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Abstracts

BEH-01

On the role of accounting information and experience on the new product development process

The paper aims at checking whether professional experience and the analysis of accounting information can improve the effectiveness of designers' decision-making processes, thus mitigating overdesign, i.e. a pathology characteristic of New Product Development. We test the hypothesis that the effect of cognitive biases on overdesign is lower when designers carefully analyse the accounting information on the new product. To test our research framework, we carried out a survey on designers from Italian companies engaged in design-based industries. The empirical evidence shows that accounting information can act as a moderating factor over professional experience, reducing the overdesign attitude of older designers.

Belvedere Valeria, Grando Alberto

BEH-02

Understanding operational affordances using work domain analysis

Operations innovation emerges as organisations identify affordances that allow a user to carry out work or perform actions. This affordance represents a particular blend of the attributes of a domain with reference to users/stakeholders and plays an important role in how operations are managed. Along these lines, this research evaluates the benefits of using the Work Domain Analysis (WDA) approach for analysing operations management with a view to identifying operational affordances. WDA scrutinises the functional configuration of systems and applies an abstraction-decomposition space visualisation to illustrate how physical forms relate to the overall goal of a system.

Durugbo Christopher

BEH-03

Promoting healthcare employees' pro-environmental behaviours. Evidence From Italy.

This study provides empirical support for i) the positive impact of Green Human Resource Management practices on the adoption of Organisational Citizenship Behaviour toward the Environment, ii) the role that Perceived Organisational Support and Affective Commitmnet to Environmental Management play as mediators of the former relationship. The paper, therefore, contributes to Operations Management research shedding light on how the adoption of discretionary behaviours toward the environment can be fostered in order to support the successful implementation of environmental practices in healthcare organisations.

Pinzone Marta, Lettieri Emanuele

BEH-04

Do portfolio managers love to receive the integrated information while they mostly make decision relying on their intuition? Why?

Generally, in the project-based and project-oriented organizations, the project data are collected, manipulated and controlled by the project management office (PMO). This information is integrated to be reported to the strategic level, which hopefully would use them for making appropriate decisions. Undeniably, choices are impacted by external factors as well as the decision maker's attitudes. Regarding the nature of human behavior and also nature of projects, portfolio manager could have different orientations in different themes, so it is significant to have psychological understanding of the decision making process in this area.

Rashidi Bajgan Hannaneh

BEH-05

Behavioral causes of the bullwhip effect: Mscs Vs. Lscs

The purpose of this study is to investigate how a multinational supermarket chain (MSC) is different from local chain (LSC) in managing the BWE. This paper examines whether the BWE can be attributed to managers' behavioral issues. Demand management issues were embodied in a survey distributed to managers of conveniently selected supplier firms, wholesale Distribution Centers (DCs) and retail stores in Indonesia. Results indicate that BWE is yet evident in MSCs and LSCs, and appears to emanate from managers' cognitive behavior of extra inventory ordering.

Shee Himanshu, Kaswi Surahman

LEA-20

Lean implementation in the face of uncertainty and complexity: Operational performance implications in ETO

This study aims to investigate lean implementation in Engineer-to-order (ETO) context. Operational environment in ETO is characterized by uncertainties and complexity which are unavoidable and should be well managed for better performance and competitiveness. This study extends the limited consideration of lean practices in such environment by discussing that uncertainty and complexity factors positively influence lean implementation using case study methodology. The findings suggest that ETO context provides ample opportunity to gain strong operational performance benefits from lean practices though challenges are inevitable. Future research directions include statistical investigation and verification of findings at larger scale.

Birkie Seyoum E., Trucco Paolo, Kaulio Matti

LEA-21

Effective lean knowledge transfer across manufacturing units in multinational corporations

Several multinational corporations (MNCs) have faced the challenge of transferring lean knowledge across manufacturing units in past years. This paper focuses on early stages of lean knowledge transfer (LKT) projects, considering initiatives carried out by lean knowledge owners to instill the lean philosophy to non-lean plants. Seven cases were analyzed to investigate major problems found by European MNCs in transferring lean to two polar contexts, U.S. and China, and their impacts on LKT process. It emerges that major criticalities are context-specific. Problems linked with recipient's context as well as organizational culture of source unit influence how LKT projects are conducted.

Boscari Stefania, Danese Pamela, Romano Pietro

LOG-01

New packaging solutions for sustainable fresh food supply chains and research agenda

Food Supply Chains are paying more and more attention to adopt innovative packaging systems for their products in order to guarantee quality and to decrease their environmental and economic impacts. In this paper, a critical analysis of traditional packaging solutions, such as cardboard boxes and reusable plastic containers (RPCs), has permitted to introduce two innovative packages: cardboard boxes with removable plastic films and RPCs with cardboard bottom. The solutions have been evaluated and analysed with new analytical models in several scenarios. At the end the research agenda shows the next steps of this study.

Battini Daria, Calzavara Martina, Persona Alessandro, Sgarbossa Fabio

LOG-02

The influence of reverse flow on the dynamics of closed-loop supply chains

The purpose of this paper is to study the impact of reverse logistics' factors on the order and inventory variance amplification in a closed-loop supply chain. We adopt a difference equation math approach for analysing a closed-loop supply chain. Results show how the return flow positively affects both the inventory variance and the bullwhip effect independently of the number of echelons. On the contrary, an increasing remanufacturing lead-time negatively affects both the two metrics studied independently of the above mentioned settings. However, when the number of echelons increases, the benefit provided by the return flow tends to decrease.

Cannella Salvatore, Teresi Pierfabio, Bruccoleri Manfredi

LOG-03

Design and analysis of Brazilian mineral bottled water value chain

This paper makes an analysis of the Brazilian mineral bottled water chain. This analysis is done starting from the perspectives legal, economic and logistics, allowing for an integrated management with the full inclusion in the market. The bottled mineral water product achieves high profit margins, and this occurs because the raw material is cheap for the detriment of the end product. The enterprises use a structured logistics model to reduce the cost of shipping and extensive distribution network. The Brazilian production of mineral water is highly fragmented, with many small and medium enterprises, dividing market share with big multinational companies.

De Oliveira Luciel H., Renata Paes Leme Roquette, Stephanie Cristine Lourenço Silveira

LOG-04

Packaging strategy optimization in case of products sold as a single item or sold as a kit

Packaging is typically the last task in an assembly system. In case a finite assembled product can be sold as a single packaged unit, as a kit, or, in the most complex case, as different possible kits, the packaging strategy optimisation becomes more complex. The present paper aims to analyse the packaging problem in an assembly production system defining the main packaging strategies. Secondly, the authors compare these strategies, providing a decision-making procedure able to help operations managers to set optimally the packaging strategy. The findings from an industrial case study are also reported to validate the proposed methodology.

Faccio Maurizio, Gamberi Mauro, Pilati Francesco, Bortolini Marco

LOG-05

A study of periodic vehicle routing problem allowing delivery in advance

This paper investigates a special periodic vehicle routing problem which accepts some goods can be delivered before the due date within a given cycle. The customer service includes either pickup goods or delivery goods. The objective of this study is to minimize total cost including the moving distance cost, the fixed cost per route, and the penalty for early delivery. The concept of early delivery provides one possible arrangement for management in the periodic vehicle routings. A numerical example illustrated at the end of this paper indicates benefit for cost reduction.

Huang Chikong, Shih Meng-Hui

LOG-06

Development of Cross-Channel Logistics Processes in Online Food Retailing

The underlying work identifies challenges as part of developing combined traditional stationary with online food retail concepts. Because online concepts have a consumer-centric character, service and quality expectation in this context is high and crucial. Online food retailing requires current logistics and supply processes in the food sector to be supplemented or adapted. It primarily refers to the storing, picking, handling and delivery process likewise. Are existing logistics distribution processes for supplying the stationary food retail meant to be appropriate? The paper contributes towards the understanding and knowledge of fundamental structures in food retailing in terms of cross-channel logistics implications.

Plasch Michael, Kellermayr-Scheucher Marike, Lengauer Efrem

LOG-07

Returnable vs. one-way packaging – variables affecting supply chain cost and CO2 emissions

The design and choice of packaging is important in achieving an efficient materials supply, and a central choice is between returnable and one-way packaging. This paper seeks to identify contextual variables governing the choice, from a cost and CO2 footprint perspective. Data are analysed in a case of an automotive company, covering approx. 900 components. Results show how much five cost/CO2 variables and three contextual variables (cubic utilisation, transport distance, packaging size) contribute to the cost and CO2 difference between the packaging options, and that both types of packaging systems should be utilized to minimize costs and CO2 emissions.

Pålsson Henrik, Wallström Henrik, Johansson Mats

LOG-08

From integrating logistics into organizations to "logistics-oriented organizations"

Following on from work underlining how organizations can be oriented around "marketing," "design" or "projects," this paper attempts to show that one possibility is to be "logistics" oriented. Based on a study of two extremely logistics-oriented organizations (IKEA and Médecins Sans Frontières) the paper clarifies the concept of "logistics-oriented organization", to include three dimensions: offer, actors, and supply chain. Secondly, it shows that orienting an organization towards logistics is appropriate in an environment where the majority of product distribution costs are taken up by logistics and/or where logistics are the key element in customer service quality.

Rouquet Aurélien, Vega Diego

The influence of reverse flow on the dynamics of closed-loop supply chains

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Abstract

The purpose of this paper is to study the impact of reverse logistics' factors on the order and inventory variance amplification in a closed-loop supply chain. We adopt a difference equation math approach for analysing a closed-loop supply chain. Results show how the return flow positively affects both the inventory variance and the bullwhip effect independently of the number of echelons. On the contrary, an increasing remanufacturing lead-time negatively affects both the two metrics studied independently of the above mentioned settings. However, when the number of echelons increases, the benefit provided by the return flow tends to decrease.

Keywords: Bullwhip effect, Closed-Loop supply chain, Reverse Logistics

Introduction

Sustainable supply chain management is the management of material flows, information and funds, as well as cooperation between firms along the supply chain that simultaneously consider the three dimensions of sustainable development: environmental, social and economic (Seuring and Müller, 2008; Elkington, 2002). In this context, the scientific community has demonstrated a growing interest in the subject of green supply chain management and, specifically, in "*Closed Loop Supply Chains*" (CLSCs), designed to manage the recycling and recovery process of end-of-life products (Guide *et al.*, 2002).

A CLSC generally involves a manufacturer taking care for the reverse logistics process. The goods are returned and recovered directly by the original manufacturer or through indirect channels. The goods usually recovered can be: failed products, products that are obsolete but still have value, unsold products from retailers, recalled products, items that have secondary usage (i.e. items that have another usage after they have exhausted their original use), waste that could be used for energy production. A simple conceptual model of Reverse Logistics (Srivastava, 2008) considers the customers as the sources of product returns to collection centres. From collection centres, used products can be shipped to two distinct rework sites: repair and refurbishing centres (that repair/refurbish goods in order to make them almost “as good as new”) and remanufacturing centres (produce upgraded remanufactured goods). All the returned goods are resold in primary or secondary market after necessary disposition (Turrisi et al. 2013).

The focus of the studies on CLSCs mainly relies on assessing their effective performance in terms of economical sustainability (Georgiadis and Besiou, 2010), environmental sustainability (Paksoy *et al.*, 2011), and operational performance (Zhou and Piramuthu, 2013). Regarding this last stream, many of these works have merely focused on the optimization of the remanufacturing process (Zhou and Piramuthu, 2013). Concerning this last stream, just few works have investigated the dynamical behaviour (i.e. bullwhip effect, inventory stability) of closed loop SC in multi-echelon structures (Adenso-Diaz et al. 2012). Moreover the few studies dealing with the performance of CLSCs in terms of bullwhip effect present significant contrasting results among them. Currently it is still not clear if a reverse flow affects positively chain dynamic performance (Turrisi et et al., 2013). In particular there is not a common agreement about how key parameters of the inventory management (i.e. remanufacturing lead time, return rate, etc.) can impact on supply chain behaviour.

Motivated by these conflicting results, in this paper we first aim at contributing to the existing literature by investigating and justifying such eventual discrepancies among different researches about the impact of adopting a closed loop structure on supply chain performance, in terms of inventory and order variance amplification. To this purpose, through a differential equation systems approach we model a CLPS and by adopting a rigorous design of experiment we analyse the effect of four logistics' factors on dynamics response. More specifically we test the effect of (1) the return yield of recycled products, (2) the remanufacturing lead-time performance (3) number of echelons and (4) and two different order policies properly designed for inventory management under return flows (i.e. Tang's and Naim's (2004) order policy and Zhou's and Disney's (2006) order policy). We assess the performance in terms of bullwhip effect and inventory stability by adopting two well-known non-financial performance metrics (i.e. Order Rate Variance Ratio and Inventory Variance Ratio).

Simulation output shows how the existence of a return flow positively affects both the inventory variance and the bullwhip effect independently of the number of echelons considered. On the contrary, an increasing remanufacturing lead-time negatively affects both the order and inventory stability. Furthermore we note that if the number of echelons rises, the benefit provided by return flow tends to decrease. Concerning the inventory policy, results show how a higher information transparency increase order and inventory stability.

CLSC Model

We model the closed loop SC through difference equations. The following assumptions characterise our model:

- Single-product, K-stage production-distribution serial system. Each echelon in the system has a single successor and a single predecessor. The generic echelon’s position is represented by index i. Echelon i=1 stands for the manufacturer and i= K+1 for the final customer.
- Only a percentage $0 \leq a \leq 1$ of market sales can be collected in the reverse loop; the remaining $1 - a$ quantity is hypothesized to be unusable or disposed to a landfill. An important element of the remanufacturing loop is the time gap

existing between the sale of products and the remanufacturing process. Before products become available for recycling, in fact, they are hold by customers for a time known as "consumption lead-time" or "time for the customer to keep the product". Once the fraction of products is collected the remanufacturer spends time for the recovery process. This time is known as remanufacturing lead time.

- We adopt two different replenishment order policies, specifically designed for the recovery process. The former is the order policy used by Zhou and Disney (2006). The latter is the type-3 policy proposed by Tang and Naim (2004). The former is a modification of the APIOBPCS policy (John et al. 1994, Disney and Lambrecht 2008). According to the authors the policy works as follows: “the order place is equal to the sum of forecasted demand plus a fraction of the discrepancy between the actual and target net stock of serviceable inventory plus a fraction of the discrepancy between the actual and target work-in-process. Furthermore only a fraction of the demand is returned, brought up to a good as new condition and added to the net stock of serviceable inventory after a random delay". The latter is a further modification of the above mentioned smoothing replenishment rule. Even in this policy, the return flow of “Remanufactured products” is directly pushed into the serviceable inventory. However, unlike the design of Zhou and Disney (2006), collected and remanufactured products in pipeline are considered in the computation of the order quantity, by obtaining a greatest degree of pipeline information transparency. Furthermore, the completion rate of remanufactured items is subtracted to the forecast of customer demand.
- Simple Exponential Smoothing as forecast technique for incoming order is adopted.
- Non-negative condition of order quantity. Products delivered cannot be returned to the supplier.
- Unconstrained production-distribution capacity. No quantity limitations in production, buffering and transport are considered.
- Backlogging is not allowed. Therefore, orders not fulfilled in time convert in lost sales.

The mathematical nomenclature is reported in Table 1. The mathematical model is reported in Table 2.

Table 1 – Model nomenclature

VARIABLES			
B	Orders backlog	I	Inventory
C	Collected products	W	Work in progress
d	Market demand	O	Replenishment order quantity
$\hat{d}$	Market demand forecast	TI	Target work in progress
R	Remanufactured Products	TW	Target inventory
S	Units/orders delivered		
PARAMETERS			
α	Forecast smoothing factor	T	Time horizon
Tr	Remanufacturing lead time	Tc	Consumption lead-time
Tm	Manufacturing/distribution lead time	Tp	Estimated pipeline time
i	Echelon’s position in the SC	Tw	Wip proportional controller
a	Return rate of collected products	Ty	Inventory proportional controller

K	Total number of echelons		
STATISTICS			
σ_d^2	Variance of the market demand	σ_O^2	Variance of the order quantity
σ_I^2	Variance of the inventory	μ_d	Steady state market demand

Table 2 – CLSC mathematical model

Zhou's and Disney's policy	$O_i(t) = \hat{d}_i(t) + \frac{1}{Tw_i}\left(TW_i(t) - W_i(t)\right) + \frac{1}{Ty_i}\left(TI_i(t) - I_i(t)\right)$	(1)
Tang 's and Naim's policy	$O_i(t) = \hat{d}_K(t) + \frac{1}{Tw_i}\left(TW_i(t) - W_i(t)\right) + \frac{1}{Ty_i}\left(TI_i(t) - I_i(t)\right) - R_1(t)$	(1)
Work in progress for Zhou's and Disney's policy	$W_i(t) = W_i(t-1) + S_{i-1}(t) - S_{i-1}(t - Tm)$	
Work in progress for Tang 's and Naim's policy	$I_i(t) = \begin{cases} W_i(t-1) + S_{i-1}(t) + C_1(t) - R_1(t) - S_{i-1}(t - Tm) & \forall i = 1 \\ W_i(t-1) + S_{i-1}(t) - S_{i-1}(t - Tm) & \forall i \neq 1 \end{cases}$	(3)
Inventory	$I_i(t) = \begin{cases} I_i(t-1) + S_{i-1}(t - Tm) + R_1(t) - S_1(t) & \forall i = 1 \\ I_i(t-1) + S_{i-1}(t - Tm) - S_i(t) & \forall i \neq 1 \end{cases}$	(4)
Target Work in Progress	$TW_i(t) = \begin{cases} Tp \cdot \hat{d}_i(t) & \forall i = 1 \\ Tm \cdot \hat{d}_i(t) & \forall i \neq 1 \end{cases}$	(5)
Target Inventory	$TI_i(t) = \hat{d}_i(t)$	(6)
Demand forecast	$\hat{d}_i(t) = \alpha O_{i+1}(t-1) + (1-\alpha)\hat{d}_i(t-1)$	(7)
	$O_{K+1}(t) = d(t)$	(8)
Orders finally delivered	$S_i(t) = \min\{O_{i+1}(t); I_i(t-1)\}$	(9)
Non-negativity condition of order quantity	$O_i(t) \geq 0$	(10)
Uncapacitated raw material supply condition	$S_{i-1}(t) = O_1(t);\; i = 1$	(11)
Collected Products	$C_1(t) = a \cdot S_k(t - T_c)$	(12)
Remanufactured Products	$R_1(t) = C_1(t - T_r)$	(13)

Experimental Design

To fulfill the research objectives, we adopt the design of experiment approach. DOE lets investigate which factors influence the performance of the supply chain. We analyze the following 4 factors:

- F1. Return yield *a*. Due to the several contrasting statements about the impact of such factor on the two metrics (Zhou & Disney, 2006; Turrisi et al., 2013, Huang and Liu, 2008, Qingli et al., 2008) including that showing a non-linear behaviour of the bullwhip effect (Adenso-Dìaz et al., 2012), we chose to set three levels for our experiments design: 0%, 40%, 70%. The first level allows us to also compare a Closed-Loop supply chain with a traditional one.

- F2. Remanufacturing lead-time T_r. Even for this factor we chose three levels: 1, 4, 7.
- F3. Number of echelons K. A recent study (Chatfield, 2013) suggests that decomposition of a multi-stage supply chain into a set of two-stage models systematically underestimates the bullwhip effect. Given these consideration we set two levels for this factor: 1, 3 (echelons). With reference to the latter configuration we calculated both the metrics for the last echelon of the chain. Furthermore we assume the absence of information sharing. In this way each node generates its own forecast, based on local information, and the forecast is then used to generate a new order-up-to value, and consequently, the order size for the current period (Chatfield et al., 2004).
- F4. Information transparency: By modelling and testing the response of the closed loop supply chain for the Tang's and Naim's policy and for the Zhou's and Disney's policy, respectively, we can infer on the impacto of information transparency in closed loop supply chain.

Table 3 report the level values of the four studied factor.

Table 2 – CLSC mathematical model

Tr	*Remanufacturing Lead-Time*	1 time unit 4 time units 7 time units
a%	*Return Yield*	0% 40% 70%
K-echelon	*Number of echelons*	1 3
Policy	*Degree of transparency information*	Zhou and Disney (2006) Tang and Naim (2004)

We assume a i.i.d. customer demand $N(100,10)$. Regarding the other parameters, following John et al. (1994), we chose to set $T_i=T_w=T_m$ and $T_a=2T_m$ as good comprise solution for the APIOBPCS rule. In particular, we use the same values adopted by Tang and Naim (2004) for their simulations. These are: $T_i = 8$, $T_w = 8$, $T_m = 8$, $T_a = 16$, $T_c = 32$. Regarding the estimate pipeline lead time, we adopt the values of proposed by such authors in order to avoid the inventory offset. Given the lack of information about this parameter in the work of Zhou and Disney (2006) and due to the similarities between their model and the Type 1 system of Tang and Naim (2004), we use their notation for the Tp proposed for such system by the latter authors. They are so formulated: $T_{p\ (\text{Zhou and Disney})} = (1-\alpha)T_m - \alpha T_w$; $T_{p\ (\text{Tang and Naim})} = (1-\alpha)T_m + \alpha T_r$.

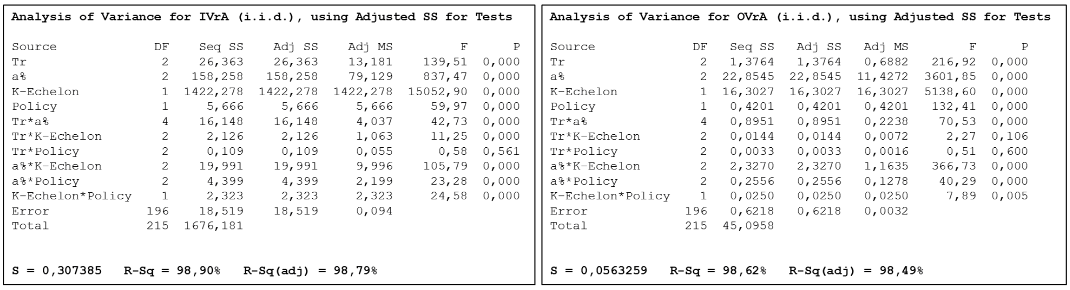
The SC operational performance is measured via a set of metrics, whose reduction reflects improved cost effectiveness of members' operations (Cannella and Ciancimino 2010), i.e., the Order Rate Variance Ratio (Eq. 14) proposed by Chen et al. (2000), the Inventory Variance Ratio (Eq. 15), proposed by Disney and Towill (2003).

$$Order\ Rate\ Variance\ Ratio_i = \frac{\sigma^2_{O_i} / \mu_{O_i}}{\sigma^2_d / \mu_d}, \quad (14)$$

$$Inventory\ Variance\ Ratio_i = \frac{\sigma^2_{I_i} / \mu_{I_i}}{\sigma^2_d / \mu_d}, \quad (15)$$

Numerical analysis

The time length chosen is 700 periods, with the first 200 periods of each replication removed as a warm-up used to set-up the system. We replicated our 3^2 x 2^2 = 36 treatments 10 times for a total of 360 simulations for each response set analysed. The statistical analysis is performed using Minitab statistical software with a level of significance a=0.05. Figure 1 shows the results of the ANOVA for both the performance metrics, IVrA and OVrA, respectively. Figure 2 reports the effect of the main factors.



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Analysis of Variance for IVrA (i.i.d.), using Adjusted SS for Tests

Source             DF    Seq SS    Adj SS    Adj MS         F      P
Tr                  2    26,363    26,363    13,181    139,51  0,000
a%                  2   158,258   158,258    79,129    837,47  0,000
K-Echelon           1  1422,278  1422,278  1422,278  15052,90  0,000
Policy              1     5,666     5,666     5,666     59,97  0,000
Tr*a%               4    16,148    16,148     4,037     42,73  0,000
Tr*K-Echelon        2     2,126     2,126     1,063     11,25  0,000
Tr*Policy           2     0,109     0,109     0,055      0,58  0,561
a%*K-Echelon        2    19,991    19,991     9,996    105,79  0,000
a%*Policy           2     4,399     4,399     2,199     23,28  0,000
K-Echelon*Policy    1     2,323     2,323     2,323     24,58  0,000
Error             196    18,519    18,519     0,094
Total             215  1676,181


S = 0,307385   R-Sq = 98,90%   R-Sq(adj) = 98,79%
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```
Analysis of Variance for OVrA (i.i.d.), using Adjusted SS for Tests

Source             DF   Seq SS   Adj SS   Adj MS        F      P
Tr                  2   1,3764   1,3764   0,6882   216,92  0,000
a%                  2  22,8545  22,8545  11,4272  3601,85  0,000
K-Echelon           1  16,3027  16,3027  16,3027  5138,60  0,000
Policy              1   0,4201   0,4201   0,4201   132,41  0,000
Tr*a%               4   0,8951   0,8951   0,2238    70,53  0,000
Tr*K-Echelon        2   0,0144   0,0144   0,0072     2,27  0,106
Tr*Policy           2   0,0033   0,0033   0,0016     0,51  0,600
a%*K-Echelon        2   2,3270   2,3270   1,1635   366,73  0,000
a%*Policy           2   0,2556   0,2556   0,1278    40,29  0,000
K-Echelon*Policy    1   0,0250   0,0250   0,0250     7,89  0,005
Error             196   0,6218   0,6218   0,0032
Total             215  45,0958


S = 0,0563259   R-Sq = 98,62%   R-Sq(adj) = 98,49%
```

Figure 1 – Output of the General Linear Model for OVrA and IVrA

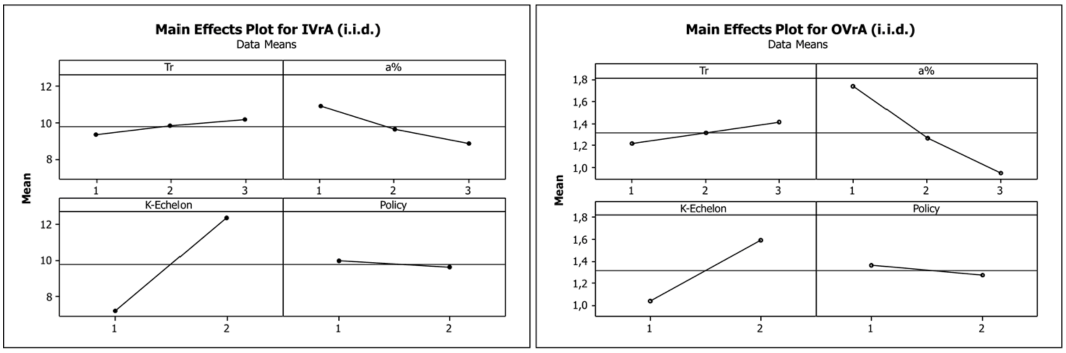

Figure 2 –Main factors Plots on IVrA and OVrA

First, we note that all the main factors and most of the interactions are significant (p-value < 0.05). The following comments concerning the two metrics can be done:

- *Inventory Variance Ratio Amplification*: More than of 85% of variance can be explained by the main effect of the number of echelons of the supply chain. The percentage of return and the remanufacturing lead time account for the next 10%.
- *Order Variance Ratio Amplification*: Under a stationary demand, more than 95% of variance can be explained by the main effects of the percentage of return, the number of echelons, their interaction and the remanufacturing lead-time.

These results suggest that the main factors responsible of changes in the two selected metrics are the number of echelons and the return yield. On the contrary, the remanufacturing lead-time and the transparency information show a significant lower influence in comparison with the formers.

By analyzing the “Main Factor” plots, the following consideration can be made:

- *The impact of the Remanufacturing Lead-Time on the Inventory variance and the Bullwhip effect***:** Both IVrA and OVrA increase when the remanufacturing lead-time rises. Such an influence is confirmed for all the interactions with the other factors. Furthermore the way in which it impacts is identical for the two metrics.
- *The impact of the Return Yield on the Inventory variance and the Bullwhip effect***:** Both IVrA and OVrA decrease when the percentage of return rises. Such an

influence is confirmed for all the interactions with the other factors. However, the increasing value of this factor shows a more significant impact on the OVrA rather than the IVrA.

- *The impact of the Transparency Information on the Inventory variance and the Bullwhip effect:* Both IVrA and OVrA slightly decrease when adopting the system with higher transparency information. Such a minor influence is confirmed for all the interactions with the other factors except for the first level of the return yield, obviously because such factor doesn't affect the order calculation in a traditional supply chain.
- *The impact of the number of Echelons on the Inventory variance and the Bullwhip effect*: Both IVrA and OVrA increase when the number of echelons rises. Such an influence is confirmed for all the interactions with the other factors. The impact of such factor is more significant on the IVrA rather than the OVrA.

Findings

From this study four main findings can be listed:

a) The existence of a return flow positively affects both order and inventory stability and. Furthermore, as the percentage of return increases, bullwhip and inventory stability decrease.
b) The remanufacturing lead time negatively affects both the Inventory variance and the Order variance. Even in this case, as the lead time increases, the performance of the supply chain decreases.
c) The information transparency of the inventory policy positively affects both the Inventory variance and the Order variance. Thus, considering the remanufacturing pipeline in the computation of the order quantity increases the positive effect on performance provided by the inverse flow of material.
d) The number of echelons can strongly limits the benefit provided by the closed loop supply chain, in particular in terms of bullwhip effect.

From these finding we obtain four main managerial implications. Of course, the results could inspire several reflections; the following brief discussion reflects the authors' knowledge and point of view, the former of which is inevitably incomplete while the latter is certainly subjective.

- Managers should consider the reverse flow in the calculation of the order quantity of the echelon collecting the recycled material to its upper stage in the chain. In this way, thanks to the return flow, they could benefit from both a smoothed order variance and a lower inventory variance.
- Lead time compression principle continues to be a key point for avoiding detrimental time-varying phenomenon in supply chain. In a CLSC managers have to improve the performance of their recycling process in terms of remanufacturing lead-time. By reducing this time, the echelon collecting the recycled material could achieve lower order and inventory variance.
- Third, the implementation of a high level transparency information system is always recommended in order to have a better control of the dynamic behaviour of the supply chain. As the transparency of remanufactured products can be realised by the implementation of collaboration mechanisms between manufacturer and retailer, incentive scheme for the sharing of benefits should be taking into account for increasing the performance of the CLSC
- Finally, in multi-stage CLSC, the number of echelon is the main responsible factor of order variance. In this case, if the "elimination of intermediate channel"

cannot be implemented for avoiding the bullwhip, a solution for increasing the performance could be to increase the percentage of remanufactured products.

Conclusion

The present work represents a first attempt to analyze the bullwhip effect and the inventory variance under various settings suggested by different researchers we considered in our systematic literature review. Thanks to a design of experiments, we compare the impact of the return yield of materials and the remanufacturing lead-time on such metrics when considering both a mono-echelon and a multi-echelon supply chain and by adopting different levels of transparency information of the replenishment rule system. The analysis has been carried out using the differential equations approach and the models of two important works have been reproduced with the system dynamics modelling and validated in order to confirm the legitimacy of our methodology.

Our results confirm the positive and the negative impact of respectively the percentage of returns and the remanufacturing lead-time on the two metrics selected under all the settings of the experimental frame. The return yield and the number of echelons were found to have the most significant impact on the two metrics. However, also the transparency information becomes very influent for the inventory variance in presence of a dynamic demand pattern. Because of the exploratory nature of this study, we report below the limitations of this paper that constitute future research lines:

The present work is limited by fixed operational factors such as the values of the parameters not analyzed in the design of experiment (forecasting, adjustment controllers, manufacturing lead-time, etc.). The results of our configuration should be confirmed also under different parameter’s values settings.

Another limitation arises from the analysis of two policies that both consider (even if in different way) the return flow in the calculation of the order quantity. It would be interesting to analyze a policy that ignores the return flow.

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