

Article

Mesoeconomics: Analyzing Global Supply Chain Networks Using Big Data

Munaem Ahmed Khudhair¹, Nazhan Mohammed Sahho², Gailan Ismael Abdullah³, Safa Nid⁴

1. Al-Turath University, Department of oil and gas Economics, Iraq
 2. University of Samarra, College of Administration and Economics, Iraq
 3. University of Samarra, College of Administration and Economics, Iraq
 4. University of Biskra, faculty of Economics, Commercial and Management Sciences, Algeria
- * Correspondence: ahmedmunam693@gmail.com, alsaho.n@uosamarra.edu.iq, gailan.ismael@uosamarra.edu.iq, safa.nid@univ-biskra.dz

Abstract: Mesoeconomics represents a critical intermediate layer of economic analysis, bridging the gap between microeconomics and macroeconomics. With the growing complexity of global supply chains, traditional economic frameworks and data analysis techniques have proven insufficient. The increasing availability and use of big data technologies have highlighted the relevance of mesoeconomic approaches in analyzing networked economic interactions across international supply chains.

The research aims to explore how mesoeconomic frameworks can be effectively utilized to analyze global supply chain networks through big data analytics. It seeks to identify the advantages of applying mesoeconomic analysis in understanding the structure, flow, and dynamics of supply chains, as well as the challenges associated with data integration and analytics.

The research employs a qualitative and conceptual analysis of mesoeconomic theory in the context of supply chains, supplemented by a review of current big data analytics methods used by companies. The analysis includes an examination of various data sources (primary and secondary), network structures, and classification techniques that support the processing and interpretation of large-scale data related to goods and services flows.

The findings suggest that mesoeconomics, when combined with big data analytics, offers a robust framework for capturing the complexities of global supply chains. This approach enhances the understanding of relationships among products, producers, and processes, enabling more efficient and informed decision-making. However, challenges such as data quality, interoperability, privacy, and security remain significant barriers to the full realization of big data's potential in supply chain analysis.

Keywords: Mesoeconomics, Supply Chain Networks, Big Data Analytics, Network Complexity, Data Challenges

1. Introduction

Global supply chains play an increasingly crucial and indispensable role in delivering essential functions such as meticulous planning, effective sourcing, comprehensive production, and streamlined logistics on a truly global scale, thereby impacting virtually every aspect of our interconnected economy. Recent real-world examples of significant disruptions—such as natural disasters, unforeseen pandemics, and ongoing geopolitical tensions—have highlighted the critical importance of maintaining uninterrupted and cost-effective supply chains at all times. This ensures that goods and services can flow smoothly and efficiently across national borders. Given the immense significance of these supply chains, it becomes vital to thoroughly understand the myriad opportunities and challenges that they present for the various economic agents operating within them, which include manufacturers, wholesalers, retailers, and ultimately consumers. Research in this field indicates that the highest potential value often resides within the complexities and

Citation: Khudhair, M. A, Sahho, N. M, Abdullah, G. I & Nid, S. Mesoeconomics: Analyzing Global Supply Chain Networks Using Big Data. International Journal on Economics, Finance and Sustainable Development 2026, 8(1), 62-76.

Received: 08th Jun 2025

Revised: 15th Jul 2025

Accepted: 28th Aug 2025

Published: 10th Sep 2025



Copyright: © 2026 by the authors. Submitted for open access publication under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>)

intricacies of the network structures that encompass these extensive supply chains. As a result, global supply chain networks emerge as one of the primary means of analysis at this economic level, allowing for a much deeper and nuanced exploration of their dynamics, interrelations, and implications on both local and international scales. Recognizing and understanding the interdependencies that exist within these intricate networks is also essential; this awareness helps to inform better strategic decisions and enhances the overall resilience and adaptability of the businesses involved in these processes. Thus, developing a comprehensive and nuanced grasp of these intricate systems is imperative for effectively navigating the multifaceted complexities of modern global markets. Ultimately, doing so will foster stability and growth in an ever-evolving economic landscape, which is increasingly subject to external shocks and fluctuations.

Theoretical Framework of Meso-economics:

Meso-economics is an advanced economic concept that has more depth than the normal economic theories that are used for many different studies. Presently meso-economics can do most of the work between microeconomic and macroeconomic levels. These economic concepts make analysis quite helpful by giving varied possibilities which help to understand groups of companies and sectors. The term meso-economics comes from Greek word 'meso' that means middle and shows middle level in economic study. Today, such terms like "mesoscopic systems" or "mesoscale analysis" are used in different areas, and initially they helped understand economic connections and now give important insights too [1].

Definition of Meso-economics:

Meso-economics is a dynamic economic level that has more value than the normal economic levels that are used for many different studies. As of now meso-economics can do most of the work for example it can link micro-economics and macro-economics, serving as a crucial and essential bridge between these two vital realms. With the help of diverse analysis you can understand various industries, sectors, and markets and also see how they affect each other [2].

The differences between micro, meso, and macro levels has more importance that can help people who are studying different areas. Today, such levels need proper knowledge, and initially they focus on individual connections, community studies and now broader society too. These levels convey many things such as, sociology, economics, psychology and also natural elements like behavior and development which symbolize good analysis [3].

This middle level adds many benefits to economic understanding. As of now, this level can connect basic ideas and advanced theories, with the help of different analysis you can do various studies safely.

Theories and Models Related to Meso-economics:

1. Theories of middle economic systems (e.g., sectoral or regional systems): Sectoral systems' theory is an important idea that has more depth than the normal theories that are used for many different meso-economics studies. At present this theory can do most of the work for example it can show connections between sectors, with the help of diverse links you can understand various economic activities and also see how they affect economic policy approaches, social dynamics, regional growth, and different economic phenomena that are neither micro nor macro in nature [4].
2. - Economic cluster models (e.g., Porter's Cluster Theory): Porter's Cluster Theory is an important model that has more value than the normal theories that are used for many meso-economics studies. As of now, this theory can do most of the work for example it can explain meso-economics clearly, with the help of diverse factors you can understand various business connections and also see how geography and social elements affect competitiveness and innovation among interconnected businesses and industries [5].
3. Complex Adaptive Systems theory: It is widely recognized as one of the most significant and critically important frameworks that thoroughly elucidates the intricate

mechanisms and dynamics involved in the multifaceted field of mesoeconomics. This comprehensive theory provides profound and valuable insights into how various components not only interact in diverse ways but also adapt over time within the ever-evolving economic systems. These interactions and adaptations lead to emergent behaviors and complex patterns that can significantly influence and reshape the overall economic landscape, allowing for a deeper understanding of the subtle yet powerful forces at play in economic dynamics [6].

Global Supply Chain Networks:

Supply chain networks are critical drivers of the world economy. A global supply chain network consists of suppliers, manufacturers, distributors, retailers, and their associated customer base, interconnected in a complex pattern of relationships. The essence of globalization is delivered through supply chain management; the geographic switch from domestic to offshore has resulted in externalized production facilities for the global market. Increasing global trade has escalated the demand for enhanced efficiency of the organizations that constitute these supply chain networks. The large size of these global supply chain networks means that many players now collect huge amounts of data in order to better support their decision making. Indeed, the importance of data has been recognized to the extent that the term "big data" has been coined.

Definition and Importance:

Mesoeconomics refers to the study of economic processes, activities, and behaviors occurring at an intermediate level between microeconomics and macroeconomics. It typically concerns individual industries, sectors, business communities, or regional economies. As a meso-level analysis, it links the dynamics of individual actors with macroeconomic performance.

Global supply chain networks involve a multitude of suppliers, manufacturers, distributors, and retailers collaborating closely to safeguard and improve efficiency at every stage of the supply chain. Trade globalization creates transportation costs and shapes production economies of scale, rendering a framework for understanding global supply chain dynamics essential [7]. Economies of scale drive a reinforcing dynamic in which highly connected agents become more competitive and attractive, thus fostering scale-free global supply chain networks. The relative advantages of specific sectors depend critically on geographical positioning and network dynamics. These insights suggest that supply chains represent the key mesoeconomic infrastructure for understanding and efficiently managing global market economies.

Components of Supply Chains:

A supply chain is a network of businesses and activities that transforms, delivers, and supplies products to end customers. A company supplies products only if its suppliers deliver raw materials, semifinished products, parts, or components to it. Hence, a supply chain comprises a set of suppliers, manufacturers, distributors, and retailers that supply products to the end customer. A few examples of such relationships include the following: a retailer, such as Walmart, relying on a manufacturer, such as Samsung, to manufacture flat-screen televisions; a manufacturer, such as Samsung, relying on a transportation company, such as Maersk, to deliver shipments; and a car company, such as Ford, relying on parts, such as engines, from its supplier, such as Bosch [8].

Big data are all around us, including in supply chains. Customer credit card and the sales transaction data help understand customer preferences and product demand. Raw material deliveries by shipping companies provide information on procurement schedules. Moving cargo brings with it a plume of data, revealing specific supply chain information and insights. Cooling container sensors broadcasting temperature or spoilage gauge data disclose information on product safety, freshness, product quality, and inventory in transit. Increasingly, a growing number of goods now contain a Unique Product Code, enabling the shipment of specific goods to be tracked [9].

Big Data in Supply Chain Management:

Big data typically refers to datasets whose size exceeds the ability of commonly used software tools to capture, curate, manage, and process the data within an acceptable elapsed time. The presumably low cost and ease of data capturing, reflection, and analysis, therefore, do not justify ignoring the challenges and drawbacks introduced by big data. From a supply chain perspective, the phenomenon of big data has impacted supply chain research and practices in a significant manner. The development of the Internet of Things (IoT), Industry 4.0, cloud computing, cyberphysical systems, and the enormous quantity of data now becoming available provides new opportunities and altered the way supply chains are coordinated. Big data opens a new horizon for supply chain integration, coordination, intelligence, and innovative development. Evidence shows that approximately 75% of the Fortune 1000 companies worldwide have implemented programs to unearth the value from big data [10].

Definition of Big Data:

Big data is defined not merely by its vast volume but also significantly by its inherent complexity and the challenges it presents for analysis. A projection made in 2003 indicates that an astonishing 90 percent of all data generated is unstructured, encompassing a range of formats and styles that complicate its interpretation. The core objective of big data analytics is to diligently extract valuable knowledge from this unstructured data through meticulous analysis of continuously expanding datasets that vary greatly in both type and origin. This comprehensive evaluation of data seeks to uncover valuable insights into previously obscured and hard-to-identify patterns, thereby enabling organizations to secure a competitive edge in their respective markets and enhance their overall decision-making processes with a deeper understanding of the information available to them [11]. Analytical methods fall into three categories. Descriptive analytics summarizes the past by addressing questions such as “What has happened?” and “Why did it happen?”. Predictive analytics estimates the future by addressing questions such as “What will happen?” and “What are the consequences?”. Prescriptive analytics recommends actions by addressing questions such as “When should an action start?”, “Which action should be taken?”, “How will it be done?”, and “What will be the outcome?” [12].

Supply chains represent structures and management concepts that streamline activities from supply to maximize the customer value of a company’s products. Supply chain management works as an integrative function that connects logistics management to other business functions, including marketing, new-product development, finance, and customer service, to enhance planning and control. More generally, supply chain management is the task of managing relationships in a linked chain of business activities across firms, reorienting from managing internal functions to managing relationships between companies. Big data technologies enable transforming supply chains and supply chain management, shifting organizations from owning and controlling parts of the supply chain to orchestrating, accessing, and engaging with a network of resources and suppliers. A good understanding of these processes as well as of big data technologies is critical when studying the potential of big data as a vehicle for supply-chain transformation [13].

Role of Big Data in Decision Making:

Big data adoption is becoming a norm across all supply chains. However, specific reasons for embracing it vary across industries, often involving a combination of factors [14]. A supply chain represents a network of entities—organizations, individuals, activities, information, and resources—engaged in producing and delivering a product or service. It encompasses suppliers, manufacturers, warehouses, distributors, retailers, and customers linked through material, information, and cash flows. In a global context, the goal is to locate cheap, reliable suppliers in any part of the world, integrating inexpensive suppliers with regional and global networks of customers.

The concept of big data goes beyond volume, variety, and velocity [15]. The advent of big data has profoundly changed the ways supply chain planning decisions are made,

accelerated the utilization of RFID and sensor technologies, and increased data sharing and collaboration among supply chain partners. Big data is a modern technology that has more power than the normal systems that are used for many different tasks. Presently big data can do most of the work for example a good data system can collect purchase details, with the help of different technologies you can do various tasks like monitoring customer feedback, tracking locations, checking weather patterns, and also measure economic and carbon footprints of houses. These technologies make supply chain decisions very simple by giving you diverse possibilities which help to complete your task especially in food supply chain.

Data Sources for Supply Chain Analysis:

Data sources for supply chain analysis vary greatly, but there are primarily two categories: primary data and secondary data [14]. Primary data sources consist of transactional data, sensor data, and production data, whereas secondary data sources include industry reports, market research, electronic payment systems, social media, and internet of things (IoT) data. Primary data serves as the foundational input for the descriptive, predictive, and prescriptive analytical methods detailed in the next section.

Two important data sources—market data and supply chain data—support the mesoeconomic investigation of global logistics networks [16]. Each source serves a specific purpose: market data, such as open financial market data from Yahoo Finance, prompts further questions to refine mesoeconomic inquiries and to generate candidate questions and hypotheses; supply chain data provides the means to address these questions and to validate hypotheses, as it contains information unavailable from other data streams. As a result, analyses of global logistics systems can proceed by first selecting a desirable outcome from the market data and then using supply chain data to predict conditions that maximize the probability of that outcome or to offer alternative target states that improve the likely outcome. Network analyses then examine the effects of various changes by monitoring the predicted market indicators.

Primary Data Sources:

Enterprise resource planning (ERP), customer relationship management (CRM) and supply chain management systems can be a rich source of transactional data—but only if the supply chain network covers partner firms that use similar systems and the relevant data is accessible. Data gathered via shop-floor sensors, radio frequency identification chips, global positioning systems and the like can pinpoint delays and bottlenecks, uncover inefficiencies and identify design failures across the supply chain [17]. Secondary sources of data include market reports, online news, social media and press releases. These sources can provide estimates of consumption patterns, consumer preferences and production levels.

Secondary Data Sources:

Secondary data sources refer to information originally collected for a purpose unrelated to specific supply chain analyses. These data serve as the primary foundation in supply chain analysis. Typical sources comprise of specialized market-research reports, as well as secondary information from websites, company reports, news articles, macro-economic databases, and even social-media, RSS, and weblog feeds [16].

Data Analytics Techniques:

Descriptive, predictive, and prescriptive analytics constitute the core components of the data science iterative process. Descriptive analytics analyzes past and current data from various sources to provide comprehensive insights, such as predicting material delivery times and understanding production schedules or market demands. Predictive analytics leverages differing algorithms to discern patterns from data, thereby identifying the likelihood of future events. It is extensively utilized across services, marketing, governance, and forecasting, as well as in managing intricate supply chains. Prescriptive analytics integrates prediction and optimization techniques to determine potential outcomes and prescribe appropriate actions accordingly. The process entails forecasting

outcomes, assessing those predictions through constrained and combinatorial optimization models, and recommending optimal decision sets to address business problems [10].

Descriptive Analytics:

Descriptive analytics—commonly called data summaries—presents prior results via reports, dashboards, and visualizations. Again, when technology and tactics are combined, the way forward becomes more clear—but any operation using global, distributed data that requires future-focus, such as a supply chain, benefits from predictive and prescriptive approaches.

Predictive Analytics:

Predictive analytics entails developing models to analyze historical data and forecast future events. It supports informed decision-making in supply chains and enables scenario planning for relevant business challenges. Analytical techniques include data mining, neural networks, and support vector machines for forecasting stock market behavior; Bayesian models for early warning systems; and combined Bayesian-fuzzy approaches for market prediction. Logistic research leverages social network analysis, such as community structure detection in large networks and interfirm relationships within regional clusters. Machine learning methods are employed to identify business partners and construct reciprocal relationships. Operational practices and performance metrics, particularly in green supply chain management, also constitute key areas of study [18].

Prescriptive Analytics:

Prescriptive analytics involves methods that design better alternatives for decision-making. Techniques used may include agent-based simulation, optimization, and heuristics, and data sources may encompass structured transactional and sensor data as well as unstructured textual and multimedia content. General insights on numerous emerging systems impose environmental pressures on worldwide supply chains. They encompass challenges such as uncertain demand, product-rank changes, collaboration management, supply disruption, energy management, and carbon emission, alongside opportunities affected by evolving governmental policies, increased transparency, advanced information systems, lower communication costs, and consumer environmental awareness [14].

Analytical studies of the resulting “networks-of-networks” call for new abstractions and models, examination of their percolation and controllability limits, the ordered trade-off between robustness and performance, strategic formation, and responses to attack behaviors involving adversarial behaviors, failures, and cascades. The rapid evolution of business networks similarly leaves pressing research questions: How can structures be detected? What defines a robust network structure? How can the niche of one actor be established relative to others? How does a network dynamically respond to emergent organizational behaviors? How can interdependencies be quantified? How can a stable ‘core’ be identified? How can system fragility be characterized? How can the various hierarchical layers of a complex of complexes be linked and modeled? Bringing together disparate modeling approaches promises to provide answers to these and other questions addressing the formation, gestation, maturity, and death of structure in complex evolving ecosystems. It is posited that only within module structure and via modular interdependencies can the system be understood and modeled [18].

Challenges in Data Integration:

Integrating data from numerous sources poses obstacles related to data quality, accessibility, privacy, and security [19]. Organizations dependent on external datasets experience limited control over their integrity and availability, leading to data silos and compromised accounting and auditing. Confidentiality concerns counter the desire to share data for collaborative advantage, while the operation and maintenance of data-intensive computer networks remain resource-intensive [20].

Data Quality Issues:

Data-driven supply chain management enhances the quality and scope of decision support through sophisticated analytics. Big data analytics integrates these analytics with relevant information to allow operational, tactical, and strategic decisions and optimise performance. Supply chains generate vast data volumes across stages in diverse formats from transactional, physical, and human interactions. Their integration reveals relationships and informs predictive analytics but exposes data quality issues pertaining to data accuracy, validity, reliability, and timeliness. Third-party information and media reporting raise authenticity, non-repudiation, and surveillance concerns. Additionally, information sharing is hindered by poor interoperability across organisations and systems, while the increasing convergence of supply chain management with digital technologies and cyber-physical systems amplifies privacy and security risks [21].

Interoperability Challenges:

Interoperability is the ability of different systems, devices, applications, or products to connect and communicate in a coordinated way, without effort from the end-user. Within supply chain networks, private and public entities interact regularly, and department- or sector-spanning collaborations are necessary to enable the flow of information and goods, ultimately bringing supplies to the end customers.

Intragovernmental communication relies frequently on insecure, insecure-to-moderately secure, or mostly secure but not strictly formalized communication channels (e.g., email or messenger services), thereby effectively limiting information flows between agencies, forums, and other stakeholders. If the same protocols are not leveraged between private organizations, intermediaries emerge that—on the one hand—may negatively affect delivery times and service levels and—on the other hand—open new attack vectors for a plethora of supply chain strikes. Legal and administrative enforcement of cybersecurity guidelines may be required to reduce such vulnerabilities in communication [19].

Data Privacy and Security Challenges:

Big data introduces critical challenges related to data privacy and security. The accumulation of vast and varied datasets amplifies concerns about individual privacy and the protection of sensitive information. Securing data against unauthorized access and potential breaches becomes increasingly difficult as the volume and complexity of data escalate [22]. Legal and ethical questions emerge about information collection, usage, and sharing, which shows need for strict rules. As of now technical problems can affect data security, with the help of diverse methods you can do various tasks like maintaining privacy, protecting information, and also keep data safe from misuse. These problems make data protection very important by giving you varied solutions which help to complete security goals through proper methods and strong systems [23].

Case Studies of Big Data in Supply Chains:

The retail and manufacturing sectors are an upgraded business area that has more impact than the normal sectors that are used for big data transformation. At present retail sector can do most of the work for example a good e-commerce platform can give high quality data, with the help of varied technologies you can do various tasks like real-time monitoring of events linked to production and sales [10]. These technologies make supply chain very efficient by giving you varied possibilities which help to complete your task. Manufacturing sector uses many sensors and geospatial positioning technologies that help in tracking supply network movements, and initially they used this data for demand prediction and now optimization too. These distinct use cases underscore the importance of employing big data analytics to augment understanding of supply networks, highlighting the need for continued investigation into the challenges and opportunities presented by extensive data integration.

Case Study 1: Retail Sector

Connected devices, sensors, and mobile applications render the retail sector an illustrative testbed for the deployment of big data tools and the associated range of

logistical applications [24]. Important themes include availability, assortment, pricing, and layout planning. Historical sales data and records collected through loyalty schemes provide one source of customer insight for operational planning, while granular sales data may be highly beneficial with respect to availability and assortment decisions. Secondary-data research indicates how external variables such as competitors' pricing strategies and prevailing weather conditions can underpin more accurate demand forecasting and price adjustment. Important challenges concern a shortage of skilled personnel, limited supplier support, integration issues at the information-technology level, managerial concerns about operational information sharing, and the inherent ability of the physical supply structure to respond effectively to rapidly emerging intelligence. The framework of mesoeconomics provides appropriate interpretive support, offering cross-disciplinary integration between economics, data science, and supply-chain management at the critical intermediate level between micro- and macro-analyses.

Case Study 2: Manufacturing Sector

Among the manufacturing industries, automotive production exemplifies a sector where the utilization of big data has transformed the management of global supply-chain activities. In the automotive sector, suppliers provide a range of products, including original-equipment, after-market, and spare parts, while finished products undergo assembly downstream in the process-network representation [25]. A single mid-sized company deals with thousands of materials, and "information lag" remains the most common cause of disruption detachment [16]. The evolution of information and communication technology enables the integration of an increasing number of external data sources to the company's internal material requirements-planning (MRP) and enterprise-resource-planning (ERP) systems through cloud outside the enterprise system. Fessina et al. (2023) have recently studied the automotive supply chain under the mesoeconomic framework, focusing on the interplay between manufacturers, suppliers, and products. Supply chain structure at mesoeconomic level has more importance than the normal economic levels that are used for many works, and it is instrumental in identifying vulnerabilities and resilience propagation within the network. Presently big data technologies can do most of the work for example in manufacturing sector especially in automotive and electronics industry by giving varied possibilities which help to complete production tasks globally [26].

Table 1. Case Studies of Big Data Applications in Supply Chains (Mesoeconomic Perspective)

Case Study	Sector	Key Applications of Big Data	Benefits	Challenges
Retail Sector	Retail / E-commerce	<ul style="list-style-type: none"> - Use of sensors, connected devices, mobile apps - Analysis of sales data, loyalty programs, social media - External data: competitor pricing, weather 	<ul style="list-style-type: none"> - Improved availability and assortment planning - Real-time insights into sales and customer behavior - Enhanced demand forecasting 	<ul style="list-style-type: none"> - Shortage of skilled data analysts - Supplier data limitations - IT integration issues - Managerial resistance to sharing data - Inflexible physical supply systems
Manufacturing Sector	Automotive Manufacturing	<ul style="list-style-type: none"> - Use of big data across OEMs and aftermarket parts 	<ul style="list-style-type: none"> - Improved supply-chain coordination - Better identification 	<ul style="list-style-type: none"> - Information lag causing disruptions - Complex supplier networks

		<ul style="list-style-type: none"> - Integration of ERP/MRP systems with external data - Application of cloud technologies for global data access 	<ul style="list-style-type: none"> of vulnerabilities- Enhanced network resilience - Streamlined operations using real-time data 	<ul style="list-style-type: none"> - Need for cross-platform data synchronization
--	--	---	--	--

Impact of Big Data on Supply Chain Efficiency:

Key performance indicators (KPIs) is a good technique that has more importance than the normal techniques that are used for examining big data analytics in supply chain network. At present KPIs can do most of the work for example examining lead time, demand forecast accuracy, and production schedule performance. These indicators make supply chain very efficient by giving you different possibilities which help to reduce cost, improve inventory turnover and customer service levels through better demand forecast accuracy and improved production schedule performance [27] [28].

Big data technologies are an upgraded system that has more capabilities than the normal systems that are used for many different tasks and facilitating in-depth analysis of various processes. Currently, big data can do most of the work for example real-time analysis and decision-making, ensuring they are more informed and timely [29] [30]. Moreover, it increases operational agility within complex supply chain networks, allowing businesses to adapt seamlessly to dynamic market conditions. With the ability to respond more swiftly to changes in market demand, organizations are positioned to seize opportunities as they arise, ultimately improving overall efficiency and positioning themselves competitively in the marketplace.

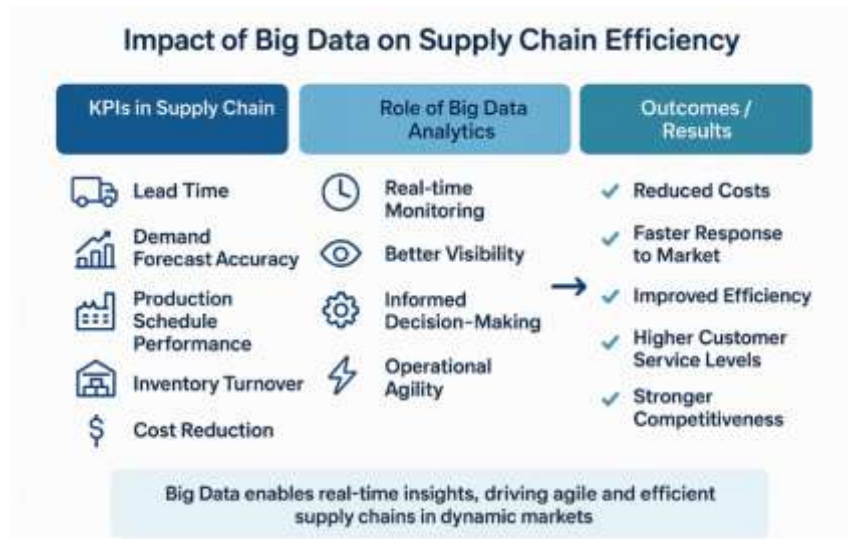


Figure 1. Impact of Big Data on Supply Chain Efficiency

Future Trends in Supply Chain Analytics:

Data analytics in future scenario can do most of the work for example advanced analytics can give high quality results, with the help of different technologies like process mining and blockchain can do various tasks like overcome big data challenges and also make supply chain analysis more efficient. These technologies make data sharing very easy by giving you varied possibilities which help to complete the tasks and facilitate the exchange of supply chain data, thereby improving visibility and reducing fraud. Artificial intelligence adds many benefits to research work. Today, such technologies need proper understanding, and initially they need good implementation and now regular updates too. These developments convey many things such as expanding scope and significant growth in data-driven supply chain analysis [10].

Artificial Intelligence Integration:

Artificial Intelligence is an upgraded technology that has more power than the normal technologies that are used for many different tasks. As of now AI can do most of the work for example virtual assistants help customers with different services, such as the response on consumer queries. In the pharmaceutical sector, the adaptation of AI capabilities to specific operational contexts leads to notable improvements in customer-centricity. This shift not only amplifies the overall function of the workforce but also enhances operational efficiency and the visibility of electric vehicles alongside battery supply chains. Nevertheless, the integration of AI into these systems introduces several risk factors that stakeholders must carefully consider. These risks can include potentially poor implementation practices, substantial resource requirements, significant cyber-security threats, and, most importantly, labor displacement concerns that could affect many individuals in the workforce [31].

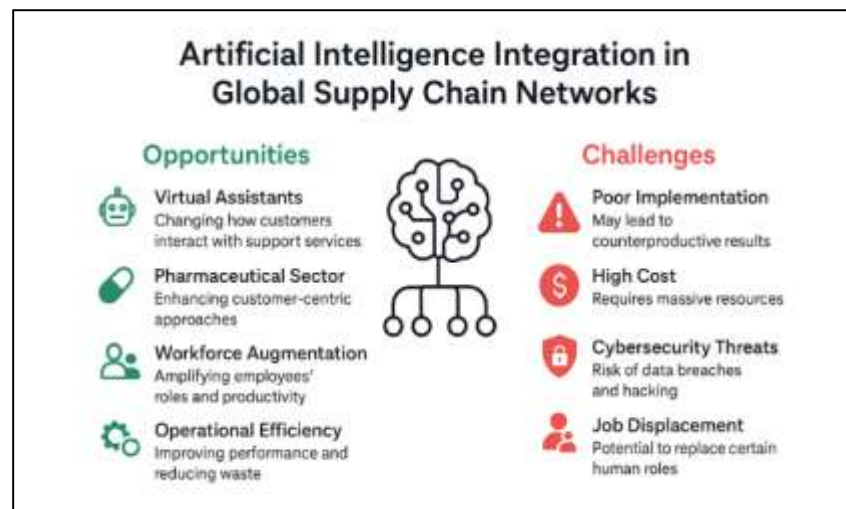


Figure 2. Opportunities and Challenges of Artificial Intelligence Integration in Global Supply Chains

Blockchain Technology:

A blockchain is a record-keeping technology capable of coordinating interactions between entities in a supply chain despite limited mutual trust. This capability positions the technology as a means of enhancing supply chain resilience. Blockchain can be used both as a transactional engine and a data repository, supporting a broad range of fall-back measures in contingency models. Transaction cost theory, an overarching theory in supply chain management, explains the economic mechanisms through which blockchain can improve supply chains, focusing on whether blockchain reduces transaction costs, transaction cost uncertainty, or both.



Figure 3. Enhancing Supply Chain Resilience through Blockchain Technology
Policy Implications of Big Data Use:

Government bodies increasingly recognize the powerful role that digital technologies and big data can play for various economy actors at mesoscale levels. Built on existing statistical and data technologies and geared towards facilitating a mesoeconomics analysis, a wide range of freely available applications that analyze large micro-level datasets can support mesoeconomics practitioners and academics, as well as policymakers in state and private economic-development organizations. This architecture could be adapted for real-time data collection and analysis on almost any medium-term economic issue. Given the growing interest in economic rebalancing of national and regional economies, mesoeconomics is shaping an agenda for the re-examination of many of the world's leading economies [33].

Table 2. Policy Implications of Big Data Use in a Meso-economic Context

Area	Impacts / Potential Applications
Mesoeconomic Analysis	Supports analysis at the mesoscale using open-source tools and big data technologies
Policy Development	Enables real-time, data-driven decision-making on medium-term economic issues
Economic Development Organizations (EDOs)	<ul style="list-style-type: none"> - Job creation - Growth in high-wage sectors - Strengthening supply chains - Stimulating regional capital flows - Supporting surplus labor sectors
Social Development	Inclusion and gender equality are integral parts of the growth agenda
Alternative Economic Models	Facilitates philosophies balancing efficiency, sustainability, and fairness
Economic Rebalancing	Informs national and regional rebalancing efforts with emphasis on inclusiveness as well as efficiency

Key issues for Economic Development Organizations (EDOs) include employment creation, boosting high-paying sectors, aiding logistic chains in key business in- and outflows, unlocking capital flows across regional areas, and supporting the development of surplus labor sectors. Social development also receives attention, with inclusiveness and gender equality constituting integral parts of the growth agenda. Mesoeconomics remains broad enough to enable the adoption and application of economic philosophies having equal commitments to efficiency, sustainability, and fairness. Economies are not always selected on diverse efficiency scenarios or modeled competition outcomes: they are also selected based on their degrees of inclusiveness and equity. The viability of a paradigm that trades efficiency and growth for greater inclusiveness, or a more microeconomic approach that sees rebalancing essentially as an understanding that addresses trade imbalances, is becoming one of the great unresolved issues across the emerging economies. Mesoeconomics can both inform and deepen the debate and clarify the short-, medium-, and long-term benefits for broader policymaking.



Figure 4. Policy Implications of Big Data Use in Meso-economic Development
Regulatory Considerations:

The use of big data in US supply chain and logistics management presents a host of security, ethical, regulatory, and practical concerns that merit consideration. In light of increased attention to data-management policies, new regulations, lack of data governance, and the neglect of data fundamentals have emerged as challenges conducting big-data analytics in supply chain and logistics management.

Simply having access to unprecedented amounts of data does not automatically equal expertise in analytics. Many companies continue to wrestle with the basics of analytics, especially concerning data-quality issues, regulatory restrictions on the use of that data, and regard for data ethics [16]. According to [34], US regulators have enacted a number of laws, legislative regimens, and government mandates relevant to big-data programs for firms operating in the supply chain and logistics sector, the most prominent of which are described as follows.

The National Institute of Standards and Technology (NIST) Cybersecurity Framework, developed to provide companies with a uniform framework for managing cybersecurity risks and requirements. By adopting the framework, companies operating in the supply chain and logistics sector can implement more efficient and effective cybersecurity policies and procedures. The California Consumer Privacy Act (CCPA), which confers consumers the right to know what personal information is collected and for what purpose, the right to delete personal information, the right to opt out of the sale of personal information, and the right to non-discrimination in the event that consumers opt out of the sale of personal information.

Ethical Considerations:

Policy, ethics, and governance shape big data's value across economic, social, and individual levels. Ethical decisions on collaboration, data-driven interventions, and privacy affect organizational and individual well-being. The rising risk of misuse fosters a conflict between leveraging data-driven innovation and maintaining trust [35]. Competition frameworks must tackle new challenges, especially when big data's benefits remain concentrated among few firms.

Policymakers can play a key role in balancing big data's benefits and risks. Efficient digital infrastructure and inclusive upskilling reduce the digital divide. Rethinking competition rules to limit social and political risks becomes necessary as big data's economic value concentrates. Regulatory responses are emerging in several countries. Finally, uncertainty surrounding AI's impact calls for increased efforts toward shared

global understandings and reinvigorated international cooperation on artificial intelligence.

Table 3. Summary of Policy, Regulatory, and Ethical Implications of Big Data Use in Supply Chain and Economic Development

Section	Focus Area	Key Points
Policy Implications	Mesoeconomics and Development	<ul style="list-style-type: none"> - Big data supports mesoeconomic analysis and real-time decision-making - Enables regional economic rebalancing - Supports EDO goals: job creation, high-wage sector growth, capital flow, logistics - Promotes inclusive growth and gender equity - Encourages fair and sustainable economic models
Regulatory Considerations	Data Governance & Compliance	<ul style="list-style-type: none"> - Security, ethical, and regulatory concerns in supply chain analytics - Lack of data governance and quality limits effectiveness - Regulations like NIST Cybersecurity Framework and CCPA enforce data protection - Firms need to improve their data analytics maturity and cybersecurity policies
Ethical Considerations	Ethics, Trust & Global Cooperation	<ul style="list-style-type: none"> - Ethics shape how big data impacts individuals and organizations - Concerns over privacy, data misuse, and unequal data-driven advantages - Policymakers must reduce the digital divide through infrastructure and upskilling - Need for fair competition rules and global AI governance frameworks

2. Conclusion

Big data has emerged as a pivotal resource within global supply chains, rendering traditional sources, techniques and tools of data analytics largely inadequate. The indiscriminate application of big data analytics across supply chain disciplines and industries, though seemingly unavoidable, is fraught with difficulties. These challenges emanate primarily from the distinct and diverse underlying characteristics of the big data-driven supply chain processes, resources and activities. As global supply chain networks are complex and intertwined communities of meso-level economic agents, mesoeconomics provides the optimal theoretical framework for articulating the roles of big data within the supply chain process.

The strategic application of big data begins with the correct conceptualization of the longitudinal movement of goods and services flow from upstream to downstream supply chain members. This involves the delineation of relationships at the product, producer and process levels, which generate a highly related but heterogeneous set of big data sources. Defining the nature of the big data supply chain problem enables scholars and practitioners to locate and classify the appropriate primary and secondary big data sources and apply more meaningful descriptive, predictive or prescriptive analytics techniques and tools to generate optimised solutions. However, the discernment and application of big data is constrained by the critical and ongoing challenges of data quality, interoperability, privacy and security.

REFERENCES

- [1] R. Matkovskyy, *A meso-level representation of economic systems: A theoretical approach*, MPRA Paper No. 44093, University Library of Munich, Germany, 2012. Available: https://mpra.ub.uni-muenchen.de/44093/4/MPRA_paper_44093.pdf
- [2] V. Erokhin, T. Guo, and J. V. Andrei, *Contemporary macroeconomics: New global disorder*. Singapore: Springer, 2023. Available: <https://doi.org/10.1007/978-981-19-9542-2>
- [3] C. E. Willging, E. T. Jaramillo, E. Haozous, D. H. Sommerfeld, and S. P. Verney, "Macro- and meso-level contextual influences on health care inequities among American Indian elders," *BMC Public Health*, vol. 21, no. 1, p. 636, 2021. Available: <https://doi.org/10.1186/s12889-021-10616-z>
- [4] R. G. Tiller *et al.*, "Understanding stakeholder synergies through system dynamics: Integrating multi-sectoral stakeholder narratives into quantitative environmental models," *Frontiers in Sustainability*, vol. 2, Art. no. 701180, 2021. Available: <https://doi.org/10.3389/frsus.2021.701180>
- [5] C. F. Lehene, M. Jaradat, and R. L. Nistor, "An interdisciplinary and multilevel analysis of local economy determinants and their impact on firm performance—Considering Porter's diamond model, clusters, and industry," *Systems*, vol. 12, no. 3, p. 82, 2024. Available: <https://doi.org/10.3390/systems12030082>
- [6] M. M. Ali and J. G. Vargas-Hernández, "Circular economic system under political economy through institutional participation and good governance: In search of attainment of dynamics of macroeconomic stability," *Abhigyan*, vol. 42, no. 2, pp. 150–171, 2024. Available: <https://doi.org/10.1177/09702385241239476>
- [7] C. Han, D. Witthaut, M. Timme, and M. Schröder, "The winner takes it all — How to win network globalization," *PLoS ONE*, vol. 14, no. 2, e0225346, 2019. Available: <https://doi.org/10.1371/journal.pone.0225346>
- [8] J. A. Jiputra, Z. J. H. Tarigan, and H. Siagian, "The effect of information technology on retailer satisfaction through supply chain management practices and retailer-distributor relationship in modern retailer Surabaya," *International Journal of Business and Society*, vol. 3, no. 2, pp. 126–134, 2020. Available: <https://doi.org/10.9744/ijbs.3.2.126-134>
- [9] Q. A. Nisar *et al.*, "Sustainable supply chain management performance in post COVID-19 era in an emerging economy: A big data perspective," *International Journal of Emerging Markets*, vol. 18, no. 12, pp. 5900–5920, 2022. Available: <https://doi.org/10.1108/IJOEM-12-2021-1807>
- [10] K. Govindan, T. C. E. Cheng, N. Mishra, and N. Shukla, "Big data analytics and application for logistics and supply chain management," *Transportation Research Part E: Logistics and Transportation Review*, vol. 114, pp. 343–349, 2018. Available: <https://doi.org/10.1016/j.tre.2018.01.011>
- [11] W. Cetera, W. Gogolek, A. Żolnierski, and D. Jaruga, "Potential for the use of large unstructured data resources by public innovation support institutions," *Journal of Big Data*, vol. 9, no. 46, pp. 1–21, 2022. Available: <https://doi.org/10.1186/s40537-022-00610-6>
- [12] M. E. Khatib *et al.*, "Predictive and prescriptive analytics tools, how to add value to knowledge-based economy: Dubai case study," in *The Effect of Information Technology on Business and Marketing Intelligence Systems*, vol. 1056, M. Alshurideh, B. H. Al Kurdi, R. Masa'deh, H. M. Alzoubi, and S. Salloum, Eds. Springer, 2023, pp. 1807–1829. Available: https://doi.org/10.1007/978-3-031-12382-5_99
- [13] L. Ma and R. Chang, "How big data analytics and artificial intelligence facilitate digital supply chain transformation: The role of integration and agility," *Management Decision*, 2024. Available: <https://doi.org/10.1108/MD-10-2023-1822>
- [14] G. Ji, L. Hu, and K. H. Tan, "A study on decision-making of food supply chain based on big data," *Journal of Systems Science and Systems Engineering*, vol. 26, no. 2, pp. 183–198, 2017. Available: <https://doi.org/10.1007/s11518-016-5320-6>
- [15] C. Bischof and D. Wilfinger, "Big data-enhanced risk management," *Transactions of FAMENA*, vol. 43, no. 2, pp. 73–84, 2019. Available: <https://doi.org/10.21278/TOF.43206>
- [16] K. M. Lavassani and B. Movahedi, "Firm-level analysis of global supply chain network: Role of centrality on firm's performance," *Journal of Global Business and Competitiveness*, vol. 16, no. 2, pp. 86–103, 2021. Available: <https://doi.org/10.1007/s42943-021-00026-8>
- [17] S. Dey, "Surviving major disruptions: Building supply chain resilience and visibility through rapid information flow and real-time insights at the 'edge'," *Sustainable Manufacturing and Service Economics*, vol. 2, p. 100008, 2023. Available: <https://doi.org/10.1016/j.smse.2022.100008>
- [18] Y. Zuo, Y. Kajikawa, and J. Mori, "Extraction of business relationships in supply networks using statistical learning theory," *Heliyon*, vol. 2, no. 6, e00123, 2016. Available: <https://doi.org/10.1016/j.heliyon.2016.e00123>

- [19] J. Pennekamp *et al.*, "An interdisciplinary survey on information flows in supply chains," *ACM Computing Surveys*, vol. 56, no. 2, Article 32, pp. 1–38, 2023. Available: <https://doi.org/10.1145/3606693>
- [20] Y. Zhan and K. H. Tan, "An analytic infrastructure for harvesting big data to enhance supply chain performance," *European Journal of Operational Research*, vol. 281, no. 3, pp. 559–574, 2020. Available: <https://doi.org/10.1016/j.ejor.2018.09.018>
- [21] K. Shaar, *Reconciling international trade data*, MPRA Paper No. 81572, Munich Personal RePEc Archive, 2017. Available: <https://mpra.ub.uni-muenchen.de/81572/>
- [22] M. Dabab, R. Craven, H. Barham, and E. Gibson, "Exploratory strategic roadmapping framework for big data privacy issues," in *2018 Portland International Conference on Management of Engineering and Technology (PICMET)*, Oct. 2018, pp. 1–9. Available: <https://core.ac.uk/reader/222976040>
- [23] B. Alabdullah, N. Beloff, and M. White, "Rise of big data – Issues and challenges," in *2018 21st Saudi Computer Society National Computer Conference (NCC)*, Apr. 2018, pp. 1–6. Available: <https://doi.org/10.1109/NCG.2018.8593166>
- [24] E. Aktas and Y. Meng, "An exploration of big data practices in retail sector," *Logistics*, vol. 1, no. 2, pp. 1–28, 2017. Available: <https://doi.org/10.3390/logistics1020012>
- [25] Brintrup, Y. Wang, and A. Tiwari, "Supply networks as complex systems: A network-science-based characterization," *IEEE Systems Journal*, vol. 11, no. 4, pp. 2170–2181, 2017. Available: <https://doi.org/10.1109/JSYST.2015.2425137>
- [26] M. Fessina, A. Zaccaria, G. Cimini, and T. Squartini, "Pattern-detection in the global automotive industry: A manufacturer-supplier-product network analysis," *Chaos, Solitons & Fractals*, vol. 181, p. 114630, 2024. Available: <https://doi.org/10.1016/j.chaos.2024.114630>
- [27] N. Stefanovic, "Proactive supply chain performance management with predictive analytics," *The Scientific World Journal*, vol. 2014, Article 528917, pp. 1–17, 2014. Available: <https://doi.org/10.1155/2014/528917>
- [28] S. F. Wamba and S. Akter, "Understanding supply chain analytics capabilities and agility for data-rich environments," *International Journal of Operations & Production Management*, vol. 39, no. 6–8, pp. 887–912, 2019. Available: <https://doi.org/10.1108/IJOPM-01-2019-0025>
- [29] U. Kekevi and A. A. Aydın, "Real-time big data processing and analytics: Concepts, technologies, and domains," *Journal of Computer Science*, vol. 7, no. 2, pp. 111–123, 2022. Available: <https://doi.org/10.53070/bbd.1204112>
- [30] Y. Zhang *et al.*, "Revolutionizing crop breeding: Next-generation artificial intelligence and big data-driven intelligent design," *Engineering*, vol. 44, pp. 245–255, 2025. Available: <https://doi.org/10.1016/j.eng.2024.11.034>
- [31] C. Hanson-New and J. Daniel, "The application of big data and AI in the upstream supply chain," in *Proc. 24th Annual Conference of the Chartered Institute of Logistics and Transport – Logistics Research Network (LRN)*, Northampton, UK, Sep. 4–6, 2019, pp. 21–25. Available: <http://hdl.handle.net/10545/624167>
- [32] F. Longo, L. Nicoletti, A. Padovano, G. d'Atri, and M. Forte, "Blockchain-enabled supply chain: An experimental study," *Computers & Industrial Engineering*, vol. 136, pp. 57–69, 2019. Available: <https://doi.org/10.1016/j.cie.2019.07.026>
- [33] M. Paramesha, N. Rane, and J. Rane, "Big data analytics, artificial intelligence, machine learning, internet of things, and blockchain for enhanced business intelligence," *SSRN Electronic Journal*, 2024. Available: <https://doi.org/10.2139/ssrn.4855856>
- [34] N. Yamano, *Development of global inter-country inter-industry system for various policy perspectives*, Doctoral dissertation, Univ. of Illinois at Urbana-Champaign, 2017. Available: <https://core.ac.uk/download/158323963.pdf>
- [35] S. A. Koseki, "Globalizing the digital: A cross-cultural framework for the ethics of operationalizing Big Data," conference poster presented at *Swiss Inter- and Transdisciplinarity Day 2018*, Lausanne, Switzerland, Nov. 15, 2018. Available: <https://infoscience.epfl.ch/handle/20.500.14299/151498>