The role of the customer order decoupling point in operations and supply chain management

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Magnus Harfeldt-Berg

DOCTORAL DISSERTATION

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Abstract

In the field of operations and supply chain management (OSCM), the customer order decoupling point (CODP) has been recognized as an important strategic parameter for roughly 30 years. It is the point in the value chain where forecast-driven material flows get separated from order-driven material flows. Despite its long history in the field, multiple calls for further consideration of the CODP in OSCM research have been made recently, particularly for empirical research. Since further inclusion of the CODP is warranted, this doctoral thesis sets out to identify research areas in which the role of the CODP lacks substantial, empirical verification. Once these areas have been identified, a selection of them are investigated to highlight the importance of the CODP and contribute to theory and practice. The thesis is based on the results of five articles. The first article is a systematic review of empirical research which explicitly considers the CODP. This review serves as a point of departure for the other articles by identifying areas in which the importance of the CODP lacks substantial empirical assessment. The other articles concern selected research topics where further assessment of the CODP's role can benefit theory and practice: supply chain integration (article II), mass customization and modular design (article III), and environmental supply chain sustainability (articles IV and V). The lion's share of the results is obtained via analysis of the fourth and latest round of the High Performance Manufacturing study. This is a multinational survey study which collected information from 330 manufacturing plants in 15 different countries. Multiple respondents at each plant have answered different questionnaires, making it a highly credible data source. The fourth article also includes a case analysis of an industrial symbiosis network in Sotenäs, Sweden. The results of the five papers are analyzed together and a pattern among the results becomes clear: plants operating based on forecasts who manufacture standardized products, so called make-to-stock plants, are not reaping the same benefits from improvement initiatives such as increased supply chain integration, increased customization capabilities, and more environmentally sustainable operations, as their counterparts who manufacture and customize products based on customer orders, so called make-to-order plants. These findings are largely novel to the OSCM field and plausible explanations for them are provided. Concisely speaking, external factors such as market and demand characteristics of the different product types are likely very important influences behind the results, as well the organizations' operational and competitive foci. The thesis has several important implications for both researchers and managers. Firstly, the framework presented in the literature review illustrates multiple factors and decision areas which are related to the CODP. This framework can be used as a guide for both researchers and practitioners. It allows researchers to assess whether a certain topic would benefit from considering the CODP, and practitioners can see which of their strategic decisions that have direct linkages to their CODP positions. Secondly, since the CODP has not been sufficiently included in the selected research areas before, the results highlight the need for further inclusion of this concept in the future. In fact, some of the results presented even illustrate that recommendations from research might be wrong if the CODP is ignored. Furthermore, the CODP is measured both as a categorical variable, which has been used to create sub-sets of data in articles II, IV and V, and as a continuous variable, which has been used to measure interaction effects between the CODP, mass customization and modular design in article III. Hence the thesis exemplifies two ways in which the CODP position can be measured and used in research. For practitioners, the results of the thesis emphasize the fact that organizations of different types, from a CODP perspective, should not invest in and focus on the same types of improvement initiatives. This insight can help managers strategize and avoid organizational fads which would offer little in return for the effort and money spent on them. Lastly, topics for future research are outlined.

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Abstract

In the field of operations and supply chain management (OSCM), the customer order decoupling point (CODP) has been recognized as an important strategic parameter for roughly 30 years. It is the point in the value chain where forecast-driven material flows get separated from order-driven material flows. Despite its long history in the field, multiple calls for further consideration of the CODP in OSCM research have been made recently, particularly for empirical research. Since further inclusion of the CODP is warranted, this doctoral thesis sets out to identify research areas in which the role of the CODP lacks substantial, empirical verification. Once these areas have been identified, a selection of them are investigated to highlight the importance of the CODP and contribute to theory and practice.

The thesis is based on the results of five articles. The first article is a systematic review of empirical research which explicitly considers the CODP. This review serves as a point of departure for the other articles by identifying areas in which the importance of the CODP lacks substantial empirical assessment. The other articles concern selected research topics where further assessment of the CODP's role can benefit theory and practice: supply chain integration (article II), mass customization and modular design (article III), and environmental supply chain sustainability (articles IV and V).

The lion's share of the results is obtained via analysis of the fourth and latest round of the High Performance Manufacturing study. This is a multinational survey study which collected information from 330 manufacturing plants in 15 different countries. Multiple respondents at each plant have answered different questionnaires, making it a highly credible data source. The fourth article also includes a case analysis of an industrial symbiosis network in Sotenäs, Sweden.

The results of the five papers are analyzed together and a pattern among the results becomes clear: plants operating based on forecasts who manufacture standardized products, so called make-to-stock plants, are not reaping the same benefits from improvement initiatives such as increased supply chain integration, increased customization capabilities, and more environmentally sustainable operations, as their counterparts who manufacture and customize products based on customer orders, so called make-to-order plants. These findings are largely novel to the OSCM field and plausible explanations for them are provided. Concisely speaking, external factors such as market and

demand characteristics of the different product types are likely very important influences behind the results, as well the organizations' operational and competitive foci.

The thesis has several important implications for both researchers and managers. Firstly, the framework presented in the literature review illustrates multiple factors and decision areas which are related to the CODP. This framework can be used as a guide for both researchers and practitioners. It allows researchers to assess whether a certain topic would benefit from considering the CODP, and practitioners can see which of their strategic decisions that have direct linkages to their CODP positions. Secondly, since the CODP has not been sufficiently included in the selected research areas before, the results highlight the need for further inclusion of this concept in the future. In fact, some of the results presented even illustrate that recommendations from research might be wrong if the CODP is ignored. Furthermore, the CODP is measured both as a categorical variable, which has been used to create sub-sets of data in articles II, IV and V, and as a continuous variable, which has been used to measure interaction effects between the CODP, mass customization and modular design in article III. Hence the thesis exemplifies two ways in which the CODP position can be measured and used in research. For practitioners, the results of the thesis emphasize the fact that organizations of different types, from a CODP perspective, should not invest in and focus on the same types of improvement initiatives. This insight can help managers strategize and avoid organizational fads which would offer little in return for the effort and money spent on them. Lastly, topics for future research are outlined.

Acknowledgments

Now, as my time as a Ph.D. candidate is drawing to a close, I find it difficult to summarize what it has been like. In hindsight, I think that being a Ph.D. candidate is one of those endeavors in life that falls under the simple-but-not-easy category. I say this because there was in fact a fairly simple process for me to follow: step one was to read a lot of research. Eventually, all the reading lead to the identification of questions that had not yet been explained clearly. Step two was to write about these questions, which eventually lead to drafts of papers. These two steps were then iterated until the drafts felt well-written enough to be submitted. At that point, the process restarted with the purpose of writing new papers and improving the already written ones. So, in a nutshell, it is all about reading, writing, reading, and then writing some more. Simple. But not easy. Identifying research questions and gaps, finding and understanding suitable research methods, determining if your data is sufficient to address the research questions, assessing and improving the quality of your own research, and managing reading and writing about several topics at the same time are all examples of things that I found not so easy. Luckily, I have had a lot of help along the way, and I am very grateful for all the guidance I have received. Without it, I am sure that I would neither have learned, nor grown, nearly as much as I did. There are many people deserving of a thank you for their part in making this thesis a reality. My most heartfelt thank you is given to

Professor Jan Olhager, my supervisor, co-author and mentor in the academic realm. With your knowledge, experience and creativity you have made the last few years of my life more interesting and rewarding than I could have ever expected.

My cherished wife, Lovisa, and our beloved children, Arvid and Hedda. You are all a constant, living, breathing reminder of what is most important in life, and that I should not take myself too seriously. You have made my journey over the last few years infinitely more enjoyable than it would have been without you.

My parents, Kerstin and Stefan. Although the inside joke of our family is that things are “consistently inconsistent”, you have consistently given me a fantastic piece of advice: “Just make sure you do something you find interesting, whatever it may be.” This little sentence has guided so many important choices in my life. I am fully convinced I would not have ended up pursuing a Ph.D. without it. Thank you.

My brothers, Gustav and Victor. You have always been my best friends, toughest competition and biggest supporters. I have relished all the laughter that we have shared over horrible jokes, I have been spurred on by your accomplishments, and I have felt encouraged by the fact that you believe in my ability. Having siblings like you benefits all aspects of my life.

My colleagues, who have helped me with all the practical aspects of my work and shown an interest in in what I do. I have been inspired by all your work and effort, in both research and teaching, to press on and do my best.

All my friends. You have truly made me enjoy life outside of work and spending time with you has given me joy, happiness and energy. The fact that you are not interested in what I am doing is often very refreshing. I sincerely thank you for making my life richer.

Lastly, I would like to address a question that I have been asked on a few occasions as a Ph.D., namely what valuable thing I can possibly have to say about supply chains and operations strategy. In response, I would like to quote Bruce Springsteen. In the beginning of *Springsteen on Broadway*, from 2018, he says the following: "I've never seen the inside of a factory, yet it's all I've ever written about. Standing before you is a man /…/ writing about something of which he has absolutely no personal experience." This is as true for me as it is for Bruce, but his songs have value and merit regardless. I believe that the same can be true for this thesis.

Magnus Harfeldt-Berg

Lund, August, 2024

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List of abbreviations

ATO: Assemble to order/Assemble-to-order

CODP: Customer order decoupling point

ESP: Environmental sustainability practice

ETO: Engineer to order/Engineer-to-order

HPM: High performance manufacturing

IS: Industrial symbiosis

MC: Mass customization

MD: Modular design

MTO: Make to order/Make-to-order

MTS: Make to stock/Make-to-stock

OTD: On-time delivery

OSCM: Operations and supply chain management

SCI: Supply chain integration

Populärvetenskaplig sammanfattning

Det är notoriskt komplicerat att styra och hantera en försörjningskedja. Besluten som ska fattas angående informations- och materialflöden påverkar både ett företags interna processer och de processer som är riktade mot leverantörer och kunder i kedjan. Att koordinera och prioritera alla beslut som måste fattas för att verksamheten ska fungera och vara konkurrenskraftig är en minst sagt utmanande uppgift, men det finns vissa karaktärsdrag i försörjningskedjan som kan ge vägledning. Ett viktigt sådant är kundorderpunktens position och det är just detta koncept den här avhandlingen fokuserar på.

Kundorderpunkten är den punkt i försörjningskedjan som frikopplar processer och materialflöden som är styrda av prognoser från dem som är styrda av faktiska, inkomna kundorder. Konceptet har varit känt sedan 1980-talet och ansågs tidigt vara en nyckelparameter för strategier kring hur försörjningskedjan ska hanteras. Denna punkt har en direkt påverkan på exempelvis produktionsplanering, vad och hur mycket som ska lagerhållas, hur mycket en produkt kan anpassas efter specifika kundorder och vilka leveransledtider som kan erbjudas. Dessutom har tidigare forskning visat att kundorderpunktens position hänger ihop med flera andra aspekter relaterade till försörjningskedjans utformning, så som omfattningen och effekten av integration med partners i kedjan, hur man bygger upp motståndskraft mot oförutsedda förändringar och hur man vinner kundorder.

Med tanke på att kundorderpunkten framhävts som, och visat sig vara, en strategiskt viktig parameter för försörjningskedjan är det förvånansvärt ovanligt att den åtnjuter något specifikt intresse i framför allt empirisk forskning. Detta har motiverat mycket av arbetet som presenteras i den här avhandlingen, som är en sammanslagning av fem artiklar som undersöker kundorderpunktens roll för försörjningskedjan på olika sätt. Den första artikeln som inkluderats i avhandlingen är en litteraturstudie och de nästkommande fyra artiklarna som ingår i avhandlingen är alla empiriska undersökningar som analyserar kundorderpunktens effekter med hjälp av insamlade enkätdata. Denna data kommer från den fjärde och senaste rundan av High Performance Manufacturing-studien, som genomförts i 15 länder och samlat in data från 330 produktionsläggningar. Artikel fyra i avhandlingen innehåller en komponent som är baserad på denna enkätdata, men i huvudsak är det en fallstudie av ett industriellt symbiosnätverk i Sotenäs, Sverige. Resultaten som presenteras visar att kundorderpunktens position spelar stor roll både för forskare och praktiker, eftersom den i flera sammanhang påverkar effekterna man får av olika förbättringsinitiativ. Detta innebär att forskare riskerar att komma med fel slutsatser och rekommendationer om kundorderpunktens position inte kontrollerats i samband med de utförda analyserna. Eftersom den stora majoriteten av alla resultat och slutsatser som framförs i avhandlingen kommer från verkliga data kan det med god tillförsikt påstås att de reflekterar verkliga samband. I samtliga artiklar framhävs också att kundorderpunkten har en signifikant inverkan på strategiska beslut angående försörjningskedjan, vilket bidrar till avhandlingens relevans för praktiker. Resultaten är också användbara för praktiker på så vis att de ger en klarare bild av vad man kan förvänta sig av att genomföra vissa typer av förbättringsinitiativ i försörjningskedjan.

Så vad visar då resultaten i avhandlingen mer konkret? Om man börjar från början ger slutsatserna från den bilagda litteraturstudien en bekräftelse på att kundorderpunkten är ovanlig i empirisk forskning om försörjningskedjor. Efter en omfattande genomsökning av litteraturen hittades endast 40 artiklar som både använt en empirisk forskningsmetod, så som en enkät eller en fallstudie, och behandlat kundorderpunktens position. För det andra visade det sig att kundorderpunkten, trots sin låga förekomst i empirisk forskning, har kopplats ihop med ett stort antal faktorer relaterade till försörjningskedjan och dess processer. I de 40 analyserade artiklarna återfanns 32 sådana faktorer. Alla dessa faktorer har olika egenskaper beroende på kundorderpunktens position, alternativt om de utvärderas uppströms eller nedströms från kundorderpunktens position. Detta framhäver tydligt hur viktig kundorderpunkten är för forskning och beslutsfattande.

Resultaten från de övriga artiklarna som inkluderats i avhandlingen indikerar att kundorderpunktens position spelar en viktig roll för flera strategiska frågor rörande försörjningskedjan. Analyserna som utförts visar bland annat att integration påverkar företagens prestation på olika vis beroende på var kundorderpunkten ligger. Andra resultat indikerar hur olika företags prestation påverkas av att satsa på modulär produktdesign och massanpassning beroende på var kundorderpunkten är placerad, och ytterligare en uppsättning analyser visar att sambanden mellan producenters initiativ för ökad miljömässig hållbarhet och förbättrad prestation inte alls ser likadana ut beroende på var kundorderpunkten ligger.

När man tittar på de sammantagna resultaten från alla artiklarna framträder ett intressant mönster: produktionsanläggningar som i huvudsak producerar baserat på prognoser, så kallade make-to-stock (MTS) anläggningar, upplever generellt inte lika stora eller tydliga prestationseffekter av förbättringsinitiativ som anläggningar som i huvudsak producerar baserat på order, refererade till som make-to-order (MTO) anläggningar. Den bakomliggande anledningen till att MTS-anläggningar inte upplever lika mycket positiva effekter av diverse förbättringsinitiativ som MTO-anläggningar framgår inte konkret av analyserna i de inkluderade artiklarna. Två troliga orsaker föreslås dock. Den första är kopplad till verksamheternas natur. För att det ska vara möjligt att bedriva en prognosbaserad verksamhet framgångsrikt måste miljön man arbetar i vara relativt stabil. Efterfrågan på produkter får inte variera alltför mycket, varken sett till volym eller produktvarianter. Således befinner sig MTS-anläggningar i en relativt stabil miljö där man vet i förväg vad som ska produceras, vilket gör att effektivitet hamnar i fokus för produktionen. Det som ska produceras ska helst framställas snabbt och billigt, givet att det uppfyller de kvalitetskrav som finns. Dessutom har MTS-anläggningar typiskt både lager för insatsfaktorer och slutprodukter, och dessa lager erbjuder ytterligare isolering mot yttre påverkan. Tillsammans gör detta att MTS-anläggningar mycket troligt bör fokusera på att bedriva sin verksamhet så effektivt som möjligt, snarare än att lägga mycket tid och resurser på att, till exempel, integrera kunderna i produktutvecklingsprocesser. Sådana initiativ kan lätt kosta för mycket i tid och pengar. MTO-anläggningar, å andra sidan, arbetar i en helt annan miljö, en miljö som präglas av osäkerhet och en ofta svårbedömd marknad. Detta innebär att MTO-företag måste vara mer responsiva och ha närmare kontakt med både kunden, alltså marknaden, och leverantörer för att se till att produktionen kan möta varierande behov och krav. Således blir det viktigare att till exempel integrera med andra delar av försörjningskedjan. Den andra orsaken har att göra med företagens möjligheter att påverka efterfrågan på sina egna produkter. Ökade satsningar på hållbarhet kan exemplifiera resonemanget: eftersom kunder är mer direkt involverade i verksamheten hos MTO-anläggningar kan det mycket väl vara så att exempelvis hållbarhetsinitiativ får en större positiv effekt på verksamheten för dem då MTO-produkters efterfrågan inte styrs lika entydigt av pris som standardiserade produkters efterfrågan. En mer hållbar produktion kan innebära en ökad efterfrågan på företagets produkter om detta är viktigt för kunderna. En standardiserad produkt som lagerförs inför försäljning har i regel en priskänslig efterfrågan, vilket innebär att MTS-företag inte har samma möjligheter att öka priset på grund av en mer hållbar, och potentiellt dyrare, produktion. Den jämna, stabila efterfrågan på standardiserade MTS-produkter förändras inte mycket på grund av något det enskilda företaget gör, utan bestäms snarare av kundernas och marknadens behov.

Dessa två orsakar kan troligt förklara en del av skillnaderna mellan MTS- och MTO-anläggningar, men lika sannolikt förklarar de inte allt. Framtida forskning kan förhoppnings ge ytterligare förklaringar till mönstret som syns bland avhandlingens resultat.

Avhandlingens resultat och deras potentiella förklaringar öppnar dörrar till framtida forskning, kanske framför allt rörande kundorderpunktens roll i den nära förestående framtiden där Industri 4.0, krav på ökad hållbarhet och digitalisering väntas breda ut sig mer och mer. Den genomförda forskningen visar att integration i försörjningskedjan inte medför positiva effekter för MTS-verksamhet, generellt, så hur ska sådana verksamheter hantera en framtid som kräver mer och mer integration och delade informationssystem med andra aktörer i försörjningskedjan? Liknande frågor väcks angående hållbarhetsinitiativ. Om de positiva effekterna av hållbarhetsarbete inte alls är lika påtagliga för en typ av produktion, kan man då förvänta sig att sådana producenter ska driva hållbarhetsarbetet på det sätt som till exempel de globala klimatmålen kräver? Kommer alla investeringar och förändringar Industri 4.0 för med sig vara berättigade för de produktionsbolag som kanske gör bäst i att satsa på en effektiv produktion och kärnverksamhet? Detta är exempel på frågetecken som framtida forskning förhoppningsvis kommer räta ut.

List of appended papers

Paper I

Harfeldt-Berg, M. and Olhager, J. (2024), "The customer order decoupling point in empirical operations and supply chain management research: A systematic literature review and framework", *International Journal of Production Research*, Vol. 67, No.17, pp. 6380-6399. https://doi.org/10.1080/00207543.2024.2314164.
Cite score: 18.1; Impact factor, 9.2

Paper II

Harfeldt-Berg, M., Olhager, J. and Choi, T. (2022), "Exploring the role of customer order decoupling points in operations and supply chain management: The case of supply chain integration". In Machuca, J.A.D, Matsui, Y., Matsuo, H., Sano, H. and Tomita, J., *Operations Management and Strategy in the Era of Technological Revolution: Proceedings of the 6th Conference on Production and Operations Management* 2022 (pp. 248-258), under revision before submission to journal.

Paper III

Harfeldt-Berg, M. and Olhager, J. (2024), "The role of customer order decoupling points for mass customization, modular product design and performance", under review by *International Journal of Production Economics*, second round.

Paper IV

Harfeldt-Berg, L. & Harfeldt-Berg, M. (2023), "Connecting organizational context to environmental sustainability initiatives and industrial symbiosis: Empirical results and case analysis", *Sustainable Production & Consumption*, Vol. 40, pp. 210-219. https://doi.org/10.1016/j.spc.2023.06.023.
Cite score: 12.5; Impact factor: 12.1

Paper V

Harfeldt-Berg, M. (2024), "Environmental sustainability from a decoupling point perspective", under review by *Cleaner Logistics and Supply Chain.*

Related publications

Olhager, J. and Harfeldt-Berg, M. (2024), "Reshoring before and during the COVID-19 pandemic: a longitudinal study from an advanced economy perspective", under review by *International Journal of Physical Distribution and Logistics Management*, third round.

Contribution statement

Paper I

I was actively involved in every aspect of producing this paper, from designing search strings to use for querying databases for literature, to identifying and analyzing relevant literature, as well as writing the actual paper.

Paper II

I have contributed to all aspects of this paper, although my co-authors have provided much valuable input regarding relevant literature and concepts. I have been the main responsible for the analysis of survey data on which the conclusions are based.

Paper III

Similar to paper II, I have been responsible for the data analysis on which the conclusions are based. My co-author and I both helped identify a relevant literature background for the study, and we have both contributed to writing the manuscript currently under review by the *International Journal of Production Economics*.

Paper IV

I have been involved in every part of this paper, although there was a division of main responsibilities such that my co-author was primarily responsible for designing the interview protocols used during the case study, and I was primarily responsible for obtaining and analyzing suitable survey data in the HPM data material, as I had access to it. In terms of conducting the interviews, transcribing and analyzing the material, as well as writing the paper, we contributed equally.

Paper V

I am the sole author of this paper, currently under review by *Cleaner Logistics and Supply Chain*.

1. Introduction

This section of the thesis introduces the customer order decoupling point, the most central concept of the thesis, and motivates why this concept should be the focus of a doctoral thesis. It also presents the research objectives, some delimitations, and the thesis structure.

1.1 Background and problem identification

Supply chain management is notoriously complex. The successful planning and execution of information- and material flows require multiple actors to coordinate their operations and logistics activities, which is a continuous effort that requires a long array of decisions and prioritizations. Questions that need to be addressed and answered involve, but are not limited to: what degree of product customization can we offer our customers? what do the market and demand characteristics look like, how many suppliers do we need, and should we integrate IT systems and share information with our supply chain partners? Should we prioritize efficiency or flexibility in our production systems? Can we have both? Should we use third party logistics partners or manage our own logistics network? What is considered an acceptable lead time for our product types, and, of course, how much will things cost?

The questions used to exemplify the complexity of making supply chain-related decisions were not picked at random. In fact, all of them have been found to have a close relationship with the main character of this dissertation, namely the customer order decoupling point (CODP), as described in Table 1.1. A proper introduction of this concept should likely start with Sharman (1984), even though he used the term "order penetration point" to describe the concept. Sharman describes this point as a key variable in the supply chain and does so for multiple reasons: it is normally the point where product specifications get frozen, it is typically the last inventory point, and it separates forecast-driven activities in the value chain from order-driven activities. A few years later, Hoekstra and Romme (1992) describe and explain the importance of the CODP further. They state that the positioning of the CODP is of great importance for the determination of organizational structure and the types of unavoidable risks that one will have to face (e.g. risks associated with obsolete stock and other risks associated with inventory).

Following the reasoning that an operating unit's context affects which actions that lead high performance, the CODP can be considered a contextual parameter which has far reaching implications for operations design and priorities. Producers who operate based on forecasts can determine quantities, variants and production schedule themselves, whereas producers who operate based on actual customer orders need to be flexible enough to meet their demand in a reactive manner. To further illustrate the importance of the CODP, one can think of a scenario in which a firm is considering launching a new product. If this product has a CODP positioned differently from the already existing products, it will affect the firm's risk exposure since the new product entails new inventory demands, operations and supply chain priorities for this product might need to change due to new flexibility and capacity requirements, for example, and this might also imply that the required levels of integration with partners change, among other things. The CODP's position in the value chain needs careful consideration since changing it, or establishing a new CODP, may necessitate substantial changes to the structure of both internal operations and the supply chain. The four most common CODP positions, make-to-stock (MTS), assemble-to-order (ATO), make-to-order (MTO) and engineer-to-order (ETO), are depicted in Figure 1.1 below.

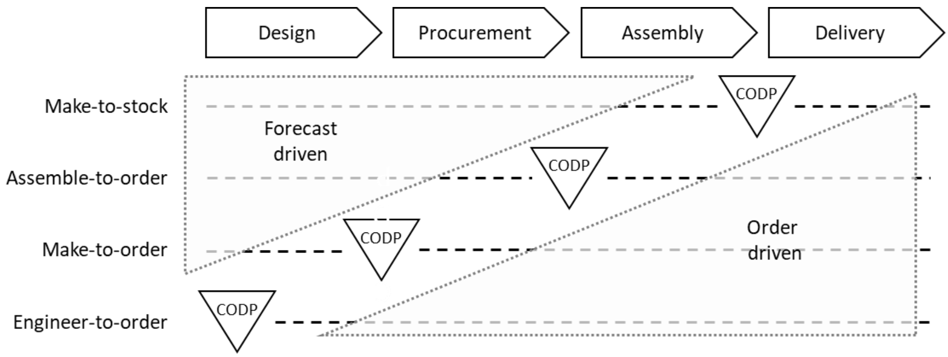

Figure 1.1 Description of the four most common CODP positions (Harfeldt-Berg and Harfeldt-Berg, 2023).

In short, the CODP is the point that separates the material flow and its associated operations into two parts: an upstream part which is driven by forecasts and a downstream part which is driven by actual customer orders. As such, it has far-reaching implications for operations as well as stipulations on their environment.

Table 1.1 Upstream and downstream aspects of selected CODP-related factors.

CODP-related factor (source)	Upstream of the CODP	Downstream of the CODP
Levels of product standardization or customization (Giesberts and van der Tang, 1992)	Standardized products, produced according to forecast.	Customized products, produced based on actual customer orders.
Market and demand characteristics (Childerhouse et al., 2002; Perona et al., 2009)	Demand is predictable and demand volumes are high.	Market demand is spiky and unpredictable, volumes vary but are typically lower (per product variant).
Supplier characteristics (Fisher, 1997; van der Vorst et al., 2001)	Focus on cost and quality to facilitate cost efficiency.	Focus on speed and flexibility (besides quality) to ensure responsiveness.
Information technology integration and information sharing (Agarwal, Shankar and Tiwari, 2006; Ojha et al., 2021)	IT integration is not emphasized. Timely sharing of high-quality information has limited effects.	IT integration is emphasized. Considered an enabler of agile characteristic. Timely sharing of high-quality information is beneficial.
Capabilities of production systems (Berry and Hill, 1992; Naylor et al., 1999)	Cost-efficiency, lean, high throughput rate, and a level schedule.	Flexibility, agility, capacity to deal with demand spikes.
Logistics integration (Birou et al., 2009)	Close co-operation w.r.t delivery and inventory management is somewhat beneficial.	Close co-operation w.r.t delivery and inventory management is highly beneficial.
Important performance metrics (Childerhouse et al., 2002; Drake et al, 2013; O'Reilly et al., 2015)	Cost and fast deliveries are important. Quality is an order qualifier.	Flexibility and service level are important. Quality is an order qualifier.

The CODP and its pertinence to supply chain strategy have been known for quite some time. Despite this being the case, it is relatively rare to come across the CODP in empirical operations and supply chain management (OSCM) research. When it is explicitly included, however, it usually plays a central role for the outcomes of the research. Examples of such research are Olhager and Prajogo (2012) and van Donk and van Doorne (2016). Both these studies find that the CODP constitutes an important contingency variable in the context of supply chain integration (SCI), affecting the performance impact of different types of integration practices. Another study by Prasad et al. (2005) compares several dimensions between MTS and build-to-order (which is used analogously to MTO) and conclude that uncertainty, information complexity, and supplier complexity are higher in the MTO context, whereas operational independence, meaning that the focal firm has freedom of choice concerning stock points and flexible order fulfillment times, is higher in MTS contexts. There are numerous examples of research which corroborate that the CODP position is an important factor to consider in OSCM research, but the concept is arguably quite underutilized. Especially, it is rare to find empirical research which considers the importance of the CODP position, which is described further in appended paper I.

In fact, there have been multiple calls for further consideration of the CODP in OSCM research in recent years. Examples of this include Olhager and Prajogo (2012), Liu et al. (2015), van Donk and van Doorne (2016) and Peeters and van Ooijen (2020). Olhager and Prajogo (2012) and van Donk and van Doorne (2016) conclude that the CODP is a vastly important contingency in the context of SCI, but they also conclude that the CODP should be investigated in other OSCM contexts as well, given its significant importance in their studies. In a similar fashion, Liu et al. (2015) conclude that future research investigating the effects of contextual parameters on the CODP position is needed, since circumstances that affect the optimal positioning of the CODP are often changing and many firms produce certain products to order, while other products are produced based on forecasts. Their argument for further research is based on the fact that order-based and forecast-based contexts require different actions from the plant or firm and suggests that research comparing MTO and MTS operations is highly relevant. Peeters and van Ooijen (2020) argue that, since hybrid production systems combining MTO and MTS are commonplace in practice, more research on planning and control of such production systems is warranted. Another recent example calling for further inclusion of the CODP in OSCM research is Dittfeld et al. (2022). They argue that more research which includes the CODP as a contingency is needed in the topical subject of supply chain resilience. They found that the CODP, through its association with production strategy, also influences how firms develop resilience to supply chain disruptions. There have also been calls for the inclusion of the CODP in the contemporary research field of supply chain sustainability (Venugopal and Saleeshya, 2019). Addressing all calls for further research is beyond the scope of one thesis, why this thesis will only concern selected areas. More precisely, this thesis will address how the CODP affects the relationship between SCI and operational performance, if and how the CODP position mediates the relationship between mass customization, modular design and operational performance, as well as its role in the growing area of supply chain and operational sustainability.

1.2 Purpose and research objectives

The purpose of this thesis is to address and illustrate the importance of the CODP, especially to empirical OSCM research. In order to paint a picture that justifies the claim that the CODP is important, three, more precise research objectives are targeted:

Research objective 1: Identify research areas in the OSCM field that have empirically verified associations with the CODP position.

Research objective 2: Empirically analyze the effect of the CODP position on the relationship between selected OSCM research topics and operational performance.

Research objective 3: Explore the relationship between the CODP position and environmental sustainability in OSCM.

Section 1.1 describes that the CODP could be relevant to several other research areas within the OSCM field as well. Addressing all of them is however outside the scope of one thesis, why I limit my research to a few specific areas where further inclusion of the CODP has been warranted by extant research. Table 1.2 below illustrates which research objectives the appended papers address.

Table 1.2 Research objectives addressed by the appended papers.

	R.O. 1	R.O. 2	R.O. 3
Paper I: ”The customer order decoupling point in empirical operations and supply chain management research: A systematic literature review and framework”	X		
Paper II: “Exploring the role of customer order decoupling points in operations and supply chain management: The case of supply chain integration”		X	
Paper III: “The role of customer order decoupling points for mass customization, modular product design and performance”		X	
Paper IV: ”Connecting organizational context to environmental sustainability initiatives and industrial symbiosis: Empirical results and case analysis”		(X)	X
Paper V: ”Environmental sustainability from a decoupling point perspective”		(X)	X

The included research aims to contribute to both the OSCM research field and to practitioners by examining topics where the CODP has been requested to play a more central role. The results presented in the thesis show that the inclusion of the CODP position can enhance the analysis and inference of multiple topics in the OSCM field. In addition, empirical and statistical research methods are predominantly used, which enhances the relevance to practitioners since the results and conclusions stem from real-world observations. The research approach, data sources and methods of the appended papers will be described in the coming chapters of the thesis.

1.3 Delimitations

Like most research, there are several delimitations attached to the research covered by this thesis. Firstly, much of the included research examines the interplay between operational performance, the CODP position and other aspects of supply chain operations. The performance of a supply chain is definitely affected by many factors external to the involved supply chain actors and lie outside their control. The global Covid-19 pandemic is a good example. Macroeconomic trends and shortage of raw materials, for instance the semiconductor shortage of 2020-2023, are others. Generally, I have not accounted for such external factors.

Secondly, one focal plant has consistently been the focus of attention of my research. I have not studied entire supply networks or any other form of multi-firm partnerships, for instance dyads. The analyses presented in this thesis use data which are collected from the focal plant's perspective.

Thirdly, the topics addressed in this research are typically of strategic character and investigate high-level relationships between several aspects of supply chain management. I have not made any detailed examination of the mechanisms through which these relationships manifest themselves. Examples of how this can be done in future research are provided in section 6. Furthermore, I have primarily used statistical analyses for the research covered by the thesis. Statistical analyses of the kind I employ typically produce general results concerning the studied topic, and do not establish any causal relationship between the studied variables. If the aim of research is to investigate such matters, which it often is in the OSCM field instead, one can, and should, use qualitative or other quantitative methods, for instance case studies or simulation.

Finally, the data source used for the statistical analyses in this thesis has certain limitations. The data come from the fourth and latest iteration of the High Performance Manufacturing (HPM) study, finishing in 2016. Obviously, the contents of the HPM data limit which topics can be addressed and how they can be analyzed. Luckily, this questionnaire study is very comprehensive and includes questionnaires on almost all OSCM topics of contemporary interest. Data is gathered in 15 countries, at 330 manufacturing plants and come from three different industries: electronics, machinery, and automotive suppliers. The main limitation of the HPM data is the fact that only three industries are represented. This implies that extrapolation to other industries and sectors need to come with a caveat. Secondly, the data was gathered before the Covid-19 pandemic. The pandemic years constitute a disruptive period for OSCM practitioners and researchers, so some of the results could have changed slightly recently. The HPM data is described in more detail in section 3.2.2.

1.4 Dissertation structure

The rest of this thesis is structured as follows: chapter 2 will explain the theoretical background that underpins the appended papers. In addition, chapter 2 describes the type of contribution intended by the thesis. Chapter 3 will then move on to explain the methodologies used to conduct the presented research, as well as a section on philosophy of science, which helps explain and motivate the methodological stance taken. In this chapter, one will also find a section dedicated to the HPM data which is used for most empirical analyses in the thesis. Chapter 4 moves on to summarize the appended papers, focusing on their results, since the most important aspects of the applied methods are already explained and illustrated in chapter 3. For a more detailed description, one is encouraged to look in the appended papers. The implications of the papers' findings are discussed and elaborated on in chapter 5, and, finally, chapter 6 offers a broader, more holistic conclusion related to the research objectives, theoretical and practical implications, limitations, and ideas for further research.

2. Research background and contribution

This chapter explains the theoretical background and underlying reasoning of the research included in the thesis, both in a general sense and for the individual papers. It also describes the type of contribution intended by the thesis. Lastly, the criteria which are met to justify its addition to the existing body of knowledge are described.

2.1 Fundamental reasoning of the included research

The calls for further inclusion of the CODP mentioned in the Introduction all rest on the same fundamental idea that important contextual factors impact an organization's actions, which in turn lead to some effectiveness or performance outcome. Collis (1994) explained that the competitive advantages that organizations can achieve through developing their capabilities are highly context dependent, why it is not possible to state what exactly constitutes a valuable capability. Hayes and Pisano (1994) provided similar ideas, arguing that adopting agreed-upon best practices, attempting to become "world-class", is not a general recipe for success and will not be enough for many firms. Instead, organizations need to carefully consider what specific things they need to be great at in order to become successful. Upton (1998) implicitly explains why this is the case by describing that an organization needs to design its structure and operations such that it can adequately cope with the requirements posed by its environmental and social context.

Since the CODP divides operations into forecast-driven and order-driven sections, it also divides operations into different contexts: in the former, no explicit customer order is considered yet, and the organization can operate according to its own plan, whereas the latter implies that the organization needs to respond to an actual order as well as possible (assuming that the organization is stressed by some form of competition). This implies that improvement initiatives undertaken by an organization are likely to have different performance impacts depending on whether the targeted operations occur upstream or downstream of the CODP, since the operations then occur in different contexts. This line of reasoning suggests that the CODP is an important contingency variable in OSCM. Donaldson (2001) provides an extensive account of contingency theory and its history, and he explains that the fundamental, general idea behind the theory is that, in many cases, it is too simplistic to consider bivariate relationships such that a variable X has a certain effect on variable Y. In many practical situations, not the least in organizational research, the relationship between X and Y is moderated by a third variable, W, often referred to as a contingency variable. Identifying contingencies is important for the sake of making sure that OSCM research offers correct recommendations to both researchers and practitioners (Sousa and Voss, 2008). A failure to account for important contingencies could lead to erroneous conclusions and recommendations that lead practitioners down an ineffective or even harmful path.

Concisely, the reasoning which underpins the research in this thesis can be expressed in the following manner: the context of an organization has an impact on the appropriateness of different actions taken by the organization, and actions taken will in turn lead to some performance outcome. If an action which is appropriate for the organization's context is taken, it will lead to positive performance outcomes, other things equal. The CODP divides operations into different contexts, implying that the performance impact of an action is likely to be different on the upstream and downstream sides of the CODP. In that sense, the CODP moderates the action-performance relationship, and functions as a contingency variable. Although not always stated explicitly, the calls for further inclusion of the CODP come from the strong notion that the CODP is an important contingency variable that needs to be more carefully considered in the OSCM research.

The fact that the CODP is used as a moderating or mediating variable in papers II through V is a result of the reasoning related to contingency theory just explained. Since this is the case, it is a fair claim that contingency theory provides theoretical motivation for the research presented in the thesis.

2.2 Backgrounds of the included articles

Section 2.1 provides the common line of reasoning which motivates the inclusion of the CODP position in research in general, which is very much connected to context-action-performance-reasoning and contingency theory. This section will now make a deeper dive into the individual backgrounds of papers I through V, explaining how they intend to add to existing knowledge.

2.2.1 Literature review of empirical CODP research (Paper I)

The first included paper is motivated by three things, primarily. The first is the authors' (well-founded) notion that the inclusion of the CODP, and consideration of both the upstream and downstream sides of this point, are rare sightings in empirical OSCM research. Following the reasoning outlined in section 2.1, research which includes the CODP position could potentially be of high practical and theoretical relevance, since both supply chain and operations ought to be managed quite differently on the upstream and downstream sides of the CODP. The second thing which motivates the literature review is to some degree a confirmation of the first notion, for instance expressed by Peeters and van Ooijen (2020). They recognize that research involving both the MTO and MTS decoupling point positions can offer insights which are out of reach for research concerning only one CODP position, and that the literature landscape involving MTO and MTS decoupling points is fragmented. They also state that they had not been able to find any published literature reviews regarding the management of operations which involve both MTO and MTS. Furthermore, Tiedemann (2020) conducted a structured review of literature related to demand driven supply chains, and his review revealed that the decoupling point concept is closely related to many other areas of the OSCM field, signalling that the CODP could be a highly relevant topic for various types of research in the OSCM field.

Third, all manufacturers implicitly need to select CODP positions for their products. It should be noted that the CODP positions of the different products being produced can vary, of course, but the manufacturer nonetheless needs to receive an order for the products at some point. Since the CODP position is a parameter that all supply chains contain, regardless of their design and configuration, reviewing empirical literature which has assessed the implications of different CODP positions can offer useful insights to practitioners and researchers. Especially since no such review had been published before the publication of Paper I, to the very best of the authors' knowledge.

2.2.2 Supply chain integration and the CODP (Paper II)

The second included paper, *Exploring the role of customer order decoupling points in operations and supply chain management: The case of supply chain integration*, concerns the highly researched area of SCI, and although this is an area which has enjoyed great interest from researchers, there are arguably ways to add to this body of research.

Firstly, references such as Olhager and Prajogo (2012) and van Donk and van Doorne (2016) illustrate that the CODP is an important contingency to account for in the context of SCI, suggesting that SCI is an appropriate topic for this thesis. The idea that moderating variables, or contingencies, are important for SCI research has received additional support from a meta-study by Ataseven and Naim (2017). Secondly, many modern papers concerning SCI are using different measures of integration for suppliers and customers. One can find examples of this in Huo et al. (2016) and Wong et al. (2017). Although this is not inherently wrong, it can make it difficult to compare integration practices directed upstream to those directed downstream. There are also examples of SCI research which combines multiple SCI practices into one single SCI measure, for instance Flynn et al. (2010), Wong et al. (2017), and Qi et al. (2017), and while this also is not inherently wrong, it makes it impossible to discern which individual practices that lead to certain performance outcomes. This has been pointed out as a potential problem by for instance Ahmed et al. (2017) and Ahmed et al. (2019).

Based on these potential shortcomings of much SCI research, paper II uses both the CODP as a contingency, includes multiple measures of SCI and uses the same types of SCI measures for both supplier- and customer integration, making the results for upstream- and downstream integration comparable.

2.2.3 Mass customization, modular design and the CODP (Paper III)

Paper III, *The role of customer order decoupling points for mass customization, modular product design and performance*, concerns the well-known and thoroughly researched topics mass customization (MC) and modular design (MD), as well as their relationships to operational performance. Although these topics have been thoroughly studied, literature concerning these topics very rarely relate them to the CODP. In fact, the literature review published in paper I does not identify any empirical papers that link MC, MD and the CODP together, although product customization is identified as a CODP-related factor. One can easily find both older and more contemporary research which relates MC and MD, for instance Pine II et al. (1993), Sandrin et al. (2018) and Zhang et al. (2019), Pine II et al. (1993) even argue that MD is a prerequisite for MC, but the CODP is left outside the picture.

Intuitively, it is easy to motivate why the CODP should be included in research regarding MC. In order for a product to be customized, some manufacturing operations must remain after the customer order has been received. The degree to which a product can be customized is to a great extent dictated by the CODP position, which also implies that the CODP position impacts the degree to which an organization can use mass production-like operations. One can find a few examples of research which has related the CODP to MC. See for instance Daaboul et al. (2015) and Guo et al. (2021). It should be noted that there is a clear distinction between making multiple varieties of products and making customized products. The former could be done according to forecasts, whereas the latter can only be done once customer requirements have materialized.

MD, on the other hand, does not require any specific CODP position. A product designed and manufactured under ETO principles could use a modular design, and the same goes for products produced under MTS principles. For this reason, there is no direct linkage between MD adoption and the CODP position. Some research has however associated MD with the ATO decoupling point position (Bask et al., 2011, and Cannas et al., 2019). As mentioned earlier, though, there is research which argues that MD is a prerequisite for MC, and there is also a strong intuitive connection between MC and the CODP, which has already received some support in the literature, and this implies that both MC, the CODP, and MD could be connected. No published, empirical literature relating all three concepts has been identified, so despite MC and MD being well-researched topics, paper III adds a new perspective on these issues.

2.2.4 Industrial symbiosis and the CODP (Paper IV)

Connecting organizational context to environmental sustainability initiatives and industrial symbiosis: Empirical results and case analysis, the fourth paper included in the thesis, concerns the interplay between the CODP, environmental sustainability practices (ESPs), and industrial symbiosis (IS). There are primarily three factors that motivate the study of paper IV in the thesis. Firstly, the field of circular economy is growing and developing quickly, and calls have been made for more mixed-methods research, combining empirical data analysis with other methods (Atanasovska et al., 2022). In part due to luck, the authors had an opportunity to conduct a mixed-methods study since we had access to both an IS network in Sotenäs, Sweden, and survey data concerning ESPs of manufacturing plants. This situation provided an excellent opportunity to meet the call for increased mixed-methods research.

Secondly, it has been shown that the CODP is an important contingency for the relationship between SCI and performance. IS can be considered a specific type of integration which, to the best of the authors' knowledge, has not been included in the SCI literature before. Investigating if this type of integration is better suited for some specific CODP position would therefore add some new findings to the field. Some research has alluded to the idea that the CODP ought to be important for IS, describing that stable, predictable high-volume resource flows are important facilitators of IS (Aid et al., 2017; Ji et al., 2020; Colpo et al., 2021). These types of flows are normally more closely associated with MTS operations than MTO operations.

2.2.5 Environmental sustainability practices and the CODP (Paper V)

The fifth paper in the thesis, *Environmental sustainability from a decoupling point perspective*, revolves around the CODP's role for ESPs. To a large extent, this study is motivated by some of the results presented in paper IV: ESPs lead to different levels of experienced performance impacts for plants operating with different CODP positions. Furthermore, there have been calls for further inclusion of the CODP in the sustainable supply chain management field, which was also mentioned in the Introduction.

The results in paper IV which beg further investigation of the CODP's role in the context of environmental sustainability are, to the best of my knowledge, the first empirical results which indicate that the CODP is linked to ESPs in a significant way. However, this does not mean that there is no theoretical support upon which the study can be based. As discussed in the Introduction and section 2.1, multiple aspects of an organization's OSCM practices need to be designed and planned according to the CODP position. Since this is the case, it is not a far-fetched idea to think that ESPs might also need to be adjusted such they are appropriate for the current CODP position. For instance, the competitive priorities of the organization's manufacturing will have implications for which ESPs that might be appropriate. Lean and agile principles are prime examples of this. These two manufacturing paradigms are associated with the CODP such that lean principles are closely related to MTS operations on the upstream side of the CODP, whereas agile principles are a better fit for MTO operations on the downstream side. This is emphasized in the literature regarding leagility (Naylor et al., 1999 and Gaudenzi and Christopher, 2016).

Lean and agile principles have also been associated with improved environmental sustainability. Examples of this are found in Gunasekaran et al. (2019) and El-Khalil and Mezher (2020) who relate agile principles to environmental sustainability, and Azevedo et al. (2011) and Prasad et al. (2016), who explain that lean practices can be beneficial for environmental sustainability. Interestingly, Ciccullo et al. (2018) find that lean and agile principles relate to environmental sustainability through different mechanisms. Lean operations' focus on waste minimization can often be unified with low levels of emissions, for instance, whereas the flexibility of agile operations enable an organization to efficiently transform their manufacturing systems and products to become more sustainable. This implies that existing research has related the CODP position to environmental sustainability, at least indirectly, since environmental sustainability has been associated with other, well-known concepts that are also connected to the CODP.

In short, even though the results presented in paper IV which initiated the study presented in paper V are new, there are theoretical notions and prior results which suggest that the CODP could have a significant role to play in supply chain sustainability research. Paper V is one of the first papers, if not the first, which attempts to empirically investigate and verify this.

2.3 Type of contribution made by the thesis

Although contingency theory forms a theoretical backdrop for the included research, no theories are explicitly tested in the thesis. Rather, the presented research primarily uses empirical evidence to add to the body of knowledge regarding a few selected OSCM topics. As mentioned earlier, some of the studied topics are already extensively researched, primarily SCI and MC and MD, and since this is the case, one cannot merely state that a studied topic could use further investigation. In order to motivate the contribution of the thesis to the existing body of knowledge, I have used the following criteria: firstly, the objective of the research should concern a question which has not been completely explained in the literature, implying that it identifies a research gap and discusses something new. Secondly, the findings of the data analysis, be it quantitative or qualitative, must reveal something which has not been shown before. Third, and lastly, the research must provide plausible explanations as to why the new findings occur. It should be noted that studying something which has not been investigated before, or presenting new findings, does not require that research concerns a wholly new, unchartered topic. Adding layers of nuance to existing findings also expands the body of knowledge, since it increases the granularity and precision of our understanding. The criteria I have used have been inspired by Whetten (1989), Ketchen Jr. and Hult (2011), and Rindova (2011), three papers that discuss theory building in the context of organizational science.

For the sake of the thesis, paper I serves the purpose of discovering and assessing CODP-related knowledge which has been empirically verified. It also reveals research areas within the OSCM field that have not been completely mapped out from a CODP point of view. Therefore, it functions as a primer for the other papers. The rest of the included papers expand on existing knowledge by analyzing topics which have been identified as inconclusively studied in the existing literature. Plausible explanations behind the findings of the included papers are then provided. In that way, the thesis 1) identifies research areas in the OSCM field which can benefit from further investigation, 2) conducts empirical investigations in a selection of these areas, and 3) motivates the new findings through plausible reasoning. This implies that the thesis fulfills the three criteria outlined above.

3. Methodology

The methodology chapter introduces philosophy of science to help position the work of the thesis from an ontological and epistemological perspective. This stance helps guide the choice of methods and the way in which inference is made. Furthermore, this section provides an overview of the research structure and explains the major methods of analysis that have been adopted in the appended papers.

3.1 Philosophy of science

Two central concepts when discussing the philosophy of science are ontology and epistemology. The philosophical field of ontology concerns the nature of reality. The most central question is the following: "What is the form and nature of reality, and what can be known about that reality?" (Ponterotto, 2005, p. 130). The related field of epistemology, theory of knowledge, concerns the relationship between the knower and the known and the creation and development of knowledge (Arlbjørn and Halldorsson, 2002; Ponterotto, 2005). Together, these two fields can be combined to form the foundations of different research paradigms, each having its own implications for what the focus of research should be and how it ought to be conducted, implying that certain methodologies are advocated in each paradigm.

Guba and Lincoln (1994) outline four research paradigms with their respective stances on ontological, epistemological, and methodological questions: positivism, postpositivism, critical theory, and constructivism. Three of these, positivism, postpositivism and constructivism, are also described by Arlbjørn and Halldorsson (2002).

The oldest and most classic paradigm, used in for instance physics and chemistry, is *positivism*. The world is considered a real entity that can be studied objectively, without bias. Therefore, it also stipulates that quantitative methods and experiments should be used, such that confounding variables and factors can be controlled. Research findings are typically considered true, and an emphasis is put on confirming hypotheses. As such, positivism often premiers research based on deductive reasoning.

Postpositivism rests on more or less the same ontological foundation as positivism. However, postpositivism does not assume that all facets of reality can be apprehended and understood by flawed human intellects. This implies a different stance on epistemological and methodological issues. Objectivity should be a guiding star, but since it is not fully attainable, it is very important that a critical community of, for example, reviewers, editors and professional peers examines findings. If research findings have been vetted and approved by the critical community, they are considered probably true. In terms of methodology, postpositivism opens up for more qualitative methods, even though quantitative methods are still very important. It also stresses that triangulation is important, meaning that an issue is studied and examined using different methods. Emphasis is put on falsifying hypotheses, as opposed to confirming them.

A third paradigm, which Guba and Lincoln (1994) describe as an umbrella covering multiple, similar theoretical perspectives, is *critical theory.* From an ontological point of view, reality is viewed as a plastic construct that has been shaped by numerous man-made factors, such as economic, cultural, and political factors. Facts can never be truly isolated and viewed without our own values affecting our perception, implying that we can only observe a virtual representation of reality (Ponterotto, 2005). From an epistemological perspective, critical theory suggests that there is an interaction between the researcher and the studied object, and that this interaction is always affected by the values of the researcher. From a philosophical point of view, this implies that the reality is in part created as it is being studied. Discourse and dialogic methods are very important, especially in social sciences, making qualitative methods and a community of peers essential for knowledge creation.

The last paradigm described by Guba and Lincoln (1994) and Arlbjørn and Halldorsson (2002), *constructivism,* also views reality as a relative concept, which is perceived through filters of our own experiences. This necessitates that the ontology and epistemology of constructivism are intertwined and not separated from each other, similar to the critical theory. Reality is shaped as it is being studied, since the act of studying it can create new experiences and nuances that affect how it is perceived. In terms of methodology, constructivism prescribes that interpretation, interaction and consensus are paramount (Ponterotto, 2005). If the researcher and his or her peers, or respondents, agree on a certain interpretation of reality, one has reached potentially valuable research findings.

The research presented in this thesis is most appropriately positioned in the postpositivist camp. I do believe that there are objective truths that we can measure, more or less accurately, both generally and in the field of OSCM, more specifically. Financial performance metrics of studied firms, for instance. On the other hand, I do not believe that we can control every potentially confounding variable and infer completely causal relationships. If, say, the unit cost of manufacturing is of interest in our study, and we are in investigating if a certain improvement initiative at the focal firm (such as the implementation of lean practices) lead to improved manufacturing costs, I do not think that we can control all external and exogenous factors that potentially affect this metric. Close to the time of data collection, multiple uncontrollable events could occur that affect the variable of interest; similar initiatives undertaken at a second-tier supplier that we do not account for, or recent fluctuations in currency exchange rates which impact the cost of material, or perhaps that the spot price of oil changes due to OPEC negotiations. Since OSCM is a social science, and not a "hard" science such as physics or chemistry, we cannot rely on experimental settings and research methods. Therefore, I believe that the postpositivist emphasis on hypothesis falsification and probable results are the best we can strive for. This is also reflected in the research methods of the appended papers, which will be presented shortly. Specifically, if the goal is to uncover probable results, inferred from the rejection of hypotheses, statistical analyses are very appropriate.

3.2 Research structure and methods

The quest to fulfill the research objectives outlined in the Introduction has been guided by the theoretical background and underlying reasoning presented in chapter 2. The described background, and additional sources presented in the individual articles, provide a foundation from which hypotheses (articles III and V) and research questions (articles II and IV) are formulated. How these hypotheses and research questions are to be investigated, i.e. the choice of methods, has been guided primarily by the ontological and epistemological stances of the postpositivist research paradigm. I primarily seek to use empirical techniques that produce results which can falsify and reject unlikely relationships among the data I have studied. The appended papers can be categorized under general types of methods, which is depicted in Figure 3.1 below.

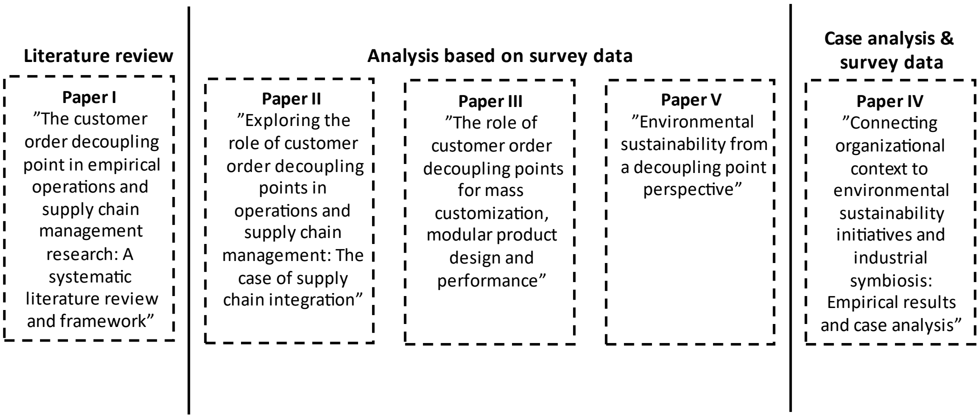

Figure 3.1 Appended papers according to general research methods.

The methods of the individual papers will be described in more detail in the following sub-sections.

3.2.1 Literature review

The systematic literature review in paper I adheres to the general guidelines described by Tranfield et al. (2003), Denyer and Tranfield (2009), Seuring and Gold (2012), and Xiao and Watson (2019). The search string used to find the initial sample of papers was formulated in the following manner: ‘decoupling point’ OR ‘penetration point’ OR ‘point of differentiation’ OR (make-to-stock AND (make-to-order OR assemble-to-order OR mix-to-order OR engineer-to-order OR build-to-order OR configure-to-order)) OR (‘make to stock’ AND (‘make to order’ OR ‘assemble to order’ OR ‘mix to order’ OR ‘engineer to order’ OR ‘build to order’ OR ‘configure to order’)) AND (operations OR production OR manufacturing OR ‘supply chain’). Although this seems cumbersome, different version of the keywords, for instance make-to-stock as well as ‘make to stock’, were included to make sure that no papers were excluded based on their formatting. The search strings were applied to two databases, Web of Science and Scopus, as these databases host peer-reviewed research from most reputable, English-language journals. Using these search strings also meant that the authors were able to identify literature which builds on the decoupling point concept, such as leagility and postponement.

The initial search resulted in a sample of 30 papers. From these 30 papers, forward- and backward searches were conducted to find 10 additional papers, resulting in a final sample of 40 papers. The evaluation of papers and criteria for inclusion are described in Figure 3.2 below, a PRISMA flow diagram inspired by Moher et al. (2009).

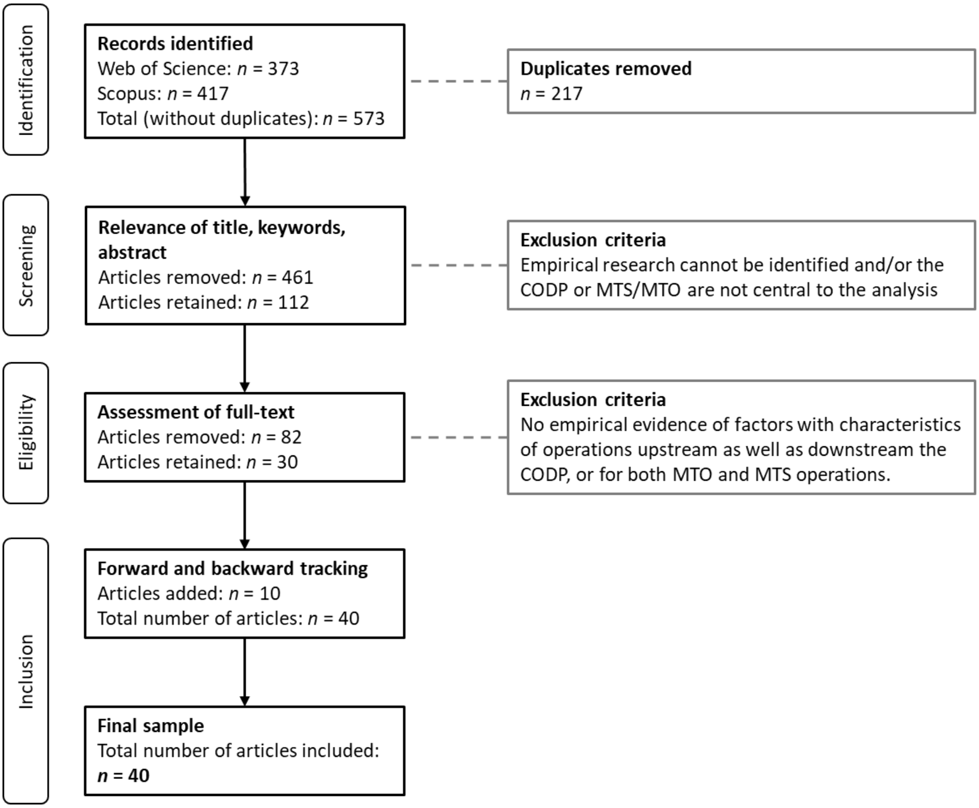

Figure 3.2 Literature review process of paper I (inspired by Moher et al., 2009).

The first step of vetting the identified papers was to exclude all duplicate search results. Once this was done, the titles, keywords, and abstracts of all the remaining, unique papers were checked. If there was no clear indication that the papers adopted empirical research methods, concerned both up- and downstream sides of the CODP, or that the CODP was a concept of central concern in the papers, they were removed from the sample. This concluded the screening of the sample, and 82 papers were retained after this step. These 82 papers were then read more thoroughly. In order for a paper to be eligible for inclusion in the final sample, it had to be apparent that it primarily used an empirical method to derive its findings, and that it concerned both up- and downstream sides of the CODP. After this step, 30 papers remained. Forward and backward tracking was then performed based on these papers, resulting in the final sample of 40 papers.

The content analysis process entailed both authors reading the sampled papers and recording the adopted methodology, the concept used as the point of departure for the analysis (decoupling point-concept or MTS vs. MTO), and classifying the factors that pertained to the up- and downstream sides of the CODP, or MTS and

MTO operations. The information was recorded in an Excel-based extraction form. Once all papers had been read by both authors, their respective interpretations were compared and, in case of differences, thoroughly discussed until agreement was reached. The factors pertaining to different sides of the CODP (or MTS vs. MTO operations) were grouped into themes, which will be presented in chapter 4.

3.2.2 Statistical methods and the High Performance Manufacturing study

The analyses of papers II, III, and V in this thesis are based on the same data source: the fourth and latest round of the HPM study. This round of data collection was finalized in 2016 and, in its raw format, contains answers from 330 manufacturing plants from 15 different countries. Three different industries are sampled: electronics, machinery and automotive suppliers. Stratified sampling (Scheaffer et al., 2011) has been used to attain similar samples from the different countries with respect to the number of respondents from each industry. All questionnaire items used for analyses in this thesis ask the respondents to provide information regarding the individual plant at which they are currently active, implying that the unit of analysis is the individual plant.

The master codebook of the HPM study is maintained in English and contains twelve sections with questions directed at different plant functions. This design relies on using key informants (Bagozzi et al., 1991) and, since it involves multiple respondents, greatly reduces the risk of common method variance, which according to Craighead et al. (2016) is a significant obstacle to overcome for theory-building research. Before being administered, the questionnaires are translated into the countries' local language by one of the HPM project research members, and back-translated into English to ensure consistency. Examples of research using HPM data are Turkulainen et al., (2017), Wurzer and Reiner (2018), Ye et al. (2018), Danese et al. (2019), Beraldin et al. (2022), and Marin-Garcia et al. (2023). Table 3.1 below shows the distribution of respondents according to industry and country.

Table 3.1 HPM respondents according to country and industry.

Country	Industry			Total
	Electronics	Machinery	Automotive suppliers	
Brazil	5	7	12	24
China	10	17	3	30
Finland and Sweden	10	10	6	26
Germany	6	13	9	28
Israel	21	5	0	26
Italy	7	17	5	29
Japan	6	7	9	22
Korea	8	5	13	26
Spain	8	7	10	25
Switzerland	3	6	2	11
Taiwan	19	10	1	30
UK	4	5	4	13
USA	5	7	3	15
Vietnam	10	7	8	25
Total	122	123	85	330

Two things should be clarified at this point. Firstly, the focus of this thesis and the appended papers is the CODP. The HPM data contains four questions related to the respondent's CODP position. These questions ask the respondent to provide the percentage of production that is produced according to MTS, MTO, ATO, and ETO principles. The respondent is also instructed that the sum of these percentages should add up to 100. These questions have not been answered by all the respondents, unfortunately, which reduces the theoretical maximum sample size to 232. Secondly, I have not personally been part of the data collection. The research that underpins this thesis commenced in 2018.

Based on the questions regarding the respondents' CODP positions, sub-sets of responding plants were created. These sub-sets contain plants that predominantly manufacture according to either MTS, ATO, MTO, or ETO principles. The subsets have been created using the *k*-means clustering procedure (Rencher, 2002; Hair Jr. et al., 2014). The procedure was carried out in IBM SPSS 29, with the percentages allocated to the four different production modes, and simultaneously different CODP positions, as classifiers. The 232 plants which had answered the questions regarding production modes were subject to this analysis, and the following clusters were produced:

Table 3.2 Percentage allocation of production modes for data sub-sets.

Percent allocated to…	Cluster			
	ETO *n*=20	MTO *n*=118	ATO *n*=43	MTS *n*=51
…ETO	**82.3**	3.4	9.4	1.9
…MTO	11.6	**85.2**	17.9	17.8
…ATO	0.6	4.1	**63.8**	4.7
…MTS	5.5	7.3	8.9	**75.6**
Total	100.0	100.0	100.0	100.0

The two most important sub-sets of data for this thesis are the largest ones, the MTO- and MTS clusters. This is for two reasons. Firstly, MTS and MTO operations are both very recognizable for people involved in the OSCM field, and they are also distinctly different on numerous levels, as MTS implies that almost all value-adding operations are performed according to forecasts, whereas the opposite is true for MTO. ATO is a form of operations that combine MTS and MTO flows (see Figure 1.1), and ETO is, from a material flow perspective, the same as MTO. Hence, MTS and MTO are the two most archetypical and distinct CODP positions. Secondly, for the statistical analyses to be as meaningful as possible, it is advisable to use as large samples as possible. The MTO and MTS sub-sets do not only represent plants which are very different in terms of operations, but they also happened to be the two largest sub-sets, which makes them very good candidates for comparison. Both Paper II and Paper V compare and contrast these sub-sets of plants.

Another type of statistical analysis that has been important for this thesis is factor analysis. This type of analysis has been used in all papers except for paper I, the literature review. The reason for using factor analysis so frequently is that the HPM data, which constitutes the primary data source used in the thesis, contains multiple items (or variables) which are supposed to measure different facets of the same underlying dimension. For instance, the HPM codebook contains no less than 42 items that concern a plant's environmental practices. If all of these are included in a statistical model, it would severely decrease the number of observations per variable, and the risk of multicollinearity among the variables would be very high. Factor analysis mitigates these issues, since it functions as a dimension reduction technique which combines multiple, individual variables into constructs, while still preserving the majority of the variables' information (Hair Jr. et al., 2014).

There are two types of factor analyses, broadly speaking: exploratory factory analysis (EFA) and confirmatory factor analysis (CFA). They differ in their underlying assumptions regarding the nature of the constructs. CFA requires that the relationships between variables and constructs are specified before the estimation ensues, implying that the researcher needs to specify a model which the analysis will confirm. Hence the name "confirmatory". EFA, on the other hand, comes with no stipulation on the amount or type of relationships there ought to be. Instead, one uses the data to explore how many underlying constructs or dimensions there are (Marsh et al., 2014). Another difference between EFA and CFA lies in the estimation of the magnitude of the relationships between the individual variables and the underlying dimensions, the so-called factor loadings. CFA typically uses parametric techniques, such as multivariate maximum likelihood estimation to estimate factor loadings. These techniques come with their own sets of assumptions regarding the underlying variables' probability distribution. In EFA, one can use estimation techniques which do not have any assumptions regarding the variables' probability distribution, for instance principal component analysis (PCA). An overview of the mathematical techniques mentioned can be found in Rencher (2002).

Factor analysis is a very common method in the OSCM field. Some examples using it are Koufteros et al. (2005), Wong et al. (2011), Huo (2012), van der Vaart et al. (2012), Flynn et al. (2016), Panghal et al. (2023), and Singh et al. (2023). Some researchers in the OSCM field argue that EFA is perhaps outdated, and that solely relying on CFA is the state-of-the-art or best practice. As explained by Marsh et al. (2014) though, this is not always wise. Since CFA requires that the model is stipulated before the analysis, the researcher needs to define all possible relationships which are to be estimated. If the hypothesized model is not in good or near-exact correspondence with reality, the results will provide a faulty view of the interplay between variables and constructs in the data set. EFA, which is applied without any underlying model, will instead reveal the plausible number of underlying constructs that exist among the variables. This means that combining EFA and CFA provides an indication of both the number of plausible constructs and potential testing of model fit for any hypothesized model. This is the reason why papers II and III use both EFA and CFA.

IBM SPSS 29 has been used to conduct all EFAs in this thesis, and IBM SPSS Amos, version 28, has been used to conduct all CFAs. In papers II and III, the resulting constructs from the EFA have been used in the sub-sequent regression models. The reason for this is that EFA generates linearly independent (uncorrelated) constructs if it is applied with a principal component method for construct estimation. Using these constructs in the following regression analysis mitigates any potential issues with multicollinearity, increasing the overall quality and interpretability of the regression model (IBM, 2024).

Regression analysis, which also plays a crucial part in this thesis, is a very common and well-known statistical technique in the OSCM field. Examples of research employing different types of regression models are Zhu and Zarkis (2004), Vachon and Klassen (2006), Bode and Wagner (2015), Flynn et al. (2016), Yadav et al. (2022) and Essila and Motwani (2023). Regression analysis is used to assess the relationships between a set of explanatory variables, often termed independent variables, and one or more response variables, or dependent variables. There are many different versions of regression analysis, including non-linear models, non- or semi-parametric models, models with binary or multiple-choice response variables, etc., but the regression models used in papers II, III and V of this thesis are linear models, where it is assumed that linear relationships exist between the explanatory and dependent variables. If a linear regression model is supposed to fit data well, certain underlying assumptions regarding the nature of the data need to be fulfilled (Rencher, 2002, Hair Jr. et al, 2014). Firstly, the relationships between the response variables and the explanatory variables are assumed to be linear. If one has reason to suspect otherwise, the variables' relationships need to be examined before conducting the regression analysis. Secondly, homoscedasticity is assumed. This concept refers to the fact that the variance of the model residuals is the same for any values of the explanatory variables. Third, the observations are independent, meaning that the response variable's value taken by one individual in the sample is independent of any other individual's response. Fourth, normality of the response variable is assumed, conditioned on any value of the explanatory variables. If these assumptions are fulfilled, a linear model will be appropriate for modelling the data. Violating some of these assumptions is however not a big issue in most cases (Norman, 2010). This will be discussed further in chapter 5 of the thesis.

Evaluating the quality of a regression model is typically done by looking at the individual coefficient's size and statistical significance, the coefficient of determination (R^2), and a few diagnostics that assess whether the underlying assumptions of the model are fulfilled. The examples of research employing regression analysis referenced above contain good examples of this. In this thesis, I have assessed the quality of the regression models using the variance inflation factor (VIF) scores (Verbeek, 2012; Hair Jr. et al., 2014) to assess multicollinearity, (although this should not be an issue, by design, as explained earlier), correlations between explanatory variables and model residuals to assess endogeneity (Zaefarian et al., 2017) and the Breusch-Pagan test (Verbeek, 2012) to assess the homoscedasticity assumption regarding the residuals (paper III). None of these test statistics have indicated a problem with any of the regression models. For the sake of inference, I have relied heavily on the estimated effect sizes and the significance of the model coefficients, and not so much on R^2 values. The reason for this is first and foremost that the R^2 value is not comparable from one study to the next. As explained by Verbeek (2012), it is not possible to objectively assess what constitutes a high, or good, R^2 value. Secondly, the R^2 measures the quality of the linear approximation, not the quality of the assumed data generating process. For these reasons, it is stated that "/…/ the R^2 is typically not the most important aspect of our estimation results." (Verbeek, 2012, p. 22). The research question in paper II and the hypotheses in paper III and V also concern the coefficients of the regression models, their magnitude and direction to be precise, and not the entire models per se.

In paper V, a substantial amount of the findings stems from an analysis of variance (ANOVA). Once again, this is very common technique in the OSCM field. Examples of research within the field that use ANOVA include Quesada et al. (2008), Bourlakis et al (2014), Hao et al. (2022), Lozano (2023) and Fantozzi et al. (2024). ANOVA is used to determine whether one or several variables' mean or means differ between groups of data, which are supposed to represent different populations (Rencher, 2002). To compare groups of data in the manner prescribed by ANOVA, which involves comparing intra-group to inter-group variances, the data needs to fulfil certain assumptions, similar to those of regression analysis. Firstly, it is assumed that the all the variables compared between groups are normally distributed. Secondly, one also assumes that the distributions of the variables have the same variance across groups, and thirdly, one assumes that the groups of data are independent. Once again, these assumptions, and the consequences of violating them, will be discussed further in chapter 5 of the thesis.

The results of the ANOVA are evaluated by an *F*-test. This test is formed by a ratio between the so called "between" and "within" mean sum of squares for the analyzed groups (Rencher, 2002). The ratio follows the *F*-distribution, or Fisher-distribution, after Sir Ronald Fisher, hence the name *F*-test.

The last of the methodologies which will be described in this chapter is the qualitative method employed in paper IV, which is primarily a case study of an IS network in Sotenäs, Sweden. It should be noted that this paper also contains some analysis of HPM data, but the techniques used in this analysis (*k*-means clustering, EFA and ANOVA) have already been described.

The case study can be described as an embedded case study design (Yin, 2018), as the Sotenäs IS network can be seen as an overarching case in which sub-units, the individual IS network collaborators, are active. Figure 3.3 below illustrates the constellation of actors involved in the IS network at the time of data collection.

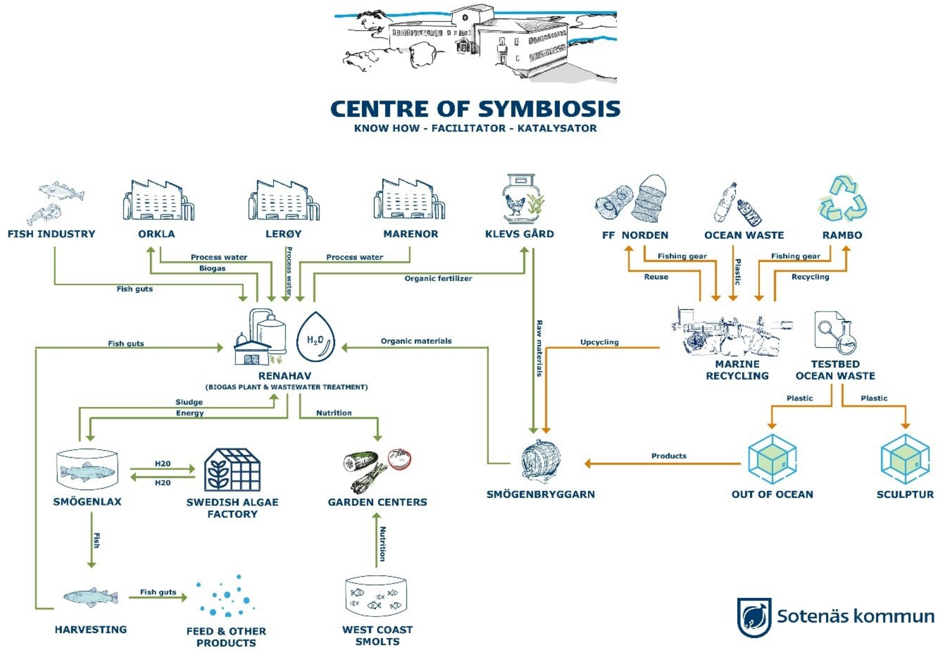

Figure 3.3 Illustration of the Sotenäs industrial symbiosis network (Harfeldt-Berg and Harfeldt-Berg, 2023).

The symbiosis actors who participated in the study of paper IV are found on the right-hand side of Figure 3.3, connected by orange arrows. More precisely, FF Norden, Rambo AB, the Sotenäs Marine Recycling Center, Smögenbryggar'n, Sotenäs Municipal Office, and Sotenäs Center of Symbiosis participated in the study. The data collected from the six study participants were collected in two steps. In the first step of the study, the participants were asked to complete a short survey questionnaire, and in the second step, longer interviews were conducted during visits to the study participants. The formulation of the questionnaire was discussed iteratively between the pair of researchers and external, senior researchers to ensure content validity. Once finished, the questionnaire was distributed electronically, and it filled two purposes. In part, it functioned as a primer before the interviews, prompting the participants to think about the central talking points to be discussed during the interviews, but it also gathered information regarding the study participants operations and organizational context, enabling the determination of the study participants' CODP position.

The interviews, constituting the larger, more comprehensive part of the data collection, were recorded and later transcribed by the authors. They followed a semi-structured format with talking points covering the drivers for, barriers to, and outcomes of IS participation. The interview transcriptions were proof-read by both research members and then analyzed systematically. Keywords regarding drivers, barriers and outcomes were searched for in the transcripts, and segments concerning these concepts were extracted and analyzed further by both researchers. The individual interpretations and conclusions drawn by the researchers were compared and discussed to reach a common understanding of the data.

4. Summary of appended papers

In this chapter, one will find summaries of the five appended papers. The focus lies on the results and findings of the papers as the backgrounds and methodologies have been described in chapters 2 and 3, respectively.

4.1 Paper I

The first appended paper of this thesis, "*The customer order decoupling point in empirical operations and supply chain management research: A systematic literature review and framework*", is a literature review examining OSCM research which has explicitly addressed the CODP and used empirical research methods. The literature review method employed is described in section 3.2.1 and the motivation behind the study is presented in sub-section 2.2.1. It can however be repeated that conducting such a literature review was motivated by the CODP concept's long history, its importance, which has been stressed by for instance Olhager and Prajogo (2012), van Donk and van Doorne (2016) and Dittfeld et al. (2022), and the fact that it is rarely included in empirical OSCM research. In addition, Peeters and van Ooijen (2020) stated that no review paper concerning the CODP had been conducted, lending support to the notion that the CODP topic had not been thoroughly addressed in any prior reviews. As this is the case, we set out to conduct a review which provides an overview of empirically verified impacts of different CODP positions on supply chain and operations management.

The 40 papers which were included in the final sample were thoroughly and independently read by both authors. Many aspects of the papers and their context were recorded in an Excel-based data extraction form. This information included facts about the source, factors that exhibit differences on the upstream and downstream sides of the CODP, the characteristics of these factors, details about the case or survey analyzed in the paper, and the core concepts used as a point of departure in the conducted research (e.g. CODP or leagility). Once the data had been extracted, the researchers compared and discussed their findings iteratively until a mutual understanding was reached. The factors that exhibited different characteristics on the upstream and downstream sides of the CODP were grouped into second order and aggregate themes. These aggregate themes and second-order themes are depicted in Figure 4.1 below, which also illustrates the main findings of paper I.

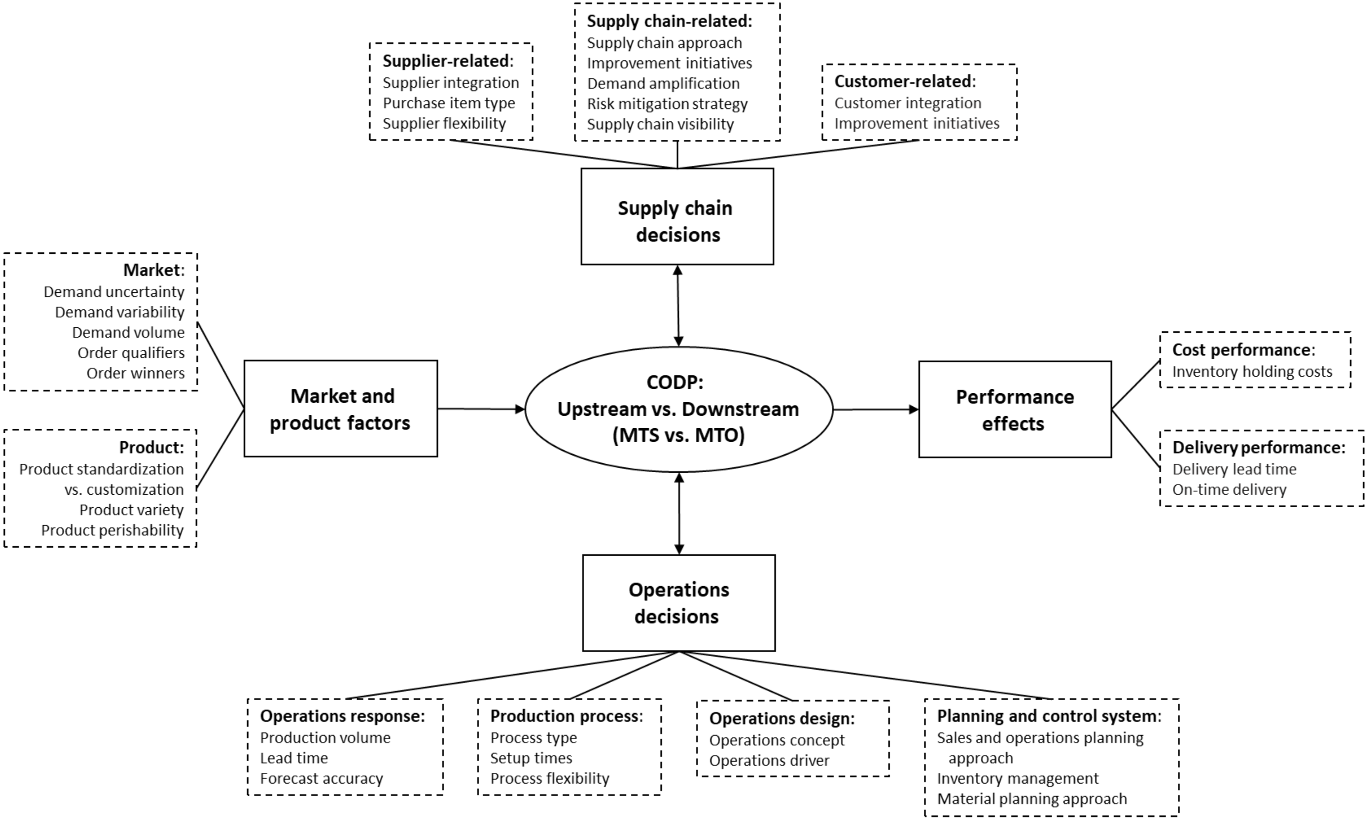

Figure 4.1 Framework illustrating differences among factors for different CODP positions (Harfeldt-Berg and Olhager, 2024).

The framework above shows that the CODP is related to both internal and external aspects of OSCM. Furthermore, some factors, such as demand characteristics of the market one is serving, will have an impact on where the CODP ought to be positioned. If the demand is very stable, for instance, it is feasible to operate based on forecasts and MTS production is an option. If the demand is very unpredictable and fickle, forecasting will not be fruitful, and it is likely better to produce according to actual, existing customer orders. Other factors, on the other hand, should be adapted according to the CODP once the decoupling point has been positioned. One such example is the amount of SCI that a firm pursues. Existent research suggests that integration is more beneficial for firms with order-based production. These findings have implications for both practitioners and researchers. Firstly, since the results of the analyzed papers stem from empirical research, the findings of the review indicate that managers need to consider the CODP position along with many other issues of strategic importance. Secondly, the findings also corroborate that the CODP is a contingency which requires consideration by researchers of many different topics within the OSCM field, as described in chapter 2.

4.2 Paper II

Paper II, "*Exploring the role of customer order decoupling points in operations and supply chain management: The case of supply chain integration*", considers the relationship between SCI and operational performance. This is a topic which has received much attention in the OSCM field since the seminal paper by Frohlich and Westbrook (2001). Despite the considerable amount of attention the topic has been given, there are still aspects of this relationship that remain blurry. Over the years, multiple studies have found differing and sometimes conflicting results regarding SCI's performance impact. Terjesen et al. (2012) and Zhao et al. (2015) found that the impact of SCI on performance follows an inverse U-shape, indicating that SCI can even have negative performance impacts. Terjesen et al. (2012) used operational performance measures and Zhao et al. (2015) used financial performance. Wiengarten et al. (2019) provide another good illustration of the murky relationship between SCI and performance. They compare the SCI-performance relationship attained with multiple rounds of data from the International Manufacturing Strategy Survey and find that SCI has different performance impacts in every round of the survey.

There are several potential reasons behind the less than clearcut results regarding the SCI-performance relationship. Two such reasons are described in sub-section 2.2.2: the omission of important contingencies or moderators (Ataseven and Naim, 2017) and too crude SCI constructs which do not capture the effects of different integration practices (Ahmed et al., 2017 and Ahmed et al., 2019). Paper II in this thesis considers both the role of the CODP as an important moderator of the SCI-performance relationship, as well as the performance impact of multiple integration practices. In this way, the paper contributes with both theoretical and managerial insights. The research model tested in the paper is depicted in Figure 4.2 below.

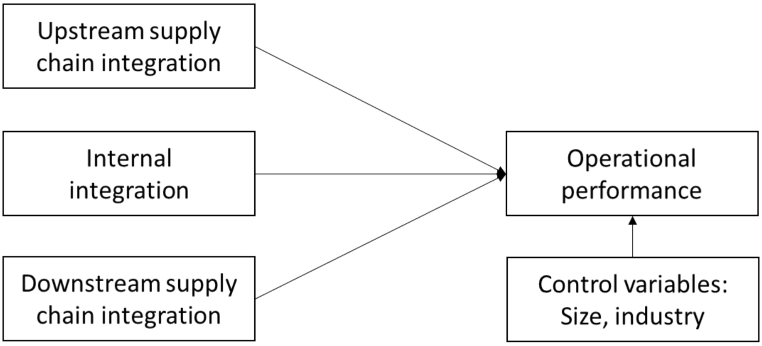

Figure 4.2 Research model of paper II, illustrating associations between SCI and performance.

The method applied to test this model is described in sub-section 3.2.2. The model is analyzed by linear regression and the rectangles on the left-hand side are constructs established by use of factor analysis, conducted on a set of HPM variables related to different aspects of SCI. In order to illustrate the importance of the CODP as a contingency, the same model is tested for a generic, full sample of plants, a sub-sample containing MTS-plants only, and one sub-sample containing MTO-plants only. The sub-samples stem from the *k*-means division of the HPM data described in sub-section 3.2.2. Table 4.1 below illustrates the significant regression coefficients attained from each of the samples, as well as their sign (positive or negative).

Table 4.1 Summary of all significant regression coefficients.

Construct	Cost	Quality	Delivery speed	Delivery reliability	Product mix flex.	Volume flexibility
SI-1: Information sharing	-	-	Full + (MTS) *	-	(MTS)+	(MTS) *
SI-2: Collaborative improvement	(Full) *** (MTO)+	-	-	-	MTO+	-
SI-3: NPD involvement	-	-	-	-	-	-
II: Functional integration	Full *** MTO ***	Full ** MTO *	Full *** MTO **	Full *** MTO ***	Full *** MTO ***	Full *** MTO ***
CI-1: Information sharing	-	-	-	-	-	-
CI-2: Collaborative improvement	-	MTO+	Full * MTO **	Full * MTO * (MTS) *	MTO+	-
CI-3: NPD involvement	-	-	Full+	-	-	-

Significance levels: + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
(x): parenthesis indicates negative impact.

The parentheses in Table 4.1 denote negative coefficients. The results depicted in the table above provide multiple insights. Firstly, it appears that internal integration, that is, cross-functional integration within the plant, appears to be the most vital form of integration, but primarily for plants operating in MTO mode. The coefficients are significant even for the full sample in which the plants' CODP positions are ignored. This is largely due to the fact that the positive performance effects are so distinct for MTO plants that they carry through even in the general, full-sample case. Recall from section 3.2.2. that the MTO-group is the largest sub-set.

A second insight provided by Table 4.1 is that significant coefficients attained from the analysis of the MTS sub-sample are all negative. This implies that SCI is often detrimental for performance if the plant operates in MTS-mode. On the other hand, the analysis conducted using only the MTO-plants generated eleven significant coefficients, and ten out of these were positive. It appears that SCI is far more beneficial for MTO-plants than MTS-plants.

Since there is such a stark difference between the performance effects experienced by plants with different CODP-positions, the CODP constitutes an important contingency in the context of SCI and performance. If the CODP is ignored, the results appear generally positive, and one risks providing the wrong recommendations to both practitioners and researchers regarding the efficacy of SCI. By incorporating the CODP as a moderating variable, paper II showcases its importance to both practitioners and researchers. In research regarding SCI, the CODP should be included in the analysis to ensure accuracy of results and recommendations. For practitioners, the results indicate that SCI is not uniformly a wise investment. Whether one's operations are conducted based on orders or forecasts should be considered before committing investments and efforts to increase SCI.

4.3 Paper III

Paper III in the thesis, "*The role of customer order decoupling points for mass customization, modular product design and performance*", concerns three concepts important to product design and supply chain design: MC (Pine II, 1993; Boynton et al., 1993), MD (Sanchez and Mahoney, 1996) and the CODP. As mentioned in sub-section 2.2.3, MC and MD have been thoroughly discussed in extant literature, but the combination of the CODP, MC, MD and their interactions has not been examined empirically in the same study before. Hence paper III adds to existing theory regarding MC and MD, at the same time as it sheds light on another context in which the CODP plays an important, moderating role.

The well-known concepts MC and MD have both been associated with multiple performance benefits. See for instance Gershenson (2003), Wang et al. (2016), Trentin et al. (2019), Kubota et al. (2022) and Persson and Lantz (2022). This enabled the formulation of hypotheses regarding the positive performance impact of these concepts. Similarly, different CODP positions are associated with certain performance characteristics: MTS operations are cost-efficient and have short delivery lead times, as the product is stored in a finished state, ready for delivery. MTO operations are associated with flexibility and quality, as the customers' orders dictate what is built and which qualities the end-product should possess. There are also examples of research relating the CODP to MC, allowing the formulation of hypotheses regarding the interplay between the CODP position and MC. There is however no clear-cut relationship between the CODP and MD, such that MD would be more suitable for a CODP positioned near either endpoint of the CODP scale, ETO or MTS. Therefore, an exploratory approach is adopted towards the interplay between the CODP and MD. The hypotheses formulated and tested in paper III are the following:

H1a: A late CODP position, close to MTS, will lead to higher levels of cost and delivery performance.

H1b: An early CODP position, close to ETO, will lead to higher levels of flexibility and quality performance.

H2: Higher levels of MC lead to higher levels of operational performance.

H3: Higher levels of MD lead to higher levels of operational performance.

H4a: Higher levels of MC and a late CODP, close to MTS, lead to higher levels of cost performance.

H4b: Higher levels of MC and an early CODP, close to ETO, lead to higher levels of flexibility performance.

H5: Higher levels of simultaneous MC and MD lead to higher levels of operational performance.

These hypotheses are tested using hierarchical regression analysis. The CODP position is modelled as a continuous variable in paper III (Olhager and Selldin, 2007; Mishra et al., 2019), ranging from 1 to 5, which allows the formation of interaction terms in the regression model. A high value corresponds to a late CODP position, close to MTS, and a low value corresponds to an early CODP position, close to ETO. The research model of paper III, depicted in Figure 4.3 below, illustrates the hypothesized relationships between the CODP, MC, MD and several dimensions of operational performance.

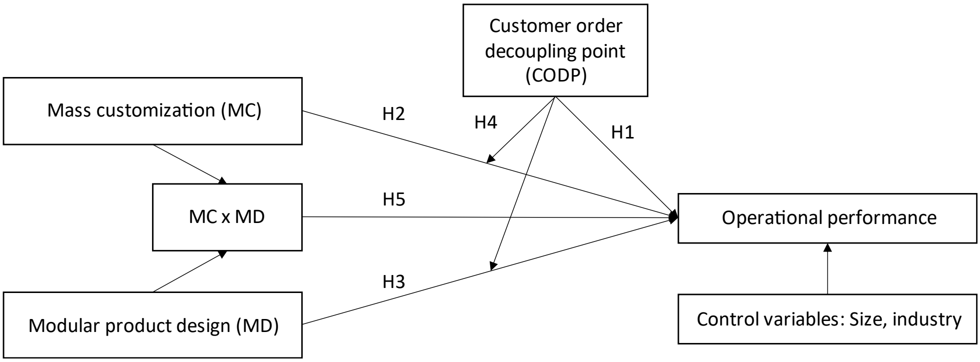

Figure 4.3 Research model of paper III, illustrating hypothesized relationships between the CODP, MC, MD, and performance.

The main results and all significant coefficients attained from the tested models are presented in tabular form below. The negative interaction terms associated with CODP x MC are non-trivial and indicate that MC is perhaps not a viable option for all plants, depending on where the CODP is positioned.

Table 4.2 Summary of significant coefficients from paper III.

	Cost	Quality	OTD	Delivery Speed	Product Mix Flexibility	Volume Flexibility
Size	0.117+	0.130*				
Industry: Machinery					-0.170*	-0.208**
Industry: Automotive		0.239**			-0.150+	-0.224**
CODP			0.159*	0.119+		
MC				0.245**	0.293***	0.302***
MD		0.154*				
CODP x MC		-0.160*	-0.166*			
CODP x MD		0.125+				
MC x MD						

(+p < 0.010, *p < 0.05, **p < 0.01, ***p < 0.001)

The results in Table 4.2 show that a late CODP, close to MTS, is indeed associated with better delivery performance. This lends partial support to H1a. H1b is however not supported by the results of the analysis. H2 can be considered supported, as MC is associated with multiple performance improvements, although the conclusions regarding this are not trivial when one also considers the negative interaction terms including both MC and the CODP. H3 is partially supported, since only improved quality performance was indicated. H4a is not supported and H4b is not supported. The interaction term between the CODP and MD is associated with improved quality performance, which implies that MD is especially beneficial for quality if it is adopted by plants with a late CODP position, close to MTS. Finally, H5 is not supported.

These results indicate that the performance benefits of MD and MC are perhaps not as clear cut and evident as extant research suggests. Yes, there are significant, positive relationships between MC and performance, as well as between MD and performance (although this only pertains to quality performance), but most of the hypotheses are not supported by the analyzed HPM data. Furthermore, the negative interaction terms, combining MC and the CODP scale, suggest that adopting MC practices while having a late CODP position (close to MTS) could be detrimental to quality and on-time delivery (OTD) performance. MC on its own is associated with improved delivery speed and flexibility performance, regardless of the CODP position, which suggests that plants operating with a late CODP position may face a trade-off if they are considering pursuing MC: improve flexibility and delivery speed, at the cost of quality and delivery reliability.

Paper III has shown that the performance effects of MC and MD are not uniform across all potential CODP positions. Hence it confirms the suspicion that the CODP is an important contingency to consider in this context. This has implications for both managers and researchers. From a practical point of view, the trade-off mentioned above is the most noteworthy result. It will be discussed further in chapter 5 of this thesis. In terms of research implications, the results of paper III imply that the CODP ought to be controlled for when conducting research regarding MC and MD and their performance implications. If the sample of plants or firms studied contains plants or firms operating with different CODP positions, it can be expected that the plants or firms experience different performance outcomes from MC and MD.

4.4 Paper IV

The fourth paper included in this thesis, "*Connecting organizational context to environmental sustainability and industrial symbiosis: Empirical results and case analysis*", revolves around IS. IS can be explained as a collaboration network involving multiple parties in industry, government bodies, and/or non-profit organizations, designed to increase circularity by using waste products generated by some processes in the network as resources in other network processes. As described in sub-section 2.2.4, IS can be considered a special form of SCI and is interesting from a CODP perspective. To the best of the authors' knowledge, this is the first example of a paper which relates the CODP to IS collaboration, hence providing novel insights while simultaneously addressing the request by for instance Venugopal and Saleeshya (2019) to further include the CODP in sustainability research.

The purpose of the paper is to compare results derived from the HPM data to results attained from the embedded case study in Sotenäs, Sweden, which is illustrated in Figure 3.3. The survey-based component of the study concerns drivers of, barriers to, and outcomes of ESPs in general, whereas the case study component concerns drivers of, barriers to, and outcomes of IS collaboration specifically. Therefore, paper IV also contributes with insights regarding the possibilities of transferring findings between studies that have utilized different research methods. More specifically, it sheds light on the possibilities of transferring general, survey-based results to case-specific results. I will present the main results of each component of the paper separately and then briefly describe the notable similarities and differences between the results.

The survey-based component of the paper compares drivers, barriers and outcomes of ESPs between the MTO and MTS plants responding to the HPM survey. The division of plants, once again, stems from the *k*-means analysis presented in sub-section 3.2.2. Table 4.3 below contains the descriptive statistics and results of an ANOVA including drivers and barriers associated with commitment to ESPs.

Table 4.3 Descriptive statistics and ANOVA results regarding drivers and barriers of ESPs.

		MTO	MTS	F-value
Drivers	Employee-driven	3.23 (0.76)	3.41 (0.80)	2.10
	Customer-driven	3.54 (0.85)	3.54 (1.00)	0.00
	Legally driven	3.88 (0.69)	4.12 (0.74)	4.24*
	Management-driven	3.60 (0.80)	3.83 (0.76)	3.04+
	Cost-driven	3.88 (0.88)	3.80 (0.87)	0.34
Barriers	Lack of org. support	2.67 (0.81)	2.45 (0.78)	2.72+
	Lack of resources	3.14 (0.61)	3.19 (0.71)	0.19

('+': Significant at the 0.10 level, '*': Significant at the 0.05 level)

The results in Table 4.3 indicate that there are some differences in terms of how plants with different CODP positions perceive the drivers and barriers associated with environmental sustainability. ESPs at MTS plants seem to be driven by management and legal requirements to a greater extent than they are at MTO plants. On the other hand, MTO plants seem to experience more difficulties related to lack of organizational support than MTS plants, although it should be noted that both plant types' average is a number smaller than three on that particular measure, indicating that lack of organizational support is not an important concern in this context. Table 4.4 below provides the same information as Table 4.3, except that the results presented now concern outcomes of ESPs.

Table 4.4 Descriptive statistics and ANOVA results regarding outcomes of ESPs.

Improved…	MTO	MTS	F-value
…Environmental perf.	4.03 (0.72)	4.07 (0.62)	0.11
…Regulatory perf.	4.18 (0.74)	4.14 (0.74)	0.09
…Cost perf.	3.51 (0.70)	3.32 (0.73)	2.40
…Revenue perf.	3.41 (0.60)	3.26 (0.59)	2.10
…Product quality	3.48 (0.62)	3.26 (0.64)	4.15*
…Product perf.	3.44 (0.65)	3.36 (0.67)	0.54
…Manu. perf.	3.45 (0.60)	3.22 (0.76)	4.52*
…Financial perf.	3.30 (0.53)	3.10 (0.63)	4.51*
…Corporate image	3.96 (0.69)	3.88 (0.77)	0.39

('*': Significant at the 0.05 level)

The results in Table 4.4 show that there are not many significant differences between the outcomes of ESPs for MTS and MTO plants. However, the three significant differences that appear indicate that MTO plants fare better than MTS plants, as all those beneficial outcomes are greater for MTO plants than they are for MTS plants.

This result is not trivially explained and is in fact subject to further analysis and discussion in paper V.

In short, the results of the survey-based component of paper IV indicate that there are some significant differences between MTO and MTS plants when it comes to both drives, barriers, and outcomes associated with ESPs.

In order to compare the survey-based results to the case analysis, I will first present the case study participants' perception of drivers for participation in the IS collaboration. The top row of Table 4.5 below also includes the case study participants' CODP position.

Table 4.5 Case study participants' perception of drivers of IS collaboration.

Driver	FFN (MTO)	SMRC (MTO)	Rambo (MTS)	Smögen-bryggar'n (MTS)	SMO (Mix)	SCS (MTO)
Employee-driven	2	4	4	3	5	2
Customer-driven	1	3	3	2	.	.
Legally driven	3	3	4	2	3	.
Management driven	1	5	4	3	2	.
Cost-driven	4	5	3	3	.	.
The identification of new business opportunities	3	5	4	5	5	.
The desire to become energy and resource efficient	5	5	4	4	5	.

'1': To no extent '2': To a limited extent, '3': To some extent, '4': To a large extent, '5': To a very large extent, '.' : Not indicated.

The participants of the case study were asked to rate the importance of each driver on a scale of one to five. Multiple of the drivers assessed are formulated exactly like those in the HPM data, but there are two additions: the identification of new business opportunities and the desire to become more energy efficient. These have been added since the data gathered in the embedded case study constitutes the basis for a larger study. The answers in Table 4.5 do not indicate any systematic differences between the case study participants based on their CODP position. To further compare the case study results with the survey-based results, the perceived outcomes of IS collaboration are compared to the experienced outcomes of the respondents to the HPM survey. For the sake of diligence, it should also be mentioned that the case-study participants' view on barriers to IS collaboration were also recorded, but the vast majority of these were ranked as either one or two on the five-point scale, indicating that the case study participants did not experience any significant barriers. See table 6 in the published version of the paper.

Table 4.6 below contains the case study participants' perceived outcomes of IS collaboration.

Table 4.6 Perceived outcomes of IS collaboration.

Outcomes from IS collaboration	FFN (MTO)	SMRC (MTO)	Rambo (MTS)	Smögen-bryggar'n (MTS)	SMO (Mix)	SCS (MTO)
Environmental performance	(+)	Not applicable	(+)	(+)	.	.
Regulatory performance	(+)		.	(+)	.	.
Cost performance	(-)		(+)	(+)	(-)	.
Revenue performance	(+)		(-)	(+)	(+)	(+)
Service/product quality	.		(+)	.	(+)	(+)
Service/product performance	.		(+)	(+)	(+)	(+)
Manufacturing/Service process performance	(-)		(-)	.	.	.
Financial performance	(+/-)		(+/-)	(+)	(+/-)	(+)
Corporate image	(+)		.	(+)	(+)	(+)

(+): Positive effect, (-): Negative effect, (+/-): Both positive and negative effects identified, '.': Not indicated.

Once again, it is very difficult to find any systematic differences between case study participants with order-based operations compared to those with forecast-based operations. Generally speaking, the case study participants have indicated positive outcomes across the board, with only a few exceptions. FFN and Rambo experience a negative impact on their Manufacturing/service process performance due to the fact that the recycled resources used in the IS network were more demanding to work with than virgin resources. Multiple actors also experience mixed results on their financial performance since they need to commit time and resources to the IS network in order for the collaboration to work, but they also felt that participating in the IS network could improve their products, corporate image, and generate other positive marketing effects, ultimately having a positive impact on their profits. In general, the case study participants had not made any serious efforts of quantifying the effects of the IS collaboration, which makes it hard to gauge exactly what the net effects are.

In summary, there are some similarities between the results at a high level. Firstly, both ESPs in general and IS collaboration appear to have positive impacts on the business in a broad sense. All mean values in Table 4.4 are above three, which corresponds to the neutral option of the scale, and the symbiosis participants in Sotenäs have indicated mostly positive outcomes. Secondly, it appears that barriers are not as highly considered as drivers, or phrased differently, the drivers appear to outweigh the barriers when it comes to commitments to environmental sustainability. Comparing the results of Table 4.3 with the fact that the case study participants experienced very few and no severe barriers provides this insight. That, arguably, is where the similarities between the studies stop. The CODP appeared to play an important role for both drivers, barriers and outcomes of sustainability practices in the analysis of the HPM data, but this result was not repeated in the case study. According to extant literature, this is somewhat surprising. A stable environment with high-volume resource flows has been found to be conducive to successful IS collaboration (Liu et al., 2015; Päivärinne et al., 2015; Aid et al., 2017; Ji et al., 2020; Colpo et al., 2021), which suggests that organizations operating in an MTS fashion ought to be well suited for this type of collaboration. The findings of this paper do not falsify that notion, though. Recall Figure 3.3, depicting the Sotenäs symbiosis network. This study concerns the organizations on the right-hand side in the figure. On the left-hand side, connected by green arrows, are some large organizations who operate in the food processing industry. Fish processing, more precisely. These large corporations produce high volumes of both end-product output and waste in the forms of, for example, excess heat, wastewater, and biological waste from processed fish. It could very well be the case that the presence of these organizations is a prerequisite for the IS collaboration to work. This is a topic which could be investigated in future research. Lastly, the results of paper IV highlight the difficulties associated with extrapolation of case study findings, as well as the case-specific applicability of general, survey-based results. I do not think that any of them are more "true" than the other, merely that context matters greatly when drawing conclusions and providing recommendations based on research findings.

4.5 Paper V

The fifth paper included in this thesis also concerns environmental sustainability in an OSCM context. It empirically investigates if plants operating with different CODP positions commit to different EPSs, experience different types and levels of beneficial outcomes from commitment to ESPs, whether they implement different levels of lean and agile manufacturing principles, and whether the CODP moderates the relationships between ESPs and outcomes, as well as the association between lean and agile manufacturing principles and ESPs. As such, the paper addresses the role of the CODP in environmental supply chain sustainability on multiple levels.

Four hypotheses are developed based on extant literature.

H1: Higher levels of ESPs are associated with more beneficial outcomes of such practices.

H2: Plants operating with different CODP positions commit to different ESPs.

H3a: Plants operating with a CODP positioned far upstream (MTO) exhibit higher levels agility than plants operating with a CODP positioned far downstream.

H3b: Plants operating with a CODP positioned far downstream (MTS) exhibit higher levels of lean characteristics than plants operating with a CODP far upstream.

H4: The relationships between lean and agile characteristics and different environmental sustainability practices are moderated by the CODP position.

The comparison between plants operating with different CODP positions uses the same clusters of HPM respondents as papers II and IV, stemming from the *k*-means procedure described in section 3.2.2. The statistical analyses conducted to test the hypotheses include t-tests, correlations, ANOVA and regression analyses. Figure 4.4 below illustrates the analysis process of paper V.

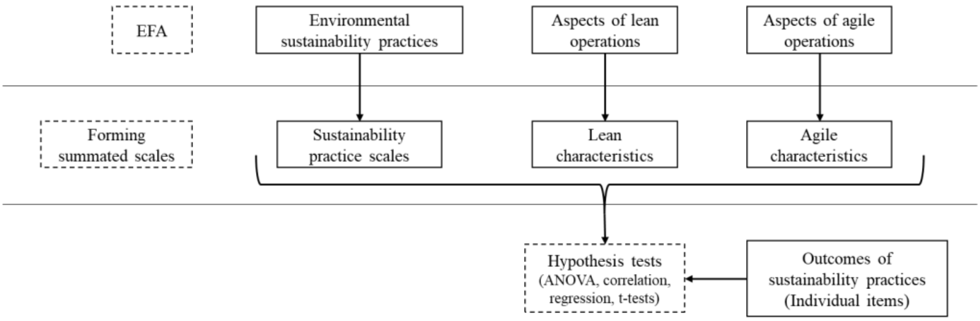

Figure 4.4 Statistical analyses used in each step of the analysis process in paper V.

As the figure illustrates, the EFA is used as a foundation for forming summated scales in paper V. Summated scales, in this case in the form av averages across individual variables, were needed since the ANOVA compares means across groups. IBM SPSS always outputs factor scores in a standardized format (IBM, 2024) with mean equal to zero and variance equal to one, which implies that the factor scores themselves cannot be used in the ANOVA. Furthermore, factor analysis can be considered an objective basis for forming summated scales (Deselle, 2005; Hair Jr. et al., 2014) Bootstrapping is employed to determine the significance of the correlation and regression coefficients (Efron, 1981; Hair Jr. et al., 2014). In both instances, 1,000 bootstrap samples were used to generate confidence intervals for the coefficients.

Potential support for hypotheses 1 and 2 is assessed by looking at correlations between ESPs and the outcomes of such practices, for both groups of plants (MTO and MTS), and two sets of ANOVAs, comparing MTO and MTS plants with regard to outcomes of ESPs and the levels of commitments to ESPs. The results show that MTO plants experience more beneficial outcomes than MTS plants on three accounts: product quality, manufacturing performance, and financial performance. This result is replicated from paper IV. Generally, the association between commitment to ESPs and the beneficial outcomes of such practices is far more evident for the sampled MTO plants. Tables 4.7 and 4.8 below to replicate the results from the paper.

Table 4.7 Correlations between environmental practices bundles and outcomes of environmental sustainability initiatives (MTO).

Improved…	Resource efficiency	Emissions reduction and control	Environmental sustainability collaboration
…Environmental perf.	.543** (.411/.663)	.221* (.022/.428)	.334** (.132/.511)
…Regulatory perf.	.394** (.211/.555)	-	.290** (.096/.465)
…Cost perf.	.215* (.019/.406)	.322** (.148/.491)	.198* (.002/.413)
…Revenue perf.	-	.292** (.104/.457)	-
…Product quality	-	.329** (.137/.504)	.194* (.013/.380)
…Product perf.	-	.312** (.136/.494)	-
…Manu. perf.	.239** (.089/.375)	.301** (.149/.452)	-
…Financial perf.	-	.266** (.059/.437)	-
…Corporate image	.453** (.276/.597)	.304** (.125/.486)	.356** (.211/.488)

‘*’: p-value < 0.05, ‘**’: p-value < 0.01, ‘***’: p-value < 0.001

Table 4.8 Correlations between environmental practices bundles and outcomes of environmental sustainability initiatives (MTS).

Improved…	Resource efficiency	Emissions reduction and control	Environmental sustainability collaboration
…Environmental perf.	.465** (.198/.679)	-	-
…Regulatory perf.	.449** (.210/.644)	-	.303* (.014/.558)
…Cost perf.	-	-	-
…Revenue perf.	-	-	-
…Product quality	-	-	-
…Product perf.	-	-	-
…Manu. perf.	-	-	-
…Financial perf.	-	-	-
…Corporate image	.405** (.234/.586)	-	-

‘*’: p-value < 0.05, ‘**’: p-value < 0.01

Hypothesis 3 is tested with simple t-tests as it concerns a straightforward comparison of the averages across two groups. Furthermore, the hypothesis is one-sided, such that H3a claims that MTO plants are more agile, and H3b asserts that MTS plants are leaner. The results of the tests indicate that MTO plants are more agile. They have greater customization capabilities (p-value < 0.10), more flexible manufacturing systems (p-value < 0.10), and they use flexibility as an order winner to a greater extent (p-value < 0.05) than MTS plants. In terms of lean characteristics, MTS plants are leaner than MTO plants on two accounts: they employ statistical process control and monitoring to a greater extent (p-value < 0.05) and they put a higher priority on adherence to production schedules (p-value < 0.01).

Hypothesis 4 is tested using regression analysis and the results of this analysis are found in Tables 6 and 7 of the paper. Only a limited number of coefficients were found significant so I will not reproduce the entire tables here. For MTO plants, the following lean characteristics were associated with significant positive coefficients: *Statistical process control and monitoring* was significantly related to resource efficiency and environmental sustainability collaboration. The relationship between *adherence to production schedules* and environmental sustainability collaboration was also significant and positive. *Continuous improvement* was negatively associated with environmental sustainability collaboration and *small lot sizes* was negatively associated with emissions reduction and control. The only agile characteristic which was significantly related to the ESPs was *customization capabilities,* and even though this was the only agile characteristic associated with environmental practices, it was positively related to all three ESP constructs.

Looking at the MTS plants, the only agile characteristic associated with ESPs was *customization capabilities*, and it was negatively related to environmental sustainability collaboration. The lean characteristics also exhibited a different pattern compared to the MTO plants. *Statistical process control and monitoring* was significantly and positively related to both resource efficiency, emissions reduction and control, and environmental sustainability collaboration. Interestingly, *continuous improvement* was negatively associated with both emissions reduction and control and environmental sustainability collaboration. When comparing the results between the plant types, the coefficients are far greater in magnitude for MTS plants, implying a stronger association.

In terms of the hypotheses of the paper, the results have the following implications: H1 is supported, especially for MTO plants. The relationships between the levels to which EPSs are pursued and their outcomes are not as clear for MTS plants. H2 is not supported. There are no clear differences between the plant types regarding which ESPs they prioritize and commit to. H3 is supported. MTS plants are leaner than MTO plants, typically. All lean characteristics have higher means for MTS plants, although only two were significantly different between MTO and MTS plants: statistical process control and monitoring, and adherence to production schedules. MTO plants are indeed more agile than MTS plants, as all agile characteristics exhibit higher values and are significantly different from the MTS plants' values. Lastly, H4 is supported, as the CODP indeed plays a distinct role in moderating the associations between lean and agile characteristics and ESPs, even if far from all coefficients in the regressions were significant.

5. Discussion

The results and findings of the papers are considered and discussed jointly in this chapter, as they make up individual parts of a larger study. Aside from the results of the papers, one will also find a discussion regarding the methods used to analyze the survey data that underpins many of the results presented in the thesis.

5.1 Findings from the appended papers

In this sub-section, I will not repeat the results of the analyses in the papers per se, as an overview of all results are provided in chapter 4 and detailed descriptions can be found in the respective papers. Instead, I will focus on the findings and conclusions of each paper. Logically, I would like to start this discussion by bringing attention to the findings of paper I, the literature review.

One aspect of this paper, which serves as both motivation behind the study and a finding in its own right, is that empirical research in the OSCM field involving the CODP is scarce. I think this is important to dwell on for a moment, both since it motivates much of the work presented in this thesis, but also since the framework presented in the paper (see Figure 4.1) indicates that the CODP concept has real-world, practical implications for a wide range of issues and decisions. The most immediate conclusion from this is that the CODP should be included in empirical OSCM research more often. The framework identifies 32 factors that affect or are affected by the CODP position, ranging from aspects pertaining to a firm's internal operations, such as the approach taken to material planning, inter-organizational collaboration, exemplified by supply chain visibility, and performance, for instance delivery speed and reliability.

Another finding worthy of reflection is the fact that there are exogenous market factors that govern which CODP positions that are feasible. Demand volatility and total demand volume are clear examples of such factors. This means that a manufacturer implicitly decides on multiple aspects of their OSCM processes already when deciding on the type of product to make, as the market conditions for that product determine which CODP positions are viable, which in turn determines a substantial portion of the operations and supply chain processes that need to be in place to produce and sell that product successfully. This is an especially important insight if one considers the scenario where a firm is about to launch a new type of product. If the newly developed product is vastly different from the ones already produced, enough so that its CODP position should be different from the other products', it is very likely that it will necessitate substantial investments and changes to multiple aspects of the operations and supply chain.

Papers II through V use empirical methods to examine the CODP's role in various research topics in the OSCM field. The focus areas of all these papers can be derived from the framework in paper I. The foci of papers II and III can be directly inferred from paper I: SCI and product customization. The CODP's role in supply chain sustainability, the focus of paper V, is however not identified directly by the literature review. Concepts that have been of explicit concern in the field of supply chain sustainability are identified in the framework of paper I, though: lean and agile operations. Paper IV, which concerns IS, focuses on a combination of a special form of integration and environmental sustainability and can therefore also be derived from the framework in paper I.

Broadly speaking, the empirical results of papers II through V indicate that the CODP is an important moderator, or mediator (paper III), in multiple OSCM areas. Paper II revolves around SCI, which is already a highly researched area within OSCM. Despite that fact, no hypotheses have been formulated regarding the performance effects of SCI. The reason for this is simply that the results and conclusions of existing SCI research are not consistent. Multiple sources present findings that point in different directions, suggesting that an exploratory approach is more appropriate. The results of paper II align quite well with, for instance, Olhager and Prajogo (2012), who find that external logistics integration is more beneficial for MTO firms. In that sense, the paper can be considered only a minor extension to existing theory. However, since the paper includes both the CODP as a moderator and multiple SCI practices directed both upstream and downstream, it offers a more nuanced perspective than extant literature on the CODP's role in SCI. The results indicate that the CODP does not moderate SCI efforts directed at suppliers and customers equally for MTO and MTS plants. Hence, I argue that the results presented in the paper provide a substantial extension to existing theory; especially since all significant coefficients associated with MTS plants are negative. SCI efforts appear to be wasted for MTS operations, and one of the most plausible explanations behind this is that inventories positioned on both the upstream and downstream sides of the focal firm, the raw material inventory, and the finished goods inventory, respectively, function as buffers that reduce both the need and the usefulness of SCI.

In a similar vein, paper III concerns topics that have a relatively long history in OSCM. Both MC and MD are classic concepts that have been the focus of plenty of research already. The explicit inclusion of the CODP as a mediating variable in this context is however a new and, to the best of my knowledge, unique feature of the paper included in this thesis. By introducing the CODP as a mediating variable, the analysis of the paper enables the examination of interaction terms. The results of the paper reveal non-trivial combined effects of the CODP and MC, as well as the CODP and MD. These interaction terms suggest that there is a trade-off between

MC and certain performance metrics for plants operating with a CODP positioned far downstream. For such plants, MC can increase flexibility performance, but it comes at the cost of OTD and quality performance. On the other hand, the results suggest that plants operating with a CODP far downstream benefit significantly from MD: the positive effect on quality is further enhanced for such plants. If one compares these results to those of paper II, it once again appears that benefits are less clear-cut for MTS plants, or at least for plants operating in a fashion close to MTS. The potentially problematic performance trade-offs are more pronounced for such plants.

Papers IV and V, concerning environmental sustainability, also offer novel results due to the explicit inclusion of the CODP in the empirical analysis. In both these papers, the CODP is included as a moderator, and it indicates a distinct difference between the studied plants. These papers also exhibit the pattern described above: MTS plants seem to be at a relative disadvantage when it comes to realizing benefits, in this case from commitment to environmental sustainability. Table 4.4 in the thesis, which occurs in both papers IV and V, indicates that MTO plants experience more benefits from committing to environmental sustainability than MTS firms. The analysis of paper V also indicates that there are distinctly more evident relationships between ESPs and their beneficial outcomes for MTO plants than there are for MTS plants (Tables 4.7 and 4.8). The case-based analysis of paper IV, however, does not indicate that the CODP has a significant role to play concerning drivers of and barriers to IS. Whether these results can be extrapolated outside of the IS network in Sotenäs could be tested in future research. As mentioned in sub-section 4.4, existing research has indicated that large-volume and predictable resource flows, which are typically more closely associated with MTS operations, are often considered prerequisites for IS. Research on other IS networks, including larger firms from other industries, is needed to confirm or reject the results of paper IV.

When the results of the included papers are compared for the sampled MTO and MTS plants, the relative lack of positive performance effects and outcomes experienced by the sampled MTS plants is notable. There are however plausible explanations for this. The first explanation I posit is that the observed pattern among the results is due to the market characteristics of products produced according to MTS principles. Since market characteristics determine the viability of the different CODP positions, and products produced according to MTS principles often enjoy stable, predictable demand in high volume, the market characteristics of MTS products are such that many improvement initiatives will only have a limited impact on operational performance. Simply put, the demand is determined by factors exogenous to the firm and hence can only be minutely affected by a firm's commitment to, for instance, increased sustainability. Secondly, I would like to posit that MTS firms need to compete through price (Berry and Hill, 1992) and maintain a high throughput rate, which makes commitment to SCI, product customization and customer interaction, or sustainability initiatives, potentially disadvantageous.

Such commitments can both disturb the throughput rate and affect the cost-effectiveness of production, as the pursuit of such initiatives requires resources, time and potential changes to the production system. Therefore, there is perhaps an inherent danger for MTS firms in focusing too much on factors outside their core operations.

MTO firms, on the other hand, compete through flexibility and the ability to meet specific customer needs. Typically, they operate in environments characterized by much greater uncertainty and produce more fashionable products with more fickle demand. I posit that the demand for such products is not as price sensitive as the demand for standardized products, and that the customers are accepting longer lead times. In combination, this reduces the risk associated with the pursuit of for instance SCI and improved sustainability. Product customization is a must for MTO firms, so they need to develop that capacity. Furthermore, I think that MTO firms inherently are in more control of the demand for their specific products than MTS firms, since the customers buy the products because of the firm's ability to meet their specific requests. If an MTO firm invests in a more sustainable production system or sustainably sourced materials, for instance, it is likely due to an expressed or clearly perceived customer requirement.

In summary, I believe that the observed pattern of differing results for MTO and MTS plants stem from the market characteristics that the different types of operations are grappling with. One type of operations, MTO, is more capable of affecting its demand and leverage investments and commitments to practices such as SCI, increased customization capabilities, and improved (environmental) sustainability. The other operations type, MTS, needs to focus on the efficiency of its core operations to be successful, as market characteristics are not within their control to the same extent.

5.2 Reflections on the survey data analysis

Producing the results presented in this thesis, which are primarily derived from the analysis of HPM data, has been associated with multiple of the usual, potential problems that follow with the analysis of survey data. Chapter 3 brings up the matter of violating the assumptions of regression analysis and ANOVA. This is a good place to start the discussion regarding the choice of methods. As a reference for much of this, I will use Norman (2010) since this source offers a very clear overview of and response to multiple so-called issues, often regurgitated by reviewers and critics.

Firstly, ANOVA and regression analysis assume normality. This is often cited as a problem when working with survey research, since Likert scale data, technically speaking, is not continuous and does not follow the normal distribution. The assumption of normality does not concern the distribution of the sampled data points, though, as Norman (2010) explains on page 628. The sampled data does not need to follow the extremely geometric bell-curve that we all associate with the normal distribution. What is required is the normality of the distribution of means, and this occurs naturally, as per the central limit theorem (Rencher, 2002), when the sample size grows. Norman (2010) even cites research that has indicated that the distribution of means is approximately normal with sample sizes as small as ten individuals.

Related to the sample size, some will argue that mean comparisons, such as the ANOVA or t-tests, can only be made if the sample sizes are large enough. Interestingly, the statistical procedures do not postulate any cut-off or lower limit for sample sizes. This is also brought up by Norman (2010). If one takes the t-test as an example, the sample size, *n*, is included in the formula used to calculate it, and it affects the calculation such that a small *n* makes it harder to detect a significant difference between an observed sample mean and the hypothesized population mean. As such, the sample size is already accounted for when calculating the t-value. There is no additional rule stating that a sample size of less than some arbitrary number is too small. For the sake of this thesis, the smallest sub-set of data that I have used in the analyses is 51 (see Table 3.2), and therefore I draw the conclusion that there is no risk that the results presented in the thesis are incorrect due to small samples or non-normal data being used.

In order to conclude this part of the discussion, I will quote Norman (2010, p. 631):

> "Parametric statistics can be used with Likert data, with small sample sizes, with unequal variances, and with non-normal distributions, with no fear of 'coming to the wrong conclusion'. These findings are consistent with empirical literature dating back nearly 80 years. The controversy can cease (but likely won't)."

For the second and last part of the discussion on methods used to analyze the survey data, I would like to address the choice of factor analysis technique. I have chosen to rely primarily on the results of EFA in papers II through V, as opposed to CFA. It would be reasonable to think that this choice was made in order to avoid violation of the distributional assumption of multivariate normality made in maximum-likelihood-based CFA. As was pointed out earlier, though, this assumption is most likely not violated even if the observed data do not appear to be normally distributed. Instead, I chose the EFA approach because the EFA, using principal components as an estimation method for factor loadings, does not stipulate any specific structure among the individual items or hypothesized constructs. CFA, on the other hand, requires the researcher to specify which relationships among the individual variables and constructs that exist. This implies that if the researcher's hypothesized model is not a close representation of reality, the CFA model will not represent the actual relationships between the variables and constructs. This reasoning is explained in Marsh et al. (2014). Since the EFA, as suggested by the method's name, allows the researcher to explore which relationships that exist in the data before proceeding with the rest of the analysis, it offers the opportunity to continue working with the analysis even if the sample data does not conform to existing theory. Furthermore, the content validity of the EFA results can still be compared to existing theory. If the items form theoretically sound groupings and load on single constructs without problematic cross-loadings, then the results do align with existing theory. One does not need to do a CFA to confirm theoretical implications.

Lastly, I would like to address the way that constructs have been formed in papers II through V. In papers II and III, the constructs are created using the factor scores from the EFAs, and in papers IV and V the constructs are created using summated scales, in the form of averages. Reviewers of all these papers have commented on this and, interestingly, never been quite satisfied with the way in which the constructs were generated. Using summated scales is not considered state-of-the-art, and using scores from the EFA is apparently not entirely trustworthy, as they stem from an exploratory approach, which is sometimes frowned upon.

As illustrated in sub-section 5.1, adopting an exploratory approach is sometimes necessary since the existing research is not coherent in terms of findings and recommendations. Secondly, using the EFA can be appropriate even if hypotheses can be developed from existing research, as in paper III. There is always a risk that the sample data, for some reason or other, does not adhere to the suggestions of theory. If that is the case the EFA will still allow the analysis to continue. In my personal opinion, such analyses can offer very interesting results and insights and potentially extend theory by illustrating where and why it breaks down.

Using summated scales, such as the average, to create a construct may not be state-of-the-art, but it does bring a few advantages. Firstly, it is very easily interpreted and understood by managers and researchers in other fields, potentially enabling a wider spread and implementation of research findings. Secondly, the constructs can be reproduced exactly. If five items make up a construct, and they are all weighted by one fifth, the formation of this scale can be replicated exactly, even if the sample is different. Note that the construct's score, or value, will not be exactly the same across samples. I speak of its formation. Imagine that the exact same questionnaire is used to survey two different populations and that an EFA is conducted on each sample. In such a situation, the resulting constructs will be formed (or calculated) differently since the loadings of the items will differ depending on the respective samples' responses. If one would have used summated scales to form the constructs instead, the calculation of factor scores would have been exactly the same, and the factor scores could be compared across samples. Hence, the use of summated scales increases the reproducibility of research. Lastly, if the EFA produces results that are considered to be of high quality, exhibiting unidimensionality, high loadings from each included item, etc., the individual items will carry very similar weights in the calculation of factor scores. This means that there is very little difference between using factor scores and summated scales in most practical situations.

6. Conclusions and future research

This chapter revisits the research objectives presented in the Introduction and explains how they have been addressed by the appended papers. It also expands on the theoretical and managerial contributions of the thesis, outlines some limitations of the research conducted in the thesis, and presents ideas for future research.

6.1 Returning to the research objectives

Three research objectives have been addressed by this thesis. Research objective one, which concerned the identification of OSCM research areas where the CODP has empirically verified importance, was addressed by paper I. The framework depicted in Figure 4.1 illustrates the 32 factors identified by the paper. The identification of these 32 factors, together with the fact that empirical OSCM research including the CODP is scarce, motivates further examination of the CODP's role in OSCM.

The second research objective was to empirically analyze a select few of the 32 factors identified in paper I. Papers II and III fulfill this research objective by addressing research areas and topics directly derived from the results of paper I, namely SCI and product customization. These are well-researched topics that have enjoyed much attention, but the results of prior research are not consistent, as is the case for paper II, or have not included the CODP in a mediating or moderating role, as is the case for paper III. Therefore, these papers extend existing knowledge regarding these issues and illustrate how the CODP can be an important contingency to explicitly account for in empirical OSCM research.

Research objective three, which concerns the contemporary subject area of (environmental) supply chain sustainability is addressed in papers IV and V, and it was derived from literature involving the CODP. Supply chain sustainability is not directly identified in the framework of paper I, but it has been directly related to both lean and agile operations, two concepts that are identified in the framework of paper I. Additionally, the CODP has been included in research on supply chain sustainability on a few occasions, and these examples indicate that it potentially has an important role to play. The empirical results of the papers indicate that the sampled MTO plants experience more benefits from ESPs than MTS plants. They also show that there is a more evident connection between commitment to ESPs and their beneficial outcomes for MTO plants than there is for MTS plants. This result has not been reported in any prior research and offers novel insights regarding the

CODP's role in the field of supply chain sustainability. The case analysis of paper IV does not indicate that the CODP affects drivers, barriers and outcomes associated with IS in any significant way.

It should be noted that the empirical analyses of papers IV and V also contribute to the fulfillment of research objective two, since they both contain an empirical analysis of a CODP-related topic.

6.2 Theoretical contributions

When one considers the results of the five papers jointly, there appears to be a consistent pattern: MTS plants are not experiencing as clear-cut benefits as MTO plants from improvement initiatives such as SCI, increased product customization, and improved environmental sustainability. This implies that the CODP is highly important in several areas of OSCM research. If it is not accounted for, there is a risk of providing faulty recommendations since the research might have missed an important contingency and therefore produced too crude results.

The findings of this thesis, underpinned by the framework of paper I and the empirical analyses of papers II through V, can offer some practical advice on how researchers might treat the CODP. First, it should be noted that every product or item, in theory at least, could have its own CODP. The position of the CODP is governed by external factors, such as market and demand characteristics. Once a feasible CODP position has been established for the given product or item, manufacturing- and supply chain processes need to be aligned with the requirements of the CODP position and the external characteristics upstream and downstream from the CODP. If a suitable configuration has been adopted, the firm will reap positive performance outcomes. Figure 6.1 below illustrates this.

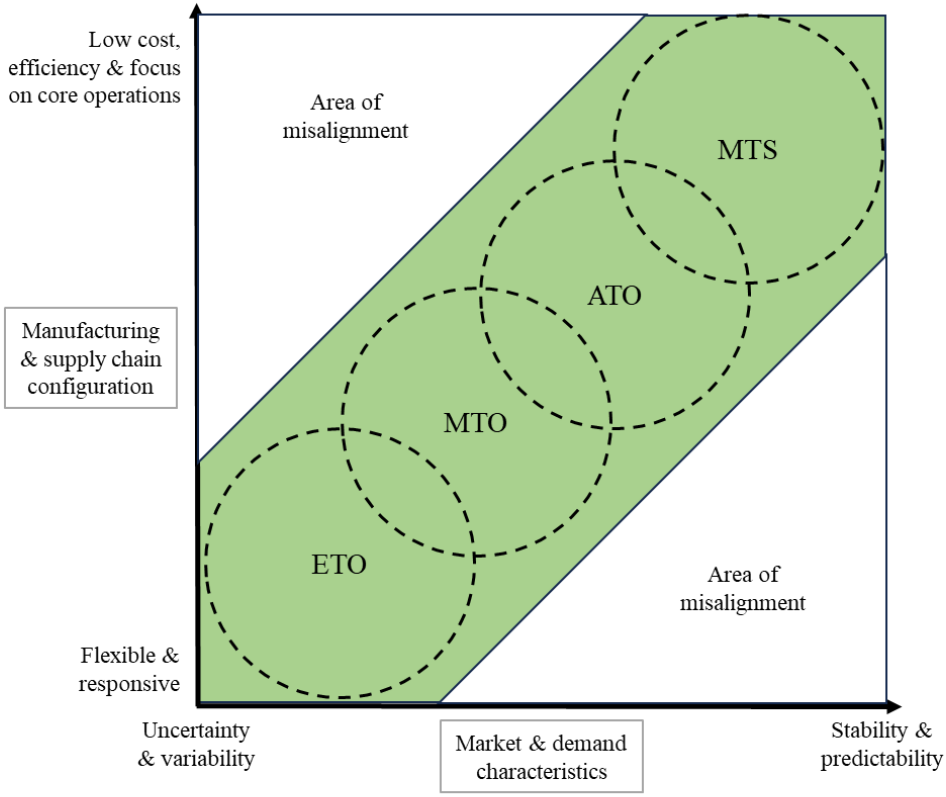

Figure 6.1 Stylistic illustration of matching the manufacturing and supply chain configurations to external characteristics.

The configurations on the y-axis are enabled by the CODP positions. The diagonal section in the figure illustrates the continuum where manufacturing and supply chain configurations match the requirements of the firm's external environment. The farther away from the diagonal line one strays, the harder it will be to generate successful business outcomes. The reasoning outlined here, describing that an organization and its partners need to adapt to external requirements and find suitable configurations to improve their performance are well aligned with the theoretical underpinnings of this thesis, as described in chapter 2. The findings, indicating that MTS plants have a more difficult time reaping the benefits of several improvement initiatives, and their suggested explanations, constitute novel insights that add to theory regarding operational performance.

Craighead et al. (2016) warranted the development of more middle-range theories in OSCM. Stank et al. (2017) describe that such theories consolidate well-tested knowledge into propositions that reflect a body of evidence. Although the evidence presented in this thesis is not enough on its own, I believe that the empirical results brought forward, together with the support of the literature review, constitute well-observed knowledge and can be considered a starting point for the development of a middle-range theory regarding the CODP. Especially since the results indicate a pattern of differences between firms with different CODP positions. Such a theory would ideally explain how the firm context affects the viability of different CODP positions, how the positioning of the CODP impacts the manufacturing and supply chain configuration, and, in the end, the mechanism through which this configuration generates positive performance outcomes.

6.3 Managerial contributions

Since the results of the thesis are derived from empirical analyses, they show that there is a real-world connection between many issues in OSCM field and the CODP. Therefore, I also see that the results have implications for practitioners and managers.

To start with, one can again return to the framework derived in paper I. The framework offers a good overview of topics where the CODP has notable implications. When managers are making decisions about these dimensions, they are well advised to consider where their CODPs are positioned, since this dictates the outcomes of many improvement initiatives.

Based on the results of the thesis, decisions involving the launch of new products that potentially require a new CODP position, as well as decisions that might require the repositioning of existing CODPs, warrant extra attention. As the CODP has implications for the set-up of the manufacturing system through product customization capabilities and the efficacy of SCI, for instance, changing or establishing new CODP positions will entail changes to manufacturing and supply chain configurations as well. If a firm produces its major product families in an MTS fashion, it almost certainly cannot launch a product built according to MTO principles and hope that this will be equally successful without looking into new production technologies and new forms of collaboration, both between in-house functions and its supply chain partners.

Additionally, the pattern of results indicating that MTS-type operations are not as clearly associated with positive outcomes from multiple improvement initiatives has implications for managers. This pattern suggests that managers of MTS firms should focus on the firm's core operations and not invest too many resources in other initiatives.

Lastly, a very pragmatic insight comes from paper III: for certain CODP positions, there are trade-offs related to performance. For MTS firms, increasing customization capabilities through enhanced MC capability will come at a cost.

Therefore, management needs to prioritize between performance dimensions and determine what one truly needs to be good at. MC was the case where this trade-off materialized in the thesis, but this does not mean that there are no other areas where this is also the case, of course.

In summary, managers need to be aware that their CODP positions are important contingencies that might cause improvement initiatives to have adverse performance effects. Proceed with caution.

6.4 Limitations and opportunities for future research

6.4.1 Limitations

This thesis has several limitations that should be acknowledged. They will be presented in sequence, but the order in which they occur does not necessarily represent their severity or magnitude.

Firstly, papers II and III use operational performance measures. This is not a problem per se, but since most businesses are looking to make a profit, financial performance measures would have added an extra dimension to the insights drawn from the papers. Arguably, the use of financial performance measures would have made the results even more interesting to practitioners and managers. The HPM data does in fact contain items that concern the financial performance of the respondents, but many of these questions are unfortunately suffering from low response rates and were ultimately excluded from the analyses.

Secondly, the HPM data used throughout papers II to V is arguably getting old. Although many surveys at the scale of the HPM survey are not conducted annually, it is fair to say that quite a few years have passed since the data were collected. Personally, I do not think that the CODP has lost its importance in the last few years. After all, it has been recognized as a key parameter in OSCM strategy since the 1980's. However, I do think that the Covid-19 pandemic has had a profound impact on supply chain strategies and priorities of multiple firms. Managers' views on SCI, lean and agile production, inventory policies, etc. could very well have changed. Therefore, some of the results generated in the statistical analyses might not be the same post-pandemic as they were at the point of data collection.

Lastly, the analyses conducted offer no direct explanation as to why the differences between plants operating with different CODP positions occur. Explanations are instead inferred from prior knowledge about the CODP expressed in the literature, and my own reasoning, based on my knowledge of the field. There is a possibility that the explanations posited in this thesis are not entirely correct. Some pieces of the puzzle might be (and likely are) missing. I do believe that future research can address and straighten many of the questions marks, though, which is a fine segue to the next sub-section.

6.4.2 Future research

One direction for future research pertains to the pattern that emerged in the joint analyses of papers II through V. Why are MTS firms not experiencing beneficial outcomes from the investigated improvement initiatives to the same degree as MTO firms? I believe that more qualitative research could unveil the underlying reasons and confirm, or potentially reject, the potential explanations I posited in the discussion. A topic related to the idea that SCI is not beneficial for MTS operations concerns the role of SCI in the coming Industry 4.0 era. One of the foreseen hallmarks of Industry 4.0 is increased digitalization and connectivity, which can be seen as a form of SCI. An ambitious but interesting suggestion for future research is to perform a longitudinal study with MTS organizations, where expectations and anticipated effects of increased digital connectivity across the supply chain are studied in the first period, and the actual effects are examined at a later stage in the study. Such research would in some sense capture the treatment effect of Industry 4.0 on SCI for MTS firms.

The results in papers IV and V also indicate that the CODP could be an important contextual factor to include in research regarding supply chain sustainability. I dare say that it is established and well-known by now that the CODP is related to other concepts, such as lean and agile, which have clear relationships to supply chain sustainability. This, in combination with the results of papers IV and V, lead me to suggest that future research on this subject explores the role and importance of the CODP further. As firms are experiencing increased pressure to become more sustainable, both from consumers and policy makers, research can be of real practical guidance by determining which paths organizations of different types need to follow in order to accomplish this while, still maintaining their profitability. Case studies explicitly targeted at MTO and MTS firms, respectively, could help unveil what the best practices are in this regard.

The results of the appended papers indicate that the CODP is an important contextual variable and contingency in multiple areas of OSCM. Since this is the case, I suggest that future research in the field, especially empirical research, includes the CODP position of the studied firms or plants more explicitly. Doing so would imply that the CODP needs to be considered before the data collection stage commences. If a survey questionnaire is being designed, questions regarding the CODP need to be included. How these should be phrased depends on the purpose of the research and how one might picture the CODP's impact. In some situations, the CODP can be used to create sub-sets of data, as illustrated by papers II, IV and V, and in other circumstances, it is perhaps best to use a continuous scale to capture the CODP, as in paper III. If a qualitative method of analysis is to be employed, as is often the case in case research, questions regarding the CODP need to be included in the interview protocol. It is very difficult to account for the CODP after the data has been collected if it was not included to begin with. I hope to see more empirical OSCM research addressing the CODP's position in the future.

Lastly, I think that one can use the CODP as a proxy for multiple, other variables. Paper I identifies 32 factors which are related to the CODP. Hence, different CODP positions reflect differences in multiple, other contingencies. As such, the variable can be a useful inclusion in much of OSCM research. Due to its close relationship to many aspects of firm context, it can, most likely, be used as an instrumental variable in survey research if researchers suspect potential endogeneity.

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Appendices

Replicated appendix from Paper I

First-order codes (factors)	Second-order themes (subcategories)	Aggregate themes (categories)
Demand uncertainty Demand variability Demand volume Order qualifiers Order winners	Market	Market and product
Product standardization/customization Product variety Product perishability	Product	
Production volume per individual product Production lead time Forecast accuracy	Operations response	Operations
Process type Setup times Process flexibility	Production process	
Operations concept Operations driver Inventory focus	Operations design	
Sales and operations planning Material planning	Planning and control system	
Supply chain strategy Supply chain improvement initiatives Demand amplification Risk mitigation strategy Supply chain visibility	Supply chain-related	Supply chain
Customer integration Customer-facing improvement initiative	Customer-related	
Supplier integration Purchase item type Supplier flexibility	Supplier-related	
Inventory holding costs	Cost	Performance
Delivery lead time On-time delivery	Delivery	

Replicated appendices from Paper II

Appendix A. Measurement model for supply chain integration constructs, items and sources.

Constructs /Informants (Cronbach's alpha)	Items	Factor loadings	Sources
SI-1: Information sharing /Upstream SC manager (0.897)	Our key suppliers have access to the following information about our plant:	-	
	Delivery information	0.827	Frohlich and Westbrook (2001)
	Demand change information	0.862	Nyaga et al. (2010), Prajogo and Olhager (2012)
	Demand forecast information	0.833	Cao and Zhang (2011), Flynn et al. (2010), Huo (2012), Huo et al. (2014)
	Inventory information	0.809	Cao and Zhang (2011), Frohlich and Westbrook (2001), Huo (2012), Huo et al. (2014)
	Quality information	0.778	Flynn et al. (2016), Huo et al. (2016), Swink et al. (2007)
	Schedule information	0.762	Frohlich and Westbrook (2001), Huo et al. (2014), Schoenherr and Swink (2012), Swink et al. (2007), Wong et al. (2017)
SI-2: Collaborative improvement /Upstream SC manager (0.708)	We are comfortable sharing problems with our suppliers	0.751	Cao and Zhang (2011), Chen and Paulraj (2004), van der Vaart et al. (2012)
	In dealing with our suppliers, we are willing to change assumptions in order to find more effective solutions	0.708	Chen and Paulraj (2004), Schoenherr and Swink (2012), Turkulainin et al. (2017), van der Vaart et al. (2012)
	Cooperating with our suppliers is beneficial to us	0.729	Cao and Zhang (2011), Flynn et al. (2016), Huo (2012), Huo et al. (2016), Nyaga et al. (2010), Wong et al. (2017)
	We emphasize openness of communication in collaborating with our suppliers	0.742	Cao and Zhang (2011), Chen and Paulraj (2004), Prajogo and Olhager (2012)
SI-3: NPD involvement /NPD manager (0.855)	We consult suppliers early in the design of new products	0.896	Chen and Paulraj (2004), Flynn et al. (2010), Flynn et al. (2016), Kannan and Tan (2010), Koufteros et al. (2005), Swink et al. (2007), Wong et al. (2017)
	We partner with suppliers for new product design	0.856	Chen and Paulraj (2004), Flynn et al. (2010), Flynn et al. (2016), Huo (2012), Huo et al. (2016), Koufteros et al. (2005), Swink et al. (2007), Wong et al. (2017)
	Suppliers are frequently consulted about the design of new products	0.802	Chen and Paulraj (2004), Flynn et al. (2016), Narasimhan and Kim (2002)
	Suppliers are an integral part of new product design efforts	0.787	Cao and Zhang (2011), Chen and Paulraj (2004), Flynn et al. (2016), Huo (2012), Huo et al. (2016)
II: Internal integration /Plant manager (0.904)	The functions in our plant are well integrated	0.825	Flynn et al. (2016), Huo (2012), Huo et al. (2014), Turkulainen et al. (2017), Wong et al. (2017)
	Functional coordination works well in our plant	0.808	Flynn et al. (2016), Turkulainen et al. (2017)
	The functions in our plant work well together	0.894	Flynn et al. (2016), Huo et al. (2016), Turkulainen et al. (2017)

	The functions in our plant cooperate to solve conflicts between them, when they arise	0.748	Flynn et al. (2016), Huo et al. (2016), Turkulainen et al. (2017)
	Our plant's functions coordinate their activities	0.816	Flynn et al. (2016), Huo (2012), Huo et al. (2016), Turkulainen et al. (2017), Wong et al. (2016)
	Out plant's functions work interactively with each other	0.853	Flynn et al. (2016), Huo (2012), Huo et al. (2016), Turkulainen et al. (2017), Wong et al. (2016)
CI-1: Information sharing /Downstream SC manager (0.874)	Our key customers have access to the following information about our plant:		
	Delivery information	0.781	Frohlich and Westbrook (2001), Gimenez et al. (2012)
	Demand change information	0.857	Gimenez et al. (2012), Nyaga et al. (2010), van der Vaart et al. (2012)
	Demand forecast information	0.834	Cao and Zhang (2011), Gimenez et al. (2012), van der Vaart et al. (2012), Wong et al. (2017)
	Inventory information	0.768	Cao and Zhang (2011), Flynn et al. (2010), Frohlich and Westbrook (2001), Huo (2012), Huo et al. (2014)
	Quality information	0.730	Chen and Paulraj (2004)
	Schedule information	0.736	Frohlich and Westbrook (2001), Gimenez et al. (2012), Schoenherr and Swink (2012), van der Vaart et al. (2012)
CI-2: Collaborative improvement /Downstream SC manager (0.669)	We are comfortable sharing problems with our customers	0.679	Cao and Zhang (2011), Chen and Paulraj (2004), van der Vaart et al. (2012)
	In dealing with our customers, we are willing to change assumptions in order to find more effective solutions	0.703	Gimenez et al. (2012), Schoenherr and Swink (2012), Vachon and Klassen (2006), van der Vaart et al. (2012)
	Cooperating with our customers is beneficial to us	0.699	Gimenez et al. (2012), Nyaga et al. (2010)
	We emphasize openness of communication in collaborating with our customers	0.789	Cao and Zhang (2011), Chen and Paulraj (2004), Kannan and Tan (2010)
CI-3: NPD involvement /NPD manager (0.846)	Customers are involved early in product design efforts	0.845	Koufteros et al. (2005), Wong et al. (2017)
	We partner with customers for the design of new products	0.784	Koufteros et al. (2005), Wong et al. (2017)
	Customers are frequently consulted during the design of new products	0.828	Flynn et al. (2016), Huo et al. (2016), Wong et al. (2017)
	Customers are an integral part of new product design efforts	0.851	Cao and Zhang (2011), Gimenez et al. (2012), Koufteros et al. (2005)

Appendix B. Construct mean, standard deviation, average variance extracted (AVE), and inter-construct correlations.

Construct	Mean (Std.Dev.)	SI-1	SI-2	SI-3	II	CI-1	CI-2	CI-3
SI-1: Information sharing	3.436 (0.958)	66.01%						
SI-2: Collaborative improvement	3.879 (0.412)	.218**	53.71%					
SI-3: NPD involvement	3.956 (0.776)	.191**	.250**	69.93%				
II: Internal integration	3.971 (0.533)	.080	.259**	.219**	68.08%			
CI-1: Information sharing	2.109 (0.636)	.326**	.162*	.181**	.184**	61.67%		
CI-2: Collaborative improvement	3.698 (0.410)	.050	.237**	.180**	.203**	.325**	51.66%	
CI-3: NPD involvement	3.521 (0.588)	.149*	.151*	.360**	.268**	.253**	.163*	68.46%

Construct's AVE are found on the diagonal of the matrix.
* Correlation is significant at the 0.05 level; ** Correlation is significant at the 0.01 level.

Appendix C. Results from the regression analysis for the ETO sub-sample (N=20).

Dependent variable	Cost	Quality	Delivery speed	Delivery reliability	Product mix flex.	Volume flexibility
Control variables:						
Plant size	-0.244	0.472+	-0.531*	-0.416	-0.585+	-0.298
Industry: Machinery	-0.634+	-0.363	-0.288	-0.361	-0.322	-0.553
Industry: Auto supplies	-0.664*	-0.424	-0.137	0.029	-0.105	-0.092
Independent variables:						
SI-1: Information sharing	0.177	0.374	0.010	0.442	0.028	0.327
SI-2: Coll. improvement	-0.423	-0.860*	0.603*	-0.124	0.241	-0.433
SI-3: NPD involvement	0.274	0.573	-0.410	0.304	0.128	0.308
II Internal integration	0.764*	0.493+	0.493*	0.505	-0.023	0.744*
CI-1: Information sharing	-0.192	-0.754	-0.070	-0.725	-0.460	-0.725
CI-2: Coll. improvement	-0.456	0.558	-0.255	0.390	0.216	0.406
CI-3: NPD involvement	0.115	-0.347	0.862*	0.237	0.691	-0.117
R^2	0.752	0.781	0.921	0.714	0.617	0.659
F-value	2.729+	3.208*	10.442***	2.250	1.453	1.743

Significance levels: + p < 0.10, * p < 0.05, ** p < 0.01, *** p < 0.001.

Appendix D. Results from the regression analysis for the ATO sub-sample (N=43).

Dependent variable	Cost	Quality	Delivery speed	Delivery reliability	Product mix flex.	Volume flexibility
Control variables:						
Plant size	0.346*	0.227	-0.044	0.072	-0.031	0.172
Industry: Machinery	-0.029	0.055	0.142	0.132	0.313+	-0.064
Industry: Auto supplies	-0.238	-0.187	0.070	-0.054	0.208	0.003
Independent variables:						
SI-1: Information sharing	0.118	0.323+	-0.177	0.156	-0.079	-0.275
SI-2: Coll. improvement	0.033	0.199	0.130	0.186	0.002	-0.102
SI-3: NPD involvement	0.187	0.112	-0.058	-0.205	-0.231	-0.254
II Internal integration	0.403*	0.236	0.148	0.357*	0.233	0.150
CI-1: Information sharing	-0.150	-0.028	-0.054	0.044	-0.120	0.113
CI-2: Coll. improvement	0.113	-0.123	0.019	-0.131	0.162	0.149
CI-3: NPD involvement	-0.435*	-0.247	0.174	0.082	0.248	0.266
R^2	0.361	0.266	0.099	0.225	0.237	0.280
F-value	1.805+	1.158	0.352	0.927	0.992	1.242

Significance levels: + p < 0.10, * p < 0.05, ** p < 0.01, *** p < 0.001.

Appendix E. Residual analysis from regressions models using the full sample and the sub-samples for MTO and MTS plants.

Correlations between residuals and independent variables, Full sample.

Dependent variable	**Cost**	**Quality**	**Delivery speed**	**Delivery reliability**	**Product mix flex.**	**Volume flexibility**
Independent variables:						
SI-1: Info sharing	-9.5E-17	-5E-17	1.65E-17	-1.2E-16	-6E-17	-1.8E-17
SI-2: Coll. improvement	-3.1E-16	-7.1E-17	1.04E-16	-1E-16	8.24E-17	7.61E-17
SI-3: NPD involvement	-9.4E-17	-1.8E-16	-1.5E-16	-2.5E-16	-1.3E-16	-2.7E-16
II: Internal integration	-1.6E-16	-7E-17	-7.3E-17	-1.1E-16	2.04E-17	-1.5E-16
DS-1: Info sharing	1.61E-16	-8.1E-19	1.13E-17	1.29E-17	5.16E-17	1.78E-17
DS-2: Coll. improvement	2.54E-16	7.81E-18	9.8E-17	1.39E-16	2.27E-16	5.9E-17
DS-3: NPD involvement	-8.7E-17	-1.9E-16	-1.4E-16	-1.5E-16	-2.1E-16	-1.7E-16

Correlations between residuals and independent variables, MTO plants.

Dependent variable	**Cost**	**Quality**	**Delivery speed**	**Delivery reliability**	**Product mix flex.**	**Volume flexibility**
Independent variables:						
SI-1: Info sharing	4.33E-16	1.02E-16	2.43E-16	5.78E-16	2.86E-16	2.49E-16
SI-2: Coll. improvement	5.98E-17	1.47E-16	3.22E-16	3.46E-16	2.46E-16	1.98E-16
SI-3: NPD involvement	2.1E-16	1.84E-17	1.94E-16	3.77E-16	1.13E-16	1.01E-16
II: Internal integration	3.35E-16	2.4E-16	1.93E-16	3.53E-16	3.86E-16	2.67E-16
DS-1: Info sharing	3.73E-17	-3.6E-17	-3.5E-17	-1.7E-17	1.6E-16	1.37E-16
DS-2: Coll. improvement	1.94E-16	5.29E-17	1.61E-16	2.2E-16	2.56E-16	1.6E-16
DS-3: NPD involvement	3.49E-16	1.61E-16	2.55E-16	2.99E-16	1.66E-16	1.3E-16

Correlations between residuals and independent variables, MTS plants.

Dependent variable	**Cost**	**Quality**	**Delivery speed**	**Delivery reliability**	**Product mix flex.**	**Volume flexibility**
Independent variables:						
SI-1: Info sharing	-5.1E-16	3.5E-16	8.29E-16	1.03E-15	3.56E-16	4.82E-16
SI-2: Coll. improvement	1.16E-16	1.93E-16	-6.6E-16	3.43E-16	-9.6E-16	-4.9E-16
SI-3: NPD involvement	9.71E-17	3.47E-16	5.38E-16	3.71E-16	5.34E-16	6.19E-16
II: Internal integration	-3.8E-17	2.15E-16	-8.4E-16	1.77E-16	-8.6E-16	-6.5E-16
DS-1: Info sharing	-2.7E-16	-6.8E-17	-5E-16	1.03E-16	-6.9E-16	-6E-16
DS-2: Coll. improvement	-1.6E-17	-1.5E-16	-6.4E-16	4.46E-16	-8.4E-16	-4E-16
DS-3: NPD involvement	-2.2E-16	3.73E-16	4.92E-16	4.49E-16	3.14E-16	3E-16

VIF scores for the independent variables in the full sample and MTO and MTS sub-samples.

VIF scores	Full sample	MTO	MTS
Independent variable:			
SI-1: Information sharing	1.213	1.200	1.508
SI-2: Coll. improvement	1.222	1.317	1.431
SI-3: NPD involvement	1.261	1.253	1.460
II: Internal integration	1.187	1.150	1.360
CI-1: Information sharing	1.306	1.348	1.521
CI-2: Coll. improvement	1.224	1.377	1.113
CI-3: NPD involvement	1.269	1.190	1.464

Replicated appendix from Paper III

Appendix Factor analysis results and data quality measurements.

Results from EFA

Mass customization construct					
Item	Loading	Cronbach's α	AVE	Composite reliability	Discriminant validity
We are highly capable of large-scale product customization	0.796				
We can easily add significant product variety without increasing cost	0.751				
We can customize products while maintaining high volume	0.804	0.840	0.611	0.887	0.611 > 0.030
Our capability for responding quickly to customization requirements is very high	0.799				
We can quickly elect individual customer's preferences	0.757				

Modular design construct					
Item	Loading	Cronbach's α	AVE	Composite reliability	Discriminant validity
Our products are modularly designed, so they can be rapidly built by assembling modules	0.863				
We have defined product platforms as a basis for future product variety and options	0.693	0.725	0.647	0.845	0.647 > 0.030
Our products are designed to use many common modules	0.847				

Results from CFA

Mass customization construct					
Item	Loading	Cronbach's α	AVE	Composite reliability	Discriminant validity
We are highly capable of large-scale product customization	0.742	0.840	0.497	0.831	0.497 > 0.089
We can easily add significant product variety without increasing cost	0.641				
We can customize products while maintaining high volume	0.752				
Our capability for responding quickly to customization requirements is very high	0.715				
We can quickly elect individual customer's preferences	0.668				

Modular design construct					
Item	Loading	Cronbach's α	AVE	Composite reliability	Discriminant validity
Our products are modularly designed, so they can be rapidly built by assembling modules	0.806	0.725	0.509	0.845	0.509 > 0.089
We have defined product platforms as a basis for future product variety and options	0.501				
Our products are designed to use many common modules	0.792				

Model fit results from CFA

Fit indices: CFI = 0.956, IFI = 0.925, SRMR = 0.055 , $\chi 2/df = 2.295$, RMSEA = 0.076

Regression model diagnostics

Multicollinearity: VIF scores for dependent variables

	Plant size	CODP index	MC	MD	MD x MC	MD x CODP	MC x CODP
R^2	0.034	0.112	0.198	0.049	0.089	0.106	0.159
1-R^2	0.966	0.888	0.802	0.951	0.911	0.894	0.841
VIF score	1.035	1.126	1.247	1.052	1.098	1.119	1.189

Endogeneity: Correlations between residuals and explanatory variables

	Plant size	CODP index	MC	MD	MD x MC	MD x CODP	MC x CODP
Cost residuals	-0.256	0.083	-0.129	0.012	-0.065	0.055	-0.158
Quality residuals	0.049	0.028	0.003	0.076	0.051	-0.104	0.023
OTD residuals	0.030	0.041	-0.013	0.152	0.015	-0.038	0.069
Del. speed residuals	-0.049	0.203	-0.133	0.097	0.087	0.182	-0.033
Prod. flex residuals	-0.147	0.02	-0.015	0.161	-0.093	0.150	-0.068
Vol. flex residuals	-0.132	-0.067	-0.085	0.169	-0.041	0.080	0.021

Supplementary material from Paper IV

The supplementary material referred to in paper IV is available electronically and can be retrieved from accessing the paper's DOI link: https://doi.org/10.1016/j.spc.2023.06.023.

Replicated appendix from paper V

Detailed description of EFA results

Lean operations constructs				
Construct	**Items**	**Loadings**	**Cronbach's α**	**Average Variance Extracted**
Statistical process control and monitoring	Charts showing defect rates are posted on the shop floor	0.708	0.904	0.614
	Charts plotting frequency of machine breakdowns are posted on the shop floor	0.747		
	Processes in our plant are designed to be "foolproof"	0.737		
	A large percent of the processes on the shop floor are currently under statistical quality control	0.826		
	We make extensive use of statistical techniques to reduce variance in processes	0.851		
	We use charts to determine whether our manufacturing processes are in control	0.785		
	We monitor our processes using statistical process protocol	0.822		
Efficient shopfloor layout	We have laid out the shop floor so that processes and machines are in close proximity to each other	0.796	0.810	0.665
	The layout of the shopfloor facilitates low inventories and fast throughput	0.801		
	Our processes are located close together, so that material handling and part storage are minimized	0.849		
Continuous improvement	We strive to continually improve all aspects of products and processes, rather than taking a static approach	0.655	0.716	0.621
	If we aren't constantly improving and learning, our performance will suffer long term	0.845		
	We believe that improvement of a process is never complete; there is always room for more incremental improvement	0.848		
Small lot sizes	We have small lot sizes in our plant	0.911	0.873	0.833
	We tend to have small lot sizes in our master schedule	0.914		
Adherence to production schedule	We usually meet the production schedule every day	0.922	0.895	0.854
	We usually complete our daily schedule as planned	0.926		

Agile operations constructs				
Construct	Items	Loadings	Cronbach's α	Average Variance Extracted
Customization capabilities	We are highly capable of large-scale product customization	0.796	0.783	0.576
	We can add significant product variety without increasing costs	0.679		
	We can customize products while maintaining high volume	0.812		
	Our capability for responding quickly to customization requirements is very high	0.741		
Flexible manufacturing systems	Ability to rapidly change over products on short notice	0.843	0.751	0.629
	Ability to vary volume of product produced on short notice	0.814		
	Rapid customization of orders	0.717		
Flexibility as order winner	Flexibility is the most important criterion used by our customers in selecting us as a supplier	0.781	0.719	0.617
	Our customers select us because we deliver flexibility for their needs	0.733		
	Our customers can rely on us for flexibility	0.839		

Environmental practices constructs				
Construct	Items	Loadings	Cronbach's α	Average Variance Extracted
Resource efficiency	**Degree to which the plant is engaged in…**		0.795	0.518
	...Energy efficiency or renewable energy	0.656		
	...Reducing waste in internal processes	0.728		
	...Pollution prevention	0.817		
	...Pollution control	0.708		
	...Seeking or maintaining ISO 14001 certification	0.640		
	...Environmental improvements in the disposition of your organization's scrap or excess material	0.755		
Emissions reduction and control	...Improvements in inbound transportation, such as fuel efficiency or load matching	0.863	0.825	0.663
	...Improvements in outbound transportation, such as fuel efficiency or load matching	0.878		
	...Carbon tracking/carbon footprint calculation for the supply chain	0.736		
	...Life-cycle-analysis of the "cradle to grave" environmental impact of materials/products	0.771		
Environmental sustainability collaboration	...Complying with a customer's supplier code of conduct	0.810	0.783	0.698
	...Working with customers to help them achieve environmental objectives	0.863		
	...Encouraging suppliers to improve the environmental performance of their processes	0.832		

Plant functions responding to items associated with each construct	
Lean operations constructs	
Statistical process control and monitoring	Quality management
Efficient shopfloor layout	Process engineering
Continuous improvement	Plant supervision
Small lot sizes	Production control
Adherence to production schedule	Production control
Agile operations constructs	
Customization capabilities	Process engineering
Flexible manufacturing systems	Plant management
Flexibility as order winner	Downstream supply chain management
Environmental practices constructs	
Resource efficiency	Environmental affairs
Emissions reduction and control	Environmental affairs
Environmental sustainability collaboration	Environmental affairs

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