A Three-Level Game-Theoretic Trade Credit Model in a Supply Channel

Abstract

Two-party channel setting has been a choice study-setting for trade credit. This work considers a three-member channel setting using Stackelberg game theory. The study considers the manufacturer as channel leader, with the distributor as the first follower, and the retailer as the last follower. The manufacturer gives credit goods to the distributor, who similarly gives credit goods to the retailer. The retailer engages in the promotion of the product. Using a promotion effort, price margins and credit periods dependent credit function, the work examines three game-theoretic models on the manufacturer, the distributor and the retailer's payoffs. The work uses backward induction to determine the promotion effort, the credit period and the payoffs. It observes that the margins are motivational enough to drive product promotion which reduces with credit period so that in the long-run the promotion effort stabilizes. The work further observes that the distributor's involvement is very crucial to the payoffs.

Keywords: Trade Credit, Stackelberg Game, Supply Channel, Promotion, Credit Function, Credit Period

1. Introduction

Trade credit is a short-term business financing strategy in which the manufacturer or supplier gives credit goods to the retailer, and allow delayed payment [1]. In the midst of financial crunch, trade credit is a means of funding especially for small businesses, younger firms and start-ups [2-4]. A number of trade credit studies are based on economic order quantity models. Only quite a few employed game theory. Further, trade credit models considering the interaction between product promotion and other market variables are quite scarce, especially in a supply channel involving three parties. This is the centre of work.

Wu et al. [5] considered a supply channel involving a manufacturer and two asymmetric retailers were demand is uncertain. They modelled a situation where the weak retailer is constrained by capital, and the dominant retailer has the advantage of lower wholesale price from the manufacturer, as suggested by his bargaining power. In other to optimally determine trade credit period as well as cycle time of the retailer, Mahata et al. [6] developed a two-level trade credit inventory model on a supply channel with payment default risk. They considered the existence and uniqueness of the solution of the model. Palacin-Sanchez et al. [7] explored the relationship between trade credit from a manufacturer or supplier and credit from a bank by jointly determining both resources on business enterprises, and analysing how factors relating to institutions in a country affect both resources. From empirical analysis, they showed that decisions on both are reached simultaneously in the short term, but negatively related in small and medium-sized enterprises, and that these resources depend on institutional factors. Panda *et al.*[8] developed a two-warehouse mathematical model involving advertisement, price, stock and trade credit. They incorporated product deterioration into their model, and used sensitivity analysis to show that the model is effective. Wang et al. [9] considered trade credit financing and the depreciating value of from inflation on finite horizon. They modelled inventory replenishment for deteriorating item in a product class in which demand and shortages vary with time. In a quest to obtain optimal allowable credit length and product replenishment cycle [10] developed an infinite horizon payment delay EOQ model involving deteriorating goods, and incorporated a fuzzy number to simultaneously examine linearity and non-linearity. Considering optimal length of a cycle, preservation technology, product price and trade credit financing, Mashud et al. [11] studied how trade credit and product preservation technology can influence the rate of deterioration of a product and flexible retail financing. In a study of a manufacturer-retailer conventional channel and a manufacturer-consumer online channel, a dual-channel system, Wan et al. [12] formulated a model on pricing strategies, and inferred that credit should be strategically provided instead of unconditional provision. Mahata and Mahata[13] considered a dynamic situation involving the sale of deteriorating items with varying demand rate with respect to inventory level and length of credit period. Using a model they determined an appropriate strategy that can optimize the retailer's payoff. Using a large sample obtained from listed firm, Machokoko et al. [14] observed an obvious reduction in the use of trade credit by firms in developed economies in comparison to firms in developing economies. From a number of propositions they discovered that factors associated with a country's institutions, events in given a decade, and the level of development of the financial sector can explain the downward trade credit trend. They also observed that diminishing return to credit is higher in developed economies when compared with the developed ones. In an investigation of the effect of product deterioration and provision of credit on the control of inventory of items possessing imperfect quality, Tiwari et al. [15] formulated an inventory model based on two warehouses to study product quality deterioration

The importance of game-theoretic models in supply chain studies cannot be overemphasized. This tool plays an important role in the consideration of the interest of channel members and their interaction with each other [16-20]. Game-theoretic trade credit models are quite scarce. Some noteworthy contributions have made giant-leaps in opening this research field. Shi [21] modelled a Nash bargaining trade credit problem involving a supplier and a retailer, and showed that the relationship between the costs of financing the players' strategies affects the credit given to the retailer. Chern et al. [22] developed a vendor-buyer channel mathematical model based on the fact that allowing delayed payment positively affects demand, but negatively affects cost of goods and payment default risks. They determined the conditions for optimal solution for obtaining the non-cooperative Stackelberg equilibrium solution for both players and both Nash and Stackelberg equilibrium solutions. Considering a system involving a manufacturing process and an extension to remanufacturing using used materials [23] examined a framework in which a manufacturer uses products from his own consumed product to remanufacture his product, and product demand depends on price fixed by the retailer and the quantity of the product. They examined and compared five scenarios involving Nash and Stackelberg games. In a study in which capital investment and replenishment are the decision variables of the buyer and trade credit financing and cost of movement of goods are the decision variables of the seller, Lou and Wang [24] obtained a non-cooperative Nash solution and an integrated solution. Jaggi et al. [25] considered a supply channel involving a supplier and a retailer, and demand depends on displayed stock.

They examined decentralized Stackelberg and Nash equilibrium solution, and the impact of trade credit, product replenishment and channel integration on product deterioration. Using a newsvendor model,Wang et al. [26] investigated appropriate trade credit given by supplier and retailer to retailer and consumer respectively, and the order quantity with the assumption that credit depends on demand. They used a Stackelberg game to model the interaction between the two players. They determined the conditions for optimal credit and order quantity, and observed that trade credit and price contracts are alternatives. The above trade credit game-theoretic models are based on two players setting.

This work uses game theory to consider the interaction between promotion and credit period in a three-member trade credit setting. The study examines game scenarios which include a situation where:

- neither the manufacturer nor the distributor provides trade credit;
- the manufacturer's trade credit provision gesture is not transferred to the retailer;
- the distributor provides trade credit without any credit from the manufacturer;
- both manufacturer and distributor provide credit to the distributor and retailer respectively.

The work will determine the retailer's promotion effort and the manufacturer and the distributor's credit periods. Based on these scenarios the work will compare and establish the best channel structure that should be adopted by the members.

The rest part of the paper is organised as follows: section 2 contains the model formulation; section 3 deals with the players' strategies; various game theoretic equilibrium scenarios were considered in section 4, the results were discussed in section 5; while section 6 contains the conclusion.

2. Model Formulation

We study a three-level trade credit supply channel in which the manufacturer provides the distributor with goods on credit, and allows a payment period t_M. Similarly, the distributor provides the retailer with goods on credit and allows a payment period t_D. The retailer engages in the promotion of the product through a promotion effort ψ_R. This is done to increase the short term demand for the product.

2.1 List of Notations

In addition to the notations stated above, we employ the following set notations in this work:

M_R The retailer's price margin to the consumer

M_D The distributor's price margin to the retailer

M_M The manufacturer's price margin to the distributor

ψ_R The retailer's promotion effort

t_D The distributor's credit period

t_M The manufacturer's credit period

Π_R The retailer's payoff

Π_D The distributor's payoff

Π_M The manufacturer's payoff

2.2 The Product Demand Function

We note that both advertising and promotion campaigns are closely related as sales strategies [27]. One major exception is that while advertising is usually employed as a relatively long term strategy, promotion is deployed as a short term strategy. Thus we adopt the advertising-demand function

$$f(\psi_R) = \psi_R^{\frac{1}{2}} \quad (1)$$

as a promotion-demand function. A similar function was adopted by [28, 29]. Clearly, (1) is an increasing function of ψ_R. It is also concave. Thus, it is in agreement with the saturation effect which results from diminishing marginal returns [30].

2.3 Credit Function

We assume that a wide manufacturer's margin implies large revenue through the distributor. In compensation to the distributor, the manufacturer can provide a large credit to the distributor. Thus, we assume the existence of a proportional relationship between the trade credit given to the distributor by the manufacturer, and the manufacturer's price margin. Similarly, we assume that an increase in the distributor's price margin would imply large revenue to the distributor via the retailer. To compensate the retailer, the distributor can provide a large credit to the retailer. As such, we assume that a proportional relationship exists between the credit from the distributor to the retailer, and the distributor's price margin.

The retailer's promotion effort as a sales strategy is an expenditure which can exert strain on the retailer's financial resources. The effect of the strain can be contained by the availability of trade credit. This can encourage the retailer to promote the product. As such, we assume that the provision of trade credit is proportional to the promotion expenditure which however eventually exhibits diminishing returns. That is $C_D \propto \sqrt{\psi_R}$.

Similarly, with transfer of credit from the manufacturer to the retailer through the distributor, we have that $C_M \propto \sqrt{\psi_R}$.

The credit period that the manufacturer allows the distributor and that which the distributor allows the retailer are very important to the manufacturer and the distributor respectively. We observe that rationality requires that the manufacturer gives large amount of credit to the distributor if his payment time is short, and reduces it with increasing payment time. This also applies to the situation where the distributor gives trade credit to the retailer. Thus we have that $C_D \propto \frac{1}{t_D}$ and $C_M \propto \frac{1}{t_M}$.Thus, the manufacturer's credit function is

$$C_M = \frac{k_M M_M \sqrt{\psi_R}}{t_M},$$

where k_M represents the proportionality constant.

Similarly, the distributor's credit function is

$$C_D = \frac{k_D M_D \sqrt{\psi_R}}{t_D},$$

where k_D represents the proportionality constant.

2.4 Decision Sequence

The manufacturer who is the Stackelberg leader informs the distributor of his allowable credit period t_M. The distributor in turn informs the retailer of his allowable credit period t_D. The retailer's decision variable is his promotion effort ψ_R. We will determine the equilibrium through backward induction. Thus based on the distributor's decision, the retailer's optimal problem is given by

$$\max \Pi_\mathrm{R} = M_R\sqrt{\psi_R} - \psi_R + \frac{k_D M_D \sqrt{\psi_R}}{t_D} \quad (2)$$
$$\text{s.t.} \quad \psi_R \geq 0.$$

In his anticipation of the retailer's reaction, the distributor will consider the optimal problem

$$\max \Pi_\mathrm{D} = M_D\sqrt{\psi_R} + \left(\frac{k_M M_M}{t_M} - \frac{k_D M_D}{t_D}\right)\sqrt{\psi_R} \quad (3)$$
$$\text{s.t.} \quad 0 \leq t_D \leq t_M.$$

Also, based on his anticipation of the distributor's reaction, the manufacturer's optimal problem is

$$\max \Pi_\mathrm{M} = M_M\sqrt{\psi_R} - \frac{k_M M_M \sqrt{\psi_R}}{t_M} \quad (4)$$
$$\text{s.t.} \quad t_M \geq 0.$$

The idea of a three-level supply channel game-theoretic model was first conceived by [31] in a cooperative advertising model, with a clear incorporation of resource transfer in the form of subsidy in [32] with a bypass of the middle-man in [33] for the first time.

3. The Player's Strategies

Now,

$$\frac{\partial \Pi_\mathrm{R}}{\partial \psi_R} = \left(\frac{t_D M_R + k_D M_D}{t_D}\right)\left(\frac{1}{\sqrt{\psi_R}}\right) - 1 = 0$$

$$\Longrightarrow \quad \psi_R = \left(\frac{t_D M_R + k_D M_D}{2t_D}\right)^2. \quad (5)$$

Using (5) in (3) we have

$$\max \Pi_D = M_D\left(\frac{t_D M_R + k_D M_D}{2t_D}\right) + \left(\frac{k_M M_M}{t_M} - \frac{k_D M_D}{t_D}\right)\left(\frac{t_D M_R + k_D M_D}{2t_D}\right)$$
s.t. $0 \le t_D \le t_M$.

$$\Longrightarrow \quad \frac{\partial \Pi_D}{\partial t_D} = -\frac{k_D M_D^2}{2t_D^2} + \frac{k_D M_R M_D}{2t_D^2} + \frac{2k_D^2 M_D^2}{2t_D^3} - \frac{k_D k_M M_D M_M}{2t_M t_D^2} = 0$$

$$\Longrightarrow \quad t_D = \frac{4k_D M_D t_M}{2t_M(M_D - M_R) + k_M M_M}. \tag{6}$$

From (4) and (5) we have

$$\max \ \Pi_M = \left(M_M - \frac{k_M M_M}{t_M}\right)\left(\frac{t_D M_R + k_D M_D}{2t_D}\right) \tag{7}$$
s.t. $t_M \ge 0$.

From (6) and (7) we have

$$\max \ \Pi_M = \left(M_M - \frac{k_M M_M}{t_M}\right)\left(\frac{M_R}{2} + \frac{M_D - M_R}{4} + \frac{k_M M_M}{8t_M}\right)$$
s.t. $t_M \ge 0$

$$\Longrightarrow \quad \frac{\partial \Pi_M}{\partial t_M} = \left(M_M - \frac{k_M M_M}{t_M}\right)\left(-\frac{k_M M_M}{8t_M^2}\right) + \frac{k_M M_M}{t_M^2}\left(\frac{M_R}{2} + \frac{M_D - M_R}{4} + \frac{k_M M_M}{8t_M}\right) = 0$$

$$\Longrightarrow \quad t_M = \frac{2k_M M_M}{M_M - 2(M_R + M_D)}. \tag{8}$$

Using (8) in (6) we have

$$t_D = \frac{4k_D M_D \frac{2k_M M_M}{M_M - 2(M_R + M_D)}}{2\frac{2k_M M_M}{M_M - 2(M_R + M_D)}(M_D - M_R) + k_M M_M}$$

$$= \frac{8k_D M_D}{M_M + 2M_D - 6M_R}. \tag{9}$$

4. The Equilibrium Scenarios

4.1 No-Credit Equilibrium

We note that for $C_D = C_M = 0$ we must have that $t_D \longrightarrow \infty$and $t_M \longrightarrow \infty$. Now, From (5) we have that

$$\lim_{t_D \to \infty} \psi_R = \lim_{t_D \to \infty} \left[\frac{M_R}{2} + \frac{k_D M_D}{2t_D}\right]^2$$

$$\Longrightarrow \quad \psi_R = \left(\frac{M_R}{2}\right)^2. \tag{10}$$

Using (10) in (2) with $C_D = 0$ we have

$$\Pi_{\mathrm{R}} = M_R\left(\frac{M_R}{2}\right) - \left(\frac{M_R}{2}\right)^2 = \frac{M_R^2}{4}. \tag{11}$$

From (3) and (10) together with $C_D = 0$and $C_M = 0$, we have that

$$\Pi_{\mathrm{D}} = M_D\left(\frac{M_R}{2}\right) = \frac{M_D M_R}{2}. \tag{12}$$

Also from (4) and (10), and $C_M = 0$

$$\Pi_{\mathrm{M}} = M_M\left(\frac{M_R}{2}\right) = \frac{M_M M_R}{2}. \tag{13}$$

4.2 Provision of Credit by only the Manufacturer

Since $C_D = 0$, it follows that $t_D \longrightarrow \infty$ which implies that

$$\psi_R = \left(\frac{M_R}{2}\right)^2 \tag{14}$$

as given in (10). Thus from (2) we have

$$\Pi_{\mathrm{R}} = \frac{M_R^2}{4}. \tag{15}$$

From (3) and (14), and letting $C_D = 0$ we have

$$\Pi_{\mathrm{D}} = M_D\left(\frac{M_R}{2}\right) + \frac{k_M M_M}{t_M}\left(\frac{M_R}{2}\right) = \frac{M_R}{2}\left(\frac{t_M M_D + k_M M_M}{t_M}\right). \tag{16}$$

From (8) and (16) we

$$\Pi_{\mathrm{D}} = \frac{M_R}{2}(M_M - 2M_R). \tag{17}$$

From (4) and (14), and with $C_D = 0$ we have

$$\Pi_{\mathrm{M}} = M_M\left(\frac{M_R}{2}\right) - \frac{k_M M_M}{t_M}\left(\frac{M_R}{2}\right). \tag{18}$$

Using (8) in (18) we have

$$\Pi_{\mathrm{M}} = \frac{M_R}{4}(M_M + 2M_R + M_D). \tag{19}$$

4.3 Provision of Credit by Only the Distributor

We note that $C_D > 0$implies $t_D \nrightarrow \infty$. As such we have that

$$\psi_R = \left(\frac{t_D M_R + k_D M_D}{2t_D}\right)^2. \tag{20}$$

Using (20) in (2) we have

$$\Pi_{\mathrm{R}} = M_R\left(\frac{t_D M_R + k_D M_D}{2t_D}\right) - \left(\frac{t_D M_R + k_D M_D}{2t_D}\right)^2 + \frac{k_D M_D}{t_D}\left(\frac{t_D M_R + k_D M_D}{2t_D}\right). \qquad (21)$$

From (9) and (21) we have that

$$\Pi_{\mathrm{R}} = \left(\frac{M_M + 2M_D + 2M_R}{16}\right)^2. \qquad (22)$$

Using (20) in (3), with $C_M = 0$ we have

$$\Pi_{\mathrm{D}} = M_D\left(\frac{t_D M_R + k_D M_D}{2t_D}\right) - \frac{k_D M_D}{t_D}\left(\frac{t_D M_R + k_D M_D}{2t_D}\right).$$

Now, substituting for t_D and simplifying we have

$$\Pi_{\mathrm{D}} = \left(\frac{M_M + 2M_D + 2M_R}{16}\right)\left(\frac{6M_R + 6M_D - M_M}{8}\right). \qquad (23)$$

Using (20) in (4) with $C_M = 0$ we have

$$\Pi_{\mathrm{M}} = \frac{M_M(t_D M_R + k_D M_D)}{2t_D}. \qquad (24)$$

Using (9) in (24)

$$\Pi_{\mathrm{M}} = M_M\left(\frac{M_R}{2} + \frac{k_D M_D}{2}\left(\frac{8k_D M_D}{M_M + 2M_D - 6M_R}\right)^{-1}\right)$$

$$= M_M\left(\frac{2M_R + 2M_D + M_M}{16}\right). \qquad (25)$$

4.4 Provision of Credit by the Manufacturer and the Distributor

Since $t_D,\ t_M \in (0,\infty)$, from (5) we have

$$\psi_R = \left(\frac{t_D M_R + k_D M_D}{2t_D}\right)^2. \qquad (26)$$

From (6) we have

$$\psi_R = \left[\frac{M_R}{2} + \frac{k_D M_D}{2}\left(\frac{2t_M(M_D - M_R) + k_M M_M}{4t_M k_D M_D}\right)\right]^2,$$

and from (9) we have

$$\psi_R = \left(\frac{2M_R + 2M_D + M_M}{16}\right)^2. \qquad (27)$$

Using (27) in (2) we have

$$\Pi_{\mathrm{R}} = M_R\left(\frac{2M_R + 2M_D + M_M}{16}\right) - \left(\frac{2M_R + 2M_D + M_M}{16}\right)^2 + \frac{k_D M_D}{t_D}\left(\frac{2M_R + 2M_D + M_M}{16}\right)$$

$$= \left(\frac{2M_R + 2M_D + M_M}{16}\right)^2. \qquad (28)$$

Using (26) in (3) we have

$$\Pi_{\mathrm{D}} = \left(M_D - \frac{k_D M_D}{t_D} + \frac{k_M M_M}{t_M}\right)\left(\frac{t_D M_R + k_D M_D}{2t_D}\right). \qquad (29)$$

Using (8) and (9) in (29) we have

$$\Pi_{\mathrm{D}} = \left[M_D - k_D M_D\left(\frac{8k_D M_D}{M_M + 2M_D - 6M_R}\right)^{-1} + k_M M_M\left(\frac{2k_M M_M}{M_M - 2(M_R + M_D)}\right)^{-1}\right]$$

$$\times\left[\frac{M_R}{2} + \frac{k_D M_D}{2}\left(\frac{2k_M M_M}{M_M - 2(M_R + M_D)}\right)^{-1}\right]$$

$$= \left(\frac{-2M_D - 2M_R + 3M_M}{8}\right)\left(\frac{2M_R + 2M_D + M_M}{16}\right). \qquad (30)$$

Using (26) in (4) we have

$$\Pi_{\mathrm{M}} = \left[M_M - \frac{k_M M_M}{t_M}\right]\left[\frac{t_D M_R + k_D M_D}{2t_D}\right]. \qquad (31)$$

Using (8) and (9) in (31) we have

$$\Pi_{\mathrm{M}} = \frac{1}{32}[M_M^2 - [2(M_R + M_D)]^2].$$

5. Discussion

We recall that the game is a Stackelberg game, thus letting the channel leader enjoy a first mover's advantage, we have that $M_M > M_D,\ M_R$. Also, we note that the distributor has a first mover's advantage over the retailer so that $M_D > M_R$. Thus, we let $M_M = 8$, $M_D = 4$and $M_R = 2$. Further, we note that as the channel leader manufacturer's credit to the distributor cannot be less than the distributor's credit given to the retailer, so that by extension we have that $k_M > k_D$. Thus we let $k_M = 0.3$and $k_D = 0.4$.

5.1 The Effect the Players' Margins on Promotion

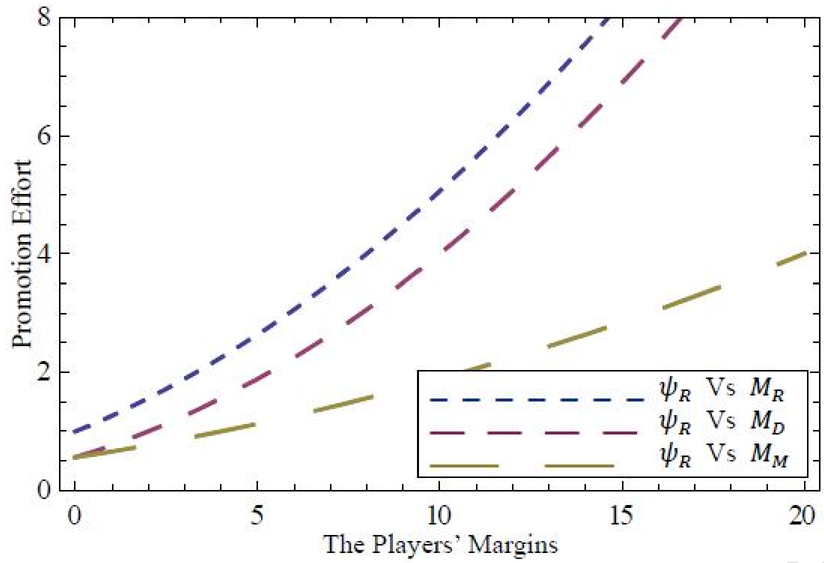

Figure 1 A comparison of the effects of the players' margins on promotion

Considering Figure 1 we observe that the players' margins are very crucial to the promotional effort. Clearly, the promotion effort increases with all the margins. This increase is more rapid with the retail margin, and least with the manufacturer's margin. This is understandable because a large margin is indicative of large turnover. As such it is an incentive motivational enough to engage more in promotion.

5.2 The Effect of Credit Period of Promotion

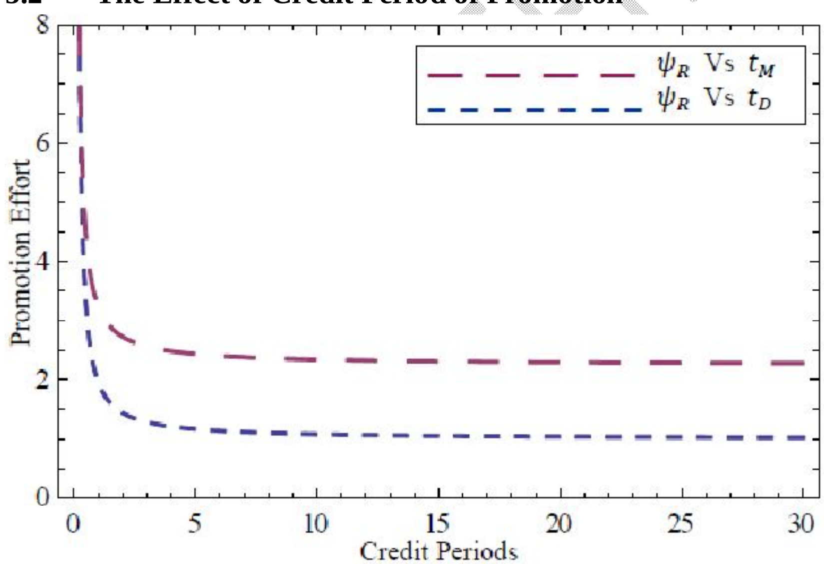

Figure 2 A comparison of the effects of credit periods on promotion effort

Clearly, Figure 2 shows that as the credit period given by either of the manufacturer or distributor increases, the promotion effort reduces. While the reduction is least for the manufacturer's credit period, it is more with the distributor's credit period. The reduction in effort is clear because with enough time lag to repay the credit, the retailer becomes a bit more relaxed since he is no longer under pressure to deliver. As such, he reduces his promotion expenditure, thereby reducing promotion effort. Further, we note from (5) that

$$\psi_R = \left(\frac{M_R}{2} + \frac{k_D M_D}{2t_D}\right)^2,$$

so that as $t_D \longrightarrow \infty$ we have that $\psi_R \longrightarrow \left(\frac{M_R}{2}\right)^2$.

Also from (5) and (6) we have that

$$\psi_R = \left(\frac{M_R}{2} + \frac{k_D M_D}{2}\left[\frac{M_D - M_R}{2k_D M_D}\right] + \frac{k_D M_D}{2}\left[\frac{k_M M_M}{4k_D M_D t_M}\right]\right)^2,$$

so that as $t_M \longrightarrow \infty$, we have that $\psi_R \longrightarrow \left(\frac{M_R}{2} + \frac{k_D M_D}{2}\left[\frac{M_D - M_R}{2k_D M_D}\right]\right)^2$.

Thus irrespective of the amount of credit period given, the promotion effort is bounded. That is, as the periods get unbounded, the effort exhibits boundedness. The implication is that it would be irrational for the distributor and the manufacturer to increase their periods indefinitely since these will not incentivise nor constrain the retailer to increase promotion proportionately!

Further, it is incumbent on the retailer to determine the optimal credit periods or at worst the long-run periods, and avoid exceeding them since a very long period means very low credit package!

5.3 The Effect of the Manufacturer's Credit Period on the Retailer's Credit Period

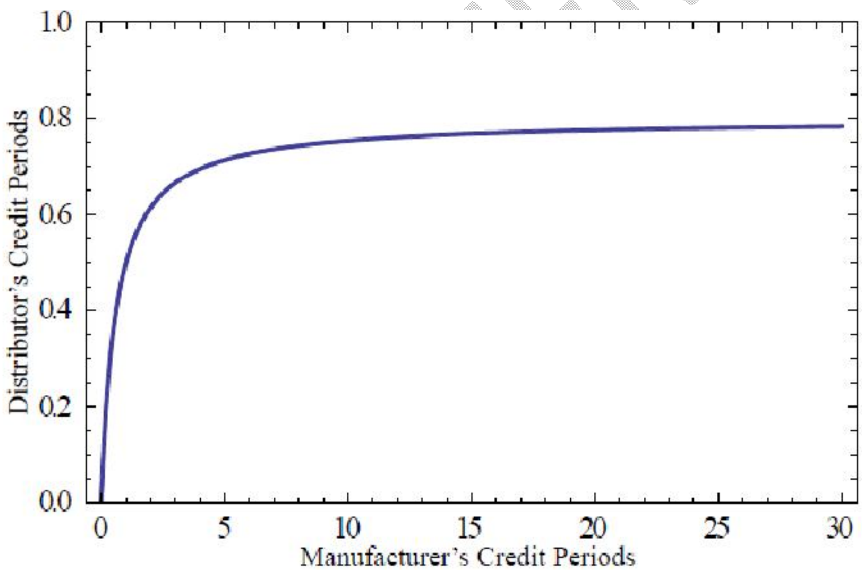

Figure 3 Relationship between the players' credit period

Considering Figure 3 we observe that as the manufacturer's credit period increases, the distributor's period increases rapidly and eventually stabilizes in the long run. This means that the distributor would not want to extend his period beyond certain time irrespective of the manufacturer's period. Thus it is necessary for the manufacturer to implement his optimal period or at least truncate his period at the first observation (expectation or even suspicion) of a stable long run period.

5.4 Comparison of Payoffs for all Scenarios

We make the following representations for the various scenarios:

$C_D = 0, C_M = 0$: Neither the manufacturer nor the distributor provides trade credit;

$C_D = 0, C_M > 0$: The manufacturer's trade credit provision gesture is not transferred to the retailer;

$C_D > 0, C_M = 0$: The distributor provides trade credit without any credit from the manufacturer;

$C_D > 0, C_M > 0$: The manufacturer and the distributor provide credit to the distributor and retailer respectively.

Further, we let Π^* represent the channel payoff in Table 1.

Table 1 Payoffs for all Scenarios

		Scenarios			
		$C_D = 0, C_M = 0$	$C_D = 0, C_M > 0$	$C_D > 0, C_M = 0$	$C_D > 0, C_M > 0$
Payoffs	Π_R	1.0000	1.0000	1.5625	1.5625
	Π_D	4.0000	2.0000	3.3750	1.8750
	Π_M	8.0000	8.0000	10.0000	12.5000
	Π^*	13.0000	11.0000	15.9375	15.9375

Clearly, the retailer's performance for $C_D = 0, C_M > 0$ (that is, when credit from the manufacturer is withheld by the distributor) is the same for $C_D = C_M = 0$ when there is no provision of trade credit. However, with intervention credit in the absence of credit from the manufacturer, the retailer's performance improves. This performance is the same for transfer of credit. It is pertinent to note the crucial role of the distributor whose involvement in any of the scenarios dictates the tone.

Considering the manufacturer's performance we see that his payoff is the same for both $C_D = C_M = 0$and $C_D = 0, C_M > 0$. Further, we observe that with the intervention credit by the distributor, he performs better. However, his performance is best with transfer. This again shows that the distributor's reaction is very crucial in the nature of the performances in the various scenarios.

Clearly, withholding of the manufacturer's credit is to the detriment of the distributor. This can be seen as a repercussive effect of not supporting the retailer who is the revenue source of the entire supply channel. "Unfortunately", it further appears that the transfer of credit worsens his payoff. However, a comparison of the entire channel performance for the various scenarios shows that the channel performance is best in the intervention and transfer scenarios. Clearly, a choice of $C_D > 0, C_M = 0$ favours the distributor, while $C_D, C_M = 0$ favours the manufacturer with the retailer being indifferent. Thus the players can opt for any of these two scenarios depending on who dictates the terms. However, to ensure fairness, the players need to agree on a sharing formula for the channel payoff which ensures that no player is short changed.

6. Conclusion

The work examined a manufacturer-distributor-retailer credit channel using game theory. The manufacturer was considered as the Stackelberg leader, while the distributor and the retailer were the first and last followers respectively. The work proposed a credit function which was used to model the players' payoffs. It considered four scenarios and obtained the promotion effort, the credit periods and payoffs, and shows that margins play a major role in determining the promotion effort, which reduces with credit period to stabilize in the long-run. The work further observes that the distributor plays a major role in a three-channel trade credit setting.

The work examined a manufacturer-distributor-retailer trade credit setting using Stackelberg game theory. An extension can use a Nash game to study a situation neither of the players is the channel leader.Such a situation can arise when the channel members consider themselves to be powerful enough not consider any other member as the channel leader. Another improvement and possible extension can employ the players' actual prices instead of simply using price margins which may not provide enough information on trade credit. Another extension can consider a channel setting where the manufacturer can bypass the distributor to provide the retailer with credit. A comparison arising this and the current work can reveal the relevance of the distributor.

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