Understanding Global Supply Chain and Resilience: Theory and Practice

Morris Cohen, Shiliang Cui, Sebastian Doetsch, Ricardo Ernst, Arnd Huchzermeier, Panos Kouvelis, Hau Lee, Hirofumi Matsuo, and Andy Tsay

Abstract This chapter summarizes the last 8 years of collaborative research of a global group of scholars on supply chain management and especially on how companies are dealing with uncertainties and disruptions. Starting with analyzing the factors that drive changes in global supply chain designs, this chapter describes how companies are coping with new types of disruptions such as trade conflicts, natural disasters, and pandemics. Commonly suggested resilience strategies like reshoring or regionalization are de-mystified and discussed based on first-level insights from interviews and survey data. Moreover, we analyzed how companies have handled different types of disruption and the underlying efficiency-resilience trade-offs. The chapter then outlines the different types of complexity and obstacles to supply chain resilience that companies have to overcome based on their individual

M. Cohen (✉)
The Wharton School, University of Pennsylvania, Philadelphia, PA, USA
e-mail: cohen@wharton.upenn.edu

S. Cui · R. Ernst
McDonough School of Business, Georgetown University, Washington, DC, USA
e-mail: shiliang.cui@georgetown.edu; ernstr@georgetown.edu

S. Doetsch · A. Huchzermeier
WHU–Otto Beisheim School of Management, Vallendar, Germany
e-mail: Sebastian.Doetsch@whu.edu; arnd.huchzermeier@whu.edu

P. Kouvelis
Olin Business School, Washington University in St. Louis, St. Louis, MO, USA
e-mail: kouvelis@wustl.edu

H. Lee
Graduate School of Business, Stanford University, Stanford, CA, USA
e-mail: haulee@stanford.edu

H. Matsuo
Institute for International Strategy, Tokyo International University, Kawagoe, Saitama, Japan
e-mail: hmatsuo@tiu.ac.jp

A. Tsay
Leavey School of Business, Santa Clara University, Santa Clara, CA, USA
e-mail: atsay@scu.edu

H. Lee et al. (eds.), *Creating Values with Operations and Analytics*, Springer Series in Supply Chain Management 19, https://doi.org/10.1007/978-3-031-08871-1_14

product characteristics, market environment, and supply chain setup. Finally, the need for measuring resilience is outlined and proposed resilience metrics are discussed.

Keywords Global supply chain design · Supply chain resilience · Resilience metrics · Implementation challenges · Empirical research

1 Introduction: Context and Research Motivation

Globalization of supply chains has increasingly become relevant to policy makers and the public. Advancements in technologies, removal of trade barriers, and growth in supply options from all around the globe have led to complex, multi-tiered supply chains. These global supply chains, which have tended to prioritize cost efficiency, have revealed their limitations in the face of disruptive events that have increased in frequency and severity. Drawing upon a large body of research on global supply chain management, an international group of supply chain scholars came together in 2014 with the goal of understanding how companies were adjusting their global supply chain design and strategies in response to a convergence of major economic, financial, political, and market changes. We started to examine how these factors were driving the redesign of supply chains and the reshaping of operational strategies and have continued to do so. This effort was not a response to any single event. At the time, labor costs appeared to be normalizing across geographies—in particular the US–China wage gap was closing fast. This, together with the strengthening of the Chinese currency, blunted one of the forces that had made China the factory to the world. Around this time frame, a series of systemic shocks disrupted thinking concerning the structure of global supply chains. This change was driven by politicians at the highest levels, who used their bully pulpit to push reshoring initiatives, US–China trade frictions, natural disasters such as Hurricane Harvey, and the global COVID-19 pandemic. Our early work was mostly directed at documenting and understanding adaptations of global supply chain design and strategies that were occurring within this context. The last 2 years have seen increased incidence of "black swan" disruptions of momentous impact, which has led some to argue that these kinds of events will not be so rare going forward. Accordingly, we directed our attention specifically to strategies intended to make global supply chains more resilient. This refocus immediately centered our attention on the tension between long-term efficiency and resilience, which has implications for key attributes of every global supply chain, including technology selection, the approach to outsourcing, the extent of multi-sourcing, and the geographical placement of activities. Our research builds on our team members' collective history of contemplating and contributing to the development of guidelines for global supply chain management, and aims to marry this perspective with data and insights collected, first-hand, from senior supply chain executives from global companies. Specifically, we wanted to understand how senior managers think about these issues,

what actions they intend to pursue in the face of recent disruptions, and how they resolve the trade-off between resilience and the usual efficiency goals. Through interviews and surveys that examined real actions taken in response to present events and evolving probability assessments about the future, we built, mostly via an empirically grounded research and analysis approach, a conceptual framework to explain and guide the design of global supply chains at a level of granularity that is necessary to be useful but is lacking in typical studies.

As illustrated by Fig. 1, this chapter gives an overview of how our research evolved over the years (Parts 1 and 2), insights regarding supply chain strategies in different industries (Part 3), and managerial interpretation of our main findings (Part 6). We also outline the limitations of the current research as well as the new issues that emerged (Part 4 and 5) along with future research directions (Part 7).

This chapter addresses the following research questions:

1. What are the factors that will drive changes in global supply chain design and related strategies?
2. Do we expect to see a fundamental shift away from the comparative advantage model that has greatly influenced the design of global supply chains since the early 1990s? Regarding the moment at hand, will disruption risks and trade policies drive widespread reshoring? Will global supply chains evolve into a portfolio of regional supply chains?
3. How do companies design a priori and execute during and after disruptions in order to achieve supply chain resilience? What is the right balance between efficiency and resilience?
4. What explains the diversity of global supply chain designs and resilience strategies observed across industries and among companies in similar industries or even in different business units within a company?
5. How can company managers understand and overcome the specific obstacles to designing and executing profitable and resilient strategies based on lessons from how companies similar to theirs have responded to supply chain challenges?
6. What measures should be used to monitor improvements in resilience?

Answers to these questions were based on a variety of empirical findings derived from a survey, a series of structured interviews from a selected sample of companies that have developed successful global supply chain strategies and interactions with senior supply chain executives in roundtable sessions. The interviews focused on exploring responses to the current crisis as well as developing an understanding of each company's approach to defining their global supply chain strategy. This included a review of the structure and management policies used to drive both efficiency and resiliency. These inputs were all based on actual decisions made by the companies as well as their intentions and plans for the future.

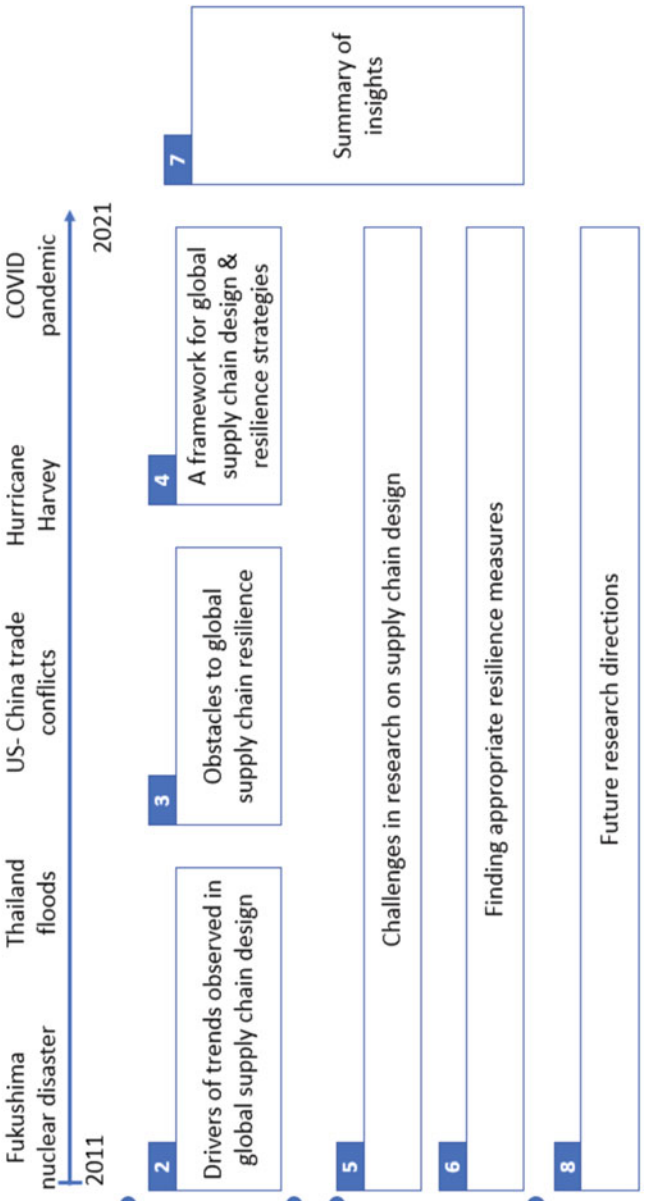

Fig. 1 Structure of this chapter

2 Pre-pandemic Study on Drivers of Trends in Global Supply Chains and Resilience

In a global benchmarking survey of 74 firms conducted in 2015–2016 on production sourcing decisions, we found that companies frequently restructured their global production footprints. The majority of firms engaged in offshoring. Following the 2016 US presidential election, the new administration focused on providing incentives to firms to reshore production activities, mostly from China. In a parallel development, the UK's decision to leave the European Union led politicians to pressure firms not to offshore from the UK. The popular media reported that reshoring to home markets (as defined by the location of the global headquarters or having the closest cultural affinity or heaviest representation in the executive ranks) was occurring. Our research, however, did not find empirical evidence of this occurring at a meaningful scale. In our survey data (85 detailed questionnaires completed by business units in companies regarding actual projects they had undertaken over the preceding 2 years), reshoring occurred rather infrequently, and seldom in response to trade tariffs and political incentives. Increases in capital investments away from Asia and into the USA or Europe were mostly not of a reshoring nature. For instance, we observed that the companies that made facility investments in the US were typically Asian and European firms seeking proximity to the US market or domestic players expanding capacity in their home market (which is not reshoring if this is not replacing supply that formerly came from offshore). None of the US companies in our sample closed a production site in Asia while expanding in the US. China remained the most attractive production location, followed by Eastern Europe and Southern Asia. In many cases, firms largely adhered to the principle of natural hedging, i.e., using a sourcing footprint that roughly matches the geographic footprint of demand. Thus, our findings support the view that the extent of actual reshoring has been exaggerated in press and industry reports (Fratocchi et al. 2014; Dachs et al. 2019).

Some other results of our previous work (see Cohen et al. 2018) point to the following factors to explain changes in global supply chain design:

1. Access to customers, quality, and supply chain performance were the main drivers for increasing production volume in China.
2. Increases in labor costs in China were the prime reason companies left China for lower cost locations.
3. Western Europe found near-shore cost advantages in sourcing from Eastern Europe and China.
4. North America was attractive as a market and attracted new production activity, but not necessarily at North American companies.
5. Multinational production activity in Japan decreased after the 2011 natural disaster.

Shortly thereafter, i.e., during 2017–2018, a major trade war between China and the US erupted. Some firms reacted by moving their operations to Southeast Asia

or Mexico. In an effort to diversify sourcing, but recognizing the necessity of using quality Chinese sources, some companies adopted a multi-sourcing strategy termed "China Plus One," i.e., using sources located in China to primarily serve the growing Chinese and Asian markets, while using alternative sources positioned elsewhere to serve other markets. In an executive roundtable we organized in 2018 on the topic of "global operations in turbulent times," senior supply chain executives of world-class global companies confirmed their use of such policies. The discussion in that roundtable and reports describing the last 4 years indicate that US trade tariffs did not work effectively as an incentive for reshoring or for a substantial reduction in sourcing flows from China for most industries. In a few cases, North American companies dealing with retaliatory tariffs in other regions ended up making capacity investments in these regions. Consumers in all regions paid higher prices or even experienced shortages as result of flow adjustments and decreased inventories of some affected goods. The tariff uncertainty led to reluctance for ordering some goods with longer lead times, and when the pandemic hit Western European and US markets, companies were caught with less buffer to absorb the early shock. Moreover, the changes in trade policies had already nudged companies to identity non-China sources that worked well for lower skill or less knowledge-intensive processes with older mature products. While our research group did not pursue a specific study of the impact of trade-tariff factors on global supply chains, some members did explore related issues in recent papers (see Cohen and Lee 2020; Dong and Kouvelis 2020).

3 Obstacles to Global Supply Chain Resilience

While our previous work focused on how global supply chains changed in response to factor changes over a long period (the first 15 years of our new century), the COVID-19 pandemic shifted our emphasis to understanding the resilience of global supply chains in the presence of major unexpected events. In Cohen et al. (2021b), we first address what constitutes supply chain resilience, and then investigate why known resilience strategies are not implemented to the extent expected.

Our first task in the above work was to distinguish between resilience and agility in the context of supply chains. The short-term reaction of companies to major disruptions is to leverage their operational flexibility to address urgent supply shortages or demand surges, consequently surviving or even thriving in the near term. The popular media, consulting reports, and even some academic work, often label this as resiliency. Lee (2004) and Cohen and Kouvelis (2021) argue that agility is the better descriptor in this case. Cohen et al. (2021b) define agility as "the ability to respond rapidly and cost-effectively to short-term changes in demand or supply disruptions." Resilience of supply chains encompasses a longer-term ex-ante behavior. Cohen et al. (2021b) frame resilience as the design and adoption of ex-post recourse actions, which are executed in reaction to the disruptive event. We thus define resilience as "the ability to adapt to structural changes by modifying

supply chain, products and technologies strategies." Agility can be achieved through rebalancing asset deployment (such as inventory) to address local shortages, using overtime, or employing expedite shipments. This will solve an immediate problem but will not provide a longer-term solution that requires resiliency. A longer-term strategy to achieve resilience can be based on identifying bottlenecks in the supply chain that lead to long lead times and uncertain supply. Policies to mitigate this problem can be derived from restructuring the supply chain network, i.e., finding different suppliers and sources. This, however, will do little to alleviate a problem in the short-term. Thus, we can only evaluate resilience based on observed performance over long periods and in response to multiple events.

While (supply chain) resilience became the center of conversation as companies around the world responded to COVID-19 and other crises, this attribute generally has not been displayed by many global companies in the last 20 years. We argue that some companies exhibit less resilience than others, not merely because they do not know the recipe for a resilient supply chain. Certainly, many books (Sheffi 2007; Hopp 2011) and articles (e.g., John et al. 2020; Cohen and Kouvelis 2021 and references therein) have discussed aspects of the recipe (e.g., including redundancy in process design, multi-sourcing, and holding inventory and capacity buffers as well as designing products with operational flexibility in mind, by using well-known principles such as component commonality and postponement). This suggests that the basic roadmap to supply chain resiliency is generally understood by managers. So why then is supply chain resilience more the exception than the rule? Cohen et al. (2021b) reported on our investigation of the implementation obstacles that are missing from or are underemphasized in the existing mainstream and academic literature, and which support the conclusion that there is a "knowing-doing gap" (Pfeffer and Sutton 2000).

We identified six obstacles based on interviews of senior supply chain executives:

1. Heterogeneity of supply chains: Companies may have different supply chains for each product group, which makes a one-size-fits-all resilience strategy inappropriate.
2. Fragmentation of the decision-making architecture: Multiple supply chain actors need to be coordinated (meaning through both synchronization of action and incentive alignment) to achieve supply chain resilience. Complexity and conflicts of interest can quickly arise without deliberate efforts to counteract them.
3. Accentuated efficiency and resilience trade-offs: The best compromise between cost efficiency and resilience is not easy to achieve even in a simple setting, let alone in one which contains multiple divisions and functions within a company that may have disparate priorities.
4. Resource limitations: All companies have limited resources (e.g., cash) and thus have to prioritize activities (e.g., moving sales online) that enable survival through COVID-19 or any other crisis at hand. This can cause de-prioritization of efforts to enhance resilience, which oftentimes require big upfront investments whose ROI might not be realized for a long time, if ever.

5. Existing factor market limitations: A company's options for resilience are constrained by the technical and business capabilities of its supply base.
6. Lack of needed supply chain financing and insufficient government incentives: A supply chain is only as strong as its weakest link. A company may therefore need to provide financial support to its supply chain partners. The required capital can be a barrier to implementation.

Our discussion with executives from companies from different industries made it clear that the nature of their product markets, technological sophistication of their products, operation of their supplier networks, production process complexity, and logistics and distribution aspects of their businesses all heavily influence which obstacles assume priority in their environment. Highly sophisticated product companies that are at the forefront of technology often struggle more with limitations in accessing factor markets for required source materials, high-quality suppliers and elite engineering talent. One example from our interviews would be a leading US company that focuses on storage and network technology, e.g., servers. Similar to many other information technology companies, it has outsourced most of its production and thus inherits the constraints of its contract manufacturers, which strongly limit the footprint of choices. Such companies are limited in the execution of a diverse manufacturing footprint and the use of multi-sourcing by the tremendous amount of financial resources and management development efforts required in their industry. Often the solution comes from using new technologies to redesign products, through increasing the product integrality, changing the scale and level of automation of production processes for creating mix flexibility, and/or making investments to increase ownership and control of their supply chains. But this "design-for-resilience" rethinking of products and processes in technology uncertainty environments is often perceived as risky long-term thinking by executives, and thus is often abandoned for easier to execute acquisition and consolidation strategies, which are favored by financial shareholders and markets.

Companies with highly diverse product portfolios to serve multiple product markets with different priorities, typically are exposed to the complex portfolio of loosely coordinated and conflicting priority supply chain processes that are present in their environment. They often end up with complex multi-tier networks of transactional suppliers, limited deep-tier visibility, and confusing global organizational structures. Companies such as Unilever, Colgate, or Nike fall into this category. Their presence in environments with weak infrastructure and supporting regulations via deep-tier suppliers is motivated by the promise of cheaper materials and low-cost labor. This logic of efficiency has motivated the modular nature of their products, with a large portion of them outsourced. This results in multi-tier networks of deep-tier, potentially problematic suppliers. For these chains, efficiency is the competitive imperative, and their shareholders view resilience strategies, such as excess capacities and buffer inventories, as wasteful investments and a bad use of working capital. The most successful among them try to reduce product and process complexity and design better-coordinated supply chain processes within a hierarchical supply chain organization (with some centralized processes that

leverage scale and global access, and some independence of activities reflecting efficiency and responsiveness trade-offs of their product markets).

One example for a successful hierarchical structuring of a very diversified product portfolio of about 1 million SKUs from over 20,000 suppliers is Emerson, a US company that manufactures products and provides engineering services for a wide range of industrial, commercial, and consumer markets. Their first-level corporate strategy is designed to set guidelines and standards across all business units, e.g., for contracts, dual sourcing or go-to-market strategies. They also leverage commodities where scale matters, e.g., steel, electronics, and use an internal, centrally operated logistics network. Management of their business units is achieved by controlling outcomes in terms of performance metrics such as lead time and customer service. Whenever possible, in terms of access to materials and suppliers, these companies revert to shortening their supply chains by reducing lead times through market-focused regional strategies. For these companies, their complex supplier network with limited ensuing visibility of often smaller and under-resourced suppliers requires attention to systematic supply risk management. But the complexity, continuous long-term commitment and resource intensity of risk management programs can result in paralysis, and abandoned or short-term, ill-fated projects. Resilience is discussed immediately after a disruptive event, but as soon as some recovery is achieved, efficiency becomes the immediate priority. Of course, these limitations can be observed in any company with poor management, but we suggest that they are especially relevant for the class of companies with diverse product portfolios.

4 A Framework for Global Supply Chain Resilience Strategies

Our research then shifted into learning from the pandemic crisis by reviewing the response of world-class supply chains. We also compared the measures used to increase resilience in practice with what the deductive analytical literature prescribes. We found a theory-practice gap that suggests that the widely accepted concepts of a "customized supply chain," meaning a supply chain that is "custom-tailored" for the business, and "supply chain resilience" are not sufficient on their own. Therefore, we introduce the concept of "Bespoke Supply Chain Resilience" which is based on the fact that different customized supply chains have different resilience requirements and therefore require different strategies to achieve resilience. Companies with a portfolio of supply chains therefore need to identify multiple supply chain specific resilience solutions that account for the different constraints and trade-offs they are facing. For example, for a company such as Henkel, which operates three different business units with three different supply chains, there is no single company-wide resilience strategy. Rather there is one

strategy for their adhesives business and another for their beauty care business, where rapid changes are needed to achieve resilience.

Our intention in this section is not to review the methodology used to build a comprehensive conceptual framework of the resilience lessons, but rather to demonstrate how executives can use the framework for developing supply chain strategies that will be effective in the face of future disruptions. There is a long history of developing normative models for supply chain design based on analytic optimization models (see relevant references in Cohen et al. 2018). These models mostly focus on supporting optimal production network configurations associated with global sourcing for an after-tax profit-optimizing firm over a long planning horizon. However, there is a lot less research and understanding of how companies should adjust in the short-to-medium term, to changes in major factors, such as labor rates in different countries, exchange rates, trade policies, and, with increasing significance over the last 10 years, as well as to major disruptions (e.g., earthquakes, tsunamis, major industrial accidents, and an unprecedented pandemic).

In Cohen et al. (2021a), we developed an empirically grounded analysis of global supply chain resilience, based on interviews of senior supply chain executives across major companies in different industries. We applied a granular unit of analysis based on product groups or business units within the companies. This allowed us to identify patterns of resilience strategies for supply chains across multiple companies and industries. This led to our "Bespoke Supply Chain Resilience" framework for clustering supply chains along two dimensions, which we referred to as the "Triple-P SC framework" (see Fig. 2). This framework represents the current thinking of supply chain executives that we observed and was compared to approaches proposed in the SC and OM literature. This led to the definition of three archetypes, i.e.,

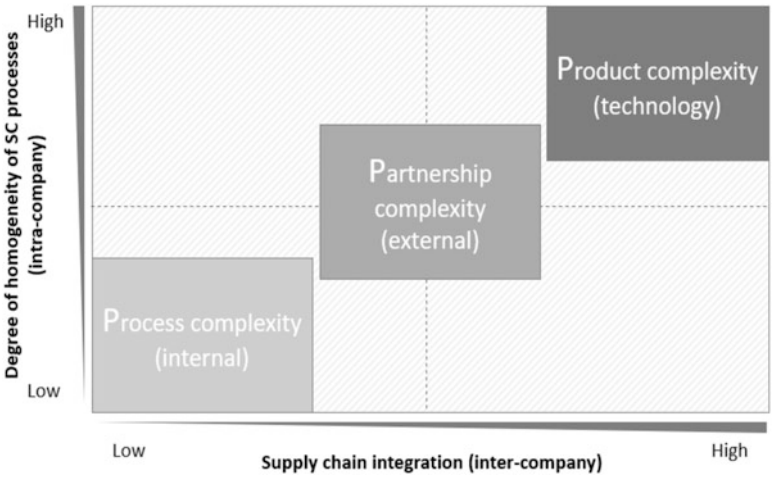

Fig. 2 Triple-P supply chain resilience archetypes

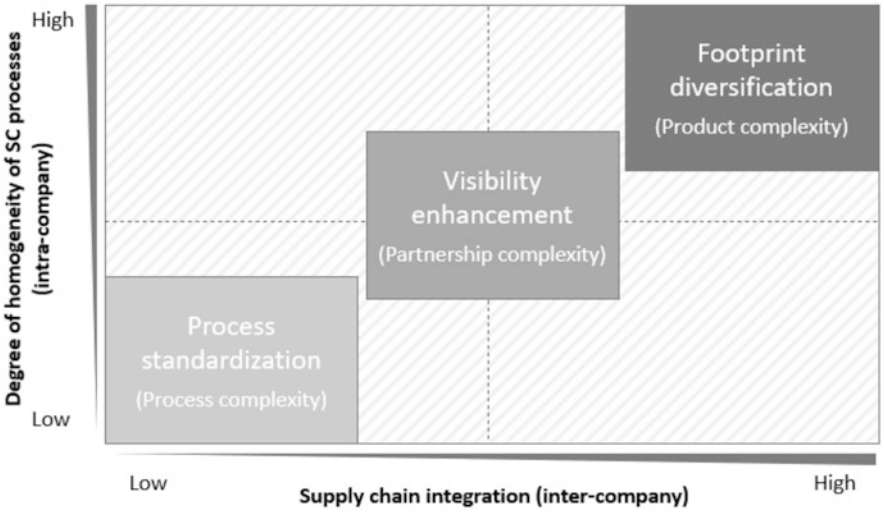

Fig. 3 Common resilience strategies based on Triple-P archetype classification

typical supply chain designs that emerged from a cluster analysis of 26 supply chains. The corresponding common resilience strategies are indicated in Fig. 3.

Our analysis revealed two main dimensions for clustering supply chains across companies and industries based on their responses to uncertainty. These two dimensions, which we refer to as "major influencers of resilience strategy," are *Homogeneity of internal supply chain processes* and *Integration with other actors in their supply chains*. In our clustering analysis, we defined four stages of SC process homogeneity (sorted from low to high homogeneity) and five degrees of supply chain integration (sorted from low to high integration). This resulted in the positioning illustrated in Fig. 2 based on the scatter plot of Fig. 4 (refer to Cohen et al. 2021a, b, for more details).

With respect to product architecture, we identified the following operational features: product complexity, homogeneity of product portfolio, degree of product modularity, and level of product customization. With respect to the supply chain process, we identified the following features: availability of potential suppliers, level of pull (vs. push), length of lead time, and degree of (manufacturing) outsourcing. Analysis of all of the supply chains in our sample showed that we could use these operational attributes to define the three supply chain "archetypes" to enhance our understanding of observed resilience strategies.

To further narrow the list of attributes, we noted that "availability of potential suppliers" and "homogeneity of product portfolio" were the two most distinguishing attributes, followed by "product complexity," "lead time," and "level of pull."

Companies that have homogeneous portfolios of high complexity products (mostly industrial, and often with B2B transactions), and with limited availability of select skills suppliers, design global supply chains using "one-size-fits-all" (usually

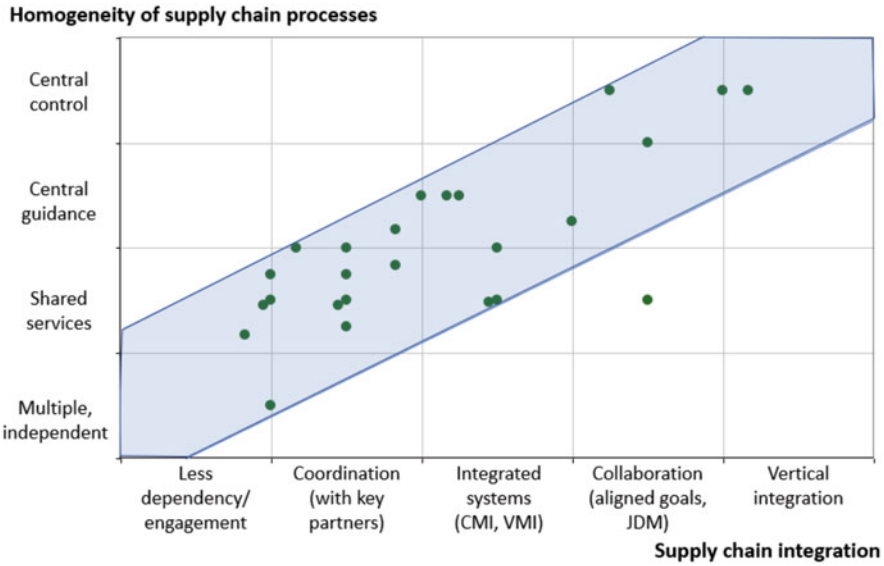

Fig. 4 Plot of supply chains with respect to two main influencers of resilience

based on high quality, high service, and emphasizing technology leadership) for all products. The vertical integration of a significant block of the required activities reduces the risk of dependence upon a small number of capable suppliers and limits dangerous knowledge spillover risks. These companies occupy one end of the diagonal in our framework.

Examples for this type of companies are ASML, Infineon, HP Enterprise. We refer to this archetype as the "Product (complexity) archetype." The other extreme in our diagonal in Fig. 4 represents companies with very diverse portfolios of more common usage (mostly consumer), and less technologically sophisticated products, but operating with a large pool of globally available efficient suppliers, often through transactional relationships. These companies have to deal with the inherent complexity of diverse products with very different competitive priority markets, and with the need to maintain multiple product finishing and market-end delivery processes to achieve the demand fulfillment priorities. Examples for this supply chain archetype are P&G, Colgate, Nestlé, or Würth. In a typically complex portfolio of both functional and innovative products, and with the need to build the portfolio of efficient and responsive chains for different product markets, these companies end up creating a loosely connected portfolio of heterogeneous supply chains. These chains rely extensively for sourcing and distribution on a large number of transactional partners using a multi-tiered structure that inhibits limited visibility to deeper tiers. The complexity of the portfolio of supply chain processes they manage creates chaotic supply and distribution networks whose usage necessitates a high level of planning. The pursuit of execution efficiency, while balancing

the flexibility needs for shifts among products as demand preferences change, is often the Achilles heel for these companies. They are the "Process (complexity) archetype" residing at the other end of the diagonal.

The companies in the middle of the diagonal face moderate levels of challenges due to product complexity and the availability of supply options. Their product portfolios are reasonably complex, with many different products but of standardized variety or with customization options. The technological complexity is not as high, but with some engineering skill complexity, making qualified suppliers reasonably available in most locations. Typical examples for this type of companies are car manufacturers such as Daimler or General Motors or producers of industrial and consumer products such as Emerson, Cisco, or Panasonic. Logistic and customer response metrics drive these companies closer to their end-product markets. Their supply chains reflect a balance of outsourced and in-house production. Their supply chains are characterized by multi-tier supply networks with large transactional suppliers operating on a global scale, but with fewer qualified "premium" partners for the higher quality engineered components needed by their products. These companies shift into a role of a supply chain integrator in fulfilling regional demand. For example, BMW, the German premium car manufacturer, operates a carefully coordinated mix of efficient and responsive processes, that shares efficiency and scale-driven processes (commodity procurement, some distribution and logistics assets, etc.), and allows for end-market differentiated processes that are relatively close to the customer. This positions BMW and other similar businesses in the middle of the "supply chain process heterogeneity" dimension. They often own their assembly and finishing/customization processes and position them near their end markets. They also shop globally for lean, qualified quality, low-labor-cost production partners and low-cost commodity procurement. These practices correspond to a position near the middle of the vertical integration/extent of outsourcing dimension. We refer to these lean supply chain integrators as the "Partner (complexity) archetype."

Our "Triple-P" framework not only uses operational attributes of product and process complexity to help executives characterize their business units, but also suggests directions for global supply chain redesign.

The 26 supply chains which we analyzed are all on the diagonal and were chosen because they belong to companies that have a leading position in their respective industries. As supply chain resilience is difficult to measure and it is still too early to see the long-term effects of some strategies, we cannot empirically prove that a supply chain needs to be on the diagonal to be successful. However, being off the diagonal means that a company is vertically integrated for multiple independent supply chains (bottom right corner), which is difficult to achieve in terms of investment and complexity. Alternatively, a company that has only one supply chain setup for all its SKUs while having loose relationships with other supply chain actors, even though only a part of the value creation is done in-house, would be position in the top left corner. This positioning makes it difficult for a company to maintain a competitive advantage as the setup does not work for complex production processes, IP protection, or exploiting economies of scope. Small companies with

niche products might be in this situation. Therefore, we believe that companies that operate supply chains off the diagonal will need to have a good reason for doing so.

Pursuing the goal of residing on the diagonal compels companies to rethink the structure of their supply chain processes. In particular, they must determine their degree of heterogeneity, i.e., where they land along the continuum defined by the options of multiple independent supply chains, shared services, central guidance, or one size-fits-all. This analysis may also stimulate a rethinking of the extent of outsourcing/vertical integration. This requires determination of where they land among options that include an arm's length relationship with suppliers, coordination with key partners, investing in highly integrated systems with partners, active aligned collaboration of strategic partners, and ownership investments in vertical integration. The framework allows for a design of a global supply chain to balance the trade-off between efficiency and resilience through the choices regarding the extent of ownership of activities (vertical integration) and organizational structure and planning processes (heterogeneity of supply chain processes).

At the same time, organizations can use the "Triple-P" framework (which we also refer to as the "Bespoke Supply Chain Resiliency" framework) in their efforts to build resilience. For this purpose, we identified obstacles to implementation that are peculiar to each identified archetype. The major obstacles for the "Product complexity" archetype unsurprisingly relate to factor market limitations, due to the highly specialized facilities and skill sets, which increase the degree of difficulty for diversifying the production footprint. Infineon, the German semiconductor company, is a company with this archetype. Adding production capacity involves high upfront investments and takes 6–12 months with existing buildings or up to 3 years for a greenfield factory. Moreover, access to a pool of highly skilled employees and talent is needed.

Furthermore, the "Process complexity" archetype suffers from the organizational complexity of diverse supply chain processes and the challenges of managing multi-tiered supplier tree structure with limited visibility and control in the deeper tiers. Such organizations need to effectively balance continuously shifting efficiency and resilience trade-offs. Their complex supplier portfolios often involve sourcing from environments with weak infrastructure and loose regulations (e.g., vis-à-vis treatment of workers and the natural environment), often with small-and-medium size suppliers needing assistance with financing and process improvements. For example, the apparel business unit of Nike operates in a fragmented supplier market with many smaller specialized factories due to the great variety of materials and clothes. Due to the pandemic-related drastic demand drop for apparel in 2020, Nike developed a grading framework to decide which suppliers they are able to "save" through prioritization of the remaining orders and supply chain financing.

Finally, the "Partner complexity" archetype may have to overcome the obstacles faced by both the "Product complexity" and "Process complexity" archetypes that present at more modest intensities. The resources available to support their needs for some owned facilities close to their customers limits the extent of regionalization. Reliance on highly qualified mid-tier partners demands their attention to careful selection, qualification, and integrated planning. At the same time, product

portfolios that mix engineered-to-order and consumer products can stretch their organizational support for supply chain processes. However, the key challenges for these supply chain integrators are partner relationship management and the need for deep visibility into their supply and logistics resources. For example, BMW uses a supply chain and logistics platform to monitor all materials and suppliers in lower tiers to do fast root cause analysis, quickly escalate potential disruptions, and initiate countermeasures. The platform is run by a cross-functional team of procurement and logistics experts and helps BMW to use its competitive power to influence the decisions of their suppliers when issues occur. Moreover, BMW also collaborated with key suppliers during the COVID-pandemic through worker sharing concepts to keep the lines of their suppliers running.

Executives that understand the Triple-P framework (Fig. 2) will know how operational attributes position a business within a cluster (Product, Partner, or Process archetype), obtain a path to enhance resilience, and identify implementation obstacles peculiar to each cluster. We summarize the nature of the solutions we propose (Fig. 3) as follows:

"Product complexity" organizations have to deal with the challenges of major design and manufacturing facilities' footprint diversification. The challenges are financial investment, skilled labor requirements, and supplier network availability in support of geographic diversification. As a result, digitalization of their supply chains and automation has a high priority. At the same time, they must pursue public (potentially government based) and private partnerships to create the needed diversified network.

"Process complexity" organizations have to address the complexity of their portfolio and processes. Their resilience depends on reduction of this complexity. We refer to this as an effort of "standardization," but note that it is far from the usual levels of expected lean standardization. It is imperative for them to rethink their complex multi-tier supplier structures and reassess where the search for low cost has compromised visibility and response flexibility. While the necessity of complexity driven by their diverse product markets will remain, these organizations have to find ways to support their planning processes through investments in integration technologies, financing support of their suppliers, and ESG initiatives in developing country sourcing locations.

"Partner complexity" organizations have to mix the above solutions for the two extreme archetypes. While the complexity of their product portfolio needs to be reassessed, their multi-tier structure and number of suppliers also requires careful revisiting. Emphasis on creating the right "premium" tier partners with aligned incentives, collaboration processes and end-to-end visibility across carefully orchestrated supply chains is what we refer as the "visibility enhancement" solution. In this case current digitalization technologies will drive investments for these organizations, and the pursuit of ESG initiatives will allow them to both narrow and select the qualified partners they need. Moreover, similar to the "product complexity" businesses, they will be challenged in expanding their owned facility footprint in pursuit of intended regionalization strategies.

5 Challenges for Research on Global Supply Chain and Resilience

With the disruptions caused by either natural disasters such as the COVID-19 pandemic or earthquakes, or geo-political frictions such as tariff wars and trade policy disagreements, the general public's awareness of the impact of such disruptions on supply chains for goods and services has increased significantly. This has led to a steady stream of academic and industry reports on operations strategies and supply chain redesigns that promise to enhance resilience.

While we welcome the increased interest, we note that many of these studies have severe limitations in their research design and analysis. In this section, we discuss some common pitfalls and limitations. This section is meant to encourage future research by suggesting how it can become more credible and therefore more impactful.

Most studies have been based on questionnaires completed by industry practitioners (Cohen et al. 2022). For online surveys, a response count in the hundreds or even thousands is not uncommon. However, the robust volume of responses might not provide meaningful information if the surveys are not designed properly. Below are issues specific to this domain.

The most critical detail to get right is the unit of analysis in these surveys. A large global company may have multiple product groups or divisions that have very different product and operating characteristics and therefore may utilize a portfolio of disparate supply chain strategies. When a representative of such a company participates in a survey, we do not know if this individual is answering for one specific, perhaps dominant, product, or instead has in mind some "composite" of all the company's supply chains. The survey's instructions must make clear the unit of analysis. Our resilience strategy research (Cohen et al. 2021a) is based on product group level data, and we clarified the unit of analysis upfront with the interviewees.

A common question in many of these surveys was on how companies would change the design of their supply chain, possibly through reshoring or more diversified sourcing. The respondents might be reporting on intent at that point in time, which might not translate into real action. For example, we have seen study results reporting that a certain fraction of the respondents adopted reshoring, when the data actually indicate that a different fraction of the respondents were *intending* to reshore. Sections 3 and 4 articulate obstacles that prevent companies from implementing their desired supply chain strategies, so we also do not know if a respondent is describing the supply chain his/her company aspires to or the one that is actually in place.

Some surveys try to capture the decision process or the logic behind certain decisions. A response would be meaningful only if the respondent was very close to the decision, or perhaps was a very senior executive with ownership of the decision. Yet we have seen surveys being completed by mid-level managers who might not have a complete perspective, making their responses somewhat speculative. To overcome this issue, in our data collection documented in Cohen et al. (2021a),

we interviewed only top-level supply chain executives well-positioned to discuss the topics at hand.

To the extent possible, surveys should obtain information about the operating characteristics of each respondent's organization and product offerings. For example, what is his/her position in the supply chain being described? What is the extent of vertical integration versus outsourcing? (This question is more involved than might be apparent at first glance, as many functions are involved in operating a supply chain, and each one can separately be performed in-house, outsourced, or somewhere in between.) What does the company's supply base look like? What is the company's distribution channel strategy? What is the product mix that flows through the supply chain in question? We have seen studies in which all the responses were aggregated into summary results, without concern for the kinds of operating characteristics mentioned above. Our "Triple-P" framework explicitly factors the operating characteristics, e.g., for example, "Availability of potential suppliers" and "Homogeneity of product portfolio," into the choice of resilience strategy (Cohen et al. 2021a).

The previous point cautions against over-aggregation of the response data. We also advise care in the choice of how to segment the data for analysis and reporting. For instance, one common approach is to present results by industry, which is not without merit. However, some companies can be difficult to place into a single industry categorization. Beyond that, a company's product groups can be quite disparate, requiring different supply chain strategies. Even if you accept the placement of Nike into the sports apparel category, Nike's shoe, clothing, sports equipment, and electronics businesses face very different challenges and constraints. In terms of survey design this is really a manifestation of the "unit of analysis" issue discussed earlier.

Moreover, surveys should not ask yes-no questions (e.g., do you reshore or not?) without specifying how much reshoring is needed for the answer to be yes. And then you would want to capture the amount of reshoring respondent by respondent so you can aggregate properly. For example, when a survey says 10% of the respondents were reshoring, we do not know if this set of companies reshored just a small fraction of their manufacturing, or reshored a substantial fraction. Unless a survey was designed to get to that level of detail, the 10% figure is not very useful.

Most studies build up to a denouement that takes the form of a list of recommendations. We do not disagree with the vast majority of the individual recommendations we have seen, but find them problematic when presented as a list without prioritization that is tailored to the individual case, given that some of the recommendations might directly conflict with others. For example, we have seen recommendations that call for both reducing risk exposure by reshoring and diversified sourcing. Of course, customized advice can be offered only if the survey collected sufficiently detailed information from each respondent, but attempting to do goes beyond the scope and purpose of a survey.

We also note that actual performance outcomes of recommended or adopted strategies are rarely documented. In some cases, the questions in the survey were not sufficiently detailed to perform a deeper analysis. For example, simply asking

whether your inventory increased or decreased due to your actions has limited value. An increase in inventory could indicate positive or negative performance depending on the underlying reason (good planning and strong relationships with suppliers enabled preferential access to materials during a shortage, versus mis-forecasting that leads to overstock of the wrong items).

6 Finding Appropriate Resilience Measures

The old saw "What you can't measure you can't improve" certainly applies to the pursuit of supply chain resilience. While the literature fully comprehends traditional process improvement and agility measures, there is a need for well thought-out supply chain resilience metrics that take the long-term perspective appropriate for assessing resiliency.

The supply chain function uses metrics that are mostly operational (e.g., On-Time-In-Full order deliveries (OTIF), fill rates), along with some asset-turn measures that link to financial performance (e.g., inventory turns). Traditional metrics are meant for short-term evaluations (e.g., how good is your customer service, what is the lead time to customers, how much is spent to expedite shipments). Investments to improve these metrics can produce results quickly (e.g., centralization of inventory would reduce inventory through pooling, design for postponement can reduce inventory while improving customer service, using digital technologies to improve forecasting can improve SC metrics). However, investments in resilience may require a longer time horizon to show positive impact. Further, in as much as investing in resilience is analogous to buying insurance, the costs might be ongoing with no guarantee ever being offset by a positive payoff. But if the catastrophic event ever does happen, you would be glad to have made that investment.

This section describes the measures supporting our Triple-P framework for achieving "bespoke resiliency" in global supply chains. These measures focus on three stages of the chronology, including the last category, which is the necessary postmortem that we feel has received inadequate attention in the discussion of resilience:

"Ex-ante agility planning" measures, which identify key vulnerabilities, and ensure the right asset investments and operational hedges are in place to guard against anticipated future disruptions.

"Agility of actual response" measures, which gauge the effectiveness in monitoring the arrival of a disruption and the agility of response.

"Exhibited true resilience" measures, characterizing the totality of recovery in terms of financial performance, customer service, time to stabilize organizational processes, and growth over competitors across potentially multiple disruptive events and for longer horizon (3–5 years).

What is frequently recommended by the literature, and what might be easier to put in place, is what we refer to as "agility" planning metrics (some others call these "resilience" or "contingency response" metrics, but they do not fit our definition of resilience in Part 2) such as the following: Time-to-Recovery (TTR), Time-to-Survive (TTS), and Expected Profit Loss (EPL)(Simchi-Levi et al. 2015, 2018). We can assess these at every node in the supply chain, where a node could be a process or facility or other key asset. These measures are easier to compute when the scope is internal to the measuring party, and more difficult when examining external suppliers and service providers. The assessment should ask the following questions:

If a disruptive event takes out one of the nodes, how long will it take for the node to recover to different levels of operational capacity (with 100% recovery used to measure TTR)?

For how long do the existing operational hedges (mostly redundant capacity or inventory buffers within the supply chain) allow the supply chain to continue serving customers (TTS)?

And, if fully serving customers is not possible, how much is the expected profit loss (EPL) (includes both short-term and long-term)?

We highly recommend using these agility-planning metrics across the supply chain to quickly identify and prioritize the vulnerabilities. This will drive preemptive actions to increase redundancy, such as inventory and capacity buffer increases, multi-sourcing, or footprint diversification, as well as modifying product designs and/or product line.

After the recovery from the disruptive event, "agility of actual response" measures will reveal failures in planning processes, partner inadequacy, and ineffective investments and operational hedges. These metrics should be monitored and aggregated over time, such as the "time of sustained shortages."

When reported to an organization's leadership and investors, measures of exhibited true resilience can motivate and justify the long-term investments in resiliency that can support long-term profitability, better servicing of customers, and market share growth.

Our Triple-P "bespoke resiliency" framework can help with the implementation of resilience metrics in the following areas:

1. An organization's position relative to the diagonal in Fig. 4 helps identify organizations to use as benchmarks vis-a-vis relevant "agility response metrics."
2. Just as the resilience strategies reflect whether a supply chain's major complexity is in process, partnerships, or product, so should the performance metrics. When process complexity dominates, measuring and controlling the complexity of the processes, becomes important. For example, measuring product modularity, the percentage of standardized components, or the percentage of multi-purpose of production facilities are metrics that are especially helpful for this type of supply chain. When partnership complexity dominates, attention turns to measures related to the effective shifting of sourcing to key premium supply partners, especially ones that encourage effective collaboration with these partners on

scenario planning and risk management. Examples would be supply chain visibility metrics that measure the quantity and quality of information sharing across tiers, e.g., up- and downstream inventory levels. Finally, when product complexity dominates, the key measures will reflect access to critical input materials, manufacturability of the product designs, and degree of diversification of the facilities' footprint. An example of such a metric is the percentage of dual sourcing or dual site sourcing of critical supplies.

7 Summary of Our Research Insights

Our group of supply chain scholars embarked on a research path to understand how the last 10 years have shaped global supply chains. This section summarizes our main learnings.

1. Is reshoring of production activities happening in North America and Western Europe? If so, what has been the role of trade and political changes of the last decade?

   Our work published in Cohen et al. (2018) offers the answer. While investment activity in manufacturing in these markets has increased, the primary investors are foreign firms are also seeking proximity to customers in these attractive markets. For Western European and North American firms, even import tariffs on raw materials or finished goods did not stimulate substantial reshoring activity, and in a few cases, the increased sourcing costs and/or retaliatory tariffs drove companies to expand in their foreign-based competitors' territories.
2. How have trade tariffs and the COVID-19 pandemic affected attitudes regarding China as a sourcing location?

   Global supply chain managers realized the significant risks due to their extensive dependence on China. Recent times have seen cost increases due to trade tariffs and expensive logistics (on top of the ongoing erosion of China's ability to provide a seemingly endless supply of inexpensive labor), leading to shortages and longer lead times resulting from COVID's impacts on China's ports and manufacturing facilities. For some industries (e.g., apparel, toys), finding alternative sourcing locations is rather easy and often multi-sourcing has already started. But for others, China's available production capacity, ability to ramp to volume for new products, and their multi-tier-deep ecosystem of qualified suppliers erect formidable barriers to switching to new sources in the short-term. The "China Plus One" compromise sourcing strategy has been a goal for some time for certain industries, but progress has been slowed as COVID's impact was obviously not limited to China.
3. To what extent do companies prioritize resilience in designing and executing their supply chain strategies? Do we see active commitment to resilience after 2019?

   The increased frequency of disruptive events combined with increased severity of the last 10 years (2011 Japanese earthquake and tsunami, 2011 Thailand

flooding, 2017 Hurricane Harvey, etc., and the COVID-19 pandemic being an event of unprecedented magnitude) has sensitized companies and managers to disruption risks. Many organizations remain in a survival and short-term response mode as of this writing, measuring any reasonable response as a success with the usual measures of agility (TTR and profit loss). However, in our framing, resilience involves thinking about the long term, and using lessons of past events to inform strategies and resource investments that will prepare their supply chains to survive and even thrive in the face of knowable and unknowable future shocks. We have empirically identified substantial obstacles to enhancing resilience, even though in many cases the roadmap to that destination is readily available and well understood. After the recovery from a disruptive event, managers and financial markets prefer to think about the next quarter's performance. We hear a lot about resilience, but we often do not see the actions needed to build the necessary redundancy and operational flexibility. These actions are perceived to be too "expensive" in the eyes of investors and markets.

4. What is our advice to supply chain managers about building resilience for the current uncertainty-fraught environment?

   Our research is very clear in eschewing a "one-size-fits-all" answer. Modern supply chains are diverse and complex, and each supply chain's product, process and organizational attributes will dictate its resilience strategies. The mapping articulated by our "bespoke resiliency" Triple-P framework is a key contribution of our empirical research. Thus, our advice to managers is to use the framework as follows:

   (a) Position your supply chain along the dimensions of "supply chain process heterogeneity" and "degree of vertical integration." This will affiliate your supply chain with one of three archetypes: Product complexity, Partner complexity, and Process complexity.
   (b) Assess the gap between your current supply chain and the recommendations of our framework for the archetype. This analysis might call for greater standardization of processes, gaining better control through increased ownership of activities, or working more closely with trusted partners.
   (c) Based on your positioning, understand the main obstacles for achieving resilience. Then study the best practices for increasing resilience of this archetype. Some adaptation for your environment will be necessary.
   (d) To monitor the progress towards resilience, use the metrics described in our Sect. 5.

Consulting reports tend to write their recommendations at an industry level and suggest that companies should emulate the approaches of the "Top 25" world-class companies as distilled into a list of 10–15 points. This perhaps caters to the tendency of top executives to prefer uniformity of practices and measures. But this is not consistent with what our research leads us to recommend. Global companies typically manage a complex portfolio of products and serve a diversity of markets, requiring that different business units and their managers pursue resilience in a bespoke fashion.

5. Are lean production and supply chain practices inappropriate when resilience is a priority? Should companies increase inventories and install excess (i.e., underutilized) capacity to prepare for future disruptions?

In the eyes of the media and popular press, the supply chain failures during the COVID-19 pandemic are an indictment of lean principles and practices. This viewpoint at best lacks nuance and may also simply misunderstand lean production. Our Triple-P framework argues that lean practices actually enhance resilience for at least two of the archetypes. This is not an issue for the Product complexity archetype. For the Product complexity archetype, resilience is built into the product design, automation of processes, excess capacity that is funded by high margins, and strong relationships with a small circle of qualified suppliers. The need for inventories is primarily at the input material level, and global access to these inventories might be constrained in some disruptions.

For the Partnership complexity archetype, which relies on a few key partners for success in general, resilience comes from strengthening these relationships, visibility into partner operations, and coordination in responding to any disruption. High interdependency, short lead time, a committed relationship with keiretsu suppliers are actually key elements of the Toyota Production System that is known more broadly as lean production. Toyota and its suppliers problem-solve cooperatively during stable times and crisis times alike. After 2011's devastating Japanese earthquake, tsunami, and brush with nuclear disaster, which disabled almost 90% of production capacity at car companies like Toyota and Nissan, Toyota was able to fully recover in unexpected ways in less than 3 months. The current pandemic has caused shortages in semiconductor chips that have become critical components in automobiles, but these companies have thus far derived some level of protection from their proactive planning and strong partnerships with suppliers. Lean processes, continuously improved, supported by a culture of attention to quality and deep commitment to relationship with suppliers, have proven to be resilient.

The same holds true for the Process complexity archetype. Some of their products are functional, and true lean supply chains, with characteristics to the above, will quickly recover without huge buffer inventories. Buffers buy short-term agility, but visibility and collaborative problem-solving buy future resilience. The implementation challenges for this archetype are: suppliers are smaller and less visible, frequently undercapitalized and located in areas with weak infrastructure. A larger number of suppliers in diversified locations may be necessary. It is important to help the existing suppliers finance their inventories and allocate business or even provide infusions of capital to sustain the suppliers through the difficult disruption periods. These gestures build trust and loyalty that translate into supply chain resilience. Lean supply chains do tend to lack flexibility in shifting among products. Moreover, lean does not necessarily advocate for extremely focused efficiency by product, and practicing lean practices such as "heijunka" improve mix flexibility. Lean principles adapted to the needs of the different archetypes can achieve efficiency, quick response in delivery, and fast recovery from crises. This is true resilience.

8 Future Research Directions

We outline some open questions in this exciting and timely area of supply chain resilience that we hope that our community will address.

1. Empirical validation of our Bespoke Resiliency Triple-P framework

   Our framework suggests multiple hypotheses concerning the relationship between operational attributes and effective resilience strategies. We hope these hypotheses can be verified through study of a larger data sets of company operating data. This will entail fleshing out ex-post resilience measures that reflect ex-post performance of companies over longer periods (5–10 years) and using them to objectively assess actions intended to enhance resilience as well as operational and financial performance.
2. Empirical validation that processes and supply chains which operated according to true lean principles are resilient.

   We can make an anecdotal case that lean practices implemented for reasons of competitiveness and profitability have also enhanced resilience (which should not be surprising if resilience is in fact critical to long-term competitive and profitability). Central to that is understanding that lean does not see the capacity and inventory levels as decision variables to be lowered to make the financials look good, but rather as outcomes whose correct levels will naturally move lower as organizational processes and problem-solving capabilities improve. That is, lean is not about choosing to reduce capacity and inventory levels, but rather improving the system so that lower levels of these resources are the right outcome.
3. How will design-for-resilience be affected by near-future challenges and opportunities in global supply chains?
4. Almost all agree that digitization (through technologies such as IoT, blockchains, robotics, machine learning, 3D printing, etc.), ESG requirements and realities (sustainability concerns, climate change, labor conditions, safety regulations, etc.), and an environment with increased political risks will force executives to rethink their global supply chain strategies. Modelling and optimization approaches for capturing global supply chain resilience are necessary

We argued that the best way to make global supply chain decisions that effectively capture relevant objective trade-offs, reflect different cost and exchange rate scenarios, include logistic and other constraints (labor availability, supplier locations, etc.), is to formulate optimization models capturing such issues (see Cohen and Lee 1989; Huchzermeier and Cohen 1996; Kouvelis et al. 2013). But what is the best way to capture this longer-term perspective of resilience suggested by our recent work, in structured mathematical programming formulations? Resilience is not the responsibility of a single firm, or even of the traditional linear supply chain for a product group. Resilience depends on other supplier and distribution partners in complex dynamic networks. It often involves unexpected and hidden bottlenecks beyond the control of the firm or the supply chain (ports,

trucking and shipping regional capacities, limited resources on a global scale for certain inputs, etc.), and all such concerns have to be captured in a longer time horizon with considerable uncertainty.

The frameworks introduced by our research and described in this chapter offer suggestions for directions for companies to pursue in the pursuit of resiliency. Further research is required to understand the impact of the strategies that are adopted.

References

Cohen MA, Kouvelis P (2021) Revisit of AAA excellence of global value chains: Robustness, resilience, and realignment. Prod Oper Manag 30(3):633–643

Cohen MA, Lee HL (1989) Resource deployment analysis of global manufacturing and distribution networks. J Manuf Oper Manag 2(2):81–104

Cohen MA, Lee HL (2020) Designing the right global supply chain network. Manuf Serv Oper Manag 22(1):15–24

Cohen MA, Cui S, Ernst R, Huchzermeier A, Kouvelis P, Lee HL (2018) Benchmarking global production sourcing decisions: Where and why firms offshore and reshore. Manuf Serv Oper Manag 20(3):389–402

Cohen MA, Cui S, Doetsch S, Ernst R, Huchzermeier A, Kouvelis P, Lee HL, Matsuo H, Tsay AA (2021a) Bespoke supply chain resilience. Stanford University Graduate School of Business Research Paper. https://ssrn.com/abstract=3873941

Cohen MA, Cui S, Doetsch S, Ernst R, Huchzermeier A, Kouvelis P, Lee HL, Matsuo H, Tsay AA (2021b) Putting supply chain resilience theory into practice. Manag Bus Rev. https://doi.org/10.2139/ssrn.3742616. https://ssrn.com/abstract=3742616

Cohen MA, Cui S, Doetsch S, Ernst R, Huchzermeier A, Kouvelis P (2022) Maximizing learning from surveys on supply chain agility and resilience. Why Operational Context Matters: Realizing the Full Potential of Supply Chain Resilience Surveys https://ssrn.com/abstract=4074109 or http://dx.doi.org/10.2139/ssrn.4074109 Forthcoming Supply Chain Management Review

Dachs B, Kinkel S, Jäger A (2019) Bringing it all back home? Backshoring of manufacturing activities and the adoption of Industry 4.0 technologies. J World Bus 54(6):101017

Dong L, Kouvelis P (2020) Impact of tariffs on global supply chain network configuration: Models, predictions, and future research. Manuf Serv Oper Manag 22(1):25–35

Fratocchi L, Di Mauro C, Barbieri P, Nassimbeni G, Zanoni A (2014) When manufacturing moves back: concepts and questions. J Purch Supply Manag 20:54–59

Hopp WJ (2011) Supply chain science. Waveland, Long Grove, IL

Huchzermeier A, Cohen MA (1996) Valuing operational flexibility under exchange rate risk. Oper Res 44(1):100–113

John G, Manenti P, Watt S, Raman K (2020) Future of supply chain: crisis shapes the profession: supply chain executive report. Gartner. https://www.gartner.com/en/documents/3994949/supply-chain-executive-report-future-of-supply-chain-cri. Accessed 15 Feb 2022

Kouvelis P, Munson CL, Yang S (2013) Robust structural equations for designing and monitoring strategic international facility networks. Prod Oper Manag 22(3):535–554

Lee H (2004) The triple-A supply chain. Harv Bus Rev 82:102–112, 157

Pfeffer J, Sutton RI (2000) The knowing-doing gap: How smart companies turn knowledge into action. Harvard Business School Press, Boston, MA

Sheffi Y (2007) The resilient enterprise: Overcoming vulnerability for competitive advantage. MIT Press, Cambridge, MA

Simchi-Levi D, Schmidt W, Wei Y, Zhang PY, Combs K, Ge Y, Gusikhin O, Sanders M, Zhang D (2015) Identifying risks and mitigating disruptions in the automotive supply chain. Interfaces 45(5):375–390

Simchi-Levi D, Wang H, Wei Y (2018) Increasing supply chain robustness through process flexibility and inventory. Prod Oper Manag 27(8):1476

Springer Series in Supply Chain Management

Hau Lee
Ricardo Ernst
Arnd Huchzermeier
Shiliang Cui *Editors*

Creating Values with Operations and Analytics

A Tribute to the Contributions of Professor Morris Cohen

Springer

Springer Series in Supply Chain Management

Volume 19