAICS data used in the pre-pandemic period. Considering the nature and

the previous year, while the U.S. real GDP decreased at an annual rate of 32.9 percent in the second quarter of 2020 (Bureau of Economic Analysis, 2020). Given the significant disruptive impacts of COVID-19 on trade and the world economy, this study further examines whether the relationships between geographic customer concentration, the correlations between domestic and foreign markets, and inventory efficiency

availability of monthly data at the M3 industry level, this study revises the inventory model as shown in Equation (4) and redefines the variables in the inventory model as follows:

$$INVM = \beta_0 + \beta_1\,ERM + \beta_2\,GCM + \beta_3\,ERM \times CORRM + \beta_4\,SGM + \beta_5\,CIM + \beta_6\,SZM + \varepsilon \quad (4)$$

- **INVM** is monthly inventory turnover measured by the monthly shipment value over the inventory value of each month.
- **ERM** is the monthly export ratio measured by the monthly export value over the monthly shipment value.
- **GCM** is the monthly geographic concentration measured by the HHI (Herfindahl Index) calculated by the monthly export's value share of destination countries.
- **CORRM** is measured by the 7-month correlation coefficient of an industry's U.S. domestic sales, which is equal to monthly shipment value minus monthly export value, with respect to the industry's foreign sales.
- **SGM** is the monthly growth of an industry's shipment value.
- **CIM** is capital intensity measured by the monthly shipment value per employee, which is collected from Current Employment Statistics (CES) maintained by the U.S. Bureau of Labor Statistics.
- **SZM** is the size measured by the logarithm of the number of employees of an industry collected from the Current Employment Statistics (CES).

Summary statistics and correlations of the variables used in the regression model based on Equation (4) are provided in Tables 6 and 7.

Table 8 presents the regression results during the pandemic period (January-July 2020). Results for the inventory model using monthly data during the pandemic are consistent with the results based on annual data during the non-pandemic period in terms of the signs of regression coefficients. A higher export ratio is associated with lower inventory turnover during the pandemic, and higher geographic concentration can improve inventory turnover. An industry with a lower correlation between U.S. domestic market and foreign markets carries less inventory given the same export ratio.

We have further noted an interesting phenomenon after comparing regression results for the pre-pandemic and the pandemic models, leading to important insights for practitioners. First, we find that the magnitude of correlations between the U.S. domestic market and foreign markets has significantly decreased during the COVID-19 pandemic. Tables 91 and 92 compare correlations between the U.S. domestic market and foreign markets before the COVID-19 pandemic (January 2018 – July 2018) and during the COVID-19 pandemic (January 2020 – July 2020). The pairwise t-tests for the correlation means of two periods show that the means of correlation coefficients are significantly lower during the pandemic period than those observed before the COVID-19 period in most regions at a significance level of 0.05. Notably, the U.S. domestic market sales became negatively correlated with foreign markets in Africa, the Middle East, and China during the pandemic.

Before the pandemic, the correlations between domestic and foreign markets mainly depend on their economic ties. During the pandemic, global supply chains may have been affected by the extent and timing of

Table 6
Descriptive Statistics during the COVID-19 Pandemic (January 2020 – July 2020).

Variable	Obs.	Mean	Std. Dev.	Min	Max
INVM	273	0.73	0.37	0.09	2.05
ERM	273	0.46	1.01	0.03	7.42
CORRM	273	0.11	0.54	−0.97	0.89
GCM	273	0.16	0.10	0.04	0.65
SGM	273	−0.05	0.14	−0.95	0.20
CIM	273	95.91	164.87	2.64	869.86
SZM	273	4.49	0.83	2.70	6.63

Table 7
Correlation Table - during the COVID-19 Pandemic (January 2020 – July 2020).

	INVM	ERM	CORRM	GCM	SGM	CIM	SZM
INVM	1.00						
ERM	−0.30	1.00					
CORRM	0.22	−0.46	1.00				
GCM	0.14	−0.13	0.30	1.00			
SGM	0.13	−0.06	−0.29	−0.16	1.00		
CIM	0.31	−0.15	0.26	−0.16	0.03	1.00	
SZM	0.14	0.18	0.03	−0.02	0.07	−0.28	1.00

Table 8
Regression Results during the COVID-19 Pandemic (January 2020 – July 2020).

MODEL	(1)	(2)	(3)
VARIABLES	INVM	INVM	INVM
ERM	−0.129***	−0.224***	−0.224***
	(0.0234)	(0.0270)	(0.0260)
GCM			0.736***
			(0.172)
ERM × CORRM		−0.186***	−0.188***
		(0.0309)	(0.0298)
SGM	0.583***	0.462***	0.434***
	(0.0640)	(0.0629)	(0.0610)
CIM	0.000558**	0.000693***	0.000646***
	(0.000233)	(0.000218)	(0.000211)
SZM	0.209***	0.248***	0.204***
	(0.0518)	(0.0487)	(0.0481)
Constant	−0.167	−0.358	−0.273
	(0.243)	(0.229)	(0.221)
Observations	273	273	273
R-squared	0.581	0.638	0.665
Number of industries	39	39	39

Standard errors in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

the COVID-19 outbreak, the vaccination rates, and the public health policies such as lockdowns, social distancing, and travel bans. These factors may have caused a dramatic shift in a country's trade practices and economic policies, resulting in reduced or even broken linkages with the U.S. domestic market. Given that the correlations between domestic and foreign markets positively moderate the impact of export ratio on inventory turnover, firms with high foreign sales could still improve inventory efficiency, while holding export ratio and other variables constant, as long as sales are made from those countries whose market characteristics are negatively correlated with U.S. markets.

We conduct further analyses of four manufacturing industries representing the spectrum of export ratio and correlation to demonstrate whether the impacts of a diversified customer base on inventory efficiency may have varied across industries during the pandemic. First, we analyze three manufacturing industries with the highest export ratios (apparel manufacturing, industrial machinery, and construction machinery). Notably, apparel manufacturing has a negative correlation, industrial machinery has a nearly zero correlation, and construction machinery has a positive correlation. Then, we examine the material handling equipment manufacturing industry which displays a low export ratio. The summary statistics of the four selected industries are presented in Table 10.

Furthermore, we conduct a trendline analysis of inventory turnovers, U.S. domestic sales, and sales to major foreign markets over the January 2019 - May 2021 period for each of the four industries.

Fig. 1 shows inventory turnovers, U.S. domestic sales, and sales to major foreign markets for the apparel manufacturing industry, categorized as the high export ratio and negative correlation industry. Before the pandemic, 56 percent of total sales for the U.S. apparel manufacturing industry were contributed by foreign customers, mainly located in Canada, Latin America, and Europe. The U.S. domestic market

Table 91

Comparison of Correlations between U.S. Domestic Market and Foreign Markets before COVID-19 (January 2018 – July 2018) and during COVID-19 (January 2020 – July 2020) – by Export Destination.

	All		Africa		East and South East Asia		South Asia		Middle East	
	Y2018	Y2020	Y2018	Y2020	Y2018	Y2020	Y2018	Y2020	Y2018	Y2020
Mean of Correlation	0.43	0.12	0.12	−0.07	0.29	0.04	0.14	0.00	0.20	−0.02
Variance	0.25	0.28	0.25	0.27	0.26	0.20	0.18	0.20	0.16	0.21
Observations	37	37	37	37	37	37	37	37	37	37
Hypothesized Mean Difference	0.00		0.00		0.00		0.00		0.00	
t Stat	4.09		1.69		2.69		1.46		2.59	
t Critical one-tail	1.69		1.69		1.69		1.69		1.69	
P(T<=t) one-tail	0.00		0.05		0.01		0.08		0.01	
Significance at 0.05	Yes		Yes		Yes		No		Yes	

Table 92

Comparison of Correlations between U.S. Domestic Market and Foreign Markets before COVID-19 (January 2018 – July 2018) and during COVID-19 (January 2020 – July 2020) – by Export Destination (Continued).

	Australia and Oceania		China		Europe		Canada		South America	
	Y2018	Y2020	Y2018	Y2020	Y2018	Y2020	Y2018	Y2020	Y2018	Y2020
Mean of Correlation	0.19	0.15	0.24	−0.01	0.27	0.06	0.43	0.25	0.30	0.00
Variance	0.18	0.16	0.22	0.24	0.21	0.23	0.17	0.21	0.20	0.25
Observations	37	37	37	37	37	37	37	37	37	37
Hypothesized Mean Difference	0.00		0.00		0.00		0.00		0.00	
t Stat	0.43		2.40		2.25		2.17		3.50	
t Critical one-tail	1.69		1.69		1.69		1.69		1.69	
P(T<=t) one-tail	0.33		0.01		0.02		0.02		0.00	
Significance at 0.05	No		Yes		Yes		Yes		Yes	

Table 10

Summary Statistics of Selected Industries.

Industry	% of Export to Shipment Value				Correlation				Inventory Turnover			Inventory Turnover	
												Y-o-Y Change %	
	Category	2019	2020	2021 May YTD	Category	2019	2020	2021 May YTD	2019	2020	2021 May YTD	2020	2021 May YTD
Apparel manufacturing	High	56%	44%	52%	Negative	−0.17	−0.68	−0.90	0.45	0.45	0.45	−1.3%	0.4%
Industrial Machinery Manufacturing	High	64%	71%	78%	Zero	0.02	0.17	0.07	0.38	0.36	0.41	−4.6%	14.9%
Construction Machinery Manufacturing	High	40%	37%	39%	Positive	0.23	0.13	0.53	0.48	0.46	0.52	−3.7%	12.0%
Material Handling Equipment Manufacturing	Low	16%	13%	14%	Negative	−0.15	−0.28	0.86	0.48	0.49	0.52	0.5%	7.0%
All Manufacturing		22%	20%	22%		0.75	0.59	0.97	0.68	0.64	0.66	−7.1%	4.0%

Industry	Percentage of Export Sales by Destination (2021 May YTD)								
	South & Central America	Europe	Canada	China	Asia - East & Southeast	Asia - Middle East	Asia - South	Australia and Oceania	Africa
Apparel manufacturing	38%	13%	33%	3%	6%	3%	0%	3%	1%
Industrial Machinery Manufacturing	5%	12%	4%	23%	54%	2%	1%	0%	0%
Construction Machinery Manufacturing	23%	11%	44%	1%	3%	2%	1%	11%	4%
Material Handling Equipment Manufacturing	22%	17%	43%	3%	5%	3%	1%	5%	1%
All Manufacturing	26%	23%	19%	10%	14%	3%	2%	2%	1%

was negatively correlated with foreign markets at −0.17 in 2019. When the COVID-19 pandemic started to impact globally in early 2020, the 12-month correlation changed to −0.68 in 2020. Foreign sales plummeted −67 percent year-over-year in April 2020 and slowly recovered to the level before the pandemic in four months.

Meanwhile, U.S. domestic sales remained strong in April and May and only started a downward trend later. Because of a highly negative correlation between apparel manufacturing's U.S. and foreign markets, total sales may have been less affected. As a result, the inventory turnover of apparel manufacturing declined only −1.3 percent year-on-year in 2020, compared with all manufacturing's decline of −7.1 percent. It

shows that a diversified customer base, if negatively correlated with the domestic market, is highly valuable during the pandemic and may help mitigate the loss of sales and maintain inventory efficiency.

Fig. 2 displays inventory turnovers, U.S. domestic sales, and sales to major foreign markets for industrial machinery manufacturing, characterized as a high export ratio and zero correlation. The correlation between this industry's U.S. domestic market and foreign markets was 0.02 before the pandemic. While export sales accounted for 64 percent of the total sales before the pandemic, about 80 percent of its exports went to Asian customers. During the COVID-19 pandemic in 2020, the U.S. domestic sales for industrial machinery manufacturing decreased
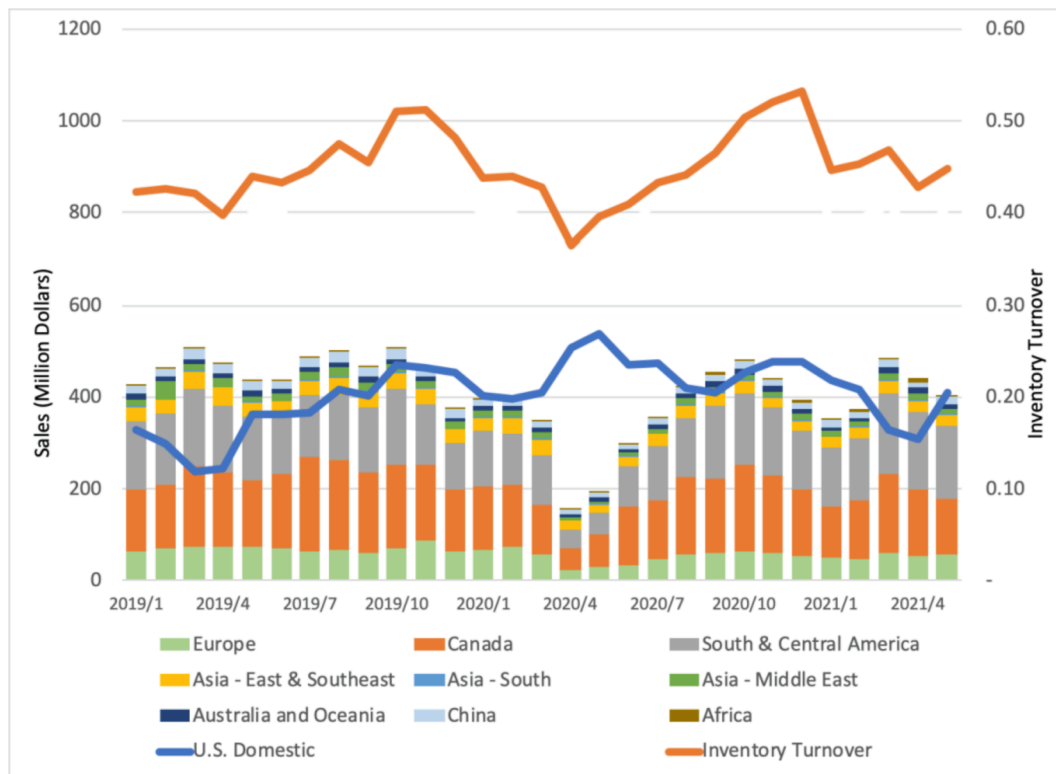
Fig. 1. Shipment Value and Inventory Turnover of Apparel Manufacturing Industry during 2019 – 2021.
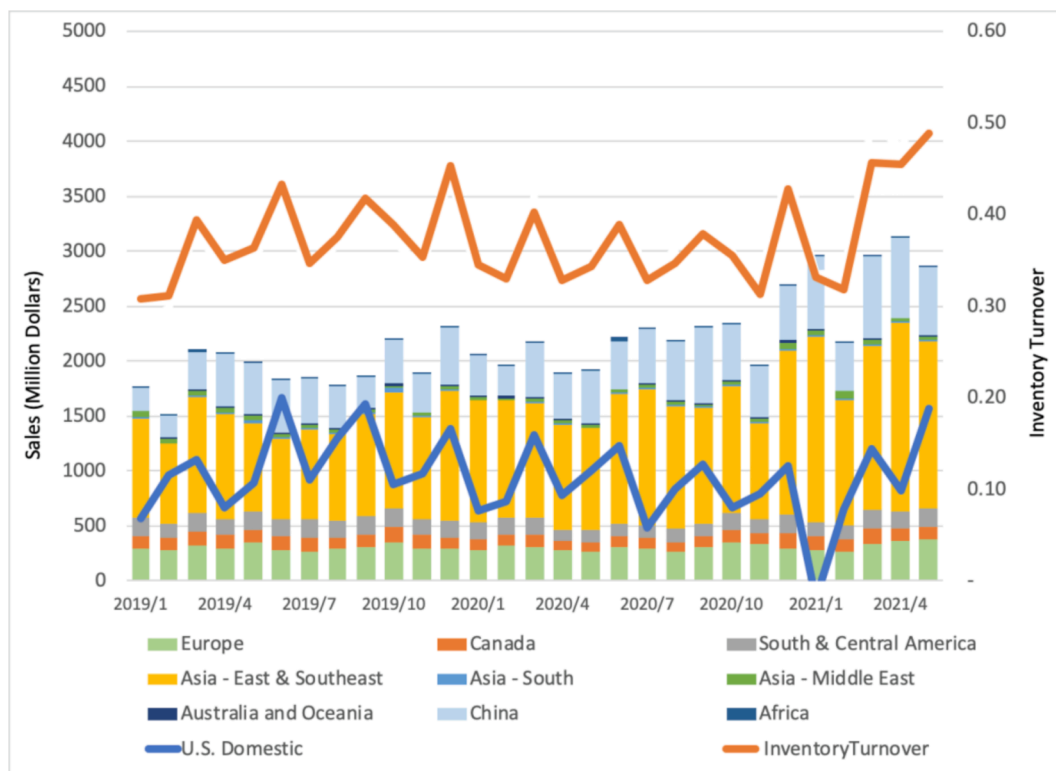

Fig. 2. Shipment Value and Inventory Turnover of Industrial Machinery Manufacturing Industry during 2019 – 2021.

steadily while its foreign sales remained stable. As a result, its inventory turnover slightly decreased from 0.38 to 0.36 or −4.6 percent year-on-year in 2020. In 2021, foreign sales rebounded more noticeably than domestic sales, resulting in a 15 percent improvement in inventory turnover, the same level of inventory efficiency as before the pandemic started. Our analysis suggests that a diversified customer base could mitigate the negative impacts of a global pandemic and expedite the recovery post the pandemic.

Fig. 3 presents inventory turnovers, U.S. domestic sales, and sales to major foreign markets for construction machinery manufacturing, featured as high export ratio and positive correlation. The correlation before the pandemic was 0.23. Exports sales account for 40 percent of total sales, and 78 percent of export shipments went to Canada, Latin America, and Europe. Both U.S. domestic sales and export sales dropped during the pandemic. Inventory turnover decreased from 0.48 to 0.46, with −3.7 percent year-on-year in 2020. When sales in both U.S. domestic and foreign markets hit the bottom in April 2020, sales recovered gradually to match the pre-pandemic level and inventory turnover rose to 0.52 in 2021, even higher than the pre-pandemic level of 0.48. Our analysis implies that an industry with a positively correlated customer base could suffer dramatically during the pandemic.

Fig. 4 shows inventory turnovers, U.S. domestic sales, and sales to major foreign markets for material handling equipment manufacturing, categorized as low export ratio and negative correlation. Only 16 percent of its total sales were generated from foreign markets, and 82 percent of its export shipments went to Canada, Latin America, and Europe in 2021. The correlation between its U.S. domestic and foreign markets was −0.15 in 2019 and changed to −0.28 during the pandemic. U.S. domestic sales decreased only −3 percent year-over-year in 2020 while, its foreign sales dropped –23 percent during the same period. Because of a relatively small proportion generated from foreign sales, its inventory efficiency was performing robustly and stayed at the pre-pandemic level. From January to May 2021, sales for both U.S. domestic and foreign markets grew 7 percent and inventory turnover increased from 0.48 in 2019 to 0.52 in May 2021.

6. Discussions, contributions, research Limitations, and future research steps

Based on the industry-level data during the pre-pandemic period and the COVID-19 pandemic, this study empirically examines the impact of geographic customer diversification on inventory efficiency using a large dataset consisting of 173 five-digit NAICS industries over 16 years and 2,684 industry-year observations during the pre-pandemic period (2003–2018). We further validate our regression models in the context of the COVID-19 pandemic through an analysis of an additional dataset consisting of 39 three-digit NAICS industries over seven months and 273 industry-month observations.

Our regression results provide support for the hypothesis that industries with higher geographical customer concentration in foreign markets have higher inventory turnover than industries with lower geographic customer concentration, a finding in favor of the operations management view. By estimate, a 10 percent point increase in geographic concentration measured by the HHI may be associated with a 13.76 percent point increase in inventory turnover based on our regression models. Furthermore, this study indicates that the impact of geographic customer concentration on inventory turnover may be moderated by the correlation between domestic and foreign markets. Our further analyses of selected industries show that the correlations between U.S. domestic sales and foreign sales across U.S. manufacturing industries are generally lower than those observed during the non-pandemic period. As a result, sales generated from foreign countries during the COVID-19 pandemic could help improve inventory efficiency, *ceteris paribus*.

This study has both theoretical and managerial implications. This research is among the first empirical studies that examine the effect of geographic customer diversification on manufacturing inventory based on a large dataset over a long time period. While validating findings reported by prior studies, we find that the impact of geographic customer concentration on inventory turnover may be moderated by the correlation between domestic and foreign markets. Based on regression analysis of data for the pandemic period and comparative analyses of four sample industries representing a spectrum of export ratios and correlations, this study proposes a customer-country diversification strategy, which may be employed by global firms to transform their global supply chains in the aftermath of the COVID-19 pandemic. For practitioners, we recommend that U.S. firms should target foreign markets whose demand characteristics are less correlated or negatively
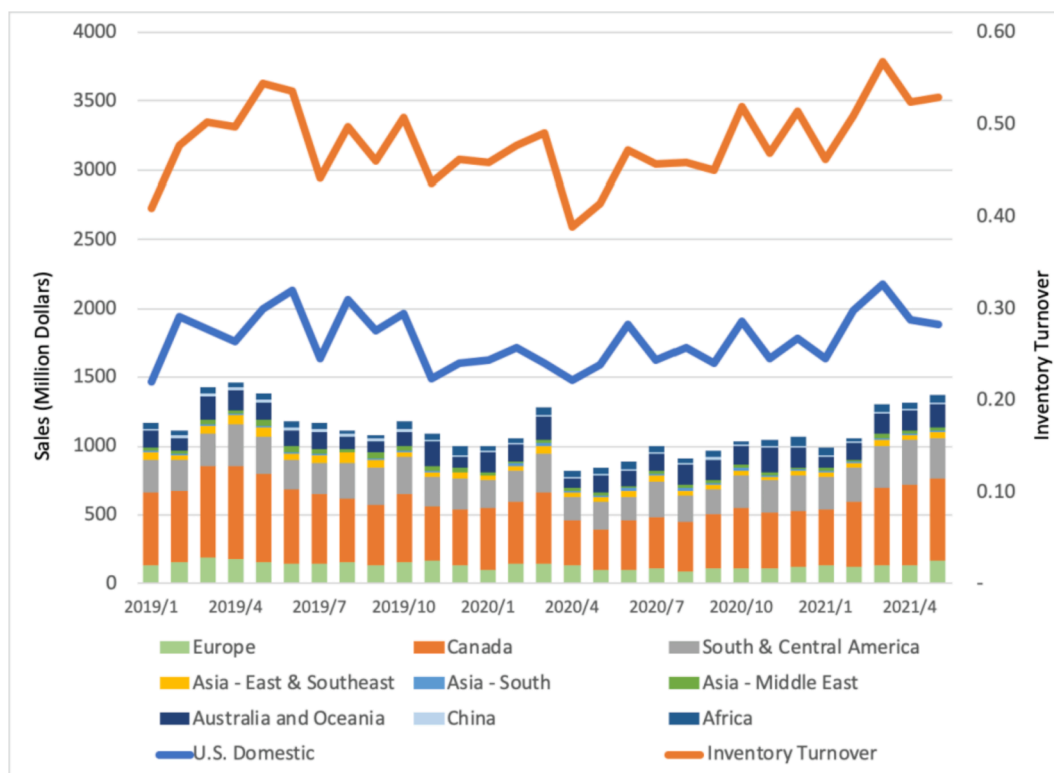

Fig. 3. Shipment Value and Inventory Turnover of Construction Machinery Manufacturing Industry during 2019 – 2021.
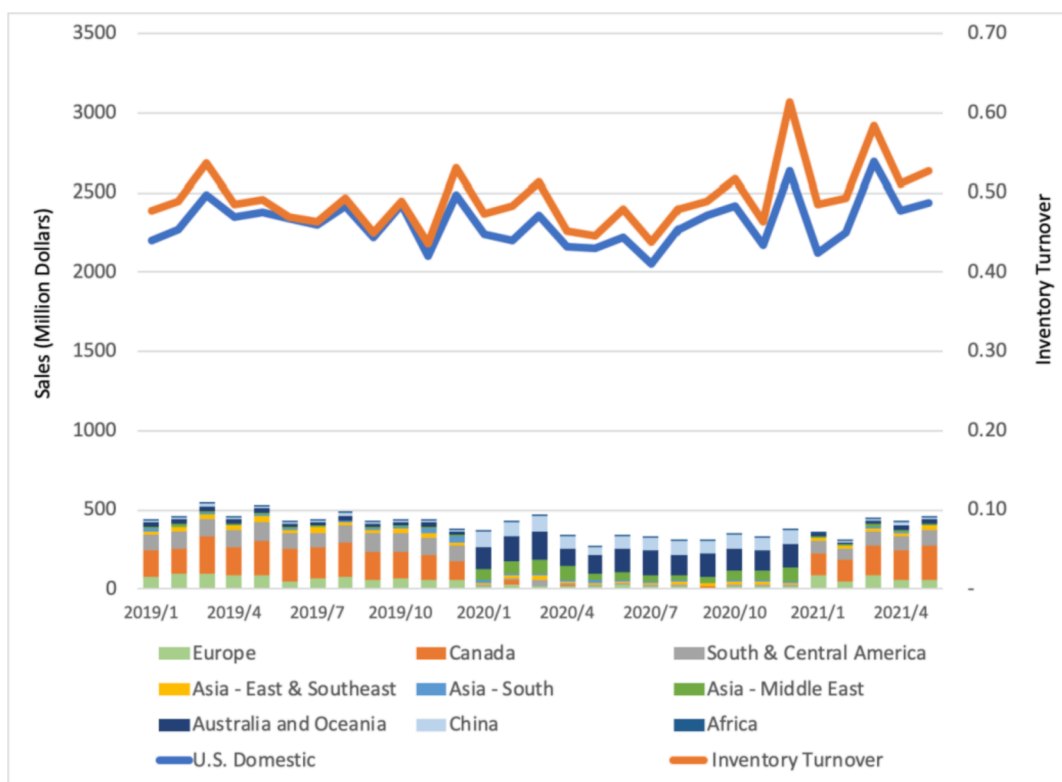
Fig. 4. Shipment Value and Inventory Turnover of Material Handling Equipment Manufacturing during 2019 – 2021.

correlated with the U.S. domestic market when redesigning their global supply chains to mitigate the negative impacts of a global pandemic and still achieve inventory efficiency.

The primary benefit of a customer-country diversification strategy, which targets global customer bases with demand characteristics less correlated with U.S. domestic demand, is the ability and flexibility for U. S. firms to sustain sales and gain inventory efficiency during the global pandemic and other natural disasters. However, the benefit may be limited by extreme geopolitics as evidenced by the disruptions to global supply chains caused by the Western responses to the Russian invasion of Ukraine (Mims, 2022). While geographical diversification may decrease overall risk at the aggregate level, diversification into countries whose cultures, political and legal systems, and economic policies differ significantly from the U.S. could expose U.S. firms to unique geopolitical risks, which may wipe out economic benefits in case of wars and economic sanctions. Alternatively, supply chain diversification may be used to support international trade and countries in need. For example, Europe is currently experiencing energy shortages because of its strong reliance on fossil fuels from Russia. U.S. exports of liquefied natural gas (LNG) to Europe could help Europe reduce dependence on Russian gas as well as the economic and political leverage that European countries cede to Russia.

Our study is subject to several limitations which may present opportunities for future research. First, this study is limited to U.S. manufacturing industries. Insights derived from this study may not apply to other countries. It is a great opportunity for future research to collect data on manufacturing in other countries to validate and complement our findings. Second, we use aggregate industry-level data to examine manufacturing inventory behavior in global supply chains. While providing a great overall picture, aggregate data are not able to capture industry-specific trends coming into the pandemic. This may reduce the managerial relevance of our findings. Future research is encouraged to collect industry-specific and firm-specific data systematically so that industry trends and firm behavior are better understood. Third, we do not have enough data points for the COVID-19 period on an

annual basis and must use monthly data for a meaningful regression analysis. Unfortunately, the M3 industry code can only partially match the four-digit NAICS industry code. As a result, there are limited observations and some variables such as the cost of goods sold are not available at the monthly level during the COVID-19 pandemic period. Note that the dependent variable, inventory turnover, in the inventory models during the pre-pandemic period and the COVID-19 pandemic period has different measures than the pre-pandemic model which is measured on an annual basis. Hence, the magnitudes of regression coefficients cannot be compared directly. As a result, our interpretations are limited to the extent that the signs of regression coefficients are comparable. Future research may use the common datasets to compare the behavior of manufacturers during different periods when data become available. Fourth, imports are more complex than exports due to the involvement of various tiers of global suppliers. Correlations between the import and export markets would be very interesting as they may affect a global firm's global risk management strategy. Due to data availability, this study is limited to exports while imports are left out. We call for future research to collect relevant data and investigate other correlations between the import and export markets.

CRediT authorship contribution statement

Jian-yu Fisher Ke: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Data Curation, Writing – Original Draft, Writing – Review & Editing, Visualization, Supervision, Project administration, Funding acquisition. **James Otto:** Writing – Original Draft, Writing – Review & Editing, Visualization. **Chaodong Han:** Writing – Original Draft, Writing – Review & Editing, Visualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence

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