Fairness and Reciprocity in the Buyer-Supplier Relationship of a Dynamic Production System

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Abstract

The purpose of this study is to explore the influence of reciprocal decision-making and fairness considerations in a buyer-supplier relationship under dynamic complexity. More concretely, as there is little systematic knowledge of reciprocal behaviour and its impact on a dynamic production system, this work contributes to the current state of research in two ways: First, the study presents an approach how to model an agent's reaction to distributive and interactional (un)fairness in a dynamic setting. Second, the effect of reciprocal behaviour on supply chain performance is exploratively assessed. Based on these simulation results, we aim to advance the understanding of the mechanisms involved in managerial behaviour and decision-making in supplier-buyer relationships. Further research opportunities are derived from the findings.

1. Introduction

With increasingly interconnected and intercultural supply networks characterised by a high degree of collaboration, the crucial role of buyer-supplier relationships for our economy is apparent. Simultaneously, disruptions in supply networks due to political, economic, or natural crises are becoming increasingly frequent. Therefore, successful buyer-supplier relationships must be more resilient and dependable for both parties than ever before. In this context, a fair and mutually beneficial relationship has a strong influence on the strength and persistence of a buyer-supplier relationship (Liu et al., 2012). Remarkably though, supply chains have been observed to be inherently unfair systems that put upstream members such as the supplier in the buyer-supplier relationship at a systematic disadvantage when it comes to adverse supply chain dynamics (Coppini et al., 2010; Đula & Größler, 2021).

These observations of systematic unfairness in supply chains raise questions regarding the agents' reciprocal reactions towards finding themselves at a (dis)advantage and the consequential impact on buyer-supplier relationships. While the prevalence of reciprocity in various forms has been the focus of a certain body of research for static one-shot dyads, there remains little systematic knowledge about dynamically complex buyer-supplier relationships (Cui et al., 2007; Du et al, 2018, Shamsollahi et al., 2020). However, since a resilient and dependable buyer-supplier relationship is implicitly designed to be long-term, an improved systematic understanding of fairness and reciprocity in dynamic settings is crucial to successfully navigate buyer-supplier relationships (Shamsollahi et al., 2020). Therefore, this work contributes to the current state of research in two ways: First, the study presents an approach how to model an agent's reaction to distributive and interactional (un)fairness in a dynamic setting. Second, the effect of reciprocal behaviour on supply chain performance is exploratively assessed. Hereby, we are most interested in the degree of mutual beneficence for the agents as well as supply chain dynamics. Based on the simulation results, we aim to advance the understanding of the mechanisms involved in managerial behaviour and decision-making in supplier-buyer relationships.

The rest of this paper is organised as follows: in the second section, a brief overview of relevant research regarding fairness and reciprocity in buyer-supplier relationships is provided. In the third section, the underlying system dynamics model of a reciprocal buyer-supplier relationship is presented, and governing assumptions and equations are explained. The simulation results for different strengths of reciprocal behaviour are discussed in section four. They are compared to model behaviour under no reciprocity to facilitate the understanding of the impact of reciprocal behaviour on dynamic buyer-supplier relationships. The fifth and final section summarises the results and provides some concluding remarks, along with perspectives for future research.

2. Literature Review

Diverse streams of economic literature suggest that the understanding of a profit-maximising, unboundedly rational economic man without any fairness concerns is a useful model for diverse application purposes but does not adequately reflect the important social dimension in interactional decision-making processes (Adams, 1965; Kahneman, Knetsch & Thaler, 1986; Rabin, 1993 Fehr & Schmidt, 1999; Beck, 2014). To adequately describe this social dimension, the terms "justice" and "(organisational) fairness" are often used interchangeably (although not without criticism). Under this term, several types of fairness can be distinguished, two of them being distributive, and interactional fairness. Interactional fairness describes whether an agent feels fairly treated by the other agent, neglecting systematically unfair circumstances. Distributive fairness, or outcome-based fairness, however, can also account for systematically unfair circumstances. It focuses on the aspect of whether or not the outcome of a common action is distributed fairly amongst agents (Cohen-Charash & Spector, 2001). Distributional fairness concerns can thus be mathematically described with the help of inequity aversion models such as the one proposed by Fehr and Schmid (1999). It is important to note that Jokela and Söderman (2017) point out that fair outcomes do not have to be numerically equal if agents have contributed different efforts to the outcome. However, for the purpose of this study, we assume numerically equal outcomes to be fair outcomes.

Reciprocity stands for the notion that an agent wants to punish unkind or unfair behaviour or circumstances while they likewise want to reward advantageous or kind behaviour or circumstances (Falk & Fischbacher, 2006; Jokela & Söderman, 2017). Reciprocity can thus be purely intention based or based on further circumstances such as outcome fairness. For the purpose of the present study, reciprocity is described a as behavioural response to fairness (utility) with the goal of (re)instating a fairer, more neutral situation (Falk & Fischbacher, 2006).

For ease of understanding, unkind behaviour is also referred to as unfair behaviour in the following sections, even though, strictly mathematically speaking, unfair behaviour could also be interpreted as behaviour which is kinder than neutral.

Therefore, a perfectly fair and mutually beneficial relationship would be a relationship characterised by neutral treatment (interactional fairness) and equal perception outcome fairness (distributional utilities) as well as equal monetary outcomes (profit). From this description alone, it can be assumed that such a buyer-supplier relationship would be difficult to find in the real world. Shamsollahi et al. (2020) find that dynamic buyer-supplier relationships are characterised by continuity, learning, and thus, different stages of relationships, and fluctuations. It is furthermore also hard to come by in models of supply chains or dyadic buyer-supplier relationships. Kim and Choi (2021) discuss that especially buyers' actions are often followed by strong, often unintended and unexpected consequences for the supplier. Especially monetary outcomes have been observed to be systematically distributed unevenly amongst supply chain members regardless of the total number of members in a supply chain including dyads (Cui et al., 2007; Coppini et al., 2010; Du et al, 2018). This leads to unequal perceptions of (distributional or outcome-related) fairness. This observation is further corroborated by the findings of Đula and Größler (2021). By implementing inequity aversion models such as the one by Fehr and Schmidt (1999) into a classic Beer Game setting, they describe that the furthest upstream supply chain member with a capacity limit has the longest period of low or negative distributional utilities. This can be interpreted as the strongest experience of distributional unfairness (Đula & Größler, 2021).

A behavioural response to this reported unfairness can take on various appearances, such as communication tone, informational fairness or transparency, customer service levels, timely fulfilment or reliability of any other agreement, etc. pp. (Jokela & Söderman, 2017). Since this study approaches the topic from an operations management perspective, reciprocal behaviour is assumed to be the adjustment of the agents' profit margin and the adjustment of order quantities.

3. Methodology/Modelling

The buyer-supplier relationship is depicted as a stock and flow structure with the stocks being the supplier's and buyer's respective inventories, as shown in Figure 1. It is assumed that both the supplier as well as the buyer have limited capacity to fulfil incoming orders. The buyer's capacity is thus restricted by the supplier's delivery rate delayed by a 3-week delay. In turn, the supplier orders their required quantity from the n-tier suppliers with a delivery delay of 3 weeks. Additionally, the buyer can decide between ordering their units (partially or completely) from the supplier or the substitute supplier. The latter is implemented to allow the buyer to have a reciprocal lever over the supplier via their ordering quantities. The worse the buyer perceives their situation compared to the supplier's, the more they order from the substitute supplier, even though the substitute supplier is characterised by a longer delivery delay as well as a relatively high purchasing price per unit.

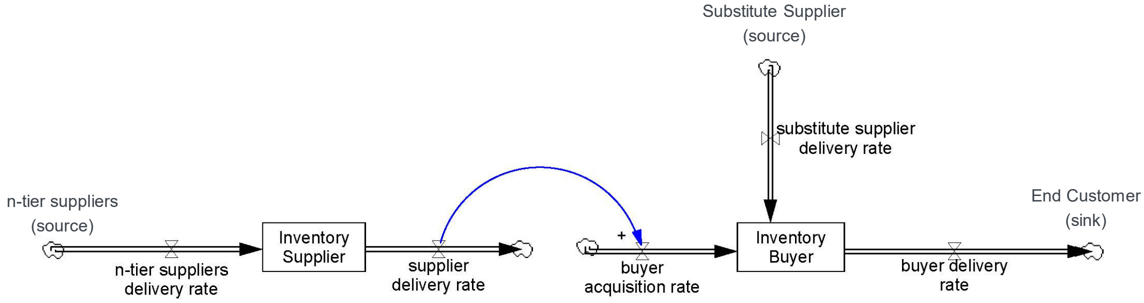

Figure 1: Stock and flow structure of a basic buyer-supplier relationship

Further, the perception of distributional fairness is measured by implementing the Fehr and Schmidt inequity aversion model of Đula and Größler (2021). This model requires profit instead of cost as a performance measure (Fehr & Schmid, 1999). Therefore, the Beer Game is extended by modelling profit as a stock and flow structure shown in Figure 2 (see also Đula & Größler, 2021). The profit for a single agent is determined by the cumulative difference between revenue and cost. Accordingly, the performance objective is no longer to minimise cost, but to maximise profit. Due to the delivery delay, ordered units are not immediately paid when being sent out, but rather paid upon delivery at the next supply chain member's inventory. Thus, the inflow "weekly revenue" is determined by the number of units arriving at the downstream supply chain partner in the current week (exemplarily for the supplier in Figure 2: buyer acquisition rate) multiplied by the price for which one unit is sold. The outflow "weekly cost" is the total weekly inventory cost per unit multiplied by the number of units currently held in inventory, the weekly backlog cost per unit multiplied by the number of units that are currently backlogged, and the purchasing price per unit, multiplied by the number of units that have been delivered to the agent this week.

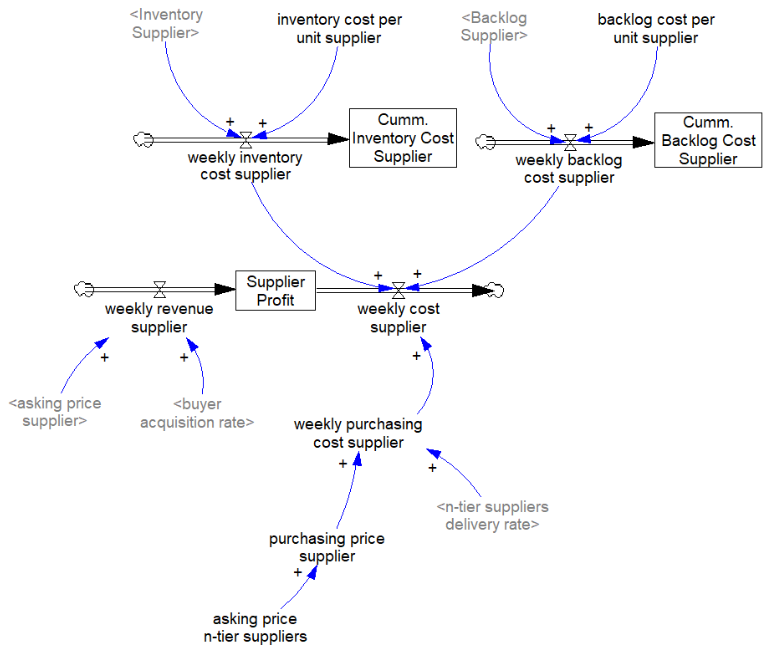

Figure 2: Stock and flow structure profit dynamics (supplier) (Đula & Größler, 2021)

In the reciprocal buyer-supplier relationship, while the buyer has no price-setting power, the supplier can adjust their profit margin and thus their asking price as a reciprocal lever against the buyer. It is assumed that the supplier adjusts their profit margin upwards from the normal profit margin to account for a disadvantageous situation, and downwards for an advantageous situation, respectively. Whether or not an agent perceives their situation as advantageous is modelled by implementing the dynamic inequity aversion model of Đula and Größler (2021; after Fehr and Schmidt (1999)). In Đula and Größler's model, the perception of distributional fairness is modelled as the agent's utility. In order to have the agents react to not only the distributional outcome but also the perceived fairness of their counterpart's actions, that model is further extended by implementing interactional fairness concerns. The stock and flow structure of the supplier's utility is exemplified in Figure 3. In line with Đula and Größler (2021), the supplier's utility is modelled as a stock which is changed by the indicated utility divided by the utility adjustment time. In Đula and Größler's model, the indicated utility is modelled as the original Fehr and Schmidt inequity aversion function

$$iU_s = P_S - (\alpha_S * MAX(P_B - P_S, 0)) - (\beta_S * MAX(P_S - P_B, 0))$$

P_B and P_S being the buyer's and the supplier's profit, respectively. α_S depicts how strongly the supplier dislikes being worse off, and β_S how strongly the supplier dislikes being better off compared to the buyer's profit (Đula & Größler, 2021). α_S and β_S are considered constants with α_S set to 1 and β_S set to 0.5.

Closing the loop between the agent's utility and their actions, we extend the structure in Figure 3 by incorporating interactional fairness concerns. For this, we calculate the interactional reciprocity factor of the supplier

$$irf = 1 - (rofss_b / eft_s)$$

with $rofss_b$ as the (reciprocal) order fraction that the buyer orders from the substitute supplier and eft_s as the fraction of orders the supplier expects the buyer to order from the substitute supplier (expected fair treatment supplier). Simply said, the agent assesses how they are being treated by their counterpart relative to their perception of what would constitute fair treatment. In the case of the supplier, this is done by comparing the fraction of orders which are ordered from the substitute supplier to the fraction of orders which the supplier would expect the buyer to order from the substitute supplier. If the agent is treated in line with their expectations, a fair or neutral interactional reciprocity factor of 0 could be observed. If the treatment exceeds their expectations (kindness), the interactional reciprocity factor would become greater than 0 (and less than 0 for unkind treatment, respectively). In the case of (un)kind treatment, the agent would be less (more) bothered by inequity. Therefore, their α_i and β_i values would be reduced. In the case of extremely kind treatment, their utility could thus even exceed their profit. This means, that extremely kind treatment and thus a high interactional reciprocity factor can compensate for an agent's low monetary utility (profit).

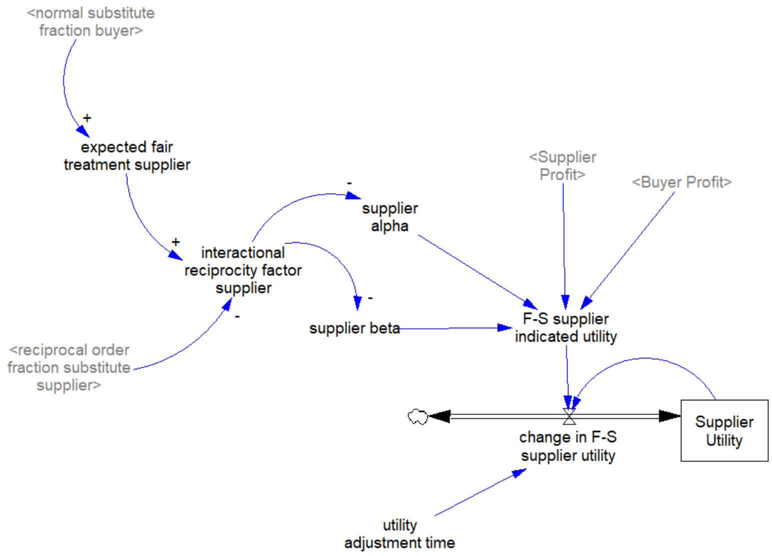

Figure 3: Stock and flow structure utility dynamics (supplier) (adapted from Đula & Größler, 2021)

Finally, the decision logic behind the treatment of the agent towards their counterpart, or in other words, the agents own reciprocal lever, follows the structure in Figure 4. Exemplarily shown for the substitute supplier, the reciprocal lever rl_i (supplier: reciprocal profit margin) is determined by a sigmoid function

$$rl_i = f(x_i) = \frac{L_i}{1 + e^{-k_i*(x_i - x_{i_0})}}$$

with L being the upper limit value of the curve (supplier: maximal profit margin), k being the growth factor which depicts the strength of the agent's reaction to unfairness (decision-making power, positive or negative), x_i being a function of the current utility ratio amongst agents and finally x_{i_0} the value of x_i for the agents utilities being equal $U_i = U_j$ (in our case, x_{i_0} is generally zero). This leads to the extreme ends of the agent's relative utility curve being systematically underweighted compared to the less extreme sections in the middle. Thus, the agent's reaction towards their utility relative to their counterpart's utility can be plotted as an s-shaped curve, with the point of inflexion being mapped for $U_i = U_j$ at the agent's neutrally set (fair) reciprocal lever (supplier: reciprocal profit margin = normal profit margin).

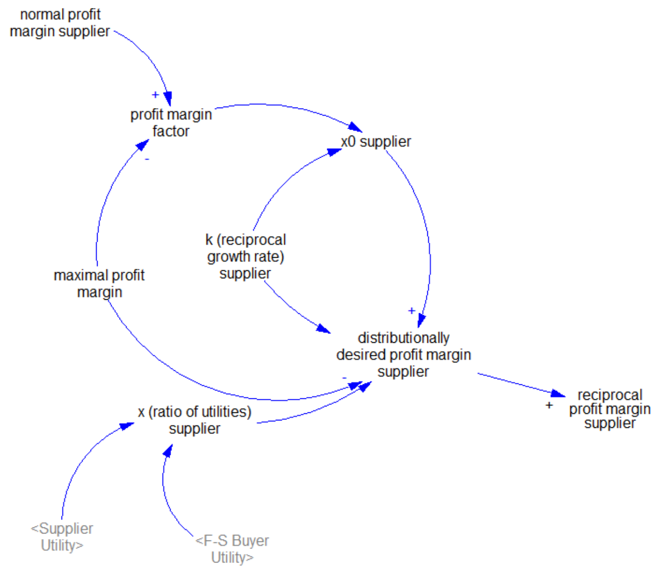

Figure 4: Decision logic for the reciprocal lever (supplier)

For the simulation, the standard set up from the Beer Game is adapted to the dyadic buyer-supplier relationship from above (Sterman, 1989). The simulation is run for 36 periods (weeks), with a time step of 0.0078125, and Euler integration. The end customer demand pattern is proportional to the original game. In the first five weeks, the end customer orders 400 units per week. In week 5, the end customer demand jumps to 800 units per week, where it stays until the end of the simulation period. Since the delivery delays for the acquisition of new units by the buyer as well as the supplier are set to 3 weeks, the desired safety inventory levels are initially at 1200 cases each. The model passes the *check units* test in the Vensim software. Since all variable units are consistent with the equations within the model as well as with their theoretically assigned units, the model is considered dimensional consistent. Additionally, a structural check of all equations with the *check model* test is passed as well. This means the basic technical aspects of model validity are ensured.

Figure 5 shows the inventory adjusted for backlog in the buyer-supplier dyad before reciprocal behaviour is turned on. The results are like those reported by various other researchers such as Đula & Größler (2021) or Kirkwood (1998). As soon as the end customer demand rises in week 5, inventories decrease from the desired safety inventories of 1200 units for supplier as well as buyer to close to zero (buyer) or sub-zero, which is to be interpreted as backlog (supplier). After a third of the simulation period, stocks begin to rise again to considerably above the desired levels, which shows the standard problem of order amplification and over-ordering also observed in the standard Beer Game (Kirkwood, 1998). The reason for the buyer rarely going into backlog is most likely due to them ordering 20% of all indicated orders from their substitute supplier as a standard setting.

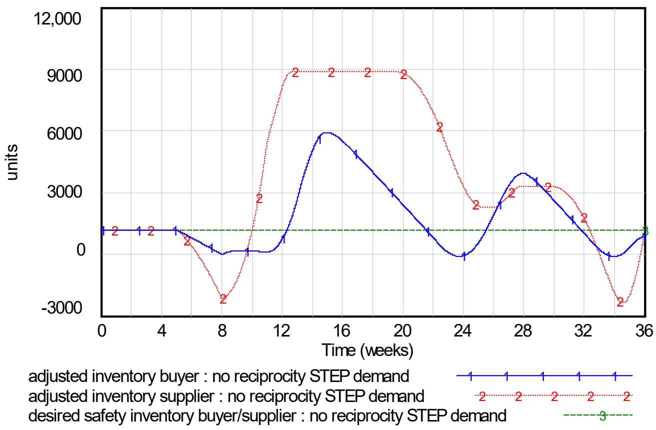

Figure 5: Simulation results for inventory levels in the standard run of the buyer-supplier dyad with no reciprocity

4. Simulation Results

The simulation is run for 36 periods to match the duration of a typical Beer Game. In this period, the supplier’s profit and utility sink dramatically due to their disadvantageous position in the supply chain even when no reciprocal behaviour is introduced (Đula & Größler, 2021). This can be observed in the left graph of Figure 6. As soon as the profits of buyer and supplier start to considerably differ after week 5, the respective utilities sink below the profits. Since the buyer still retains a higher profit relative to the supplier, their utility exceeds the supplier’s utility for the entirety of the simulation period. For the base scenario with reciprocity, the agents' profits and utilities start to differ even before the step increase in demand is introduced. This leads to the assumption that even minute differences in utility can lead to reciprocal behaviour and a self-reinforcing oscillation of utilities and reciprocal behaviour. It must be noted, however, that the supplier’s situation in the first half if the simulation period is significantly better compared to their situation without reciprocity. By introducing a reciprocal behaviour of both agents into the system, they can establish somewhat of a win-win situation as compared to no reciprocity. This, however, ends shortly before week 20, when the supplier’s profit falls considerably.

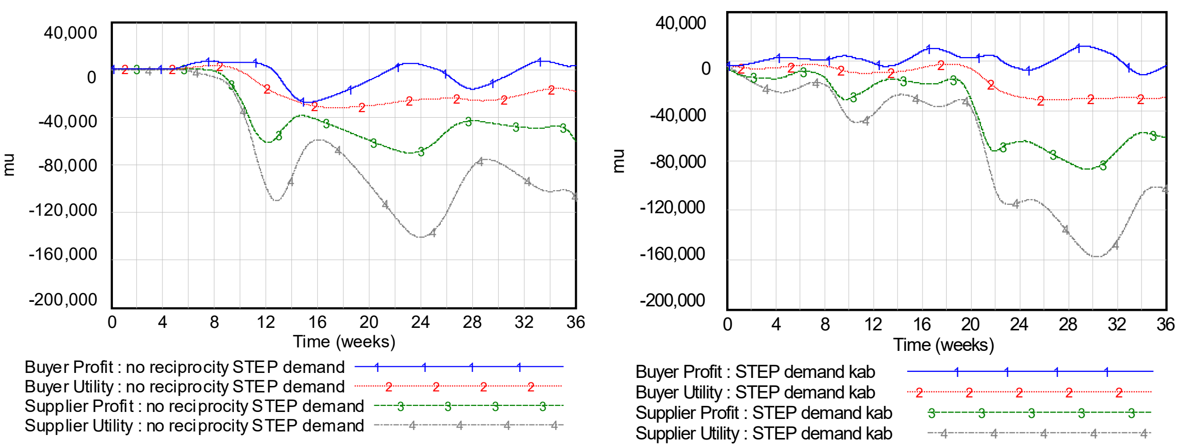

Figure 6: Profits and utilities for no reciprocal behaviour (left) and standard reciprocal behaviour (right)

This decrease is in line with the rise in inventory of the supplier observable in Figure 7. Their over-ordering compared with the buyer’s complete zero-order behaviour in the same period decreases the supplier's profits so drastically, that the utilities of either agent dips significantly. Nevertheless, the supplier's profit and utility can to some degree recover from this shock with the next increase in orders from the buyer around week 26. This indicates that long-term simulations would be interesting to make a clearer observation as to whether the oscillation of the profits and utilities will level out or behave self-reinforcing.

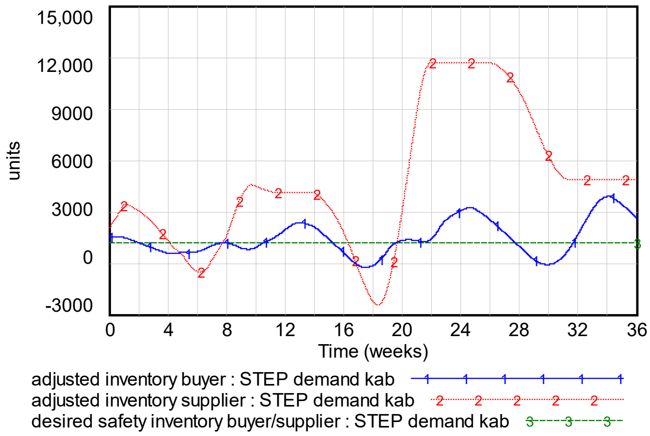

Figure 7: Inventory levels for standard reciprocal behaviour

When looking at the reciprocal behaviour in our standard reciprocity setting, the supplier's and buyer's behaviour are relatively stable. The supplier is fairly consistent in setting their profit margin at approximately 2.30 mu/unit with its slight rise and being in line with the above-described phenomenon shortly before week 20. This means, that they always treat the buyer slightly worse than the buyer would expect (marked by the reciprocal profit margin being constantly above the normal profit margin in the upmost left-hand side part of Figure 8). Correspondingly, in the lower left-hand part of Figure 8, the buyer's behaviour towards the supplier can be observed for the standard reciprocity setting. The buyer constantly behaves a bit kinder than strictly neutral towards the supplier, even though the supplier does the opposite. This can be explained by looking at their utilities. Since their reciprocal behaviour is utility-informed, the buyer is aware that he is better off than the supplier. They thus settle for a kinder treatment, making up for their utility being discounted by being considerably better off than the supplier. The supplier on the other hand makes up for their utility being (even more so) discounted by their relative disadvantage by looking a bit more after themselves and being a bit unkinder than strictly fair towards the buyer.

Since these curve characteristics are heavily influenced by the agents' decision-making power or strength of reaction towards (un)fairness k_i, the decision-making power of the systematically disadvantaged supplier is increased by factor 6 for a further simulation run depicted on the right-hand side of Figure 8. The buyers k_B remains the same as for the previous run, and no other variable is changed. Notably, the agents' behaviour changes and becomes more pronounced. For large parts of the simulation, the supplier requests an even higher (unkinder) profit margin from the buyer of above 3 mu/unit, whereas the buyers' behaviour around a similarly kind substitute order fraction than before, but with a more pronounced deviation towards neutral (less kind) behaviour around week 14. Likewise, around week 14, the supplier suddenly behaves neutrally to kind towards the buyer for a brief period of time.

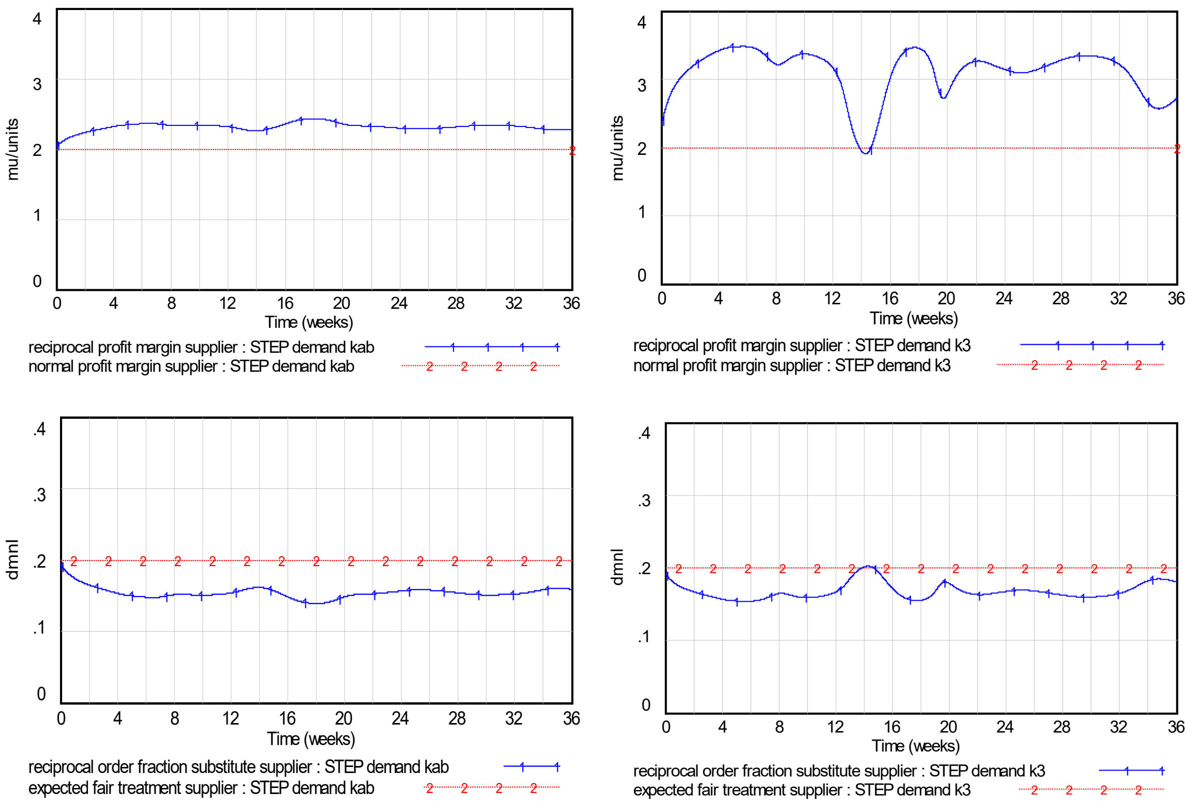

Figure 8: Perceived fairness of treatment of supplier and buyer for standard reciprocal behaviour (left) and increased supplier decision-making power (right)

When looking at the utility functions of the agents in the left-hand part of Figure 9, their above-reported behaviour around week 14 can be explained. It can be observed that the supplier's utility (due to the persistent kindness of the buyer and persistently high profit margins for themselves) shortly exceeds the buyer's utility (similar for profits) in this period. Generally, the differences in profits and utilities of the two agents seem to be considerably less. Regardless, this does not save them from the adverse effects of over-ordering and ceasing all orders which hit the supplier's profit and thus both buyer's and supplier's utility again around week 20. However, due to the supplier being able to react more strongly to their decrease in profits and utility, it seems they can recover much quicker from this shock. Again, a longer-term simulation run would be needed for a more in-depth analysis of this behaviour.

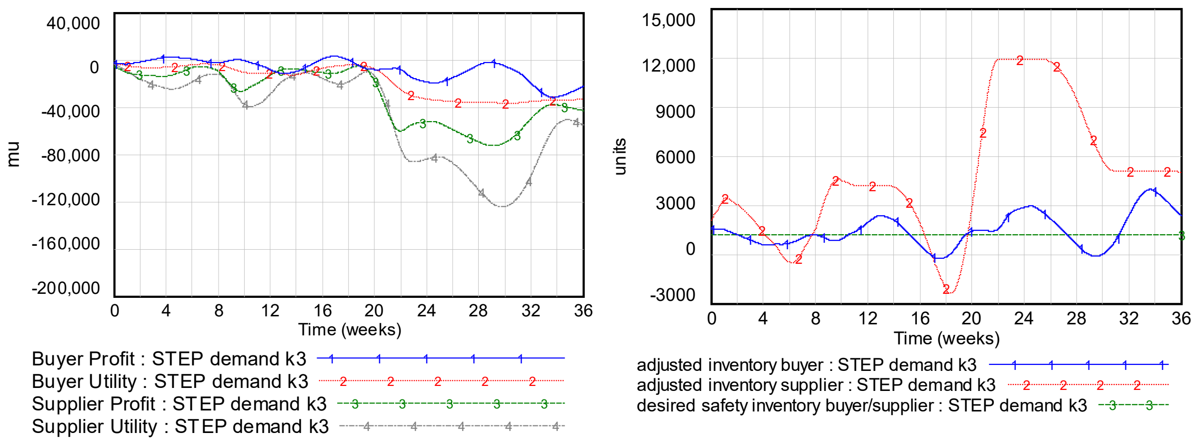

Figure 9: Profits and utilities (left) and inventory levels (right) for reciprocal behaviour with increased supplier decision-making power

5. Conclusion

Resilient and dependable buyer-supplier relationships are characterised by their long-term existence. Simultaneously, their fairness and mutual beneficence facilitate their continued existence. Therefore, an improved systematic understanding of fairness and reciprocity in dynamic settings is fundamental to successfully navigating supply networks. Applying reciprocal behaviour in a buyer-supplier dyad similar to the Beer Game, this study thus aims to extend the current state of research on fairness and reciprocity in dynamic settings. By extending the pre-existing system dynamics model of Đula & Größler (2021), its contribution is twofold: First, the study presents an approach how to model an agent's reaction to distributive and interactional (un)fairness in a dynamic setting. This is done by closing the loop between a descriptive perspective on fairness in a buyer-supplier relationship and the agents' reciprocal levers (substitute order fraction and profit margin, respectively).

Second, the effect of reciprocal behaviour on supply chain performance is exploratively assessed, aiming to further the understanding of the mechanisms involved in managerial behaviour and decision-making in supplier-buyer relationships. It is found that the normally reported systematic disadvantage of upstream supply chain members can be mitigated by awarding them (more) decision-making power over their reactions regarding said disadvantage. However, this seems to increase the part of the order amplification for which the supplier can be made responsible. Simultaneously, awarding the buyer decision-making power dampens their order-amplifying behaviour. Consequently, a generalised statement about the impact of reciprocal behaviour or the decision-making power of supply chain members on supply chain performance should only be made after further simulation runs and thorough testing of these hypotheses with greater variations in decision-making power between runs. A further observation is the partial recovery of the supplier's profits and utilities towards the end of the simulation period. Long-term simulation runs are needed to determine whether the agents' utility- and profit oscillations are made up of a self-reinforcing pattern of (partial) recovery and deterioration or whether they will level out eventually.

Jokela and Söderman (2017) point out that a fair distribution of outcomes is not necessarily the same as an equal distribution of outcomes. In this light, it would be interesting to incorporate a measure of how much individual agents have contributed to the supply chain's performance (for example their contribution to adverse supply chain dynamics such as the bullwhip effect) into our considerations of distributional fairness.

Beyond that, this study’s findings are not without their limitations. The employed model consists of a two-echelon supply chain. A short supply chain decreases the impact and frequency with which characteristics of dynamic complexity can occur (Paik & Bagchi, 2007). Therefore, the extent to which a bullwhip effect can be observed is limited (Bhattacharya & Bandyopadhyay, 2011). Additionally, it can be safely assumed that the buyer-supplier relationship does not take place in an isolated setting. Instead, the supplier can be assumed to have a reciprocal relationship with their upstream supply chain members as well, while the buyer most likely has a reciprocal relationship with their downstream supply chain members, for example, the end customer. Therefore, the proposed model should be t in a multi-tier supply chain such as the beer distribution game. Similarly, different patterns of customer demand should be simulated, as they have proven to influence supply chain dynamics (Größler, 2017).

Since the agents’ utilities are modelled as a stock, a consideration of past conduct or past fairness is indirectly implied. However, it would be interesting to systematically analyse how agents with little to no consideration of past conduct are fair in comparison to agents with high consideration of past conduct or agents who are more likely to hold a grudge. In this, the model could be extended by using known concepts from game theory. Additionally, both agents are further assumed to have a variety of constant variables, such as their understanding of fair treatment (expected fair treatment). In a dynamic setting with constantly changing behaviour and information, these variables lend themselves to being modelled as endogenous, dynamic variables, too.

Lastly, the level of decision-making power a supply chain member holds is highly dependent on their competitive position in their respective industry sector. Whereas certain sectors are characterised by single-source suppliers with high market power, others have many suppliers and few potential buyers or many buyers as well as suppliers. Therefore, the extent to which agents can behave reciprocally towards their counterparts is highly dependent on context. Different industry sectors pose interesting scenarios for future simulations as well as qualitative empirical studies to further corroborate or improve the present model.

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