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Cash flow dynamics in the supply chain during and after disruptions

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ABSTRACT

Supply chain resilience and the ripple effect have been widely studied, mostly focusing on material flow-related practices. The financial flow adjustments to cope with supply chain disruptions have received much less attention. We contribute to the literature by examining the impact of adapting payment terms during and after disruptions. In particular, we perform a discrete event simulation analysis in anyLogistix for a complex supply chain network to investigate the impact of adjusting payment terms on supply chain cash flows. Our results suggest that collaboratively adjusting payment terms is an effective strategy for coping with disruptions. In contrast, ad hoc adjustments and immediate returns to pre-disruption payment schemes do not yield visible improvements. Positive effects on cash and loans are observed if an adjustment of payment terms occurs proactively and in a coordinated manner, especially when expediting payments downstream and payment slowing down upstream. The results from our sensitivity analysis on the impact of accelerating/decelerating cash conversion cycles favour shorter cycles when coping with disruptions. We deduce useful managerial insights and reveal some new theoretical tensions related to the impact of payment adjustments on cash flows in supply chains.

1. Introduction

Supply chain resilience and the ripple effect have been significantly visible research avenues (Chervenkova and Ivanov, 2023; Dolgui et al., 2023; Sawik, 2023; Ivanov, 2024a,b). The extant literature offers numerous strategies and practices for the preparedness and recovery of supply chains (Hosseini et al., 2019; Ivanov and Dolgui, 2021; Gruchmann et al., 2024). Most of these strategies and practices are related to material flows – e.g. backup suppliers, risk mitigation inventory, and capacity flexibility (Lin et al., 2021; Mitrega and Choi, 2021; Brusset et al., 2023; Hägele et al., 2023; Aldrighetti et al., 2024). Some research examined the role of information flows in supply chain resilience, focusing on visibility, digital technology, and cybersecurity (Ivanov, 2021; Sawik, 2022; Dubey et al., 2023). However, practices of financial flow adjustments to cope with supply chain disruptions have received much less attention (Choi et al., 2023).

The role of financial flows in supply chain resilience is a distinct but underexplored topic of high practical relevance. Consider an example. In the fall of 2023, Ford's supply chain experienced a series of disruptions caused by strikes (Shepardson and White, 2023). Assembly plants stopped, leading to significant monetary losses at Ford ($1.7 billion in lost profits and about 100,000 units fewer wholesale vehicle sales from the strike) (Gomes, 2023). Adversely, the ripple effect from the disruptions at the assembly plants could have resulted in setting Tier 2 suppliers at financial risk and danger of bankruptcy because of missing liquidity, higher interest rates,

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and difficulties to get loans from the banks (Vicci, 2023).

The extant literature has extensively dealt with supply chain and supplier financing, ranging from individual buyer–supplier relationships to supply chain ecosystems (Gupta and Chutani, 2020; Choi et al., 2023). Episodically, supply chain disruptions and resilience have been included in the analysis (Huang, 2022). However, most of the existing research is grounded into analytical modelling and lacks a dynamic, simulation-based perspective which has shown a promising way to address the adaptation of payment schemes under disruption conditions (Badakhshan and Ball, 2022).

In this paper, our objective is to examine the impact of cash conversion cycle adaptation and changes in deferment periods on financial flows in the supply chain under disruptions. We perform a discrete event simulation analysis in anyLogistix for a complex supply chain network subject to two major research questions (RQ):

RQ1: What is the impact of adjusting payment terms on supply chain cash flows during and after disruptions?

RQ2: How and when should firms adjust payment terms during and after disruptions to improve resilience in terms of cash flow continuity and financial supply chain performance?

Our contribution to the literature is twofold. First, we contribute to the literature by examining the impact of payment term adaptation during disruptions. We analyse the impact of adjusting cash conversion cycles during disruptions on financial supply chain performance in dynamics. Second, we deduce useful managerial insights on payment scheme adaptation during disruptions and reveal some new theoretical tensions related to the impact of payment adjustments on cash flows in supply chains with the consideration of loans and interest rates. As an additional contribution, our study is the first to use the 'cash-to-serve' experiment in anyLogistix for the analysis of financial flows in the supply chain resilience context.

The remainder of this paper is organised as follows. Section 2 analyses the existing literature, identifying some research gaps. Section 3 presents the modelling and setups as well as explains the discrete event simulation model, along with the data used. The experimental results are shown in Section 4. The said results are then discussed from theoretical and managerial perspectives in Section 5. We conclude the study in Section 6 by summarising the major outcomes and proposing some future research topics.

2. Literature review

The existing research in the area of this study focuses on supply chain financing under disruption conditions (Choi and Ivanov, 2020). First, the *financial ripple effect* has been studied in the literature. Proselkov et al. (2024) highlighted the role of bargaining power in supply chain networks when examining the financial ripple effect. They note that 'to remain operational, they [companies] maximise their liquidity by negotiating longer repayment terms and cheaper financing, thus distributing risk onto weaker companies and propagating financial stress'. Using an agent-based supply network simulation model capturing the behaviours described above, the authors examined 'structural conditions that make supply networks vulnerable to financial stress propagation and the resultant financial ripple effects using survivability analysis' (Proselkov et al., 2024). Another relevant research stream is related to *credit and interest rates*. Agca et al. (2021) observed propagations of both favourable and unfavourable credit shocks through supply chains. Battiston et al. (2007) examined credit chains observing bankruptcy propagation in production networks.

The third relevant research stream is the quantification of *cash flow cycles*. Farris and Hutchison (2002) examined different approaches to cash-to-cash (C2C) as a supply chain management metric. The C2C metric is computed using data about accounts payable (i.e. obligations owed by a firm to its suppliers that remain due and must be paid), accounts receivable (i.e. cash that the account owner expects to receive from the facilities or customers the products were sold to), and inventory-on-hand. In the simplest version, C2C is the difference between accounts payable and accounts receivable. A firm can increase its liquidity if accounts receivable are paid by the firm's customers before the firm must pay its accounts payable to the suppliers. When including inventory, the C2C is computed as 'the cash conversion cycle, which mirrors the operational cycle, measures the interval between the time cash expenditures are made to purchase inventory […] and the time that funds are received from the sale of the finished product' (Schilling, 1996). In other words, the cash conversion cycle is the length of time a firm needs to convert resources into cash flows. The acceleration and deceleration of the cash conversion cycle can certainly impact supply chain dynamics under disruptions. However, these effects have not been studied so far. Our study is the first to examine the impact of adjusting cash conversion cycles during disruptions on financial supply chain performance.

The fourth relevant research stream is related to *capital-constrained suppliers* and *supplier financing* (Shen et al., 2020; Yoo et al., 2021). This research primarily deals with financing options in the supply chain using game theoretic methods (Jin et al., 2019; Shi et al., 2021; Zhi et al., 2022). Credits – and even supplier bankruptcy – have also been studied in this research domain (Kouvelis and Zhao, 2016, 2018; Sokolinskiy et al., 2018; Tang et al., 2018). Zhao and Huchzermeier (2019) pointed to the importance of advance payment discounts and purchase order financing when managing supplier financial distress. Most recently, the role of blockchain in supply chain financing has received considerable attention (Choi and Luo, 2019; Li et al., 2022; Leuschner et al., 2023; Shen et al., 2023). Literature on financially constrained suppliers is rich but mostly focused on models for developing optimal payment schemes in the supply chain, assuming that only suppliers have liquidity problems and the buyers remain financially stable. Settings where both suppliers and buyers can become at risk of bankruptcy are rare.

The fifth literature stream informing our study is the financial risk analysis methods and, in particular, financial resilience/robustness metrics used in the supply chain literature. For example, the utilisation of conditional value at risk (CVaR) in supply chain disruption management, as extensively examined by Sawik (2011), underscores the effectiveness of linear stochastic programs as a highly efficient computational approach. In the CVaR framework, the choice of confidence level enables decision-makers to concentrate on particular percentages of worst-case scenario outcomes. Consequently, both low-probability, high-impact scenarios and high-probability, low-impact scenarios can be addressed simultaneously, thus mitigating the issue of 'unbalanced probability'.

When analysing the literature, we could observe that only a few studies have dealt with cash flows in the setting of supply chain resilience (Choi, 2021). Huang (2022) analysed financing-disrupted suppliers, focusing on advance payments, deferment periods (i.e. the period during which the full price of the purchase must be paid), and discount rates. They observed that the buyers can retain their maximum payoff by balancing advance payments, payment timelines (e.g. deferment periods), and discount rates, which supplement one another as strategic levers in sourcing risk management. Gupta and Chutani (2020) examined supply chain financing with advance selling under disruption. Badakhshan and Ball (2022) used machine learning and simulation to identify inventory and cash replenishment policies under physical and financial disruptions and examined the impact of the said policies on supply chain performance. Their approach is effective in cases of demand increase, capacity reduction, and credit purchase increase leading to a noticeable reduction in the cash conversion cycle in the upstream supply chain echelons. Related to the COVID-19 pandemic disruptions, Mashud et al. (2021) proposed a hybrid payment scheme in supply chains under disruptions composed of multiple pre-payments and delays in payments. Hofmann et al. (2021), Hofmann et al. (2023), and Choi et al. (2023) analysed financing solutions to stabilise liquidity and net working capital in supply chains under pandemic disruptions to ensure the continuity of supply and building digital supply chain ecosystems.

To summarise, there are three major determinants in the decision-making environment concerned with the impact of financial flows on supply chain resilience. The first is a coordination of payment terms (e.g. the deferment period and advance payments). Second, loans and interest rate conditions play an important role. Third, cash conversion cycle variations can reduce the adverse impact of disruptions on financial flows in the supply chain. However, despite the progress achieved, none of the research reviewed has examined the dynamic impacts of payment term adjustment and associated variations in the cash conversion cycles as a response strategy with regard to cash flow performance using discrete event simulation – a distinct and substantial contribution made by our study.

3. Methodological and modelling setup

In this section, we describe the discrete-event methodology used in this study, along with the modelling setup.

3.1. Methodology and software

Our model is based on the discrete-event simulation methodology. It is constructed and employed within the anyLogistix simulation and optimisation toolkit. In anyLogistix, the supply chain is delineated by specifying all pertinent elements such as locations (e.g. factories, warehouses), customers, demand profiles, inventory levels, sourcing strategies, shipment control policies, costs, revenues, and potential disruption events (Schleifenheimer and Ivanov, 2024). Utilising the discrete-event simulation methodology, which has been widely acknowledged as a crucial tool for examining supply chain dynamics under disruptions (Ivanov and Dolgui, 2021; Rozhkov et al., 2022; Jackson et al., 2024a), our model offers comprehensive insights into the behaviour of supply chain systems amidst various disruptive scenarios.

There are several crucial advantages of discrete-event simulation in anyLogistix for examining supply chain resilience and recovery dynamics. The supply chain model encompasses three primary perspectives: the network, the flows, and the parameters. First, the supply chain network is structured using various location objects, including customers, distribution centres (DCs), factories, and suppliers. Second, the flows within the network can be flexibly configured to represent the specifics of different supply chains. These flows are linked to design capacities in production, warehouses, and transportation and are governed by associated production, inventory, sourcing, and shipment policies. These policies can be customised to suit the unique characteristics of the supply chain and its management principles. Lastly, various operational parameters such as demand, lead-time, and control policy thresholds (e.g. reorder point, target inventory, and minimum vehicle load) can be defined. With these functionalities, a digital model of a physical supply chain – referred to as a digital supply chain – can be established and utilised for optimisation and simulations to analyse supply chain operations and performance dynamics, particularly under disruptive conditions.

3.2. Modelling setup

In this section, we describe our modelling setup, the payment dynamics scheme, and cash conversion cycles as well as the data used for modelling.

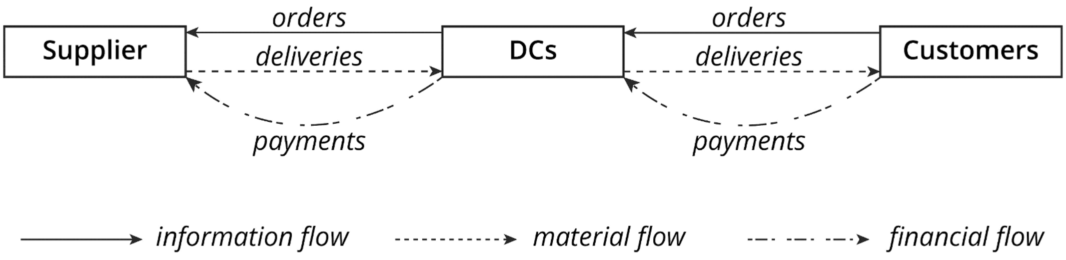

Fig. 1. Flows in the simulation model.

We model the supply chain and its material, information flows as a discrete event simulation system (Figs. 1–3).

We consider a three-stage supply chain comprising the supplier, DC, and customer layers (Fig. 1). Customers place orders at DCs with some predefined frequency. DCs operate at a continuous inventory review policy with a reorder point and a target inventory and place their orders at suppliers accordingly (Burgos and Ivanov, 2021; Ivanov, 2023). Suppliers deliver to DCs, and DCs ship to customers. Payments are organised according to the logic illustrated in Fig. 2.

In Fig. 2, the payment dynamics are shown across supply chain echelons. Note that the days on the timeline are selected randomly for illustration purposes only. Assume that a customer places an order at a DC on Day 0 and the DC just paid the supplier's invoices for the previous delivery on Day − 5. The ordering event on Day 0 is associated with a down payment p (i.e. a pre-payment) of a fraction of an order price (e.g. $p = 0.1$ means 10 % of a down payment). On Day 5, the DC delivers an order to a customer. According to some agreed deferment period t_d, say 15 days, the customer transfers the full payment for the order to the DC on Day 20.

Next, assume that the inventory at the DC reaches the reorder point on Day 25 and the DC orders at a supplier and transfers an agreed amount as a down payment. On Day 30, the supplier delivers to the customer; the full payment is due on Day 50. However, the DC has some cash deficits and asks a bank for a loan, which is transferred to the DC on Day 40, and the interest owed is payable on Day 100.

For the DC, its outgoing payments to the supplier are registered in the accounts payable, and the incoming payments from the customer are registered in the accounts receivable. The time intervals between the updating records in the accounts payable and receivable frame the cash conversion cycles for the DC.

We model a supply chain with a single supplier, five DCs, five customers, and a bank (Fig. 3).

The simulation model contains data about customer demand/orders, inventory control policy at the DCs, payment terms, cash accounts, sourcing and shipment rules, revenues, and costs. The provided dataset represents a fragment of a real-life supply chain, anonymised for confidentiality purposes.

There are 90 customers, each of whom places orders at the DCs subject to some stochastic demand which is normally distributed. DCs 1 and 2 are located in China, DC 3 in Japan, and DCs 4 and 5 in South Korea. The customers are grouped according to geographical regions and allocated to five DCs, each of which serves a fixed group of customers. A supplier ships to all five DCs. The LTL shipment policy is used. The DCs operate based on the continuous inventory review policy with some minimum (i.e. reorder point) and maximum (i.e. target inventory) stock levels and an extra safety stock to cope with demand variability. The financial flow parameters for a nominal (i.e. disruption-free) scenario such as down payments p and deferment periods t_d are shown in Fig. 3. All the DCs have some initial cash at the beginning of the simulation period, which equals 365 days. The variation of these parameters in disruption cases will be explained in Section 4. The loan interest rate is 6 %.

4. Experimental results

Our experiments have been performed according to the following logic in line with the extant literature on supply chain resilience with the help of a simulation (Ivanov, 2020; Burgos and Ivanov, 2021; Timperio et al., 2022; Saisridhar et al., 2024). First, a nominal scenario (i.e. business as usual, disruption-free) was run and analysed to validate the correctness of the model (Ivanov, 2023). The

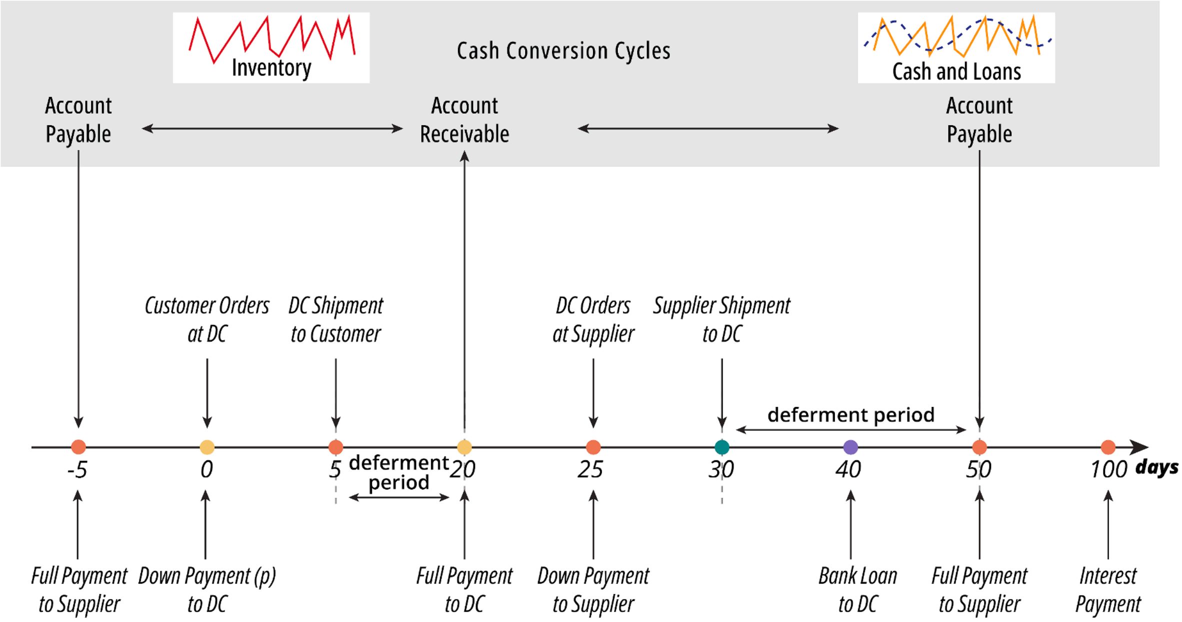

Fig. 2. Payment dynamics and cash conversion cycles.

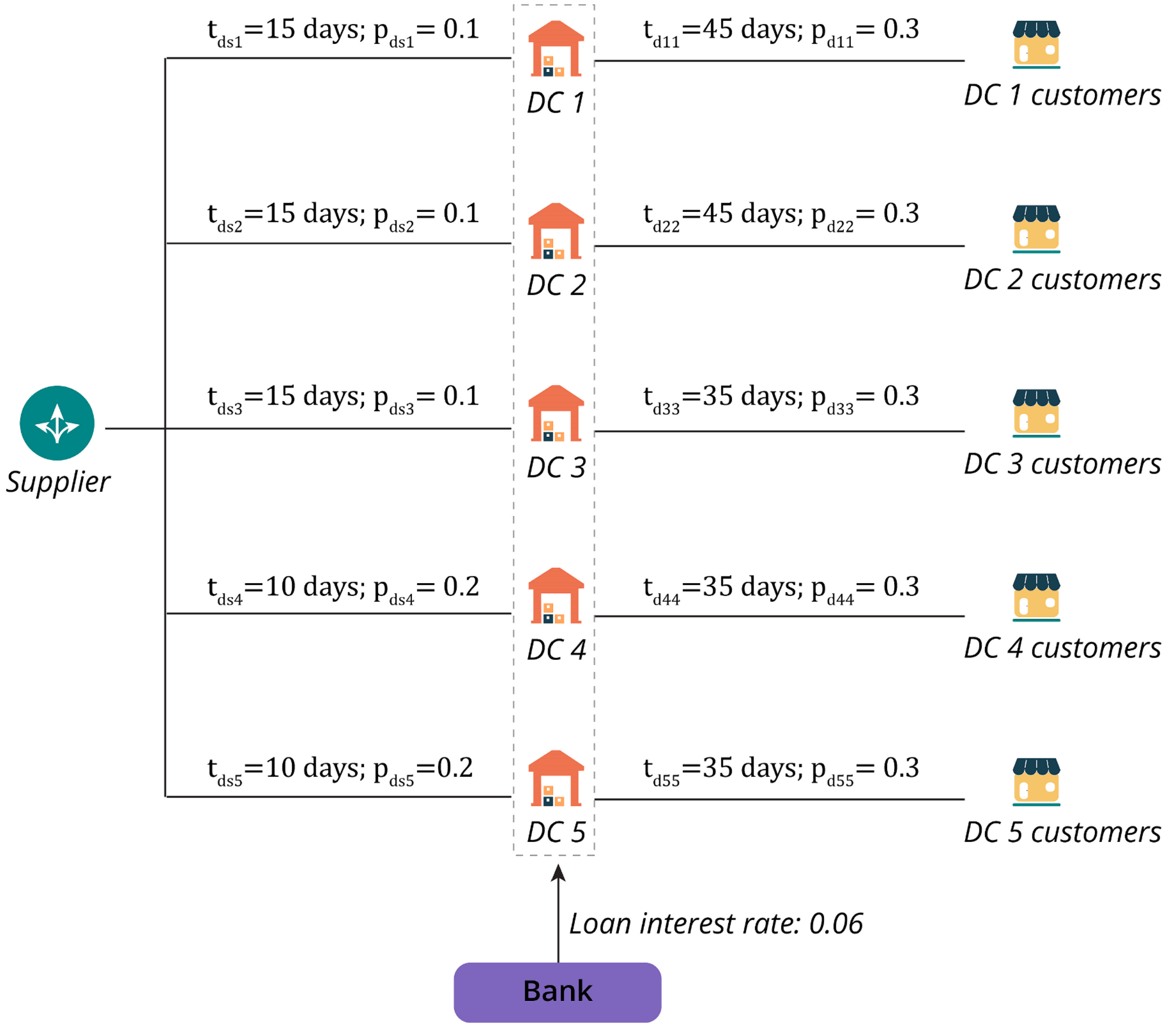

Fig. 3. Supply chain system in the model.

nominal scenario also allows creating a benchmark for comparison with disruption scenarios having an ‘ideal’ (i.e. disruption-free) picture of the supply chain operational dynamics and performance. Second, disruption scenarios have been examined subject to a disruption period of 60 days at all the DCs.

4.1. Nominal scenario

Fig. 4 illustrates the simulation results for the nominal case.

In the cash and loan-with-interest diagrams in Fig. 4, the blue lines depict cash, while the green ones show loans with interest. In the payment diagrams (i.e. accounts payable and receivable), the blue lines refer to the China DCs, the green lines the Japan DC, and the purple lines the South Korea DCs.

Fig. 4 shows that the Chinese and Korean DCs operate with some cash deficits in the first half-year of the simulation given a missing liquidity at the beginning of the year, leading them to borrow cash from a bank. The positive cash balance stabilises in the second half of the year.

4.2. Disruption scenario and no adjustment actions — Case 1

We now consider a disruption of 60 days at all the DCs, starting on Day 100 and lasting 60 days. We analyse the impact of this disruption on the cash and account dynamics (Fig. 5).

Fig. 5 reveals that the disruption impacts both cash and account dynamics. Some interesting effects can be observed. First, the cash and loan diagrams show (especially for China and South Korea) that during the disruption period, cash is increasing. This is because customers keep transferring money to the DCs for the previously delivered products subject to the deferment period. At the same time,

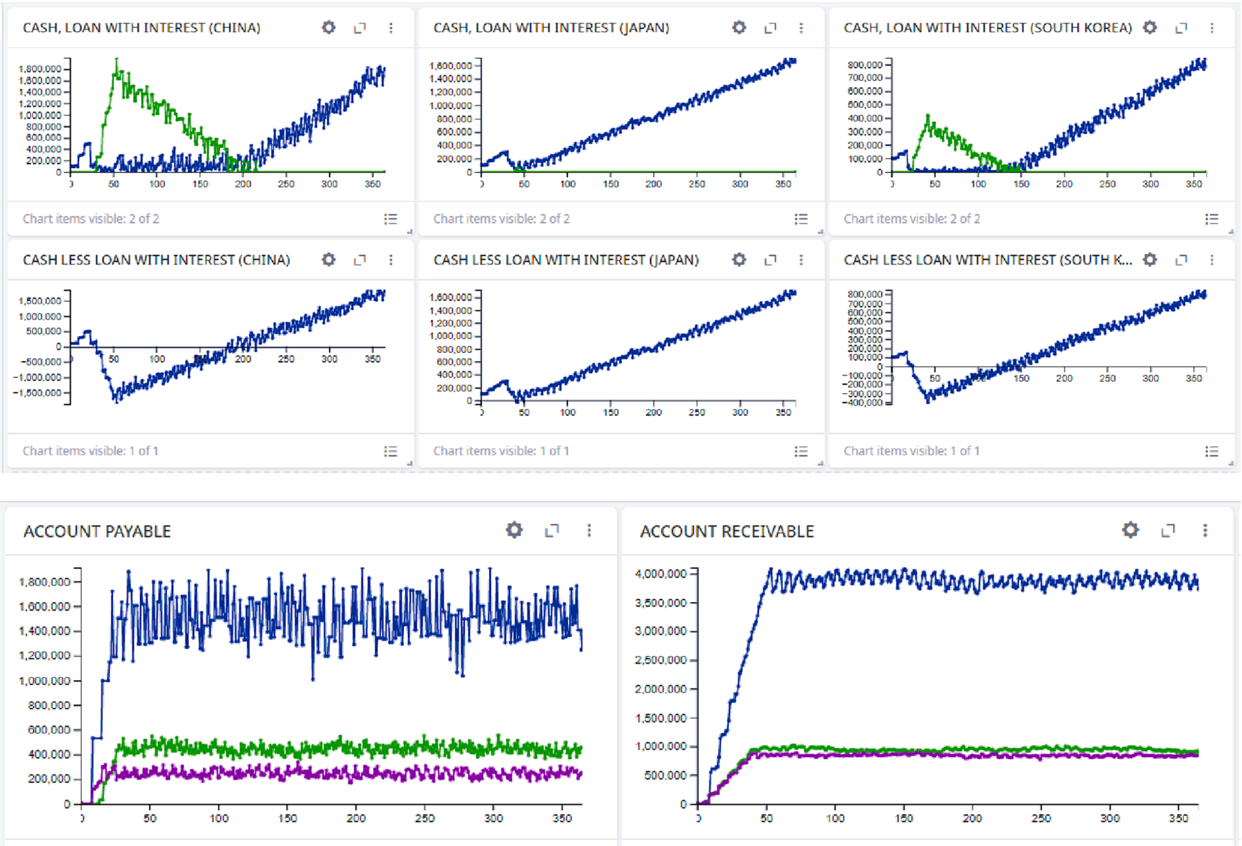

Fig. 4. Simulation results for the nominal case.

the DCs do not pay anything to the supplier because of missing new orders. As such, we can preliminarily conclude that the *determent period is an important control variable in ensuring cash availability during disruptions*.

At the same time, the cash and loan diagrams show that after the disruption, there is a disruption tail – i.e. a delayed effect of a disruption which becomes visible in the post-disruption period (Ivanov and Rozhkov, 2020; Ivanov, 2024c). We can observe a severe and rapid cash decrease at the DCs after recovery from the disruption. This can be explained by two effects. On the one hand, DCs have to purchase new products from the supplier. On the other hand, they do not receive cash for the products delivered to the customers. Both these effects intersect with each other and lead to cash deficits and new loans. We conclude that *an intersection of low accounts receivable and high accounts payable in the post-disruption period leads to cash deficits and new loans*.

4.3. Disruption scenario and ad hoc adjustment actions — Case 2

In this experiment, we consider the same setting as in Case 1 but allow an ad hoc change of payment terms during the disruption, namely a shorter deferment period to expedite the cash flows from the customers. However, this measure is not effective since during the disruption period, there are no new deliveries to the customers, and therefore, no new payments would be done.

4.4. Disruption scenario and proactive adjustment actions — Case 3

In this experiment, we simulate a proactive adaptation policy. Our rationale is based on the experimental results for Cases 1 and 2. In simulations with these cases, we observed that a missing adaptation or an ad hoc adaptation of payment terms equally leads to adverse consequences for supply chain financial health. As such, we now test the following policy. When a disruption hits the supply chain on Day 100 for 60 days, the payments downstream are expedited – i.e. the deferment period downstream is changed to five days. Contrarily, the payments upstream are slowed down, with a new deferment period of 45 days. In addition, the down payment ratios are reduced to 0 % downstream and increase to 50 % upstream to ensure higher cash flows from suppliers and lower spends downstream. In its totality, the said policy aims to avoid the disruption tails observed in Case 1, allowing for more cash coming from the customers and less payments to suppliers in the recovery and post-disruption periods. The effects of this policy are shown in Fig. 6.

Fig. 6 reveals that the proposed adaptation policy has a positive effect on the cash flows at the DCs compared to what is shown in Fig. 5. No new loans are observed in the post-disruption period, securing financial stability at the DCs. We can conclude that *a*

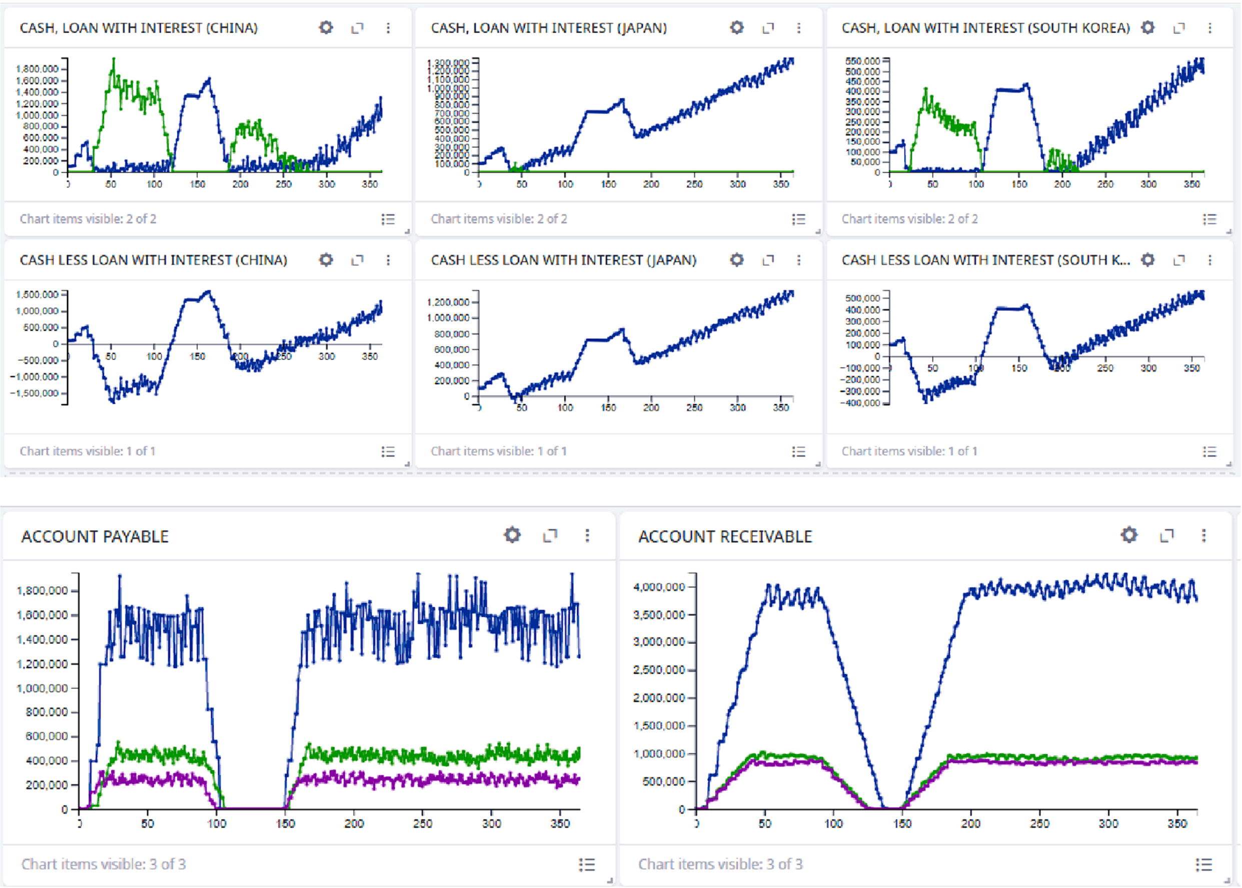

Fig. 5. Simulation results for Case 1.

collaborative adjustment of payment terms during and after a disruption in the supply chain leads to positive effects on cash availability at the disrupted facilities.

4.5. Sensitivity analysis

In this section, we perform two sensitivity analyses – namely shorter deferment periods and longer deferment periods – before, during, and after the disruption. The results are shown in Figs. 7 and 8.

In the scenario with the shorter deferment period, we set $t_{\mathrm{d}} = 5$ days both downstream and upstream for all the paths in the supply chain. The payment ratio $p = 0$. We can observe in Fig. 7 that the shorter and equal deferment periods across the supply chain have a positive effect on financial resilience and recovery. During the disruption, we observe a stop of payments, and accordingly, there are no disruption tails after the disruptions. On the contrary, in the case of longer deferment periods with down payments (i.e. we doubled the deferment periods from the nominal case, and the down payment ratios remained unchanged), the impacts are different and rather negative in terms of additional loans and missing liquidity (Fig. 8). We conclude that *the length of the conversion cycles and their balancing across supply chain echelons are important determents of cash availability at the disrupted facilities.*

5. Theoretical and managerial insights

The simulation results obtained through different experimental settings lead us to some interesting and novel managerial insights. Table 1 collates the major simulation results, their theoretical implications, and the resulting managerial recommendations.

We now elaborate on these observations and insights. The *first* observation is that variations in deferment periods impact supply chain financial performance during and after disruptions. This implies for further studies that the determent period is an important control variable in ensuring cash availability during and after disruptions. As such, it can be instructive to adjust payment terms to avoid the financial ripple effect and ensure cash availability in both the disruption and post-recovery periods. This insight is an extension to the existing body of knowledge on the ripple effect in general and the financial ripple effect in particular (Dolgui et al., 2018; Proselkov et al., 2024).

Our *second* observation is that particular attention should be directed towards the post-disruption period when utilising payment

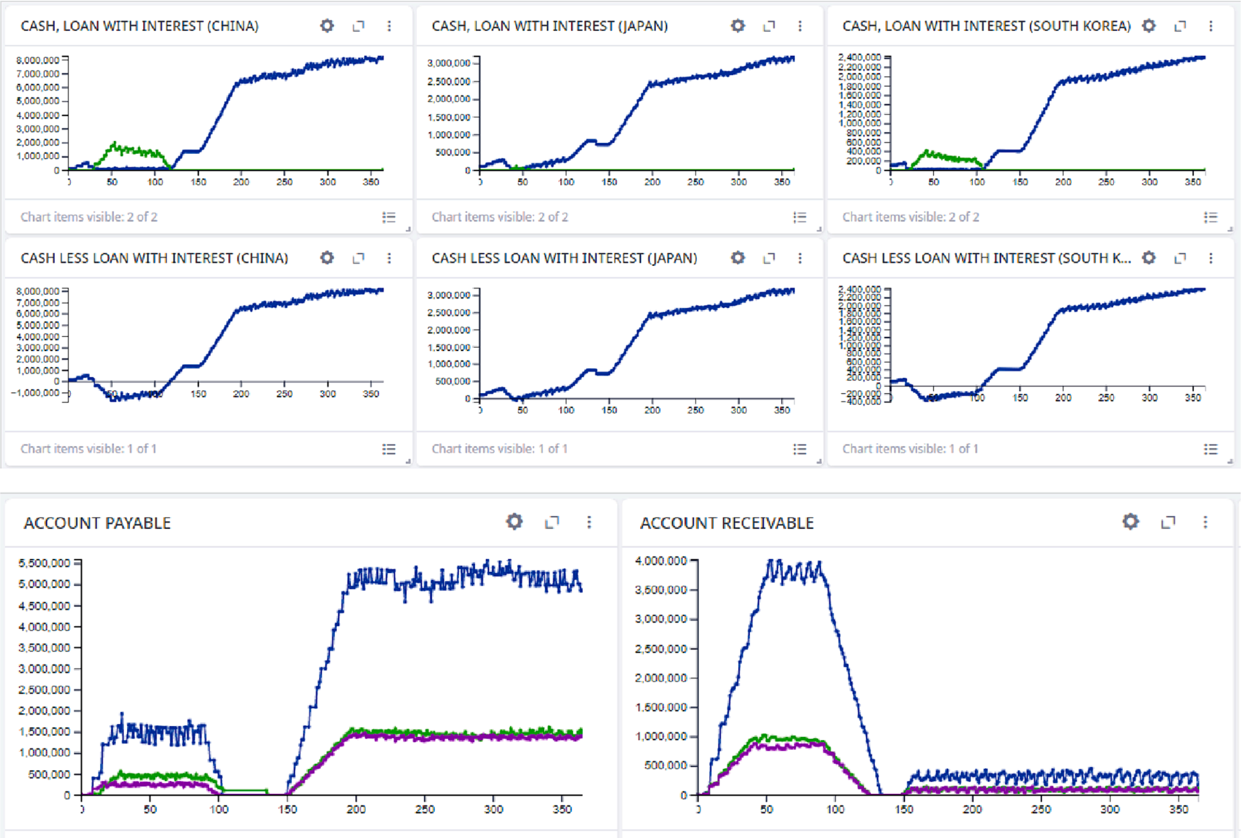

Fig. 6. Simulation results for Case 3.

term adaptation. We observed disruption tails in post-disruption periods stemming from financial flow interruptions. In particular, an intersection of low accounts receivable and high accounts payable in the post-disruption period leads to cash deficits and new loans. As such, it can be instructive to adjust payment terms in a way which allows avoiding delayed payments from customers with simultaneous short-term payments to the suppliers.

Third, positive effects of aligning payment terms along different supply chain echelons have been observed. To avoid disruption tails and cash deficits, payment expediting downstream and payment slowing down upstream as well as the adjustment of pre-payment terms can be a useful response strategy. It can be instructive to implement a collaborative adjustment of payment terms during and after a disruption in the supply chain to ensure cash availability at the disrupted facilities.

Our *fourth* and final observation is that supply chains running at shorter payment terms have been proven to be more resilient in terms of financial flows as those utilising slow cash conversion cycles. If it is impossible to implement equally short payment cycles along the whole supply chain, it can be instructive in cases of unbalanced payment terms in the supply chain to have longer conversion cycles downstream and shorter cycles upstream to ensure some cash availability during a disruption upstream. However, when recovering and resuming business-as-usual operations, this should be done vice versa – faster payments downstream and longer deferment periods upstream.

A common conclusion for all the four points mentioned above is that a synchronisation of payment terms across different echelons leads to a mitigation of both bullwhip and ripple effects in the supply chain. One important condition to achieve such a synchronisation is the use of digital technologies to achieve end-to-end visibility and real-time data availability (Pournader et al., 2020; Ivanov et al., 2021; Choi et al., 2022; Dubey et al., 2024).

6. Conclusion

In this study, we departed from the existing research gap about the role of cash flows in supply chain resilience and ripple effect analysis. The extant literature mostly focuses on strategies for preparedness and recovery related to material flows. Practices of financial flow adjustments to cope with supply chain disruptions have received much less attention. However, the practical and academic importance of this topic are unquestionable.

The main contribution of our study to the literature is an examination of the impacts of payment term adaptation during and after disruption responses, along with proposing useful coping strategies based on adjusting deferment periods and the role of coordination

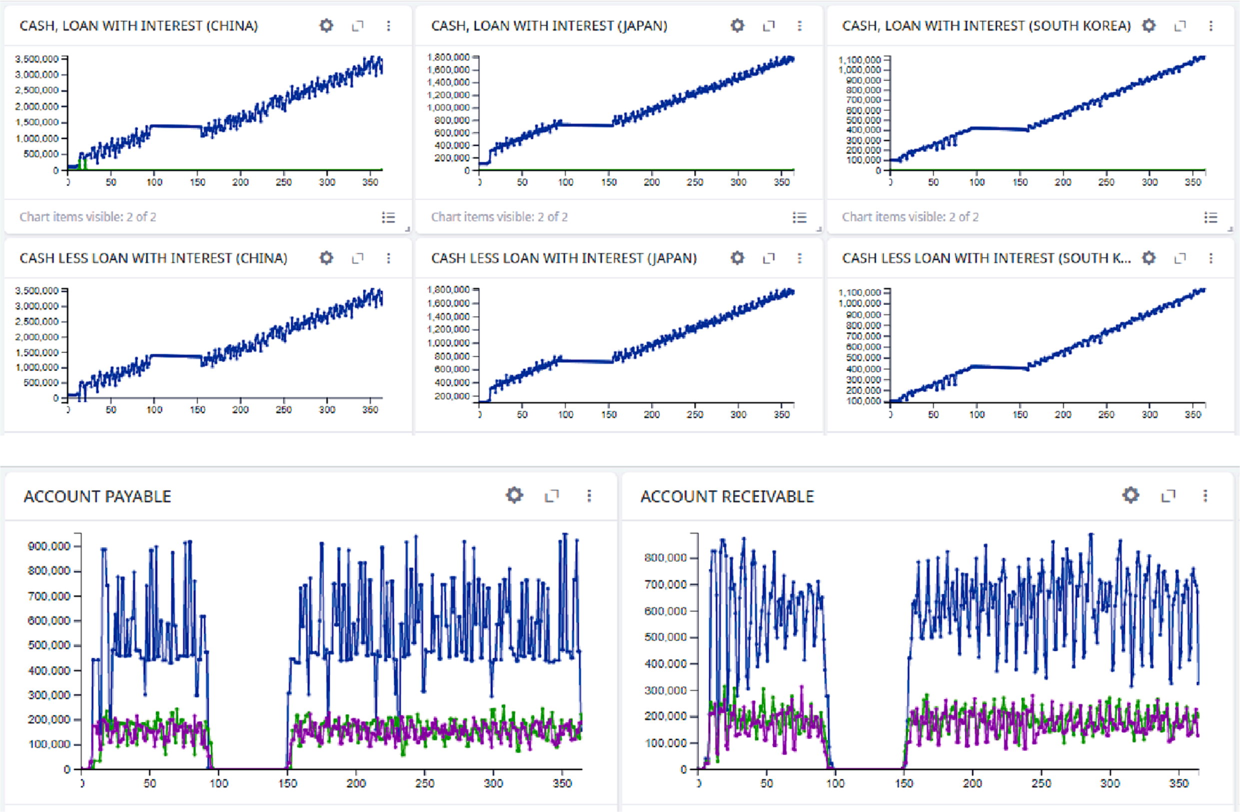

Fig. 7. Simulation results for the sensitivity analysis with shorter deferment periods.

in this adaptation. The objective of our analysis was to investigate the impact of adjusting payment terms on supply chain cash flows.

Methodologically, we utilised a discrete event simulation analysis in anyLogistix applied to a complex supply chain network. We performed simulations with nominal (disruption-free) and disruption scenarios considering different response strategies. The computational results of this study have been translated into useful managerial insights on the importance of payment term adjustment during disruptions to avoid bankruptcies in the supply chain and improve its resilience.

We deduced useful managerial insights on payment scheme adaptation during and after disruptions and revealed some new theoretical tensions related to the impact of payment adjustments on cash flows in supply chains with the consideration of loans and interest rates. Our main results are as follows. First, the outcomes of our study indicate that a collaborative adjustment of payment terms is a useful response strategy to cope with disruptions. Positive effects on cash and loans are observed if an adjustment of payment terms occurs proactively and in a coordinated manner. Contrarily, an ad hoc adjustment and an immediate return to pre-disruption payment schemes after the disruption do not bring visible improvements. In particular, payment expediting downstream, along with payment slowing down upstream, can be a useful response strategy when a supply chain faces disruptions and recovers from them.

The results of our sensitivity analysis on the impact of cash conversion cycle acceleration/deceleration are in favour of shorter cash conversion cycles when coping with disruptions. We also noted that if a coordinated adaptation of payment cycles along the whole supply chain is impossible and a supply chain is facing a disruption, it can be instructive to dampen conversion cycles downstream and accelerate them upstream to ensure some cash availability during the disruption period. However, in the post-disruption period, when recovering and resuming business-as-usual operations, this should be done vice versa – faster payments downstream and longer deferment periods upstream.

Limitations exist in this study, as with any research. First, the interrelations of cash and material flows have been considered at quite an aggregate and straightforward level. A more granular analysis could help derive some new insights. Second, the dynamics of the post-recovery period have been considered quite general and could be examined in more detail. These limitations motivate some further research areas. For example, a combination of payment policy adaptation with the adjustment of production–inventory policies could be studied (Rozhkov et al., 2022, Jackson and Ivanov, 2023). The impact of inventory in cash conversion cycle acceleration versus deceleration is an interesting topic. In future, one could also perform a study to determine the detailed timing of returning to 'normal' payment terms in the post-disruption period. The analysis could be extended by some financial resilience/robustness metrics. The estimation of cost change is rather important for the experimental results and can be included in future studies. Finally, a decentralised simulation with agents could bring innovative insights in collaborative policies to adjust cash flows in the wake of

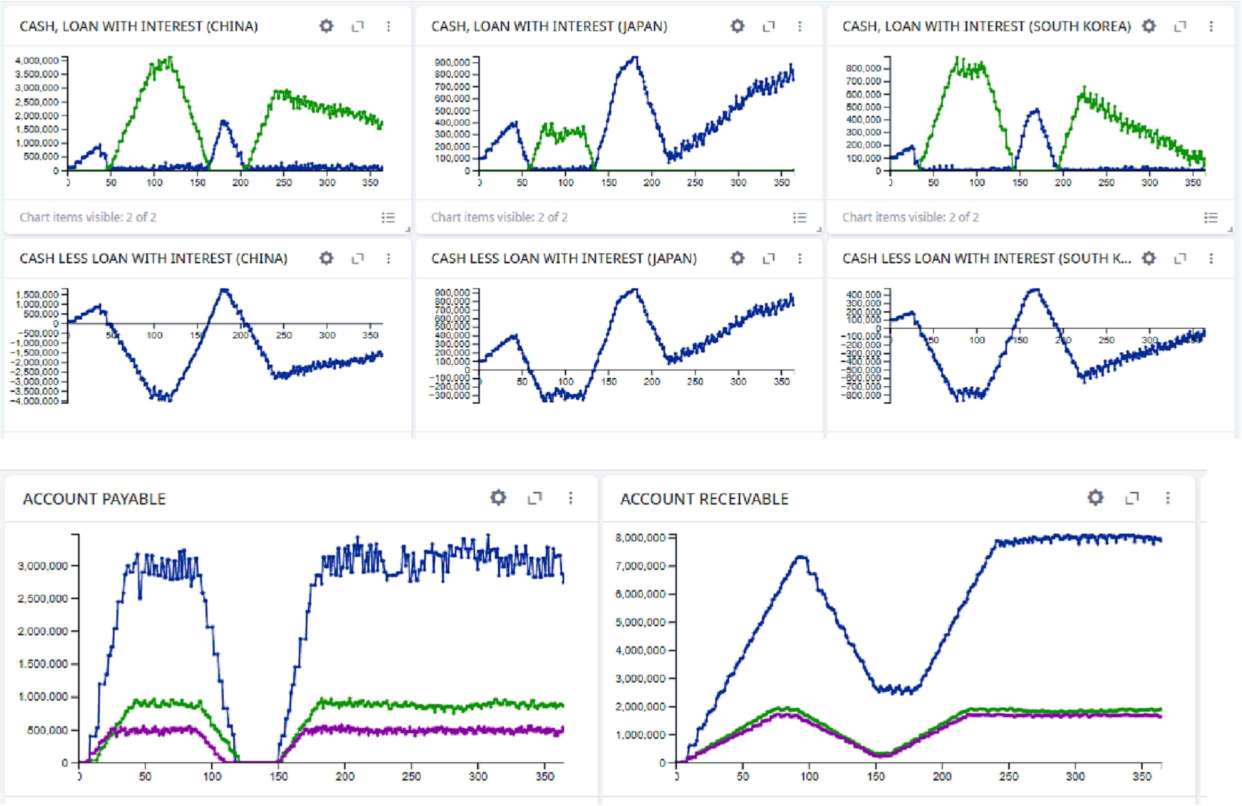

Fig. 8. Simulation results for the sensitivity analysis with longer deferment periods.

Table 1
Experimental results, theoretical implications, and managerial recommendations.

Experimental observations	Theoretical implications	Managerial recommendations
Shorter and longer deferment periods impact supply chain financial performance.	The determent period is an important control variable in ensuring cash availability during disruptions.	The ripple effect can be mitigated by the adjustment of payment terms to stimulate higher cash availability and avoid bankruptcy at suppliers upstream.
Disruption tails have been observed in the post-disruption period.	An intersection of low accounts receivable and high accounts payable in the post-disruption period leads to cash deficits and new loans.	A special focus should be directed towards the post-disruption period to avoid disruption tails and high payments upstream with simultaneous low cash flows downstream.
Changes in deferment periods and down payment ratios impact financial supply chain performance.	A collaborative adjustment of payment terms during and after a disruption in the supply chain leads to positive effects on cash availability at the disrupted facilities.	Payment expediting downstream and payment slowing down upstream as well as the adjustment of pre-payment terms can be a useful response strategy when a supply chain faces disruptions.
Positive effects are observed in cash flows if an adjustment of payment terms occurs proactively, ahead of a disruption, and is kept after the disruption. Contrarily, an ad hoc adjustment and an immediate stop after the disruption do not bring visible improvements.	The length of the conversion cycles and their balancing across supply chain echelons are important determents of cash availability at the disrupted facilities.	Accelerating the cash conversion cycle and keeping the adjusted terms after the disruption is beneficial for cash availability during recovery and after the disruption; slowing down this cycle is rather negative.

disruptions and during supply chain crises (Zheng et al., 2023, Zhu et al., 2024; Jackson et al., 2024b).

CRediT authorship contribution statement

Dmitry Ivanov: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Methodology, Investigation, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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