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Inventory Performance

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2011/103/TOM

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MANAGING GLOBAL SOURCING: INVENTORY PERFORMANCE

ABSTRACT. The shift towards sourcing products from global suppliers has been a key economic trend over the last three decades. A vast body of modeling literature has illustrated the trade-off between the cost advantage of global suppliers and the operational inefficiencies of global sourcing. However, there is a significant unresolved debate around the *actual* overall impact of global sourcing. Further, there are widely varying prescriptions and practices for diversifying global sourcing amongst suppliers. This study provides the first rigorous firm-level empirical evidence to help resolve these debates by linking the global sourcing practices of public U.S. firms and their inventory performance. We process bill of lading manifests (customs forms) to extract information on over half a million sea shipments from global suppliers to U.S. public firms. We link this information with quarterly financial data from the Compustat database. Using a simultaneous equation model, we find that, although global sourcing firms source inventory at a lower cost, this advantage is dominated by the much larger inventory amounts they must hold, so the overall inventory investment increases. A one-standard-deviation increase in the fraction sourced globally increases inventory investment by 23% in our sample. We also find that increasing the number of suppliers can mitigate this increase in inventory investment: for example, going from single to dual sourcing reduces inventory investment by about 11%. Our study provides rigorous empirical evidence on the operational impacts of global sourcing and provides actionable guidance for managing global sourcing.

1. INTRODUCTION

Over the last two or three decades, improved communication technologies, increasing differences in input costs among countries, and geographical skill specialization have all led firms to source globally (Hausman et al. (2005)). In fact, imports of goods to the US economy accounted for 17.8% of GDP in 2008.¹ The lower direct costs of global suppliers have long been cited as the primary driver of this trend, but recent observers have called for a more careful evaluation of the total costs of global sourcing, that is, the costs including supply chain costs (cf. “Supply Chain Costs crimp Globalization”, Financial Times, August 9th, 2009). Specifically, some of the benefits of global sourcing may be undermined due to rapidly changing economic conditions that require firms to build larger inventory buffers when deploying global sourcing (Tulip (2006)). Other sources cite the significant supply-chain disruptions brought about by recent natural disasters (Japan, Chile, etc.) and political turbulence (Egypt, Libya, etc.) as evidence that an increased reliance on global sourcing can come with onerous increases in inventory holdings or costly business disruptions (cf.

¹World Bank data on imports, <http://data.worldbank.org>, accessed August 20, 2011.

“Japan and the global supply chain: Broken links”, *The Economist*, March 31, 2011). Further, the management of these global sourcing flows varies considerably across firms.

For instance, there is wide divergence in the stated global supplier management strategy of similar firms in the same industry that sell virtually identical products. For example, the casual apparel retailer, Gap, follows a policy of ensuring that “no global supplier accounts for more than 3% of the dollar amount of purchases”. On the other hand, Aeropostale, another casual apparel retailer, reports that it sourced “approximately 81% of our merchandise from our top five merchandise vendors”.² In the absence of any clear, generalizable empirical evidence on the impact of global supplier management strategy, and conflicting prescriptions from theory, these choices are often made as an article of faith, or are based on corporate and regional culture or changing management fads (cf. Dyer and Singh (1998)).

In response to the centrality of global sourcing in modern economies, numerous Operations Management studies develop theoretical models to study the trade-offs between the direct and total costs of global sourcing. The subject occupies a premiere spot in many recent textbooks (e.g., Cachon and Terwiesch (2005)), and many case studies discuss and describe global sourcing strategy at idiosyncratic firms (Cachon et al. (2007a); Ghemawat and Nueno (2003); Fisher et al. (1994)). Despite extensive modeling work on global sourcing, debates around the impact of global sourcing remain unresolved. We still have surprisingly little evidence on how firms approach global sourcing or on its connection to their actual operational performance.

Multiple studies have modeled the advantages of building long-term relationships with a small group of suppliers (cf. Ren et al. (2010)), while others have modeled the advantages of diversification (cf. Tomlin (2006)). Again, despite multiple theoretical studies, the overall impact of relationships and diversification on operational performance remains unknown. Taken together, while the growing centrality of global sourcing to operations management is clearly recognized by practice and academia there is considerable debate on the costs of global sourcing and the best practices for global supplier management on account of limited empirical evidence.

The key impediment to studying firms’ global sourcing practices has been the unavailability of firm-level data. We construct the first-ever firm-level data set on imports by public US firms using information contained in bill of lading manifests. Through a combination of data mining techniques, free-text search and manual efforts, we parse over half a million purchase transactions between global

²Men’s Warehouse, the men’s dress apparel retailer, and Cato Fashions, the women’s specialty apparel retailer, are two examples of firms that follow strategies somewhere in between the two extreme strategies followed by Gap and Aeropostale (All items sourced from 2009 Annual Reports).

suppliers and public American retail and wholesale firms in 2007-2010. We link this data with financial information from the Compustat database. We use this novel and comprehensive database of import transactions to analyze the effect of global sourcing and supplier diversification on inventory investment. We estimate a system of simultaneous equations which allows us to identify the concurrent effects of the extent of global sourcing and supplier diversification on product margins, cost of goods sold, and inventory investment, while controlling for all other relevant variables identified in previous research. We obtain estimates that are remarkably robust to a very wide variety of alternate specifications, measures, samples and estimation techniques.

We use these robust estimates to establish a number of stylized facts about the global sourcing strategies that firms employ. We find that firms that employ more global sourcing also have higher inventory investments—just as classical inventory models predict, longer lead times provoke higher inventory levels. There is, however, a competing effect: an increase in global sourcing decreases product costs and hence reduces inventory investment. We show that the first effect dominates: our estimates indicate that a one-standard-deviation increase in the fraction of goods sourced globally leads to a \$230M increase in inventory investment for an average firm in our sample, an increase of about 23%. Likewise, firms that use more suppliers are expected to have lower inventory investments, for e.g., due to lead-time pooling. There is, however, also a competing effect: supplier dispersion leads to scale diseconomies, higher sourcing costs and consequently larger inventory investment. Our data again speaks to this debate—we find that the first effect dominates, and as a result multi-sourcing can be used effectively to decrease the additional inventory investment that results from global sourcing. Specifically, we find that an average firm that goes from single to dual sourcing can defray about half of the above mentioned inventory increase, or about \$113M.

This study makes at least three important contributions. First, this is the first firm-level empirical examination of global sourcing practices. This firm-level approach allows us to provide direct rigorous empirical evidence on the implications of global sourcing strategy on inventory performance, specifically the net impact of the extent and dispersion of global sourcing on inventory investment. This complements the vast body of theoretical research that has analyzed global sourcing, and it identifies the dominant of the competing hypotheses that come from the theoretical literature. Second, we describe the process of developing a new data set that records every import transaction made by public U.S. firms. This is the first data set on global supply chains that provides transaction-level details for a large sample of firms. This allows us to offer a glimpse into how much an average public firm sources globally, how many suppliers it uses, etc. Many interesting questions can be answered using these data, and this study paves the way to collect, clean and analyze it,

while documenting various difficulties involved in this process. Finally, by estimating the relationship between global sourcing and inventory investment, we extend existing techniques for estimation of inventory investment to account for simultaneous determination of inventory, demand and firm margins. These estimations prove to be remarkably robust and they allow us to demonstrate the huge economic significance of accounting for global sourcing strategies, which should further provoke re-calibration of theoretical models.

2. LITERATURE REVIEW

Classical operations textbooks (e.g., Simchi-Levi et al. (2003), Cachon and Terwiesch (2005), etc.) extensively discuss global sourcing and its importance to supply-chain management. Their discussion forms the basis of our theory. Further, two streams of empirical literature are most immediately relevant for our study. First, there is a growing literature in Operations Management that uses publicly available data to study the inventory investments of individual firms. Second, there is a vast literature in Economics studying global trade at the country or industry level (but rarely at the firm level).

In the first stream, the pioneering work of Rajagopalan and Malhotra (2001) showed that firms reduced their raw material, work in progress and finished goods inventory significantly from 1961 to 1994. Chen et al. (2005) find a similar decline in inventory for US manufacturing and wholesale firms from 1981 to 2000; however, retail firms observed the decline only after 1995 (Chen et al. (2007)). While the decline observed in these studies is contemporaneous with the increase in global sourcing, the multiple advances in logistics, operations management and information technology are all legitimate candidates to explain this reduction. Chen et al. (2007) relates the amount of inventory that the firm holds to long-term stock performance, while Hendricks and Singhal (2009) relate “demand-supply” mismatches to short-term market performance. These studies highlight the central role that inventory management plays in firms’ financial performance. In particular, the analysis by Hendricks and Singhal (2009) demonstrates that small increases in inventory levels (“excess inventory”) can have a large material impact on firm value. Likewise, Larson et al. (2011) show that large inventory write-downs are associated with significant decline in firms’ operating performance. Finally, publicly available inventory data has also been employed to identify and understand the bullwhip effect (cf. Cachon et al. (2007b); Osadchiy et al. (2010); Bray and Mendelson (2011)).

The literature most closely related to our work includes the studies that explain inventory investments using firm-level variables, or use inventory to explain/predict sales. Gaur et al. (2005) find that a firm’s gross-margins and investments in effective supply-chain management practices

significantly influence both the absolute and relative inventory level of a firm. Rumyantsev and Netessine (2007) use classical inventory theories to identify additional influential factors— demand uncertainty, lead time for procuring goods, and holding costs. In line with this work, our study identifies elements of global sourcing strategy that influence inventory levels. Kesavan et al. (2010) offer a more advanced empirical model that accounts for simultaneous dependence between product margins, demand, and inventory level and they use this model to build better sales forecasts. We employ this state-of-the-art model to explain inventories, and we extend it by incorporating sourcing information. Taken together, this literature provides clues about the relevant variables that explain inventory performance as well as on appropriate methodology for unraveling the drivers of inventory investment, but it does not study global sourcing strategies. While there is general agreement among both academics and practitioners that sourcing strategy is a key determinant of inventory investment, these studies do not possess the relevant data to examine these effects.

The second set of relevant literature studies global sourcing and global trade at a macro-economic level. This vast body of literature pioneered by economists typically employs gravitational models to identify the factors explaining bilateral trade (cf. Eaton and Kortum (2002)), the impact of trade agreements (Brambilla et al. (2007)), the characteristics of firms that participate in imports (Bernard et al. (2005)), and the impact of imports on macroeconomic performance (Foster et al. (2006)). Perhaps the most closely related study from this stream is Hausman et al. (2005), where the authors link global trade with the logistical challenges within certain countries. All these articles have an economy-wide or world-wide focus and do not link sourcing strategies with inventory investment. The only study that we are aware of which attempts to link global sourcing and inventory investment is Han et al. (2008) but, like others in this stream, it does not possess firm-level data and instead focuses on the 19 manufacturing sectors. While analysis of global trade in this stream provides important aggregate insights, it does not study firm-level global sourcing decisions and hence it cannot help individual managers make better decisions. To summarize, our study is the first to utilize firm-level data on global sourcing and to link global sourcing strategies with firm-level inventory performance, thus providing actionable insights for company managers, financial analysts and private investors.

3. THEORY AND HYPOTHESES

Inventory investment (i.e., the unit-cost of inventory times the number of units inventoried) is the capital that is deployed as inventory holdings, and it often represents one of the key assets for firms in many industries (e.g., retail and wholesale). Inventory investment decisions are of paramount

importance to the field of Operations Management, with a rich research history going back more than 50 years. This theoretical literature makes a variety of predictions regarding the impact of lead times, the number of suppliers, fixed ordering costs, demand uncertainty and variable procurement costs, on inventory investment. All of these variables are strongly affected by a firm's global sourcing strategy, and thus we expect a deep relationship between global sourcing and inventory investment. While there are a number of different questions that one can ask about the relationship between global sourcing and inventory investment, we decided to focus on two very specific questions: 1) how does the extent of global sourcing influence a firm's inventory investment? and 2), how does global supplier concentration influence a firm's inventory investment? As highlighted before, there is considerable debate on these questions in the popular press and amongst managers at different firms. Further, these two questions have attracted a lot of attention in the vast modeling literature, which provides sharp, but *conflicting* predictions. Our firm-level import data set allows us to establish the relative significance of different effects, advance the literature, and provide clear actionable insights.

3.1. The Extent of Global Sourcing and Inventory Investment. We conceptualize the extent of global sourcing as the percentage of a firm's procurement that is sourced from *foreign* sources via *sea shipments*. Sea shipments represent about 90% of all global trade, with cross-border air and road shipments constituting the rest (Hulme (2009)). Unlike sea-based global trade, cross-border air and road shipments are not sufficiently different from domestic procurement with respect to associated costs and lead times (cf. Cachon et al. (2007a)). Thus, sea shipments are most likely to significantly affect inventory investment. Based on accounts from case studies, the popular press, and supply-chain textbooks, we identify four mechanisms by which the extent of global sourcing might affect inventory investment.

Unit Procurement Cost: The key driver of the move towards global sourcing is the cost advantage of global producers on account of lower labor costs and also possibly due to scale, looser regulations, superior infrastructure and export incentives. The cost advantage translates into a lower unit cost of the inventory procured, and, all else being equal, a lower inventory investment. However, this lower cost also changes the firm's choice of inventory level. In particular, the consequences of having too much inventory are likely to now be smaller, and this incentivizes the firm to target a higher inventory level (cf. the order up-to model, in Cachon and Terwiesch (2005), pg. 242–275). Given the above competing impacts of lower procurement costs, inventory investment may increase or decrease due to sourcing globally.

Lead Times: One of the key disadvantages of sourcing globally is the increase in lead time, which now includes cross-border shipping and customs clearance. Sourcing globally typically adds between 15 and 35 days to the lead time.³ This longer replenishment time requires that firms maintain higher inventory levels for two reasons. First, an increase in the on-hand inventory at the destination is needed to cover demand happening during lead time (cf. the order up-to model, Figure 13.10 in Cachon and Terwiesch (2005)). Second, there is a possible increase in the pipeline inventory, which is linear in the lead time but may depend on who owns inventory in transit (Figure 13.11 in Cachon and Terwiesch (2005)). Thus, due to longer lead times, we expect firms that employ increasing levels of global sourcing to maintain higher inventory levels and consequently to require higher inventory investment.

Fixed Order Costs: Sourcing from global suppliers typically entails additional per-order costs due to import procedures including extra documentation, customs clearance, technical control, broker fees, terminal handling charges, etc. Typically, such additional per-order costs range from US\$ 450 (Malaysia) to US\$ 3,865 (Afghanistan).⁴ Classical inventory models such as the Economic Order Quantity model predict that higher ordering costs would lead to fewer orders but a higher amount of inventory per order, thus leading to a higher average inventory level and therefore higher inventory investment (Cachon and Terwiesch (2005), pg. 88).

Delivery Reliability: Firms have increasingly come to the realization that global sourcing exposes a firm to supply-chain disruption risks that arise due to political and economic unrest, labor strikes, acts of terrorism, and natural disasters in the exporting or transit countries (Sheffi (2007); Bakshi and Kleindorfer (2009)). In addition to these supply-chain disruptions, the low transit reliability of sea-shipments further adds to the unreliability of lead-times. According to Drewry Shipping Consultants the schedule reliability attained by the shipping industry, on average, is just 56% during Q2, 2011.⁵ Numerous theoretical models suggest that this additional variability due to global sourcing must be compensated by holding additional inventories (cf. Tomlin and Wang (2005); Wang et al. (2010)). In line with the typical results from these models, we expect more global sourcing to lead to higher inventory investments due to unreliable suppliers.

To summarize, the above mechanisms suggest two competing impacts of the extent of global sourcing on inventory investment. First, due to longer lead times, higher fixed-order costs, and lower delivery

³The transit time from Nigbo port, China, is, on average, 18 days to the Long Beach CA port, and 32 days to the New York NY port (www.searates.com).

⁴Source: Doing Business 2010, World Bank at <http://www.doingbusiness.org>, accessed August 20, 2011.

⁵Source: Container Service Reliability Rises in 2Q11 at <http://drewry.co.uk/news.php?id=93>, accessed September 29, 2011.

reliability associated with global sourcing, firms that employ higher levels of global sourcing must increase their inventory holdings (order quantities). On the other hand, on account of lower unit procurement costs, these firms may pay less per unit of inventory. Since inventory investment is the product of these two effects, the direction of the combined effect is ambiguous, and we thus provide two competing hypotheses.

HYPOTHESIS 1a. *Firms that employ more global sourcing have **lower** inventory investments.*

HYPOTHESIS 1b. *Firms that employ more global sourcing have **higher** inventory investments.*

3.2. The Dispersion of Global Sourcing and Inventory Investment. We conceptualize the dispersion of global sourcing as the degree to which company's orders are split amongst different global suppliers. As an extreme, a firm with a concentrated supplier base allocates all its global sourcing orders to one firm; on the other hand, a firm with a distributed or dispersed supplier base distributes its orders amongst as many suppliers as possible. The Operations literature offers a number of arguments regarding the effect of sourcing dispersion on the effective procurement costs and lead times that the firm faces, which, in turn, affect inventory investments. Based on accounts from this literature, we identify the four mechanisms by which the extent of dispersion in global sourcing might affect inventory investment.

Unit Procurement Cost: A firm that sources from more suppliers creates an option to dynamically assign order quantities contingent on the prices and terms offered by different suppliers. This lowers the effective unit procurement cost. Further, suppliers anticipating this *competitive dynamic* may find it in their interest to offer lower prices, thus further reducing unit costs, a typical outcome of competition. On the other hand, a firm that has fewer suppliers would source a larger volume from each supplier, granting it more bargaining power and perhaps even volume discounts due to economies of scale (cf. Cachon and Harker (2002)). Further, a smaller supplier base provides the supplier with stronger incentives to continue the *sourcing relationship*, which leads to cooperative behavior such as fairer prices, cost-reducing investments, cost-reducing information sharing and learning, etc. (see Belavina and Girotra (2011) for a detailed description of the tradeoffs between the competitive and relational dynamics in global supply chains). In light of these opposing competitive and relational dynamics, the effect of dispersion of global sourcing on unit procurement cost and consequently inventory investment is ambiguous.

Fixed Order Costs: A concentrated supplier base provides economies-of-scale based incentives for closer integration of processes, investing in electronic data interchange, etc. The resulting efficient flow of information benefits a buyer through lower fixed ordering costs (cf. Gavirneni et al. (1999)).

As the classical Economic Order Quantity model predicts, lower order costs lead to smaller order quantities per sourcing transaction which, in turn, implies lower average inventory levels and inventory investments for the firm. Thus, on account of lower order costs, we predict that higher concentration of the supplier base would lead to lower inventory investment.

Lead Time Variability: A large body of literature has studied the statistical properties of lead times under multi-sourcing (cf. Ramasesh et al. (1991) and references therein). This literature finds that under a wide range of distributional assumptions, the effective mean lead time is reduced with diversification of the supplier base. Moreover, in the case of multi-sourcing, the firm may be able to provoke supplier delivery competition that would lead to shorter lead times and lower inventory investment (cf. Cachon and Zhang (2007)). In summary, we expect a more dispersed supplier base to be associated with lower lead times and a lower inventory investment.

Delivery Reliability: Prominent recent events (such as hurricanes, tsunami and political unrest) have led firms to increasingly recognize that global sourcing is synonymous with less reliable suppliers (Sheffi (2007); Bakshi and Kleindorfer (2009)). A vast literature demonstrates that delivery reliability problems can be mitigated by multi-sourcing; by shifting orders from a disrupted source to another source, the buying firm can mitigate the consequences of unreliable delivery (cf. Tomlin (2006)). As a result, a firm working with one unreliable supplier must hold a lot of inventory in anticipation of a possible disruption, but a firm sourcing from multiple suppliers need not hold as much. Thus, we expect firms with a more dispersed supplier base to have lower inventory investments.

The above mechanisms highlight that, in line with the vast literature on the study of supplier diversification, plausible arguments can be made to support the benefits of both a small, concentrated supplier base or a large, distributed supplier base. We thus provide two competing hypotheses:

HYPOTHESIS 2a. *Firms with a more dispersed supplier base have **lower** inventory investments.*

HYPOTHESIS 2b. *Firms with a more dispersed supplier base have **higher** inventory investments.*

The above discussion illustrates that the theoretical findings of the vast body of existing analytical work lead to competing hypotheses regarding the relationship between a firm's global sourcing strategy and its inventory investment. Thus, the two questions we pose are best answered empirically.

4. DATA SOURCES

We have constructed our data-set by linking a novel, proprietary transaction-level data set on *all* US sea imports to publicly available, firm-quarter-level, accounting data. This allows us to empirically

analyze the above hypotheses, while controlling for firm-level financial characteristics that are known to influence inventory investments (Gaur et al. (2005); Rumyantsev and Netessine (2007)).

4.1. Sample Description. We restrict our attention to firms with publicly available data on inventory investment, that is listed firms that are covered by the Standard & Poor's Compustat Industrial Quarterly database. We consider all firms that are classified as retail or wholesale firms— NAICS sectors 42, 44 and 45. There are more than 300 such firms. Unlike manufacturing firms, retail and wholesale firms typically do not transform their imports, nor do they assemble components sourced from different suppliers, providing a clearer picture of inventory, imports, and suppliers. Further, past empirical research on inventory investments has often focused on these sectors (Chen et al. (2007); Gaur et al. (2005); Rajagopalan and Malhotra (2001)), and we can convincingly isolate our effects by using the controls identified in past research. We exclude non-store retailers or direct-selling firms (NAICS sector 4543) to avoid contamination on account of direct-to-consumer imports. We also exclude petroleum and related wholesalers (sector 4247) to avoid confounding the impacts of energy and transportation costs on import choices and inventory values.

4.2. US Sea Imports Data. One of the key contributions of our study is the creation of a novel transaction-level data set on *all* sea imports into the United States. We construct this data set by compiling multiple unstructured data sources through extensive data-structuring, natural language processing, and manual cleaning. US firms are mandated to report all physical imports to the Federal Customs and Border Protection agency of the Department of Homeland Security. Sea-import transactions are reported to the agency using information available on the *bill of lading* (Figure 4.1). This is a document issued by a carrier to a shipper (supplier) certifying that goods have been received on board as cargo for transport to a named place and for delivery to an identified consignee (buyer). The document includes the supplier's name and address, the buyer's name and address, a description of the goods, the quantity imported, the weight of the shipment, and other additional transaction-specific information.

In 2007, the US Customs and Border Protection Agency agreed to share this data with commercial "supplier intelligence services". These services typically sell analysis of aggregate import trends and make available small, processed subsets of the original bill of lading data. The recent availability of this processed data has attracted the attention of practitioners (Green (2009)) and it is now being used extensively by scholars of Maritime Economics and Transportation Science (Leachman (2008); Meneses and Villalobos (2010)). This is the first study to use these data sources for studying firm operations.

Bill of Lading: EGLV143797307681	House/Master: House	Estimated Arrival: 1/11/2007	Mode of Transport: 10
Vessel: Zim Xiamen (Code: 9318151)	Carrier: EGLV (MC: MOLU)	Actual Arrival: 2/11/2007	Voyage: 008E
Shipper	Consignee	Notify	Notify 2
Dhl Global Forwarding On Behavre Of Shipper Supree Creations Ltd Suit 1106,tower 2,harbour Centre,8 Hok Cheung Street,hunghom,kowloon,@	Rite Aid Hdqrts Corp.,30 Hunter Lane Camp Hill,pa 17011 Usa	Fedex Trade Networks 6001 Chatham Center Drive Suite 360 Savannah,ga 31405 Usa Tel:912-232-2101 Fax:812-233-2243 Attn:anna Arnsdorff	
Port: 57020 - Ning Bo, China Place Receipt: Ningbo, China InBond:	Port: 4601 - Newark, NJ US Dist Port: Foreign Port:	Weight: 19049 (KG) Quantity: 2197 (CTN) Measurement: 341 (CM)	TEU: 11
Container Number (Info)	Product Description	Marks & Numbers	
EISU9831031, FCIU2572469, FSCU9882017, TCKU9409536, TCNU9911615 (Qty: 1807, FCL)	Christmas Decorations(snowmen)	Christmas	
TGHU8187889 (Qty: 390, FCL)	Christmas Decorations(snowmen) Christmas Decorations (snowmen) As Per P.o.no. 4508971/4509769 Xtt 30in Caroling Snowmen Trio The Shipment Contains No Solid	Christmas Christmas Po#4508971 / 4509769 (sku#) (description) (supree#) Inner Case Upc:n/a Made In China The Same The Same The Same The Same	

FIGURE 4.1. Sample Bill of Lading

Through one such data service, we obtained direct access to raw, unprocessed bill of lading forms *for each* import transaction into the US, during the period of July 2007 to July 2010, the maximum period for which these services have obtained and digitized reliable data. Direct access to the complete set of raw data allows us to ensure sample accuracy and full transparency in constructing our data set. On the other hand, the raw bill of lading data pose a number of challenges with respect to identifying the buyers, suppliers and the transaction values, which we detail below.⁶

4.2.1. *Identification of the Importing Firm.* The importing firm's details are entered in the consignee information section of the bill of lading, but these entries are unstructured and require significant cleaning (see Figure 4.1 for an example). For each of the firms in our sample, we obtained its registered corporate names and those of associated entities. We then searched for these registered names in the "consignee name" field of the bill of lading, which yielded a large number of transactions potentially conducted by the firm in question. However, this search is imperfect: for instance, searching for the apparel retailer Gap also returned transactions for Gap Promotions, a completely different corporate entity. To separate such spurious transactions, we utilized additional importer information available on the bill of lading, specifically the consignee's address. We first standardized the consignee address for each potential transaction conducted by the firm in question to the US

⁶Transaction-level import data are also available through a direct partnership with the Center for Economic Studies of the US Census Bureau (cf. Bernard et al. (2005)). However, these data have two fatal drawbacks. First, the Census Bureau anonymizes the importing firm. Second, the import transaction value provided in these data is a self-reported estimate of the dutiable value, which is often inaccurate. Although this data set fits sector, economy-wide (cf. Han et al. (2008)), or firm-level studies on items collected in the quinquennial economic census, it does not fulfill the requirements of a quarterly study on inventory investment.

postal service’s standardized address format using an API provided by Google Maps. We then compared this location to all known corporate addresses for our firms of interest, which we constructed using three different commercial business directory services: Cortera, Manta and 411.com. Addresses that appear in only one of the three services were manually verified using secondary sources such as the corporate website, annual reports, articles in the business press, and Google Maps. As a result of this process, we obtained 504,423 import transactions for 200 Compustat firms in our sample.⁷

4.2.2. *Identification of Suppliers.* The shipper information in the bill of lading typically contains the supplier’s name and address (see Figure 4.1 for an example). For 56.4% of the above transactions this supplier name was an indexed corporate name with a verifiable address. For a little over half of the remaining transactions, the supplier information was entered in a wrong field, or was entered to include the name of the logistics company (for example: “*Maersk Logistics* on behalf of Chairworks Manufacturing Group, Shenzhen, China”). We extracted the supplier information from such transactions using text-pattern recognition algorithms and manual inspection. Taken together, we were able to identify suppliers for 407,244 of the original 504,423 transactions.

4.2.3. *Dollar Value of Goods Imported.* The bill of lading contains some self-reported information about the value of imported goods but the corresponding fields are not disclosed to supplier intelligence services. Thus, following Leachman (2008), we use the Journal of Commerce’s Port Import Export Reporting Service (PIERS) to supplement our data with proprietary data on the dollar value of imported goods. In the past, scholars have used PIERS data to study different trade-related questions such as the export market structure and pricing behavior of US firms (Patterson and Abbott (1994)) and factors determining the flow of global logistics (Hall (2004)). We merged the import values provided by PIERS into our transaction-level bill-of-lading data using the unique identification numbers for each bill of lading, which allowed us to obtain price estimates for 96.91% of transactions in our data set. As a result of these steps to identify the buyer, the supplier and the transaction value, we were left with 391,654 import transactions by 200 public firms, which includes information on the supplier, buyer, transaction values and the arrival date of the shipment.

Table 1, Panel A illustrates three sample transactions from this data set. We aggregate this transaction-level information to the (buyer) firm-quarter level and obtain the aggregated global sourcing share, and the supplier dispersion for each public buyer firm in each quarter. We include

⁷In line with previous studies that find that trade is highly concentrated in a small fraction of firms (cf. Bernard et al. (2005)), we find that import transactions for only 200 firms out of over 300 Compustat retail and wholesale firms. The fraction sourced globally by firms is also in line with that in previous aggregate studies (Orlik (2011)).

Panel A <i>Transaction-Level Imports Data</i>					Panel B <i>Firm-Quarter Level Data</i>					
<i>Bill of Lading #</i>	<i>Shipper Name</i>	<i>Consignee Name</i>	<i>Arrival</i>	<i>Value (\$)</i>	<i>Firm Gvkey</i>	<i>Qtr</i>	<i>Global Sourcing Share (%)</i>	<i>Supplier Dispersion</i>	<i>Inventory (\$ Mn)</i>	<i>Segment</i>
Polndhhlw1206267	Chateau D'ax Spa, Italy	Haverty Furniture	Sep 25, 2007	4,107	5523	Q3, 07	17.5	0.90	98.10	Retail
Cosu6004234880	Wang Feng Co., Vietnam	Big Lots Stores	Oct 27, 2007	33,476	12123	Q3, 08	14.2	0.97	828.18	Retail
Dmaltpe201763	Coppercell Tech., Taiwan	Universal Power Group	Jan 26, 2008	6,050	176325	Q1, 09	81.29	0.39	36.24	Wholesale

TABLE 1. Sample Transactions

US Ports		Sourcing Ports		Products		
<i>Name</i>	<i>\$ %</i>	<i>Name</i>	<i>\$ %</i>	<i>HS code</i>	<i>\$ %</i>	<i>Examples of Imports</i>
Los Angeles	26.25	Shanghai	16.04	61-62 ^a	25.03	Garment infant girls/boys, Ladies woven pants, Knitted pullover cardigan
Tacoma	13.45	Yantian	15.28	85 ^b	7.89	Stereo RF wireless headphones, Color video monitor, 9" Slim line portable DVD
Long Beach	11.58	Hong Kong	11.92	64 ^c	7.68	Ladies leather sandals, Sporting shoes, Mens work boot
New York	10.18	Ningpo	6.06	94 ^d	6.92	Plywood round table, Gas grill patio furniture, High back executive chair
Savannah	7.57	Kaohsiung	5.83	95 ^e	6.86	Paddle boom ball, Toilet Golf, Quad Elite helicopter

^aArticles of Apparel & Clothing accessories; ^bElectrical machinery & parts, Telecommunications Equip, Sound & Television Recorders; ^cFootwear, Gaiters & the like; ^dFurniture & the like, Prefabricated Buildings; ^eToys, Games, & Sports Equip, parts & accessories

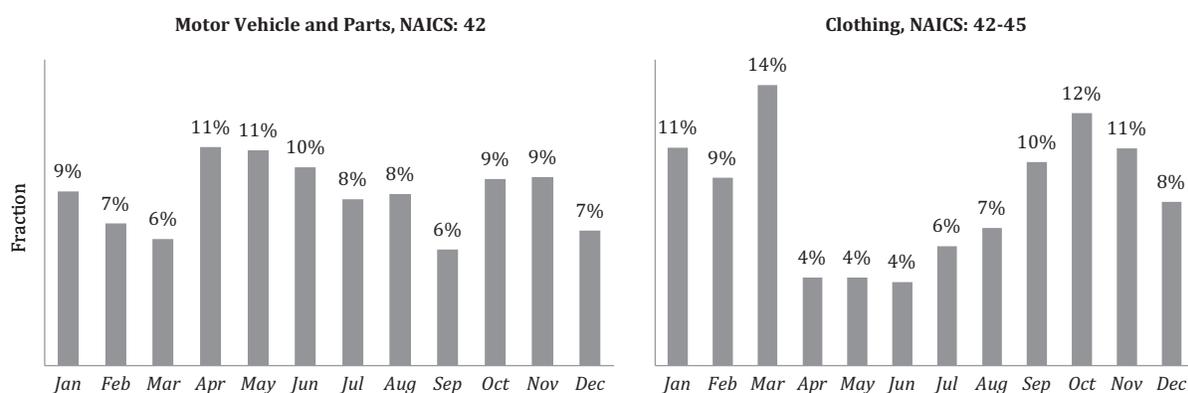


FIGURE 4.2. Imports: How, What and When?

an aggregated firm-quarter in our sample only if the supplier information is available for more than 80% of the import transactions executed by the firm in that quarter but, as we detail later, our analysis is robust to alternate inclusion criteria. We further merge the obtained firm-quarter level imports data with firm-quarter level accounting data available from the Compustat database. To perform firm-level fixed effect estimation of our models, we include a firm in our analysis only if we have more than two quarters of data available for it, which leaves us with 178 firms and 1611 firm-quarter observations. Table 1, Panel B illustrates the three rows of our panel that correspond to the importing firms in the transactions shown in Panel A.

In our sample of public US retailers and wholesalers, we find that the busiest US port for imports is Los Angeles, handling almost 26% of imported goods by value. Likewise the top sourcing port is Shanghai, China, from which approximately 16% of imported goods are sourced; it is closely trailed by Yanitan at 15%. Apparel & Clothing is the top imported product category, accounting for over 25% of the value of total imports, followed by electronics and footwear (Figure 4.2, Top).

In anticipation of the holiday season, imports peak in the months of September and October, which together account for 22% of annual imports. While May and June together constitute only 10%. But, this seasonal pattern varies widely across product categories: While clothing imports are highly seasonal and peak in the holiday season, motor vehicles and parts have a much more muted seasonal pattern that peaks in anticipation of the summer driving season (Figure 4.2, Bottom).

5. VARIABLE OPERATIONALIZATION

Inventory Investment, our main dependent variable, is operationalized as the average inventory held by firm i in quarter t , $AINV_{it}$. We compute the average investment as

$$AINV_{it} \equiv 1/2 \cdot (INV_{it-1} + INV_{it}),$$

where INV_{it} denotes the end-of-period inventory value for firm i in quarter t , i.e. the Compustat data field INVTQ. We measure the extent of global sourcing employed by firm i in quarter t , as the global sourcing share, GSS_{it} . It is defined as

$$GSS_{it} \equiv 100 \cdot (IMP_{it}/COGS_{it}),$$

where IMP_{it} is the total value of imports by firm i in period t , and $COGS_{it}$ is the corresponding cost of goods sold, Compustat field COGSQ. Finally, we measure the degree of supplier dispersion in firm i 's supplier base in quarter t , SD_{it} , as one minus the Herfindhal index of the supply shares of the different suppliers of firm i . Specifically,

$$SD_{it} \equiv 1 - \text{Herfindhal Index} = 1 - \sum_{j=1}^{N_{it}} (IMP_{ijt}/IMP_{it})^2,$$

where IMP_{ijt} are the imports by firm i from supplier j in quarter t , and N_{it} is the total number of suppliers in the supplier base in quarter t .

Figure 5.1 shows the variation in the extent and dispersion of global sourcing. Panels (a), (b), (d) and (e) show the distribution of the extent and dispersion variables in two representative sectors. Note that firms follow a wide variety of different strategies even within the same sector. Panels

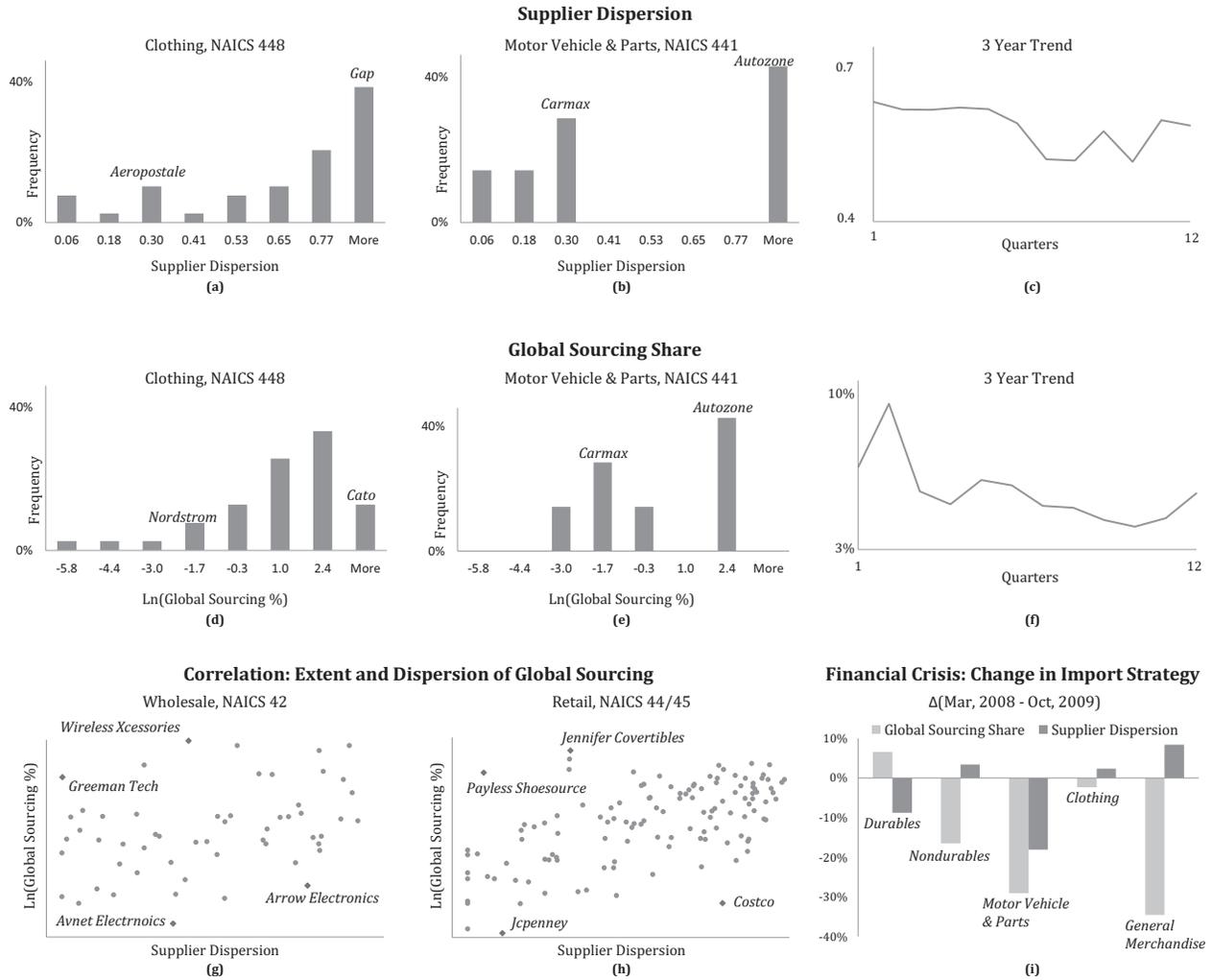


FIGURE 5.1. Global Sourcing Strategy: Within Sector and Temporal Variation

(c), (f) and (i) show the inter-temporal variation. While supplier dispersion is relatively stable in our three-year window, firms rapidly shifted to local production at the start of the financial crisis (March, 2008). This effect was most pronounced for General Merchandisers (Panel (i)). Finally, Panels (g) and (h) show a small positive correlation between the extent and dispersion of global sourcing—firms that rely more on global sourcing typically employ multiple suppliers. However, retailers like Payless Shoes and wholesalers like Arrow Electronics are exceptions to this pattern.

In addition to these key variables of interest, we use a number of control variables motivated by previous studies. Gaur et al. (2005) find that gross margins, capital intensity, and sales surprise significantly explain both the absolute and relative inventory level of a firm. Rumyantsev and Netessine (2007) identify demand uncertainty as an important additional variable. Following these studies, we include gross margin $GM_{it} \equiv (REV_{it} - COGS_{it}) / COGS_{it}$, where REV_{it} are the sales (Compustat field, REVTQ); capital intensity $CAPINT_{it} \equiv PPE_{it} / (TA_{it} - INV_{it})$, PPE_{it} is the

Variables		Mean	Standard Deviation			N	
			Overall	Between	Within	# firms	# observations
Global Sourcing Share (GSS)	%	6.38%	33.27	16.01	28.59	178	1606
Supplier Diversification (SD)	ratio	0.56	0.34	0.30	0.19	178	1611
Average Inventory (AINV)	\$ Mn	1017.23	3385.54	3063.84	148.97	178	1597
Cost of Goods Sold (COGS)	\$ Mn	1761.53	6953.26	6231.68	501.08	178	1606
Gross Margin (GM)	%	32%	0.14	0.13	0.03	178	1598
Capital Intensity (CapInt)	ratio	0.38	0.25	0.24	0.05	178	1602
Sale Surprise (SS)	ratio	1.00	0.16	0.09	0.13	178	1611
Sale Uncertainty (SU)	\$ Mn	148.81	381.71	337.27	116.24	170	1562
Sales, General & Admin (SGA)	\$ Mn	442.53	1763.26	1561.97	99.04	178	1603

TABLE 2. Summary Statistics

net investments in property, plant and equipment (PPENTQ), and TA_{it} are the gross total assets (Compustat field, ATQ). Following Rumyantsev and Netessine (2007), we compute sales forecast, SF_{it} , using a linear trend model with seasonal dummies $SF_{it} = a_1 + a_2t + b_1q_1 + b_2q_2 + b_3q_3$.⁸ We use this sales forecast to compute the sale surprise measure, $SS_{it} \equiv REV_{it}/SF_{it}$ and a measure of demand uncertainty, DU_{it}

$$DU_{it} \equiv \left(\frac{1}{3} \sum_k (REV_{ik} - SF_{ik})^2 \right)^{0.5},$$

where k is the set of observations for firm i in the same quarter as quarter t . Table 2 provides the summary statistics of the variables in our panel.

6. MODEL SPECIFICATION

We face two key empirical challenges in estimating the impact of the global sourcing strategy on inventory investment. The first challenge is the simultaneous determination of inventory investment, targeted demand, and firm margins, which makes the regressors for inventory investment endogenous. The second challenge is to consider both the direct impact of the global sourcing on inventory investments and any indirect impact that these variables may have on inventory by changing the demand or cost of procurement (measured by $COGS$). We overcome these two challenges by developing a structural model, specifically by a system of three simultaneous equations.

To estimate the impact of global sourcing strategy on inventory investment, we must control for known factors that affect inventory investment. In particular, it is well-known from multiple theoretical inventory models that the inventory held by a firm depends on gross margin and demand level (cf. Cachon and Terwiesch (2005)). Empirical studies explaining firm-level inventories confirm

⁸Our results are robust to alternative measures of sales forecasts, as we detail in Section 8.

this assertion (Gaur et al. (2005); Rumyantsev and Netessine (2007)). However, recent empirical work (Kesavan et al. (2010)) has found strong empirical support for simultaneous determination of inventory, gross-margin, demand and costs for retailers. For instance, while inventory is influenced by the gross margin, the sourcing costs and the demand level; the inventory investment itself may also influence the gross margin and the demand level; higher inventory is known to stimulate demand and a higher (lower) demand level may provoke firms to maintain higher (lower) margins, which again influences demand and inventory. This simultaneous dependence between the *dependent* variable (inventory) and several *independent* variables (demand/costs, gross-margin) creates a contemporaneous correlation between the regressors and the error term, which, if not controlled for, leads to inconsistent estimates.

We supplement the simultaneous equation model developed for sales forecasting by Kesavan et al. (2010) with our new variables on the global sourcing strategy to tackle this empirical challenge. In particular, we specify an equation for each of the three endogenous variables (Inventory, $AINV$; Gross Margins, GM ; and a measure of demand and costs, $COGS$), which unravels the simultaneous relationship between inventory, gross margins and demand/costs, and further provides us with a consistent estimation of the impact of the global sourcing strategy on inventory investment. Additionally, the simultaneous equation model incorporates the important *indirect effect* of global sourcing variables. The inventory equation in our model is given as

$$(6.1) \quad \begin{aligned} \log AINV_{it} = & \alpha_{11} \log COGS_{it} + \alpha_{12} \log GM_{it} + \alpha_{13} \log AINV_{it-1} + \alpha_{14} \log SS_{it} \\ & + \alpha_{15} \log DU_{it} + \alpha_{16} \log CAPINT_{it-1} + \alpha_{17} \log GSS_{it} + \alpha_{18} SD_{it} \\ & + F_i + \beta_{1s} q_s + \tau_{1r} y_r + \epsilon_{it}. \end{aligned}$$

The demand/cost equation is

$$(6.2) \quad \begin{aligned} \log COGS_{it} = & \alpha_{21} \log GM_{it} + \alpha_{22} \log AINV_{it} + \alpha_{23} \log COGS_{it-1} \\ & + \alpha_{24} \log SGA_{it} + \alpha_{25} \log GSS_{it} + \alpha_{26} SD_{it} + \\ & + F_i + \beta_{2s} q_s + \tau_{2r} y_r + \eta_{it}, \end{aligned}$$

and finally the margin equation is

$$(6.3) \quad \begin{aligned} \log GM_{it} = & \alpha_{31} \log COGS_{it} + \alpha_{32} \log AINV_{it} + \alpha_{33} \log GM_{it-1} \\ & + F_i + \beta_{3s} q_s + \tau_{3r} y_r + \delta_{it}, \end{aligned}$$

where i and t are the firm and quarter indices. F_i , q_s , $s \in \{1, 2, 3\}$, and y_r , $r \in \{1, 2\}$ are the firm, quarter and year dummies respectively. Together, Equations 6.1-6.3 constitute our simultaneous equation model.

There are several notable features of this model. The three equations are in the log-multiplicative form that previous research found to best fit the relationship between multiple inventory measures and a wide range of explanatory variables (Gaur et al. (2005); Rumyantsev and Netessine (2007)). Some variables exhibit significant firm-size-related variance: larger firms have larger demand ($COGS$), carry larger inventories ($AINV$) and have larger overheads (SGA). This scale-dependent variance could lead to spurious econometric inferences, especially when the size of a firm is not the variable of interest in the estimation equation. Following the guidelines in Barth and Clinch (2009), we control for such scale effects in our model by deflating all scale-dependent variables— $COGS_{it}$, $AINV_{it}$, SGA_{it} and DU_{it} — by the market value of equity for firm i , at the end of quarter t (Compustat variable MKVLTQ).

Further, macroeconomic studies have found that the global sourcing strategy of firms depends on a number of firm-specific factors (cf. Bernard et al. (2005)) and moreover, a firm's interdependent choice of inventory investment, demand and margin may also depend on unobserved firm characteristics. To account for such firm-specific unobserved characteristics, we include firm fixed effects in each of our simultaneous equations. Quarterly inventory and financial data exhibit strong seasonality so we include quarter dummies. To control for annual trends, we include year dummies. Following past work on inventory investments, we include other known control variables and, to ensure identification of our model, we follow standard practice by including lagged variables for each of the dependent variables (also termed *predetermined* variables in the context of simultaneous equation models, see Greene (2008), p 358).

In the inventory equation (eq. 6.1), past research (Gaur et al. (2005)) suggests the control variables— sales surprise (SS), demand uncertainty (DU) and lagged capital intensity ($CAPINT$). We supplement these variables with the two focal global sourcing strategy variables, the extent of global sourcing, GSS , and the supplier dispersion, SD . In the demand/cost equation (eq. 6.2), following Kesavan et al. (2010) we include the sales and general and administrative expenses, SGA , allowing firm demand to depend on marketing expenditures. As per our theory, the unit cost of goods procured depends on the global sourcing strategy, so we also include the GSS and SD variables. Finally, as with the inventory equation, the lag of $COGS$, $COGS_{it-1}$ is included. Along the same lines, in the gross margin equation (eq. 6.3), we add lag of gross margin GM_{it-1} as a control variable.

Each of the above three equations in our simultaneous model satisfies the sufficient rank-condition that ensures our model is identified (Greene (2008), p 365). The direct effect of the global sourcing strategy variables (GSS and SD) on inventory investment is captured by coefficients α_{17} and α_{18} in eq. (6.1) and the direct effect on the demand/cost measure, $COGS$, by coefficients α_{25} and α_{26} in eq. (6.2). The indirect effects of the sourcing strategy on inventory investment that operate via the demand/cost equation are $\alpha_{11} * \alpha_{25}$ for the sourcing extent (GSS), and $\alpha_{11} * \alpha_{26}$ for the sourcing dispersion (SD), where α_{11} is the direct effect of $COGS$ on inventory investment (eq. (6.1)).

Note that the direct effect of the import variables on inventory captures the effect of changes in the lead time on inventory investment, whereas the indirect effect captures the effect of changes in procurement costs (fixed and variable) due to global sourcing. Our theory captured both these effects and we developed hypotheses on the total or net effect as a results of the conflicting individual effects. From a managerial insights point of view, firms are most interested in the holistic impact of the global sourcing strategy. The total effect is computed as the sum of the direct and indirect effects.

In our data, we find strong support for the presence of endogeneity among the three simultaneous variables. The two-step endogeneity test (see Wooldridge (2006), p 532-533) suggests the presence of endogeneity in the inventory equation ($p < 0.001$), the demand equation ($p < 0.001$), and the gross-margin equation ($p < 0.07$), which further supports our simultaneous equation modeling approach.

7. RESULTS

We estimate the three-equation system one-by-one using the two-stage least squares (2SLS) single-equation method (see Greene (2008), p 371-375). We use the Error Component 2-Stage Least Square estimator (EC2SLS) to estimate the coefficients ($\alpha_{11}, \dots, \alpha_{33}$). This is a matrix-weighted estimator of the within (fixed-effect) and between estimators. This estimator is particularly suited to “smaller” panels and it outperforms the Generalized 2-Stage Least Square estimator (G2SLS) (Baltagi and Liu (2009)).⁹

Table 3 provides the estimated values for the coefficients in our model. Panel A shows the estimation results for the three constituent equations, in a "base model", i.e. a model that excludes our two focal global sourcing strategy variables (GSS and SD). As expected, we find that the lagged variables significantly explain the variance in the respective dependent variables. It is reassuring to

⁹Technically, Baltagi and Liu (2009) show that the variance of the two estimators differs by a positive-semi definite matrix. Although this difference reduces as the sample size tends to infinity, the difference can still be very substantial in small samples such as our panel data. Thus, in our case, the EC2SLS estimator is more efficient and is recommended. The Stata command, "xtivreg, ec2sls" is used for estimating each of the three equations of our model.

#	Variables	<i>Panel A</i>			<i>Panel B</i>			<i>Panel C</i>		
		<i>Base Model</i>			<i>+ Global Sourcing Share</i>			<i>+ Supplier Diversification</i>		
		Inventory Equation	COGS Equation‡	Margin Equation	Inventory Equation	COGS Equation‡	Margin Equation	Inventory Equation	COGS Equation‡	Margin Equation
1	<i>Global Sourcing Share (GSS)</i>				0.009***	-0.007***		0.015***	-0.012***	
2	<i>Supplier Diversification (SD)</i>							-0.082***	0.073***	
3	<i>Cost of Goods Sold (COGS)</i>	0.472***		-0.029***	0.484***		-0.029***	0.498***		-0.029***
4	<i>Gross Margin (GM)</i>	0.346***	-1.339***		0.340***	-1.333***		0.347***	-1.331***	
5	<i>Average Inventory (AINV)</i>		0.031**	0.018***		0.032***	0.018***		0.035***	0.018***
6	<i>Lag Avg Inventory (AINV')</i>	0.608***			0.598***			0.591***		
7	<i>Capital Intensity (CapInt)</i>	0.022			0.023			0.026*		
8	<i>Sale Uncertainty (DU)</i>	0.020			0.016			0.013		
9	<i>Sale Surprise (SS)</i>	-0.025			-0.028			-0.038		
10	<i>Lag Cost of Goods Sold (COGS')</i>		0.041***			0.039***			0.038***	
11	<i>Sales, General & Admin (SGA)</i>		0.816***			0.818***			0.814***	
12	<i>Lag Gross Margin (GM')</i>			0.946***			0.946***			0.946***
13	<i>N_observations</i> †	1528	1528	1528	1528	1528	1528	1528	1528	1528
14	<i>N_firm</i> †	170	170	170	170	170	170	170	170	170
15	<i>Within R-sq</i>	77%	89%	5%	78%	89%	5%	78%	89%	5%
16	<i>Overall R-sq</i>	93%	97%	95%	93%	97%	95%	93%	97%	95%
17	<i>B/w R-sq</i>	96%	97%	98%	96%	97%	98%	96%	97%	98%

*** -- 1% level, ** -- 5% level, * -- 10% level

†: 8 firms and 83 corresponding firm-quarters were dropped on account of insufficient data to create the sales forecast measure. ‡: The dependent variable is COGS, which proxies for demand.

TABLE 3. Model Estimates

note that our three-equation model supports the simultaneous dependence that required using it – the endogenous dependencies turn out to all be significant (Rows 3, 4 and 5 of Table 3). Specifically, as predicted by inventory theory and supported by empirical research on inventory investment, we find that inventory levels increase with an increase in demand/costs (*COGS*) and in margins (*GM*). The cost of goods sold decreases with margins but increases with inventory, indicating a demand stimulation effect of inventory. Lastly, our estimated system shows that gross margins decrease with increasing cost of goods sold, but increase with inventory. This suggests that firms may be partially leveraging the demand stimulation effect of higher inventory levels by increasing the margins charged to buyers. In our three simultaneous equations model, we do not obtain significant effects from capital intensity, sales surprise and demand uncertainty, but the coefficients have the same signs as previous research suggests.¹⁰

Panel B adds the extent of global sourcing (*GSS*) to the model, and Panel C shows our full model, which includes both the extent of global sourcing and the degree of supplier dispersion (*GSS* and *SD*). In each panel, estimates for the Inventory, COGS and Margin equations are provided (equations 6.1, 6.2 and 6.3, respectively). We note that the coefficients of the control variables do

¹⁰When we use the same model specification as past research, these variables also turn out to be significant (see Section 8 for more detail).

not change dramatically as we add global sourcing variables, which is reassuring. From here on, we focus on the results in Panel C.

With respect to our main results, we find a positive and significant direct effect of the global sourcing share (*GSS*) on the inventory investment ($\alpha_{17} = 0.015$)— all else being equal, a firm that sources more globally invests more in inventory. This direct effect supports our hypothesized mechanism, which suggests increasing inventory levels due to longer and less reliable lead times because of global sourcing. However, there are also indirect effects which we discuss shortly. We find a negative and significant direct effect of supplier dispersion (*SD*) on the inventory investment ($\alpha_{18} = -0.082$): all else being equal, a firm with a more dispersed sourcing strategy invests less in inventory. This direct effect supports our hypothesized mechanism, suggesting that enhanced competitive dynamics coupled with the statistical gains associated with a dispersed supplier base lead to shorter and more reliable lead times, which, as a whole, drives down inventory investments.

The effects of the global sourcing strategy on demand/costs are opposite. In particular, the extent of global sourcing has a negative effect on *COGS* ($\alpha_{25} = -0.012$), suggesting that increased global sourcing does indeed reduce the cost of goods sold. At the same time, the extent of supplier dispersion has a positive effect on *COGS* ($\alpha_{26} = 0.073$), suggesting that a more concentrated supplier base leads to a lower cost of goods sold. Naturally, we cannot distinguish between changes in *COGS* due to overall demand and due to unit procurement costs, so we cannot interpret these effects further.

The coefficients shown in Table 3 capture the direct effect of the extent and dispersion of global sourcing on inventory investment and cost of goods sold. In addition to these direct effects, we must consider the indirect effects that arise out of the concomitant changes in the cost of goods sold due to changes in the extent and dispersion of global sourcing. We follow Baron and Kenny (1986) in computing the size and significance of these indirect effects. To test our main hypotheses, we need to compute the aggregated impact of the direct and indirect effects, the "total effect", and we developed a bootstrap procedure to compute the size and significance of this total effect, which is based on the sample distribution of the total effect statistic. For each total effect, we run 1000 repetitions of our estimation, embedded in the bootstrap. We ensure that our bootstrapped sample has the same relative share of observations from wholesalers and retailers in each simulation run.¹¹ We provide the computed indirect and direct effects in Table 4.

The indirect effect of the extent of global sourcing on inventory ($\alpha_{11} * \alpha_{25} = -0.006$) is negative and significant, suggesting that with the increase in extent of global sourcing the effective impact

¹¹The following Stata command is used: `bootstrap, reps(1000) strata (NAICS_2__DIGIT_CODE)`.

<i>Effect on Inventory Investment</i>			
Variables	Direct Effect	Indirect Effect†	Total Effect‡
<i>Global Sourcing Share (GSS)</i>	0.015***	-0.006***	0.009***
<i>Supplier Diversification (SD)</i>	-0.082***	0.036***	-0.046***

*** -- 1% level, ** -- 5% level, * -- 10% level
†: Computed as per Baron and Kenny (1986)
‡ Bootstrapped errors, see text for details

TABLE 4. Direct, Indirect and Total Effects on Inventory Investment

of lower procurement cost is to reduce inventory investment (see Section 3.1 for discussion on competing effects of lower procurement costs on inventory investment). However, the total effect of increased global sourcing on inventory investment is positive and significant (0.009). It therefore appears that there is indeed a cost advantage to global sourcing that reduces inventory investment (indirect effect), but longer lead times cause a bigger increase in inventory levels, thus increasing the net total inventory investment. Therefore, our results support Hypothesis 1b (Section 3.1, Page 6): *firms that import more invest more in inventory.*

The indirect effect of the supplier dispersion variable on inventory investment is positive and significant ($\alpha_{11} * \alpha_{26} = 0.036$), suggesting that increased supplier dispersion leads to higher inventories due to increased procurement costs. However, the total effect of increased dispersion on inventory investment is negative (-0.046), demonstrating that, despite increased procurement costs, the improved lead times with a dispersed competitive supplier base lead to a net lower inventory investment. Therefore our results support Hypothesis 2a (Section 3.2, Page 8): *firms that distribute their sourcing amongst more suppliers have lower inventory investments.*

8. ROBUSTNESS TESTS

We test the robustness of our results at two key levels. First, we estimate multiple alternative versions of our three simultaneous equations model— we examine alternative ways to construct variables, alternative equation specifications as well as alternative estimators, plus we use only subsamples of our data. Second, to compare our results with past research, we estimate the traditionally used single-equation relative inventory model and its many variants. In our extensive robustness analysis we continue to find very strong results that support the above conclusions.

8.1. Alternative Formulations of the Simultaneous Equations Model. In Table 5 we show the results of alternative estimates, and Columns 1, 2 and 3 show the estimated direct, indirect, and total effects of the extent of global sourcing on inventory investment. Columns 4, 5, and 6

	#	<i>Global Sourcing Share</i>			<i>Supplier Diversification</i>			# of obs (firms)	<i>Robustness Test Description</i>
		Direct Effect	Indirect Effect	Total Effect	Direct Effect	Indirect Effect	Total Effect		
Original Assumptions	1	0.015***	-0.006***	0.009***	-0.082***	0.036***	-0.046**	1528 (170)	EC2SLS matrix-weighted estimator of between- and fixed-effects estimators
Alternate Variable Construction	2	0.008*	-0.006***	0.002	-0.086***	0.029**	-0.056**	1186 (147)	Sales forecast measure constructed using I/B/E/S Analyst forecast data
	3	0.014***	-0.005***	0.009**	-0.069**	0.033***	-0.036	1528 (170)	Sales forecast measure constructed using Holt-Linear's method
	4	0.016***	-0.006***	0.009***	-0.084***	0.037***	-0.047**	1576 (178)	Noncyclical demand uncertainty measure
Alternate Specification for Inventory Equation	5	0.011***	-0.005***	0.006**	-0.054**	0.031**	-0.023	1529 (170)	without sale surprise covariate
	6	0.016***	-0.007***	0.009***	-0.084***	0.036***	-0.048**	1576 (178)	without demand uncertainty covariate
	7	0.014***	-0.006***	0.008**	-0.076***	0.035***	-0.041*	1528 (170)	with sales growth covariate
Sub Samples	8	0.022***	-0.001	0.021***	-0.07	0.001	-0.069*	499 (53)	wholesalers (NAICS 2 digit code 42)
	9	-0.002	-0.005***	-0.008**	-0.005	0.035***	0.038	1029 (117)	retailers NAICS (2 digit code 44-45)
	10	0.014***	-0.006***	0.009***	-0.091***	0.036***	-0.055***	1727 (175)	reconstruction of panel data with supplier information threshold < 20%
Alternate Estimators	11	0.018***	-0.003	0.015***	-0.068***	0.008	-0.061**	1528 (170)	3 Stage Least Square (3-SLS) estimator for system of structural equations
	12	0.019***	-0.003	0.016**	-0.068***	0.006	-0.062*	1528 (170)	Fixed-Effects Estimator
	13	0.011***	-0.004***	0.007**	0.061**	0.021**	-0.039*	1528 (170)	Generalized 2 Stage Least Square (G2SLS) random effects estimator

*** -- 1% level, ** -- 5% level, * -- 10% level

TABLE 5. Alternative Formulations for the Three Simultaneous Equations Model

show the same effect for the supplier dispersion variable. For benchmarking purposes, we place the original estimates (Tables 3 and 4) in Row 1. Each subsequent row provides estimates for a different robustness check.

Alternate Variable Constructions: The accuracy of demand forecasts is a key driving variable for inventory investment. As empiricists, we have no way of knowing the true demand forecasts of the firms, and therefore we begin robustness checks by constructing alternative measures for sales surprise (SS) and demand uncertainty (DU) variables. First, we compile analysts' forecast data from the Thomson Reuters Institutional Brokers Estimate System (I/B/E/S) database (along the same lines as Gaur et al. (2007)). These forecasts are based on external analysts' opinions of the firm's external environment, strategy and operational execution. Moreover, they are also advised by the earnings guidance or forecasts provided by management, and thus represent an aggregate view of the demand forecasts by the firm and its supply-chain partners. The I/B/E/S database covers 147 firms out of the 178 firms in our panel. Typically, more than one analyst tracks a firm's performance and we thus have multiple forecasts for each firm-quarter. Suppose ASF_{ik} is the k^{th} analyst forecast of i^{th} firm's sales for quarter t . We construct the sales forecast measure as the mean

of the multiple forecasts available for firm i in quarter t , $SF_{it} = \left(\sum_{k=1}^{M_{it}} ASF_{itk} \right) / M_{it}$, where M_{it} is the number of analysts tracking the firm. We use the difference in opinions of analysts to construct a demand uncertainty measure, $DU_{it} = \left(\sum_{k=1}^{M_{it}} (ASF_{itk} - \frac{1}{M_{it}} \sum_{k=1}^{M_{it}} ASF_{itk})^2 / M_{it} \right)^{0.5}$, that is the standard deviation of the multiple forecasts for a firm i 's sales in quarter t . Finally, we calculate the sales surprise as $SS_{it} = REV_{it} / SF_{it}$.

Estimation results using these new proxies are shown in Row 2. Further, we construct an alternative measure for sales forecast by using Holt-Linear's exponential smoothing (Gaur et al. (2005)), in which we set the firm-specific parameters to minimize the in-sample sale forecast errors for the firm; estimation results appear in Row 3. Finally, in Row 4 we show the results in which the demand uncertainty variable is computed as the difference between sales forecast and realized sales, i.e., $DU_{it} = |SF_{it} - REV_{it}|$, and we apply the linear trend sales forecast method to compute SF_{it} . The intuition behind this approach is that, for a quarter, the difference between the sales forecast and the realized sales for a firm would be proportional to the demand uncertainty for the firm in that quarter. We note that, although the different measures are positively correlated, the correlation is not very high, implying that a robustness check is indeed warranted here.

Alternate Variables: Since there is no way to be sure that our demand forecasts match firms' demand forecasts, we next attempt to exclude suspect variables from the analysis. Rows 5 and 6 show the results of models in which sales surprise (SS) and demand uncertainty (DU) are removed. Furthermore, Rumyantsev and Netessine (2007) proposed the sales growth rate variable (measured as $SALGRW_{it} = COGS_{it} / COGS_{it-1}$) that impacts investment in inventory indirectly i.e., $SALGRW$ has a second-order effect on inventory investment due to the deterministic trend in sales (cf. Rumyantsev and Netessine (2007) p 422). Row 7 shows the results when $SALGRW$ is included as an additional control variable.

Different Sub-Samples: Rows 8 and 9 show the estimation results based on sub-samples of wholesalers and retailers. Further, as we describe in Section 4.2, when aggregating transaction-level data to the firm-quarter level, we only included those firm-quarters in which the supplier information was known for more than 80% of the import transactions. In Row 10 we show estimation results obtained when a threshold of 20% is used (other thresholds yield qualitatively similar results).

Alternative Estimators: Row 11 shows the results obtained by applying the 3 Stage Least Square (3SLS) system estimator to our model in (Eqs. 6.1–6.3).¹² The 3SLS estimator also incorporates the error-correlation structure between the different equations in a simultaneous equation model, thus

¹²In STATA, we run the estimation using the `reg3` command after transforming our data set for fixed-effect (within) estimation using the STATA command `xtdata, fe`.

capturing the full information structure available within the data set to estimate the coefficients. We also estimate our model with the fixed-effects estimator (Row 12), and a Generalized 2SLS random-effects estimator (Row 13).

To summarize, across the 12 robustness tests described above, we confirm the positive and significant direct impact of the extent of sourcing on inventory investment for 11 of 12 alternate robustness tests. The indirect effect is confirmed to be negative and significant across 10 tests. The total effect is positive and significant across 10 tests. The direct effect of supplier dispersion is negative and significant across 10 tests. The indirect and total effects are significant across 9 tests. In some cases we note a decrease in significance, especially when smaller samples are involved, which is expected. Further, our coefficient signs are always consistent, with just one exception in 72 tests. Taken together, these robustness tests strongly reinforce and confirm our main findings.

8.2. The Traditional Relative Inventory Investment Model. In the existing work on inventory levels, often a single-equation model is estimated with the relative inventory level as a dependent variable. Following Rumyantsev and Netessine (2007), we measure the relative inventory level of firm i for quarter t as $RINV_{it} = AINV_{it}/COGS_{it}$. Conceptually, the relative inventory measure captures the net impact or equivalently the total effect of the global sourcing strategy on a firm's investment in inventory. In other words, the relative inventory measure embeds the indirect effect of the global sourcing strategy on inventory investment due to its impact on the cost of goods sold. Although such a formulation makes it hard to accurately distill the impact of global sourcing on inventory from its impact on procurement costs, we nevertheless expect the directional impact of our global sourcing variables on the relative inventory level to be the same as that of the total effect obtained for these variables from the three-equation model: firms that employ more global sourcing should have a **higher** relative inventory level, and firms with a more distributed supplier base should have a **lower** relative inventory level.

To verify these effects, we control for previously identified salient variables and we estimate the impact of the extent and dispersion of global sourcing (GSS and SD) on the relative inventory ($RINV$) using the following multiplicative model:

$$(8.1) \quad \log RINV_{it} = \alpha_1 \log GM_{it} + \alpha_2 \log CAPINT_{it-1} + \alpha_3 \log SS_{it} + \alpha_4 \log DU_{it} \\ + \alpha_5 \log GSS_{it} + \alpha_6 \log SD_{it} + F_i + \beta_{1s}q_s + \tau_{1r}y_r + \epsilon_{it},$$

<i>InvToCOGS</i>	<i>Original Assumptions</i>			<i>Alternate Variable Construction</i>		<i>Alternate Specification</i>		<i>Sub-Samples</i>		<i>Alternate Estimators</i>	
	Base	+ GSS	+ SD	IBES	HWN	w/o Sale Surprise	w/o Sale Growth	WS (42)	RS (44-45)	GLS	Swamy Arora
<i>GSS</i>		0.013***	0.018***	0.010***	0.013***	0.022***	0.015***	0.016**	0.017***	0.019***	0.018***
<i>SD</i>			-0.070***	-0.041	-0.053**	-0.094***	-0.059***	-0.060	-0.074**	-0.077***	-0.076***
<i>GM</i>	0.238*	0.232*	0.229*	-0.022	0.291**	0.218	0.119	0.239	0.178	0.282***	0.278***
<i>CAPINT</i>	0.071	0.069	0.073	0.116***	0.046	0.129**	0.075*	0.050	0.066*	0.093**	0.092**
<i>SS</i>	-0.772***	-0.766***	-0.760***	-0.955***	-0.667***		-0.555***	-0.683***	-0.828***	-0.751***	-0.752***
<i>DU</i>	-0.062***	-0.061***	-0.061***	-0.018**	0.013*	-0.039**	-0.026***	0.004	-0.064***	-0.056***	-0.057***
<i>SG</i>							-0.355***				
<i># Obs</i>	1541	1541	1541	1190	1540	1543	1541	505	1036	1541	1541
<i># firms</i>	170	170	170	147	170	170	170	53	117	170	170
<i>Within R-sq</i>	29%	30%	31%	29%	57%	11%	52%	41%	33%	30%	30%
<i>Overall R-sq</i>	18%	20%	20%	18%	21%	21%	22%	36%	9%	22%	22%
<i>B/w R-sq</i>	19%	19%	20%	20%	20%	22%	25%	43%	6%	22%	22%

*** -- 1% level, ** -- 5% level, * -- 10% level

TABLE 6. Estimates from the Relative Inventory Investment Model

where F is a firm-level effect, and q and y are dummy variables to control for quarter and year-level effects, respectively. We test the specification using firm-level fixed-effects estimation and we assume a cluster-correlated error structure that allows for a firm's global sourcing strategy to depend on other unobservable firm-specific characteristics.¹³

Table 6 shows estimation and robustness results for the relative inventory model. The first three columns provide the single-equation model results with stepwise addition of our variables of interest. Columns 4 to 11 demonstrate the results of eight different robustness tests of the single-equation relative inventory model as follows:

Models with Alternate Variable Construction: Columns 4 and 5 of Table 6 show the estimation results when the sales surprise (SS) and demand uncertainty (DU) measures are constructed using the I/B/E/S data set and the Holt-Linear's sale forecasting model, respectively.

Alternate Variables: In column 6, we show the results obtained after dropping the sales surprise (SS) variable from the main specification. In column 7, we show the results obtained after including sales growth ($SALGRW$) as an additional control.

Sub-Samples: Columns 8 and 9 show the results for estimation performed using the sub-sample data of wholesalers and retailers separately.

¹³We use STATA command `xtreg, fe vce(cluster firmid)` to run the estimation.

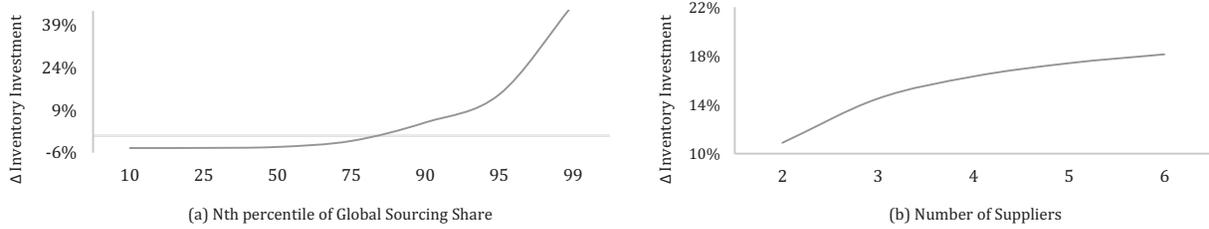


FIGURE 9.1. Changes in Extent and Dispersion of Global Sourcing

Alternate Estimators: We supplement our main results using two firm-level random-effects estimators. Column 10 shows the results with the consistent Generalized Least Square random-effects estimator. Column 11 show the results obtained with the Swamy-Arora estimator for small samples. We focus on the first two rows of Table 6, which show the impact of the extent and dispersion of global sourcing (GSS and SD) on inventory investment. We find a positive and significant impact of the extent of global sourcing on the inventory investment variable across *all* 9 potential relative inventory models described above. Further, in 8 out of the 9 relative inventory models, we find significant support for a decrease in inventory investment with the increase in supplier dispersion. These results are in line with the insights derived from the absolute inventory three-equation system and provide further support for our main findings.

9. DISCUSSION

Our results provide, for the first time, empirical evidence contributing to the ongoing debate regarding the costs and benefits of global sourcing. In particular, we find that sourcing more globally leads to a higher inventory investment, while diversification among global suppliers leads to a lower inventory investment. To understand whether these effects are economically significant and to appreciate their relative sizes, we perform counter-factual experiments. First, we calculate that if an average firm increases the share of global sourcing vis-a-vis domestic sourcing by one standard deviation, it leads to an increase of 22.64% (US \$ 230 M) in the inventory investment. Figure 9.1 (a) shows the changes in inventory investment when the sourcing share changes from an average sourcing share to that of the n^{th} percentile firm. Next, we evaluate the impact of the increase in supplier dispersion by taking a hypothetical sole-sourcing firm (i.e., a firm that purchases 100% of its global sourcing needs from a single offshore supplier). If such a firm adopts dual sourcing and distributes its business equally to two suppliers, we estimate a decrease of 11.10% (US \$ 113 M) in the inventory investment. Figure 9.1 (b) shows how this decrease continues with the increase in the number of suppliers from two to ten, assuming that an equal percentage is sourced from

each supplier. These experiments indicate that the two elements of the global sourcing strategy highlighted in this study have a highly economically significant impact on inventory investments.

Our findings have several potentially profound implications for company managers, financial analysts, and private investors. Although various ways in which global sourcing impacts inventory investments (e.g., longer lead times but lower purchase costs) are well understood, the debate around the total impact of global sourcing and its dispersion has never been resolved. Our results point out that a company moving to source more globally must be prepared to see more money tied up in inventory unless its supplier base is sufficiently dispersed. Ignoring these investments may lead a firm to grossly overestimate the benefits of global sourcing or, even worse, to employ global sourcing with an inferior supplier dispersion strategy.

Additionally, our study illustrates a new approach to obtaining information about the sourcing practices of competitors, which might also be of interest to managers for benchmarking purposes. Furthermore, financial analysts and private investors alike increasingly pay attention to the inventory holdings of a company to infer future financial performance (cf. Raman et al. (2005)). Our results demonstrate that such analysis might be less reliable if global sourcing is not accounted for. Indeed, firms in our sample easily change their global sourcing share from one quarter to another by a factor of 2-3 (cf. CATO fashions in 2008). Furthermore, changes in global sourcing strategies can affect a variety of standard financial ratios through their effect on inventory investment. Given that the sources of information that we use in this study are becoming increasingly accessible, it will become necessary to develop approaches similar to ours to analyze these data.

Our results rigorously demonstrate the association between the global sourcing strategy employed and the inventory investment. There are three potential interpretations of this association. The effect on inventory investment could be interpreted as a result of the global sourcing strategy, or a cause of the global sourcing strategy, or alternately, both global sourcing and inventory investment could be caused by some third variable, such as a firm characteristic, a time characteristic, or some firm-epoch varying economic characteristic such as margins, demand level, etc. Of these interpretations, the first, i.e. elements of the global sourcing strategy *cause* the change in inventory investment, provides the most actionable results for managers. Let us consider the other alternate explanations—potentially inventory investment causes firms to change their global sourcing strategy (reverse causality). For example, if firms have too much inventory, they might for some reason decide to change their supplier management strategy. To us, this sounds less plausible than the explanation that it is the choice of supplier management strategy that impacts inventory investments. Further, if this were true, we would expect the effects to be less contemporaneous, but perhaps more with

lags which is not found in our data. Another alternate explanation for our association relates to the existence of other variables that simultaneously influence both the inventory investment and the global sourcing strategy. Here, note that our fixed-effect design and the inclusion of time dummies exclude the possibility of any firm or time-specific variables serving this role. Further, the most viable candidates for this role are demand, procurement costs and margins— all interdependencies that we explicitly model. In fact, our three equation model is designed precisely to isolate the direct relationships between inventory investment and global sourcing strategy from the indirect dependencies via margins, demand and costs and to provide consistent estimates in the presence of this endogeneity. Our results stand even if we control for the indirect relationship.

Taken together, these arguments suggest that while the latter two explanations are somewhat plausible but far less probable than the explanation that our observed association, in fact, represents a causal effect. While only a controlled experiment can unambiguously establish contemporaneous causality, but in the light of the above arguments we feel quite confident in proposing here that an increase in global sourcing *causes* an increase in inventory investment, an increase that can be mitigated by supplier diversification.

Although the data that we analyze is extremely rich, the standard limitations around generalizability of empirical results apply. First, we only study public firms, firms that are required to report their inventory investment. It is not clear if private firms have different global sourcing strategies and consequences but at this point we have no reason to believe so. Second, some global sourcing transactions could be done through anonymous, unlisted entities or unrelated third parties. Our data excludes such imports. Third, we only focused on retailers and wholesalers in this study because they do not take an active part in transforming goods and hence imports have a more direct relationship with inventory in these cases— future studies could analyze other industry sectors. Fourth, although we have detailed transactional data on global sourcing, we only have quarterly financial data which greatly limits our analysis. Relaxing all of these restrictions offer viable avenues for future research, although data availability issues may prevent researchers from doing so in the immediate future. Nevertheless, we are pursuing some of these and other directions in the extensions of this work.

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