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# Analysing Impacts of RFID in Supply Chains Using Joint Economic Lot Size Models

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# ANALYSING IMPACTS OF RFID IN SUPPLY CHAINS USING JOINT ECONOMIC LOT SIZE MODELS

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## Abstract

*It is generally assumed that Radio Frequency Identification (RFID) has the potential to organize the flow of material in supply chains more efficiently. Based on the two-tiered Joint Economic Lot Size (JELS) model by Banerjee, this article analyzes how the increase in efficiency affects the order and production policies and therefore the total costs of the supply chain, and the individual costs of the companies in question. The analysis takes into account different bargaining power constellations and cost structures between supplier and customer. By employing simple methods of game theory it is shown in which cases the implementation of RFID is beneficial and how the disadvantaged company should be compensated.*

*Keywords: RFID, JELS, supply chain, lot size, purchasing cost.*

# 1 MOTIVATION

The Just-In-Time Philosophy (JIT) is known to be one of the main reasons for the international success of the Japanese Industry (especially automotive and electronics) (Nakamura & Sakakibara & Schroeder 1998). The main goal of the JIT philosophy is to consistently avoid waste of all kinds. A key point is a close and long-term oriented relationship between supplier and customer. From the perspective of the material flow, this commitment comprises exact arrangements concerning time and quantities of deliveries. To avoid unnecessary stock during production, delivery takes the form of small lots, which are only ordered when the need for them actually arises (Pull), so they are delivered as close to the time of production as possible (Banerjee & Kim 1995, Monden 1998). Actual lot sizes are a result of negotiations between supplier and customer. Depending on the balance of power between the two partners, a situation can arise in which the dominant partner can enforce a lot size which is optimal for him, but only suboptimal for the other partner. In the long term, this one sided optimisation leads to higher costs for the whole system and consequently, by the JIT definition, to avoidable waste (Aderohunmu & Mobolurin & Bryson 1995). Based on this perception, Banerjee created a model for the determination of a joint economic lot size (JELS) and analyzed how total costs and the costs for the individual partner change when lot sizes are mutually agreed (Banerjee 1986). He showed that mutually agreed order and production policies lead to a minimisation of total relevant costs in the supply chain.

To further decrease stocks, organisations tend to order even smaller lot sizes. This only makes sense though, if the costs to place and release an order decrease. In this context the use of RFID is discussed. In several pilot projects RFID has shown to have the potential to decrease order cost by designing the material flows more efficiently (Asif & Mandviwalla 2005, Kärkkäinen & Holmström 2002). To make use of those potential advantages, it is necessary that suppliers equip their products (or the pallets) with RFID tags. Thus, considering the balance of power mentioned above, it could happen that suppliers are forced to tag their products in this case.

This development is by no means limited to JIT. Looking at vendor-purchaser relationships in retail markets, it can be observed that it is usually the retailer who takes the dominant role. Chances are that during the introduction of RFID, purchasers will decide about the introduction of the technology and suppliers will be forced to comply (Agarwal 2001). For example, retail heavyweight Wal-Mart coerces its Top 100 suppliers to equip their products with RFID tags on the pallet and box level (Roberti 2003, Williams 2004). The costs of tagging the products with RFID have to be borne by the vendors. Additionally, the usage expectations for RFID are much higher for the purchaser compared to those for the vendor (Metro Group 2004). Therefore, it is generally assumed that the purchasers introduce RFID at the expense of the vendor.

This article aims to critically question this generalised proposition. In the following, it will be analyzed what impact the introduction of RFID has on both total and individual costs for each partner under different constellations of bargaining power. Apart from the already mentioned situation where the purchaser is in the dominant position, the article will also account for the rare situation where the vendor is in a more powerful position (monopoly position of the vendor).

The article at hand is structured as follows. Chapter 2 introduces the JELS model by Banerjee. Building on that, chapter 3 shows which parameters of the model are affected by the introduction of RFID and analyzes the effects of those variations under ceteris paribus conditions. The article concludes in chapter 4 with a summary and an outlook.

# 2 BANERJEE’S JOINT ECONOMIC LOT SIZE MODEL

The JELS model belongs to the group of integrated buyer-supplier inventory models (Goyal & Gupta 1989, Sharafali & Co 2000). The model is derived from the relatively simple economic-lot-size formula based on Harris (Harris 1915). Thus, it presumes a lot-for-lot-strategy known from various industries (e.g. automotive industry). Even though Harris’ economic-lot-size formula is not very often used in practice, derived methods (e.g. least unit cost procedure) are very common in state-of-the-art ERP systems. The model is based on the following assumptions: a vendor and a purchaser of a good with constant demand are considered. The vendor and the purchaser determine the production, respectively order lot size with the intention to minimise decision relevant costs. The decision relevant costs of the vendor comprise setup and inventory costs and those of the purchaser comprise order and inventory costs. The purchaser periodically orders a given amount Q. Upon receipt of a purchase order, the vendor starts producing and delivers once the whole lot is produced (Pull). Furthermore it is assumed that the vendor’s annual production rate is higher than the demand rate. The following notational scheme is adopted:

D = annual demand or usage of the inventory item (demand rate)

P = vendor’s annual production rate for this item,

A = purchaser’s ordering cost per order,

S = vendor’s setup cost per setup,

$r_p$ = purchaser’s annual inventory carrying charge (expressed as a fraction of monetary value),

$r_v$ = vendor’s annual inventory carrying charge (expressed as a fraction of monetary value),

$C_v$ = unit production cost incurred by the vendor

$C_p$ = unit purchase cost paid by the purchaser

Q = order ($Q_p$) or production ($Q_v$) lot size in units

TRC = total relevant cost

## 2.1 Individual Lot Size

The economic lot sizes of the purchaser and the vendor are obtained by using the well known formulas of Harris. Table 1 summarizes the results of the individual optimizations.

| | Purchaser | Vendor |
|---|---|---|
| General cost function | $TRC_p\left(Q_p\right)=\frac{D}{Q_p}A+\frac{Q_p}{2}r_p\,C_p$ (1) | $TRC_v\left(Q_v\right)=\frac{D}{Q_v}S+\frac{Q_v}{2}\frac{D}{P}r_v\,C_v$ (4) |
| Economic lot size | $Q_p^*=\sqrt{\frac{2DA}{r_pC_p}}$ (2) | $Q_v^*=\sqrt{\frac{2PS}{r_vC_v}}$ (5) |
| Minimum total cost | $TRC_p\left(Q_p^*\right)=\sqrt{2DAr_pC_p}$ (3) | $TRC_v\left(Q_v^*\right)=\sqrt{\frac{2Sr_vC_v}{P}}$ (6) |

*Table 1 Results of the individual optimizations*

Transforming the equation for $Q_v^*$ as follows

$$Q_v^* = \sqrt{\frac{2PS}{r_v C_v}} = \sqrt{\frac{2PS}{r_v C_v}}\sqrt{\frac{2DA}{r_p C_p}}\sqrt{\frac{r_p C_p}{2DA}} = \sqrt{\frac{2DA}{r_p C_p}}\sqrt{\frac{S}{A}}\sqrt{\frac{P r_p C_p}{D r_v C_v}},$$

noting that $Q_p^* = \sqrt{\frac{2DA}{r_p C_p}}$ and defining $\alpha = \frac{S}{A}$ and $\beta = \frac{D r_v C_v}{P r_p C_p}$ the relationship between $Q_p^*$ and $Q_v^*$ can be expressed as

$$Q_v^* = \sqrt{\frac{\alpha}{\beta}} Q_p^* \tag{7}$$

Assuming a lot-for-lot-strategy ($Q_v = Q_p$), $\alpha$ represents the ratio of the vendor’s setup cost per setup (S) to the purchaser’s ordering cost per order (A) and $\beta$ the ratio of the vendor’s total annual (or periodic) carrying costs to the purchaser’s total annual (or periodic) carrying costs. Due to a surcharge of the vendor, the unit purchase cost paid by the purchaser ($C_p$) is higher than the unit production cost incurred by the vendor ($C_v$). Thus with a vendor’s production rate higher than the purchaser’s demand rate and equal inventory carrying charges, $\beta$ tends to be very small ($0<\beta<1$).

Considering a lot-for-lot-strategy ($Q_v = Q_p$) we can differentiate two situations:

- (a) the dominant purchaser determines the lot size (purchaser’s economic-lot-size)
- (b) the dominant vendor determines the lot size (vendor’s economic-lot-size)

In the following we will analyse the effects of vendor’s economic-lot-size on purchaser (a) and the effects of the purchaser’s economic-lot-size on vendor (b):

(a)

If the purchaser’s economic-lot-size is adopted by the vendor as production lot size, the total relevant cost of the vendor is

$$TRC_v\left(Q_p^*\right) = \frac{D}{Q_p^*} S + \frac{Q_p^*}{2}\frac{D}{P} r_v\, C_v = \sqrt{\frac{\alpha}{\beta}}\frac{DS}{Q_v^*} + \sqrt{\frac{\beta}{\alpha}}\frac{Q_v^*}{2}\frac{D}{P} C_v r_v .$$

Noting that $\frac{DS}{Q_v^*} = \frac{Q_v^*}{2}\frac{D}{P} C_v r_v = \frac{1}{2} TRC_v\left(Q_v^*\right)$ the above equation simplifies to

$$TRC_v\left(Q_p^*\right) = \frac{1}{2}\left(\sqrt{\frac{\alpha}{\beta}} + \sqrt{\frac{\beta}{\alpha}}\right) TRC_v\left(Q_v^*\right). \tag{8}$$

The factor $\frac{1}{2}\left(\sqrt{\frac{\alpha}{\beta}} + \sqrt{\frac{\beta}{\alpha}}\right)$ can be interpreted as a vendors cost penalty factor for producing the economic-lot-size of the purchaser.

(b)

If the vendor’s economic-lot-size is adopted by the purchaser as ordering lot size, the total relevant cost of the purchaser is

$$TRC_p\left(Q_v^*\right) = \frac{D}{Q_v^*} A + \frac{Q_v^*}{2} r_p\, C_p = \sqrt{\frac{\beta}{\alpha}}\frac{DA}{Q_p^*} + \sqrt{\frac{\alpha}{\beta}}\frac{Q_p^*}{2} C_p r_p$$

This equation can be simplified to

$$\mathrm{TRC}_p\left(Q_v^*\right)=\frac{1}{2}\left(\sqrt{\frac{\alpha}{\beta}}+\sqrt{\frac{\beta}{\alpha}}\right)\mathrm{TRC}_p\left(Q_p^*\right). \tag{9}$$

Note that the purchaser's cost penalty factor for adopting the vendor's production lot size as ordering lot size is the same as the vendor's cost penalty factor for producing the economic-lot-size of the purchaser.

### 2.2 Joint Economic Lot Size

The joint TRC (JTRC) can be obtained by adding equation (1) and equation (4):

$$\mathrm{JTRC}(Q)=\frac{D}{Q}A+\frac{Q}{2}r_p\,C_p+\frac{D}{Q}S+\frac{Q}{2}\frac{D}{P}r_v\,C_v \tag{10}$$

To get the joint economic lot size, we have to set the first derivative with respect to Q equal to zero:

$$Q_j^*=\sqrt{\frac{2D(S+A)}{\frac{D}{P}C_v r_v+C_p r_p}} \tag{11}$$

With α and β this equation can be rewritten to

$$Q_j^*=Q_p^*\sqrt{\frac{1+\alpha}{1+\beta}} \tag{12}$$

and

$$Q_j^*=Q_v^*\sqrt{\frac{1+\frac{1}{\alpha}}{1+\frac{1}{\beta}}}\,. \tag{13}$$

If the purchaser's order size is $Q_j^*$ instead of $Q_p^*$ the purchaser's TRC is given by

$$\mathrm{TRC}_p\left(Q_j^*\right)=\frac{1+\frac{1}{2}(\alpha+\beta)}{\sqrt{(1+\alpha)(1+\beta)}}\mathrm{TRC}_p\left(Q_p^*\right) \tag{14}$$

and if the vendor's order size is $Q_j^*$ instead of $Q_v^*$ the vendor's TRC is given by

$$\mathrm{TRC}_v\left(Q_j^*\right)=\frac{1+\frac{1}{2}\left(\frac{1}{\alpha}+\frac{1}{\beta}\right)}{\sqrt{\left(1+\frac{1}{\alpha}\right)\left(1+\frac{1}{\beta}\right)}}\mathrm{TRC}_v\left(Q_v^*\right). \tag{15}$$

For a profound discussion on the findings refer to Banerjee (1986).

## 3 RFID IN BANERJEE'S JELS-MODEL

### 3.1 Influence of RFID on the parameters

The literature identifies a multitude of advantages which can be realised by using RFID in the supply chain (e.g. Michael & McCathie 2005, Angeles 2005). Analysing the influence of RFID on the parameters of the JELS model, it has to be noted that particularly the ordering cost per order are influenced (Asif & Mandviwalla 2005, Michael & McCathie 2005, Kärkkäinen 2003). Exemplified influences include:

- Through Track & Trace, problems in logistics can be identified and solved much quicker. Thus, logistics cost decrease, which in turn directly influences order costs.
- With RFID Gateways at the stock receipt, incoming goods can automatically be tracked. Manual labour, e.g. to verify delivery quantities compared to order quantities, can mostly be avoided.
- Through RFID, internal transportation and storage can be designed more efficient and less error prone. This allows for a higher degree of automation of repeat orders in the sense of the inter-company Kanban principle.

In fact, RFID also directly impacts the other parameters. Yet, based on the dominant influence of order costs, the other influences can and will be neglected in the following analysis.

### 3.2 Individual Lot Size Optimization

We now assume that the use of RFID reduces the purchaser's ordering cost per order (A) by the factor i: $A_{RFID} = (1 - i)A$ . Table 2 summarizes the purchaser's results of an individual optimization.

| | |
|---|---|
| General cost function | $TRC_{p,RFID}(Q_p) = \frac{D}{Q_p} A_{RFID} + \frac{Q_p}{2} r_p C_p \quad (16)$ |
| Economic lot size | $Q^*_{p,RFID} = \sqrt{1-i}\sqrt{\frac{2DA}{r_p C_p}} = \sqrt{1-i}Q^*_p \quad (17)$ |
| Minimum total cost | $TRC_{p,RFID}(Q^*_{p,RFID}) = \sqrt{1-i}\, TRC_p(Q^*_p) \quad (18)$ |

*Table 2. Purchaser's results of an individual optimization with RFID*

Assuming that the parameters of the equation for the vendor's economic-lot-size do not change by the use of RFID and using α and β, we can express the relationship between $Q_v^*$ and $Q^*_{p,RFID}$ as

$$Q^*_V = \frac{1}{\sqrt{1-i}}\sqrt{\frac{\alpha}{\beta}}Q^*_{p,RFID} \tag{19}$$

If we suppose that the vendor adopts the new purchaser's economic lot size as production lot size, the vendor's TRC is given by

$$\begin{aligned} TRC_V(Q^*_{p,RFID}) &= \frac{DS}{Q^*_{p,RFID}} + \frac{Q^*_{p,RFID}}{2}\frac{D}{P}C_V C_V \\ &= \frac{1}{\sqrt{1-i}}\sqrt{\frac{\alpha}{\beta}}\frac{DS}{Q^*_V} + \sqrt{1-i}\sqrt{\frac{\beta}{\alpha}}\frac{Q^*_V}{2}\frac{D}{P}C_V C_V \\ &= \frac{1}{2}\left(\frac{1}{\sqrt{1-i}}\sqrt{\frac{\alpha}{\beta}} + \sqrt{1-i}\sqrt{\frac{\beta}{\alpha}}\right)\cdot TRC_V(Q^*_V) \end{aligned} \tag{20}$$

In the situation the vendor has adopted the purchaser's economic lot size as production lot size and the vendor changes the economic lot size due to the introduction of RFID from $Q^*_p$ to $Q^*_{p,RFID}$, the vendor's relative saving is

$$-\frac{\mathrm{TRC}_v(Q^*_{p,\mathrm{RFID}})}{\mathrm{TRC}_v(Q^*_p)}+1=-\frac{\frac{1}{2}\left(\frac{1}{\sqrt{1-i}}\sqrt{\frac{\alpha}{\beta}}+\sqrt{1-i}\sqrt{\frac{\beta}{\alpha}}\right)}{\frac{1}{2}\left(\sqrt{\frac{\beta}{\alpha}}+\sqrt{\frac{\alpha}{\beta}}\right)}+1 \tag{21}$$

Figure 1 shows a plot of the vendor's relative saving against the two parameters α and β in the case i=0.3.

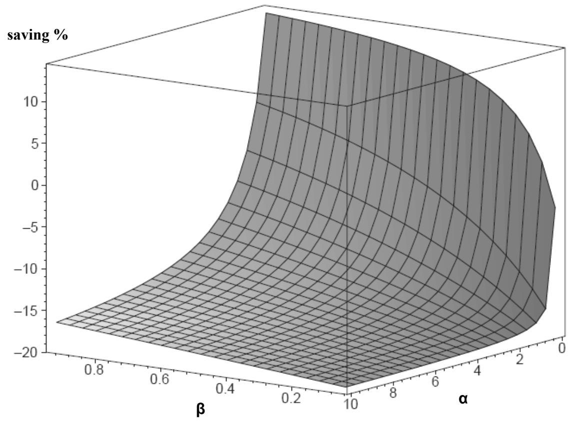

*Figure 1. Vendor's relative saving*

Figure 1 shows that in order to assess whether the use of RFID leads to increased or decreased costs for the vendor, the relation between the two parameters α and β to each other, already discussed by Banjeree, is significant. In situations where α>>β, vendor's cost increase (and for β>>α vice versa). This effect can be explained as follows. As mentioned above, with α>>β the optimal production lot size of the vendor is larger than the optimal order size of the purchaser ($Q^*_v > Q^*_p$). By introducing RFID the purchaser's optimal order size further decreases and the difference between the two optima increases. If the vendor adopts the new policy of the purchaser, his costs will also increase. In the case of β>>α the optimal production lot of the vendor is smaller than the optimal order quantity of the purchaser ($Q^*_p > Q^*_v$). Through the introduction of RFID the optimal order quantity decreases and thus approximates to the optimal production lot size of the vendor. In this way the vendor profits from the introduction of RFID, too. Figure 2 shows that the difference between the optimal production lot size and the optimal order quantity increases for α>>β and decreases for β>>α.

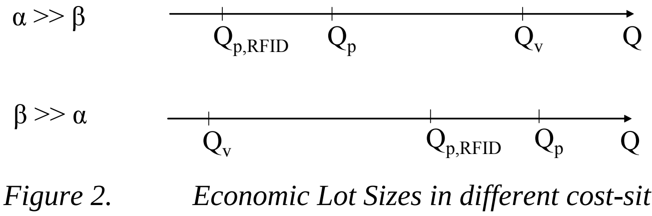

*Figure 2. Economic Lot Sizes in different cost-situations*

If we now suppose that the purchaser adopted the vendor's economic lot size as order lot size and introduces RFID, the purchaser's TRC is given by

$$
\begin{aligned}
\mathrm{TRC}_{p,\mathrm{RFID}}(Q_v^*) &= \frac{D}{Q_v^*} A_{\mathrm{RFID}} + \frac{Q_v^*}{2} C_p r_p \\
&= \frac{D}{\sqrt{\frac{\alpha}{\beta}}\,Q_p^*}(1-i)A + \frac{\sqrt{\frac{\alpha}{\beta}}\,Q_p^*}{2} C_p r_p \\
&= \frac{1}{2}\left((1-i)\cdot\sqrt{\frac{\beta}{\alpha}} + \sqrt{\frac{\alpha}{\beta}}\right)\cdot \mathrm{TRC}_p(Q_p^*)
\end{aligned}
\tag{22}
$$

Given the situation that the purchaser has adopted the vendor's economic lot size as order lot size and introduces RFID, the purchaser's relative saving is

$$
-\frac{\mathrm{TRC}_{p,\mathrm{RFID}}(Q_v^*)}{\mathrm{TRC}_p(Q_v^*)} + 1 = -\frac{\frac{1}{2}\left((1-i)\cdot\sqrt{\frac{\beta}{\alpha}} + \sqrt{\frac{\alpha}{\beta}}\right)}{\frac{1}{2}\left(\sqrt{\frac{\beta}{\alpha}} + \sqrt{\frac{\alpha}{\beta}}\right)} + 1
\tag{23}
$$

Figure 3 shows a plot of the purchaser's relative saving against the two parameters α and β in the case i=0.3.

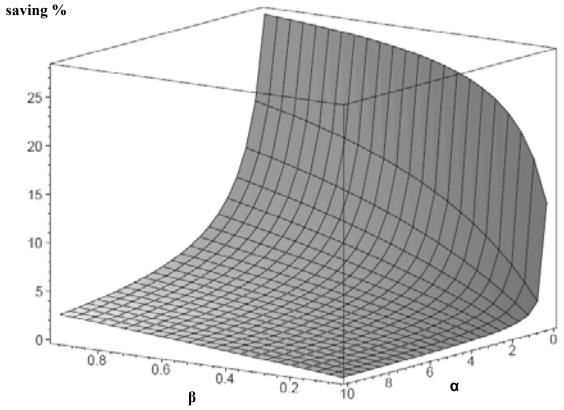

*Figure 3. Purchaser's relative saving*

The previous considerations did not account for the costs of introducing and using RFID. In the following, research will be undertaken to show how the costs of using RFID have to be distributed and what kind of compensations, if necessary, have to be made from one market partner to another so that no one is disadvantaged through the usage of RFID.

Market partners will incur costs for the introduction as well as for the usage of RFID (in the following, costs attributed to the manufacturer will be labelled $RC_{RFID,v}$, those attributed to the purchaser $RC_{RFID,p}$). It is obvious that market partners will only take on these costs if they are exceeded by the respective savings. As shown in the foregone investigations, market partners benefit to varying degrees from the introduction of RFID, so consequently in the following it will be investigated how the costs have to be distributed, so that none of the market partners is worse off afterwards. Three different situations have to be considered:

1. Dominant purchaser and α>>β: As lot sizes decrease because of the introduction of RFID, total costs for the manufacturer increase. Consequently, he will resist the introduction of RFID as long as he does not get compensated for it. Compensation could potentially take the form of increased prices. In

order for none of the partners being worse off than they were initially, that increase in price $\Delta C_p$ would have to be under the condition of

$$\frac{1}{D}\left(\left(\frac{\frac{1}{2}\left(\frac{1}{\sqrt{1-i}}\sqrt{\frac{\alpha}{\beta}}+\sqrt{1-i}\sqrt{\frac{\beta}{\alpha}}\right)}{\frac{1}{2}\left(\sqrt{\frac{\beta}{\alpha}}+\sqrt{\frac{\alpha}{\beta}}\right)}-1\right)\cdot \mathrm{TRC}_v(Q_p^*)-\mathrm{RC}_{\mathrm{RFID},v}\right)\le \Delta C_p$$

$$\le \frac{1}{D}\left(\left(1-\sqrt{1-i}\right)\cdot \mathrm{TRC}_p(Q_p^*)-\mathrm{RC}_{\mathrm{RFID},p}\right) \qquad (24)$$

2. Dominant purchaser and β>>α: As both purchaser and vendor benefit from the introduction of RFID, each individual partner has to assess whether the savings through RFID exceed the costs. If this is not the case for one partner, he would have to negotiate with the other partner whether he would compensate the difference.

3. Dominant vendor: As only the purchaser profits from the introduction of RFID, he would have to compensate for vendor's RFID cost and offer further financial incentives to him. The maximum size of the compensation and the financial incentive can be calculated as follows

$$\frac{\frac{1}{2}\left((1-i)\cdot\sqrt{\frac{\beta}{\alpha}}+\sqrt{\frac{\alpha}{\beta}}\right)}{\frac{1}{2}\left(\sqrt{\frac{\beta}{\alpha}}+\sqrt{\frac{\alpha}{\beta}}\right)}\cdot \mathrm{TRC}_p(Q_v^*)-\mathrm{RC}_{\mathrm{RFID},p} \qquad (25)$$

### 3.3 Joint Lot Size Optimization

With the assumption that the use of RFID reduces the purchaser's ordering cost per order (A) by the factor i, the joint economic lot size is given by

$$Q_{j,\mathrm{RFID}}^* = \sqrt{\frac{2D(S+(1-i)\cdot A_{\mathrm{RFID}})}{\frac{D}{P}C_v r_v + C_p r_p}} \qquad (26)$$

Using α and β we can transform this equation to

$$Q_{j,\mathrm{RFID}}^* = Q_p^*\sqrt{\frac{(1-i)+\alpha}{1+\beta}} \qquad (27)$$

and

$$Q_{j,\mathrm{RFID}}^* = Q_v^*\sqrt{\frac{1+\frac{(1-i)}{\alpha}}{1+\frac{1}{\beta}}}\,. \qquad (28)$$

We can now show that

$$\mathrm{TRC}_{p,RFID}\left(Q^{*}_{j,RFID}\right)=\frac{(1-i)+\frac{1}{2}(\alpha+(1-i)\cdot\beta)}{\sqrt{((1-i)+\alpha)(1+\beta)}}\,\mathrm{TRC}_{p}\left(Q^{*}_{p}\right) \tag{29}$$

and

$$\mathrm{TRC}_{v}\left(Q^{*}_{j,RFID}\right)=\frac{1+\frac{1}{2}\left(\frac{1-i}{\alpha}+\frac{1}{\beta}\right)}{\sqrt{\left(1+\frac{1-i}{\alpha}\right)\left(1+\frac{1}{\beta}\right)}}\,\mathrm{TRC}_{v}\left(Q^{*}_{v}\right). \tag{30}$$

The equations (31) and (32) express the purchaser's and the vendor's relative cost savings in the case that the purchaser and the vendor agreed on a joint economic lot size in the past and introduce RFID:

$$\frac{\mathrm{TRC}_{p}\left(Q^{*}_{j}\right)-\mathrm{TRC}_{p,RFID}\left(Q^{*}_{j,RFID}\right)}{\mathrm{TRC}_{p}\left(Q^{*}_{j}\right)}=1-\frac{\dfrac{(1-i)+\frac{1}{2}(\alpha+(1-i)\cdot\beta)}{\sqrt{((1-i)+\alpha)(1+\beta)}}}{\dfrac{1+\frac{1}{2}(\alpha+\beta)}{\sqrt{(1+\alpha)(1+\beta)}}} \tag{31}$$

$$\frac{\mathrm{TRC}_{v}\left(Q^{*}_{j}\right)-\mathrm{TRC}_{v}\left(Q^{*}_{j,RFID}\right)}{\mathrm{TRC}_{v}\left(Q^{*}_{j}\right)}=1-\frac{\dfrac{1+\frac{1}{2}\left(\frac{1-i}{\alpha}+\frac{1}{\beta}\right)}{\sqrt{\left(1+\frac{1-i}{\alpha}\right)\left(1+\frac{1}{\beta}\right)}}}{\dfrac{1+\frac{1}{2}\left(\frac{1}{\alpha}+\frac{1}{\beta}\right)}{\sqrt{\left(1+\frac{1}{\alpha}\right)\left(1+\frac{1}{\beta}\right)}}} \tag{32}$$

Figures 4 and 5 show plots of the purchaser's and the vendor's relative saving against the two parameters α and β in the case i=0.3.

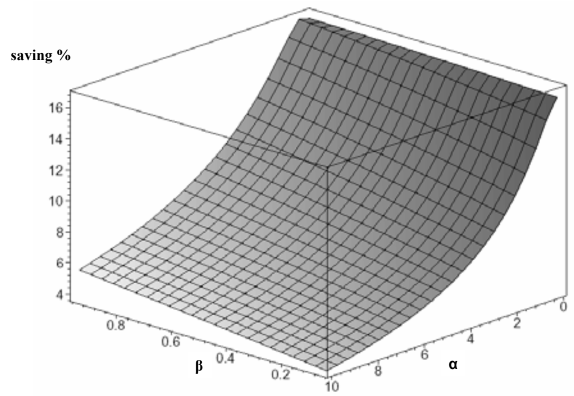

*Figure 4. Vendor's relative saving*

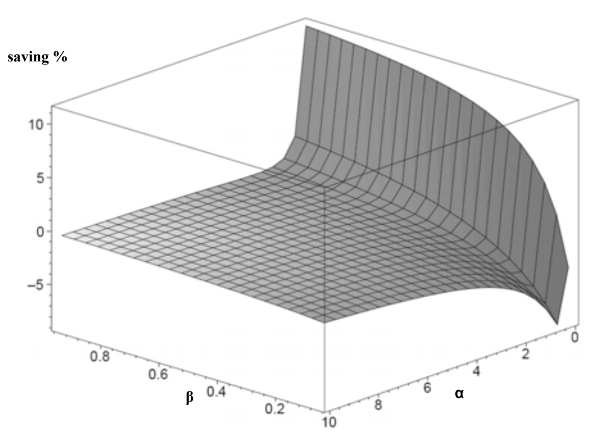

*Figure 5. Purchaser's relative saving*

Figure 4 shows that the purchaser can definitely realise cost savings through the introduction of RFID. The highest cost savings can be achieved in situations where α is very small and β very large. It also becomes clear that parameter α has bigger impact on the cost saving potentials of the purchaser. In situations in which α is very small, the proportion of vendor's setup cost to purchaser's order cost is particularly small. In case of such an isolated optimisation, the purchaser will aim to order as infrequently as possible, as order costs are very high compared to inventory costs. Considering a mutual optimisation, the purchaser has to compromise which leads to a situation, where order costs are higher than storage costs (unlike in the isolated optimisation). Thus, if the introduction of RFID decreases order costs in particular, it leads to the highest cost savings.

Figure 5 clearly shows that particularly in the situation where β is large and α is small, the introduction of RFID leads to cost savings for the vendor. Yet, for the majority of possible parameter combinations, the cost saving potential for the vendor is low or he will even incur further costs.

# 4 CONCLUSIONS

On the basis of the JELS-Model by Banerjee, the analysis so far showed in detail how the introduction of RFID impacts on both total and individual cost of the purchaser and vendor under the condition of different bargaining power structures.

As already shown, it is commonly believed that the purchaser introduces RFID at the expense of the vendor. On the basis of the findings so far (which are summarised in table 3) this over simplified statement must be revised. Due to the usage of RFID, order lot sizes can be optimised and suppliers can, under certain circumstances, benefit from the introduction of RFID, even though they do not necessarily have any direct advantages from using it and even have to bear the costs for RFID tags. Furthermore, we have proposed compensation methods, which can be applied to convince partners to introduce RFID. The article at hand should be seen as an incentive to incite companies into considering inter-company aspects when it comes to making an investment decision for or against RFID and negotiate with respective partners about potential compensation.

The abstract level in an easy to understand model, as used in the article at hand, can help to understand the complexity of the interdependencies of these inter-company considerations. Yet, due to its inherent simplifications, it is not alone suitable as a basis for decision making.

| | | dominant vendor | dominant purchaser |
|---|---|---|---|
| **Individual Lot Size Optimization** | α>>β<br>$(Q^*_v > Q^*_p)$ | $TRC_V \rightarrow TRC_P \downarrow TRC_j \downarrow$<br>→ RFID is only implemented if the purchaser covers the costs. Maximum compensation per RFID tag: $\frac{(1-i)A}{Q_V^*}$ | $TRC_V \uparrow TRC_P \downarrow TRC_j \downarrow$<br>→ RFID is used as the purchaser is in the dominant position and profits from its introduction. The purchaser could potentially compensate the vendor |
| | β>>α<br>$(Q^*_p > Q^*_v)$ | | $TRC_V \downarrow TRC_P \downarrow TRC_j \downarrow$<br>→ RFID is used as both partners benefit from its introduction. |
| **Joint Lot Size Optimization** | α>>β<br>$(Q^*_v > Q^*_p)$ | $TRC_V \uparrow TRC_P \downarrow TRC_j \downarrow$<br>→ RFID will be used as total costs decrease. The purchaser has to compensate the vendor if necessary. | |
| | β>>α<br>$(Q^*_p > Q^*_v)$ | $TRC_V \downarrow TRC_P \downarrow TRC_j \downarrow$<br>→ RFID will be used as both partners benefit from its introduction. | |

*Table 3. Summary of all considered situations*

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