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## Monitoring, Operational Manager Efforts and Inventory Policy

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## ABSTRACT

Operations managers are becoming more important in modern corporations. They do not only care on firms' inventory management but also they are involved in firms' strategic decisions. Within this setting we ask about the consequences in the inventory policy of this new role undertaken by these managers. To do so, we develop a model where a firm's Operations Manager can devote some efforts to develop non-inventory related activities. These efforts, although non-verifiable, may be known with a certain probability if the owner monitors them. Interestingly, by monitoring these efforts, a firm's owner may end up stimulating Operations Manager to achieve steep inventory cost reductions in the short-term. Basic idea is that Operations Manager, in general, avoids reducing inventory costs significantly in one period because this makes additional cost cuts difficult which, in turn, reduce expected future inventory-related retribution. However, by compensating those non-inventory-related efforts may offset these losses. Thus, although Operations Managers in modern corporations carry out non-inventory related responsibilities, this may bring about some benefits on inventory costs reduction.

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# 1/ INTRODUCTION

Operations decissions are becoming more important in the firms' overall strategy to achieve a competitive excellence. This process goes in hand with the new role adopted by Operations Managers within firms. These managers have traditionally focused their efforts on determining operational decisions such as daily production scheduling and inventory management. As D'Netto and Sohal (1999) cites, "the UK's operations managers were seen as mechanics with dirty finger nails rather than gentlemen". However, in the modern corporation, the task of Operations Managers surpasses the traditional technical role on production scheduling (Oakland and Sohal, 1989, Hum and Lee, 1992, and D'Netto, Sohal and Trevyllyan, 1998), and the managerial aspects of his job are gaining great importance (Delaney and Huselid, 1996). Thus, it has become imperative for Operations Managers to acquire managerial skills. D'Netto and Sohal (1999) shows making use of a sample of Australian firms, that current operations managers can achieve this knowledge in management because they are academically well-qualified in order to undertake staff supervision functions. Moreover, these authors argue that operations managers in the future should have a greater role to play in setting the strategic direction of the company and defining competing priorities. To make this trend compatible with an efficient management of inventories is to design adequate incentive schemes. This is what this article is about.

In principle, one could suspect that Operations Managers involvement in firm's strategic decisions may damage their efforts on the "technical" role to manage firm's inventory. This may be the case because an Operations Manager that divides her time between strategy and operations is going to be less specialized in the technical side than a more focused manager is.

We approach this problem by developing a simple model based on an operation manager compensation scheme with two channels for retribution. One linked to inventory costs reduction, and the other that pays for improvements in his "managerial" efforts. Also, we allow the principal (firm's owner) to monitor these latter efforts because they are difficult to verify. Interestingly, by shaping monitoring intensity on non-inventory related efforts, firm's owner may end up affecting firm's inventory policy.

The specific compensation scheme we model hinders steep inventory cost reductions in the short-term because this precludes relevant future cost cuts which, in turn, will reduce future retribution. Interestingly, the incorporation of a compensation package that takes into account improvements in the non-inventory related efforts, smoothes the previous behavior. This may be the case because the latter retribution may offset the expected future losses derived from the initial steep inventory cost reduction. To achieve such an outcome an Operation Manager should combine in the first period intensive efforts to reduce inventory costs with low (but non-null) *managerial* efforts. This gives wide scope for future retributions linked to improvements in these latter efforts that may offset the expected future compensation related to limited reduction in inventory costs. Thus, we get some sort of substitution between inventory-related efforts and non inventory-related ones. And, through this mechanism, firm's owner can use monitoring on managerial efforts to shape inventory cost reductions.

Paradoxically, by incorporating compensation from increases in non-inventory related efforts, we do find that inventory costs are reduced in a shorter period of time than when compensation is only based on these latter cost reductions. Also, medium-term inventory variability is lower under the former compensation scheme than under the latter. This may cover up the OM long-lasting demand to increase the number of his functions from operations to management (D' Netto and Sohal ,1999).

There are different messages that we can extract from the previous feature. Firstly, firms can try to stimulate the managerial role of their Operations Managers without giving up inventory efficient management. A correct design of the compensation package can make both objectives compatible. Secondly, high-tenure Operation Managers involved in managerial responsibilities may fix firms' inventories in their optimal inventory level in a shorter period of time than more specialized ones. This leads to a smoother medium-term inventory variability in those firms with high-tenure Operations Manager in comparison to those firms with low-tenure ones. This is partly confirmed in Alfaro and Tribó (2003). Lastly, by considering workers recruiting as non-inventory related efforts, we can recover Blinder and Maccini (1991) result. Operation Managers with additional labor hiring responsibilities may achieve stronger inventory cost reductions in the short-term with lower inventory variability in the medium-term than those fully specialized on inventory management.

This paper is divided into six sections. In the following one we build up the model, which is solved in the third section. We discuss the main theoretical findings in the fourth section. A simulation analysis is carried out in section five. In the end, we state some final remarks.

## 2/ THE MODEL

We develop a two-period model where an operations manager (OM henceforth) of a representative firm decides inventory policy as well as some non-contractible *managerial* effort. Firm's owner monitors these latter efforts to compensate accordingly the OM. The model is built on the following assumptions:

**Assumptions**

1/ The firm faces a demand $D_t = \overline{D} + \varepsilon_t$, where $\varepsilon \in [\underline{\varepsilon}, \overline{\varepsilon}]$ *and* $|\underline{\varepsilon}| \leq \overline{D}$ to avoid a negative demand. These $\varepsilon$ deviations are known at the end of each period and they are independent and uniformly distributed with a zero mean value. This allows abstracting from issues related to the demand structure and its impact on firms' inventory policy. Similar demand consideration can be found in Kahn (1991), although this paper does not specify the distribution of demand shock.

2/ Total Cost (*TC*) is defined as the sum of the costs associated to filling customers' orders, the cost to carry inventories and the stockout costs. An expression of this function[1] is:

$$TC = c_f \frac{D}{Q} + c_h \theta \frac{S^2}{2Q} + c_r \theta \frac{(Q-S)}{2Q} \qquad [1]$$

where:

$c_f$ = Filling cost per order.

D = Total demand per period.

$c_h$ = Unitary inventory holding cost.

$c_r$ = Unitary inventory stockout cost.

S = Inventory level.

Q = Lot size.

[1] We have decided to work with [1] because, although the demand includes a stochastic part, the random noise is uniformly distributed, and, on average, total cost function can be characterized by the previous function [1] once we substitute the demand by its mean value.

$\theta$ = Planning period.

In each period, a firm faces a demand that arrives at a continuous rate and, at the end of the period, total demand comes out to be $D_t$. Besides, we assume, to simplify, that demand is attended with constants lots with a *Q* size. We can think of the existence of some technological constraints to justify this simplifying assumption.

3/ OM is risk neutral with a two-period temporal horizon. Her compensation is defined as follows (we implicitly assume a zero discount rate):

$$w_t = \alpha + \beta(TC_{t-1} - TC_t + k(e_t - e_{t-1})) \qquad [2]$$

By notation, $w_t$ is period-t wage that it is composed of two terms. A fix part, $\alpha$ , and a variable part $\beta(TC_{t-1} - TC_t + k(e_t - e_{t-1}))$. This latter has also two terms. First one measures the decrease in the total inventory costs between period t-1, $TC_{t-1}$, and period t, $TC_t$. The second term measures *managerial* effort increase between period t-1, $e_{t-1}$, and period t, $e_t$ [2]. With this kind of scheme, firm´s owner stimulates OM to reduce inventory costs as well as to increase managerial effort, *e*[3].

4/ OM can implement a *managerial* effort, *e*, with a cost given by the function C[e] that satisfies C'[e]>0, C'[e=0]=0 and C''[e]>0. Moreover, the principal only observes this effort if he implements a monitoring intensity, *M*. In particular, with a probability *M*, effort, *e*, is known. To simplify, we assume that this monitoring intensity is exogenously given with the same value in both periods.

5/ An OM can be fired at the end of the first period, if she has not created net value. In this case firing costs are zero[4]. Thus, the *ex-ante* probability of an OM continuation, $p_c$,

[2] We have introduced a *k* factor, as a parameter to homogenize the units used to measure the managerial effort with those used to measure the variation in the inventory costs. This parameter will also allow us to conduct some comparative static analysis because it controls the relative weight of the managerial effort to the inventory cost reduction in the OM compensation scheme.

[3] An incentive scheme that would have compensated overall effort, *e,* in each period instead of the differences in these efforts would have introduced an asymmetry with regard to the scheme proposed to compensate for the reduction in inventory costs. In any case, this alternative incentive scheme would have produced an even clearer result.

[4] An OM signs a contract such as she accepts to be fired without compensation if she has not created net value. Although to deal with considering positive firing costs does not change any substantial result.

equals the probability to observe an increase in the value generated by the OM. This can be achieved by reducing TC, or by increasing *managerial* effort, *e*. Therefore, Pc is defined as:

$$p_c = Mprob(TC_0 - TC_1 + k(e_1 - e_0) > 0) + (1 - M)prob(TC_0 - TC_1 > 0)$$

In words, this is the *(M)* probability of knowing effort *e* times the probability of an increase in the monitored OM generated value (including *e*), plus the probability *(1-M)* of not knowing effort *e* times the probability of an increase in the non-monitored OM generated value (including *e*) (without including effort *e*).

**Time-line of the Model**

**______1________________2__________________3_________________4____**

1/ OM *simultaneously* defines inventory level, *S*, as well as effort *e*, taking into consideration her expectation over future demand realizations as well as the firm's owner monitoring intensity *M*.

2/ First-period demand realization $\underline{D_1 = \overline{D} + \varepsilon_1}$ is known at the end of that period. OM receives her wage and continues in the firm if she has generated value. If not, she is fired and a new OM is hired.

3/ OM defines second-period inventory policy as well as second-period effort. To do so she takes into consideration first-period total costs, $TC_1$, first-period effort, $e_1$, as well as her expectation of second-period demand realization $\underline{D_2 = \overline{D} + \varepsilon_2}$.

4/ Last-period demand is realized, and OM receives her payments.

## 3/ SOLVING THE MODEL

We solve the model in a backward way. Thus, we first characterize second-period OM decisions. Then, we move to the first period.

**Second-period problem**

At t=1, an OM determines second-period inventory level, $S_2$, as well as second-period managerial effort, $e_2$. The maximization problem she solves is the following:

$$\begin{aligned}&Max_{\{S_2,e_2\}}E_1\left[\alpha+\beta M(TC_1-TC_2+k(e_2-e_1))+\beta(1-M)(TC_1-TC_2)-C[e_2]\right]=\\&=E_2\left[\alpha+\beta(TC_1-TC_2)+\beta Mk(e_2-e_1)-C[e_2]\right]\end{aligned} \qquad [3]$$

With $TC_i=c_f\dfrac{D_i}{Q}+c_h\theta\dfrac{S_i^{\;2}}{2Q}+c_r\theta\dfrac{(Q-S_i)^2}{2Q}\quad and\ \ i=\{1,2\}$

Where, $e_2$, can only be observed with an *M* probability which is given by owner's monitoring intensity (M).

FOC in this case leads to:

$$\partial_{s_2}E_1\{\mathrm{TC}\}=\mathrm{p_c}(\theta c_h\frac{S_2}{Q}-\theta c_r\frac{Q-S_2}{Q})=0\Rightarrow S_2=(\frac{c_r}{c_h+c_r})Q\equiv\hat{S} \qquad [4]$$

$$\partial_{e_2}E_1\{\mathrm{TC}\}=\beta Mk-C'[e_2]=0\Rightarrow\beta Mk=C'[e_2] \qquad [4']$$

Trivially, we can see that increases in *M* and/or *k* lead to increases in second-period effort $e_2$ due to C''>0. Note also, that effort $e_2$ depends on $\beta M$ factor. Either an increase in the incentive intensity scheme, $\beta$, and/or in the monitoring intensity, *M*, can be used as substitute mechanisms to stimulate second-period OM efforts, $e_2$. In words of Chang and Lai (1999) "there is a trade-off between the wage (carrot) incentive and the supervision (stick) incentive". From [4'], we can also observe that second-period optimal inventory level does not depend on first-period decisions, nor on effort, $e_2$. This is a consequence to deal with separable functions.

**First-period problem**

At t=0, OM determines first-period inventory, $S_1$, and first-period effort, $e_1$, taking the optimal solution found in the second period. The problem she solves is the following:

$$Max_{\{S_1,e_1\}}E_0\left[\alpha+\beta(TC_0-TC_1+Mk(e_1-e_0))+p_c(\alpha+\beta(TC_1-TC_2+Mk(e_2-e_1)))-C[e_1]\right]$$

By arranging this expression, we can transform the previous maximization problem into a minimization one:

$$Min_{\{S_1,e_1\}}E_0\{TC\} = \beta(E_0TC_1 - Mke_1) + p_c\beta(E_0TC_2 - E_0TC_1 + Mk(e_1-e_2) - \frac{\alpha}{\beta}) + C[e_1] \quad [5]$$

Where [5] $p_c = M\frac{Q}{c_f\Delta\overline{\varepsilon}}\left[TC_0 - E_0TC_1 + k(e_1-e_0) - \frac{c_f}{Q}\underline{\varepsilon}\right] + (1-M)\frac{Q}{c_f\Delta\overline{\varepsilon}}\left[TC_0 - E_0TC_1 - \frac{c_f}{Q}\underline{\varepsilon}\right]$

Thus, $p_c = \frac{Q}{c_f\Delta\overline{\varepsilon}}\left[TC_0 - E_0TC_1 + Mk(e_1-e_0) - \frac{c_f}{Q}\underline{\varepsilon}\right]$

First order conditions lead to (see point 1 in the Appendix):

$$\partial_{e_1}E_0\{\mathrm{TC}\} = -M\beta kT + C'(e_1) \quad [6]$$

$$\partial_{S_1}E_0\{\mathrm{TC}\} = \beta T\frac{\partial E_0TC_1}{\partial S_1} \quad [7]$$

$$T \equiv \frac{Q}{c_f\Delta\overline{\varepsilon}}(\frac{c_f\overline{\varepsilon}}{Q} + \Delta_2 - \Delta_1 + \frac{\alpha}{\beta} + Mk(e_2+e_0-2e_1)) \ \ where \ \ \Delta_2 \equiv (E_0TC_1 - E_0TC_2) \ \ and \ \ \Delta_1 \equiv (TC_0 - E_0TC_1) \quad [8]$$

The solution of this problem leads to an equilibrium that depends on the value of [6]:

$$\hat{T} \equiv T\left(e_1 = 0, e_2 = e_2^*, S_1 = S_2 = \hat{S}\right) = \frac{Q}{c_f\Delta\overline{\varepsilon}}\left(\frac{c_f(\overline{D}+\overline{\varepsilon})}{Q} + \theta\frac{c_r c_h Q}{2(c_r+c_h)_1} + \frac{\alpha}{\beta} - TC_0 + Mk(e_2^*+e_0)\right) \quad [9]$$

**<u>Proposition 1</u>**

*The optimal inventory policy is given by:*

a) *If* $\hat{T} \equiv T\left(e_1 = 0, e_2 = e_2^*, S_1 = S_2 = \hat{S}\right) < 0$

$$e_1^* = 0 \ \ M\beta k = C'(e_2^*) \ \ S_1^* = \overline{S} \ \ S_2^* = \hat{S} \ \ where \ \ T(e_1^*, e_2^*, S_2^*, S_1 = \overline{S}) \equiv 0$$

b) *If* $\hat{T} > 0$*, in that case the equilibrium is given by:*

$$M\beta kT^* = C'(e_1^*) \ \ M\beta k = C'(e_2^*) \ \ S_1^* = S_2^* = \hat{S} \ \ with \ T^* \equiv T(e_1^*, e_2^*, S_1 = S_2 = \hat{S})$$

**<u>Proof</u>**

See Appendix 1.

## <u>4/ DISCUSSION</u>

[5] The expression of $p_c$ is obtained assuming the demand error term $\varepsilon$ follows a uniform distribution.

[6] See [4] and [4'].

The equilibrium found shows that whenever an OM implements a positive first-period *managerial* effort, $e_1 > 0$, optimal inventory TC as well as optimal inventory level that minimizes TC function [1], is ***most likely*** achieved in a single period. In this case, inventory and TC variability between period one and period two is lower (in fact it is null) than in the situation where managerial effort is null ($e_1 = 0$).

Interestingly whenever $TC_0$ is high, important reductions on TC are required, and the compensation scheme must favor *managerial* efforts, *e*, (through high *k*). This makes the $\hat{T} > 0 \Leftrightarrow e_1 > 0$ outcome more probable. Specifically, the expression of $\hat{T}$ in [9] shows that when there is an important reduction in first-period total cost ( $\Delta_1 = TC_0 - TC_1$ high), there is also a significant decrease in the *T* value, which, in turn, also decreases (by [6]) first-period effort, $e_1$. The "logic" of this result is that a remarkable reduction of $TC_1$ generates limited second-period OM gains because of reductions in *TC* ($TC_1 - TC_2$) are more difficult to achieve when $TC_1$ is low. A way to offset these "losses" is by reducing first-period effort $e_1$, because this opens the possibility of substantial second-period OM gains linked to managerial effort ($k(e_2 - e_1)$ may be high when $e_1$ is low). Thus, increasing OM effort retribution with a high *k*, favors the possibility of steep inventory cost reduction in the first period.

Other remarkable result is that there is some sort of substitution between both mechanisms (managerial effort and cost reduction) to generate firm value. When OM uses one mechanism intensively in one period which, in turn, reduces the scope for future benefits linked to this mechanism, the other is not used so intensively. And, the reverse is true in the following period. The final outcome is a more efficient management of firm's inventory policy. This is what is stated in the following Proposition.

**Proposition 2**

*OM compensation for her managerial effort allows strong reductions in the inventory-related costs in order to achieve the optimal long-term inventory level in a short period of time. This generates, in future periods, a reduced variability in a firm's inventory level and in its inventory-related costs.*

**Proof**

Directly from Proposition 1.

This result comes out to be a stimulus for the firms to promote the managerial role of OMs. In that case OMs behave less strategically. They reduce TC to the optimal level in a single period and, then, they focus on implementing high managerial efforts.

Among these other *managerial* efforts, we can consider those devoted to labor hiring as Haltiwanger and Maccini (1986) do. These authors show that in case of high demand shocks variability, a manager may decide to use inventories as well as other mechanisms like worker turnover to smooth these shocks. In our model, high demand variability (high $\overline{\varepsilon}$*)* makes the $\hat{T} > 0$ outcome in [8] more probable. This leads to the equilibrium with non-null managerial effort and smoother inventory policy, which goes in lines with Blinder and Maccini (1986) results.

Proposition 1 also allows describing those scenarios with high inventory variability in the medium term as we define it. This is the difference between the second period inventory level and the first one. Basically, this analysis relies on the inspection of the expression of $\hat{T}$ when $\hat{T} < 0$ [7], which can be rearrange d (see the appendix) as:

$$\hat{T} = \frac{2Q}{c_f \Delta\overline{\varepsilon}}(E_0(TC_1[\hat{S}]) - E_0(TC_1[\overline{S}])) \qquad [10]$$

Thus, a more negative $\hat{T}$ means an increase in the difference between $\overline{S}$ (first-period inventories) and $\hat{S}$ (second-period inventories). This means an increase in inventory variability.

Also, expression $\hat{T}$ in [9] and [10] allows making a straightforward comparative static analysis with regard to structural parameter like $\frac{\alpha}{\beta}$, $TC_0, k$. This defines the following Proposition.

**Proposition 3**

*When initial inventory costs are high enough (*$TC_0$ high)*, and/or the fix part in the OM retribution is much less important than the variable part (*$\frac{\alpha}{\beta}$ low)*, and/or firm's owner*

[7] The case of $\hat{T} \geq 0$ leads to a null inventory variability.

*monitoring intensity is low enough (M low), and/or effort incentive scheme is low enough (k low), three features follow. Firstly, inventory policy is highly variable. Secondly, inventory TC reduction is limited, since the optimal long-term (last-period) level is not achieved until the second period. And lastly, OM implements no initial managerial efforts.*

**Proof:**

Directly by inspecting $\hat{T}$ *and Proposition 1.*

This proposition allows describing the different mechanisms that a firm's owner can use in order to reduce substantially a firm's inventory costs without incurring in major increases in medium-term firm's inventory variability.

Firstly, to monitor intensively (high *M*), OM *managerial* efforts in order to give her incentives for implementing these efforts. Secondly, to design a retribution scheme that combines a high fix part with a relevant compensation for OM *managerial* effort (high *k*). Both measures will promote *managerial* effort *e*, which is the driving mechanism to achieve steep short-term TC reduction. This makes that first-period inventory level equals to its long-term level ($\hat{S}$).

Interestingly, whenever initial TC is high and, eventually, a new OM arrives to the firm to arrange this situation, what we find is that this OM implements no *managerial* efforts and focuses mainly in reducing firm's inventory TC. This is what we can expect from a newly-hired OM. On the other hand, when a high-tenure OM is in charge, she is also involved in non inventory-related activities. These OMs have developed the required skills to carry out other responsibilities not directly related to inventories (i.e. labor policy like the aforementioned manager of the Blinder and Maccini model). In that case, our model shows that, good incentives providing, these OMs are able to reduce inventory TC substantially and, on average, with a smoother inventory policy than that designed by recently-appointed OMs. This latter result is consistent with the empirical study of Alfaro and Tribó (2003).

Connected with this latter proposition, it is worth to point out an interesting connection with the literature on contract design (Milgrom and Roberts (1993), among others). In a context of information asymmetries, a standard result is that the higher the supervision intensity, *M*, the more powerful should be the effort incentive mechanism (high $\beta k$). This is because of the signal that captures agent efforts is more accurate when owner's monitoring is high. This feature, in terms of our model, leads to ambiguous results in a firm's inventory variability and in an inventory TC reduction. An increase in $M$ reduces TC and stock variability, while an increase in $\beta k$ generates an ambiguous outcome. It may increase, both, TC and inventory variability when it is the result of a raise in $\beta$, or decreases both when $k$ raises. However, we think that parameter $k$ is more relevant to give OM incentives to implement effort $e$ because it characterizes the relative weight of these efforts in the variable part of the compensation scheme. In such a situation, there is no ambiguity in the sign. A positive relationship between owners's monitoring intensity and a reduction in a firm's inventory TC as well as in its stock variability is expected.

As a final comment, we can integrate in our analysis factors related to firm's market structure as well as the characteristics of firm's goods. As a first approximation, we can consider that a high (low) value of $c_r$ represents mainly competitive (monopolistic) markets, while a high (low) value of $c_h$ is linked to perishable (perennial) goods. Simple inspection of $\hat{T}$ in (9) reveals that $\frac{\partial \hat{T}}{\partial c_r} > 0$ *and* $\frac{\partial \hat{T}}{\partial c_h} > 0$. Thus, in competitive markets with perishable goods, we expect those features linked to the $\hat{T} > 0$ equilibrium (*i.e.* steep TC reduction in the short-term and mild inventory variability in the medium term).

## 5/ SIMULATION

To show the previous comparative static results and the equilibrium outcome of Proposition 1, we have developed a numerical example that considers different values of $TC_0$. We have focused on this variable because it wraps up the initial conditions on the inventory side.

To enrich our analysis, we contemplate four different scenarios, which are contingent on the different values of $c_r$ and $c_h$ (see Table 1).

By inspecting $\hat{T}$ in [9] and the equilibrium from Proposition 1, we can deduce that for high $TC_0$ values, $\hat{T}$ can be negative, and the equilibrium involves no managerial effort, high inventory variability and limited TC reduction. We call this a "bad" equilibrium. Thus, the "good" equilibrium (low inventory variability and steep TC reduction) is achieved when $TC_0$ is lower than a threshold value, $\overline{TC}_0$. This value is obtained by solving the equation $\hat{T} = 0$ in [9]. Figure 1 shows a graphical representation of $\overline{TC}_0$ in terms of $Mk$ (a measure of the aforementioned two mechanisms that stimulate *mana*gerial effort). There is a positive relationship between both variables. Thus, to stimulate non-inventory related efforts (*Mk* high) is positive in order to achieve the "good" equilibrium as it widens the region where $TC_0 < \overline{TC}_0$.

**PUT FIGURE 1 AROUND HERE**

To carry out our simulations we consider that $C(e) = \frac{1}{2}e^2$. Table 1 shows the structural parameters of the model.

**PUT TABLE 1 AROUND HERE**

By solving the equilibrium of Proposition 1, Table 2 shows the percentage variation of TC in period one and in period two. Similarly, we compute inventory variations in both periods. In all scenarios, we have modified the value of $TC_0$ from 1.1 times its long-term value ($TC_2^*$) to 2.1 times that value[8]. And, once fixed $TC_0$, we have distinguished the case when *Mk*>0, in particular *Mk*=12.5, (to stimulate *managerial* effort) from the case when *Mk*=0.

**PUT TABLE 2 ABOUT HERE**

We can extract some conclusions from the previous table:

1/ Once we compare the *Mk*=0 situation (no effort incentive mechanism) with the *Mk*>0 situation, we find that in the first situation, there is always the "bad" equilibrium ($TC_0 > \overline{TC}_0$) independently of the $TC_0$ value considered. This is not true when *Mk*=12.5. In that case, the "good" equilibrium emerges for low values of $TC_0$ ($TC_0 < 1.5TC_2^*$), especially in scenarios 2, 3, and 4. This clearly shows the importance of giving OM incentives to implement *managerial* effort.

2/ Once we compare the "bad" equilibriums ($TC_0 > \overline{TC}_0$) between the *Mk*>0 situation and the *Mk*=0 one, we find two outcomes. Firstly, there is steeper first-period TC reduction

[8] We rule out $TC_0$ values lower than $TC_2^*$ because they lead to the "good" equilibrium in all scenarios.

in the former situation in comparison to the latter. Secondly, there is lower inventory variability in the *M*k>0 case. Thus, we can say that the "bad" equilibrium is especially bad in the *Mk*=0 situation.

3/ In terms of scenarios, we observe that $\overline{TC}_0$ does not change for Scenarios 2 and 3. They are symmetric as unit holding costs of scenario 2 (3) coincide with unit stock out costs of scenario 3 (2). Moreover this common $\overline{TC}_0$ is a middle value between the value of the low-cost scenario (scenario 4) and that of the high-cost scenario (scenario 1). In this latter costly scenario, firms have more incentive to reduce substantially TC in a single period (this is what happens in the "good" equilibrium $TC_0 < \overline{TC}_0$).

4/ Interestingly enough, when comparing scenario 2 (competitive framework and perennial good) with scenario 3 (monopolistic environment and perishable good) we find a symmetric outcome concerning TC reduction. This means that the competitive pressure over a firm from its competitors is a perfect substitute of the pressure from the perishability of their own goods. This symmetric outcome is not translated to inventory policy, where there is more pressure to decrease inventories when goods are perishable (scenario 3) than when markets are competitive (scenario 2). Moreover, in the former scenario firms show, in general, the highest inventory variability. In this scenario the combination of high holding costs with low stockout costs favors steep inventory reduction.

## 5/ CONCLUSIONS

In this paper we show that an Operations Manager (OM) that devotes some efforts to non-inventory related activities may outperform an OM exclusively devoted to the management of inventories. This is by designing a payment scheme that combines the reward of inventory management efforts with other value-generating (managerial) efforts. The idea is that an OM has low incentives to reduce significantly inventory costs in the short-term because this implies a lower margin to reduce it in the future, and this, in turn, may erode his expected future rewards. Thus, an OM will only have incentives to make such reductions if these future losses are offset with other gains. These may be achieved by rewarding conveniently his non-inventory (*managerial*) efforts. Within the scheme we propose, we find the following pattern. Initially, OMs devote more efforts to reduce inventory costs than to their managerial responsibilities . However, in the next period the managerial component of OM efforts is more important. Thus, paradoxically, by combining both types of effort there is an intense inventory cost reduction to achieve in just one period the optimal inventory level.  This may not be true when the OM only manage firm's inventory policy. This provide an explanation to OM demand to increase the number of his functions along the time (D' Netto and Sohal,1999).

Our analysis also allows highlighting different features. Firstly, in an efficient contract design framework, once we compare firms with high-tenure OM with those with low-tenure, a smoother medium-term inventory variation is expected in the former in comparison to the latter. This is partly confirmed in Alfaro and Tribó (2003). Lastly, those firms with an OM involved in an increasing amount of responsibilities, need not be worried for the apparent OM lack of focus. A correct design of the compensation package can overcome all these problems.

Our model has some important limitations. This is a two-period static model that does not allow analyzing the dynamics of the OM role within the firm. Also, we have limited the decision set of OM inventory management to just one variable. Questions of information asymmetries are also ruled out for the sake of simplicity. However, although simple, our model is able to provide a set of empirical predictions concerning firm's inventory variability. We expect lower inventory variability in those firms with high-tenure OMs (which, in principle, they are able to be engaged in those *managerial* efforts), and/or with relevant managerial bonus, and/or in those firms efficiently monitored (*i. e* with banks as shareholders). Also, from our model we get that OM compensation package is mainly based on inventory cost reduction in the short-term and on managerial efforts in the medium-term. Finally, once we incorporate some additional questions of market microstructure, we get that in competitive markets with a high unitary holding cost we find the superior inventory variability. The test of these theoretical outcomes will be the subject of some future research.

## BIBLIOGRAPHY


Alfaro, J. and J. Tribó (2003) "Operations manager turnover and inventory fluctuations" *International Journal of Production Economics*, Vol. 81-82, 51-58.

Blinder, A.S. and L.J. Maccini (1991) "Taking Stock: A Critical Assessment of Recent Research on Inventories" *Journal of Economic Perspectives*, vol.5, no.1, Winter, 73-96.

Chang, J. and C. Lai (1999) "Carrots or Sticks? A Social Custom Viewpoint on Worker Effort" *European Journal of Political Economics*, vol.28, Issue 2, 297-310.

D'Netto, B. and A.S. Sohal (1999) "Changes in the production manager's job: past, present and future trends" *International Journal of Operations and Production Management*, Vol.19, No.2, 157-181.

D'Netto, B., A. S. Sohal and J. Trevyllyan (1998) "An Empirical Assessment of the Production/Operations Manager's Job" *Production and Inventory Management Journal*, First Quarter, 57-60.

Haltiwanger and Maccini (1986) "The Stylized Facts about the Cyclical Interaction of Inventories, Hours, Temporary and Permanent Layoffs", Working Paper, The Johns Hopkins University, March, December.

Haltiwanger, J.C. and L.J. Maccini (1994) "Inventories and Multi-Period Labor Contracts: Implications for Business Cycle Analysis," in Inventory Cycle and Monetary Policy, (New York: Springer-Verlag), 175-205.

Hum, S.-H. and L.-H. Leow (1992) "The Perception of the Strategic Role of Manufacturing amongst Operations Managers: an Empirical Study Based on a Newly Industrialized Economy" *International Journal of Operations and Production Management*, vol.12, no.11, 15-23.

Khan, J. (1991) "Why is Production More Volatile than Sales? Theory and Evidence on the Stockout-Avoidance Motive for Inventory-Holding". Hoover Institution, Working Paper, E-91-7, April.

Milgrom and Roberts (1993) "Top Executive Pay: Tournament or Teamwork?" *Journal of Labor Economics*, Vol.11, Issue 4, 606-628.

Oakland, J.S. and A. Sohal (1989) "The Education, Training and Career of Production Managers in British Industry" *International Journal of Operations and Production Management*, vol.9, no.8, 63-90.

# APPENDIX

1/

$$\partial_{e_1}\{\mathrm{TC}\} = -\beta(1-\mathrm{p_c})Mk + \beta\frac{\partial p_c}{\partial e_1}(E_0\mathrm{TC}_2 - E_0\mathrm{TC}_1 + Mk(e_1-e_2) - \frac{\alpha}{\beta}) + C'[e_1] \qquad [A1.1]$$

$$\partial_{\mathrm{s}_1}\{\mathrm{TC}\} = \beta(1-\mathrm{p_c})(\frac{\partial E_0\mathrm{TC}_1}{\partial \mathrm{S}_1}) + \beta\frac{\partial p_c}{\partial \mathrm{S}_1}(E_0\mathrm{TC}_2 - E_0\mathrm{TC}_1 + Mk(e_1-e_2) - \frac{\alpha}{\beta}) \qquad [A1.2]$$

With $p_c = \frac{Q}{c_f\Delta\bar{\varepsilon}}\left[TC_0 - E_0TC_1 + Mk(e_1-e_0) - \frac{c_f}{Q}\underline{\varepsilon}\right] \Rightarrow \frac{\partial p_c}{\partial e_1} = \frac{MkQ}{c_f\Delta\bar{\varepsilon}}$ *and* $\frac{\partial p_c}{\partial S_1} = -\frac{Q}{c_f\Delta\bar{\varepsilon}}\frac{\partial E_0TC_1}{\partial S_1}$

Arranging the previous expressions, we get in:

$$\partial_{\mathrm{e}1}\{\mathrm{TC}\} = -M\beta k\left\{\frac{Q}{c_f\Delta\bar{\varepsilon}}(\frac{c_f\bar{\varepsilon}}{Q} + \Delta_2 - \Delta_1 + \frac{\alpha}{\beta} + Mk(e_2 - 2e_1 + e_0))\right\} + C'(e_1) = -M\beta kT + C'(e_1) \qquad [A1.3]$$

$$\partial_{\mathrm{S}_1}\{\mathrm{TC}\} = \beta\frac{Q}{c_f\Delta\bar{\varepsilon}}(\frac{c_f\bar{\varepsilon}}{Q} + \Delta_2 - \Delta_1 + \frac{\alpha}{\beta} + Mk(e_2 - 2e_1 + e_0))\frac{\partial E_0TC_1}{\partial S_1} = \beta T\frac{\partial E_0TC_1}{\partial S_1} \qquad [A1.4]$$

With $T \equiv \frac{Q}{c_f\Delta\bar{\varepsilon}}(\frac{c_f\bar{\varepsilon}}{Q} + \Delta_2 - \Delta_1 + \frac{\alpha}{\beta} + Mk(e_2 + e_0 - 2e_1))$ $\Delta_2 \equiv (E_0TC_1 - E_0TC_2)$ *and* $\Delta_1 \equiv (TC_0 - E_0TC_1)$

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By inspecting [A1.3] and [A1.4], we can distinguish two situations:

a) If $\hat{T} \equiv T(e_1 = 0, e_2 = e_2^*, S_1 = S_2 = \hat{S}) > 0$ with $\hat{S} \equiv (\frac{c_r}{c_h + c_r})Q$ *from* $\frac{\partial E_0TC_1}{\partial \hat{S}} = 0$ and $M\beta k = C'(e_2^*)$

In this case, the optimal inventory and effort values are $S_1^* = \hat{S}_1$ $\quad M\beta k\hat{T} = C'(e_1^*)$. Where:

$$\hat{T} \equiv T(e_1, e_2^*, S_1 = S_2 = \hat{S}) = \frac{Q}{c_f\Delta\bar{\varepsilon}}(\frac{c_f(\bar{D} + \bar{\varepsilon})}{Q} + \theta\frac{c_rc_hQ}{2(c_r + c_h)_1} + \frac{\alpha}{\beta} - TC_0 + Mk(e_2^* + e_0 - 2e_1)) \quad with \quad \beta Mk = C'(e_2^*)$$

Note that $C'[e_1 = 0] = 0$ and $\frac{\partial T}{\partial e_1} < 0$. This ensures in [A1.3] an interior solution for effort $e_1$.

Finally, the second order condition of [A1.4] for $S = \hat{S}$, ensure that:

$$\partial^2{}_{\mathrm{S}_1}\{\mathrm{TC}\}\Big|_{\hat{S}_1} = \beta\frac{\partial T}{\partial S_1}\frac{\partial E_0TC_1}{\partial S_1} + \beta T\frac{\partial^2 E_0TC_1}{\partial S^2{}_1}\Bigg|_{\hat{S}_1} = \beta T\frac{\partial^2 E_0TC_1}{\partial S^2{}_1}\Bigg|_{\hat{S}_1} > 0 \quad as \quad T(\hat{S}_1) > 0 \quad and \quad \frac{\partial^2 E_0TC_1}{\partial S^2{}_1} > 0$$

Thus, this is a minimum. Moreover, as $\hat{S}$ is a minimum for $T(S_1)$, then the condition $\hat{T} > 0$ ensures that $T(S_1) > 0$ for any $S_1$. This feature neglects the T=0 solution as a possible minimum in [A1.4].

b) If $\hat{T} \equiv T\left(e_1 = 0, e_2 = e_2^*, S_1 = S_2 = \hat{S}\right) < 0$

In this case, $C'(e_1) > 0$ in [A1.3] ensures that $\partial_{e_1}\{\mathrm{TC}(e_1 = 0)\} > 0 \Rightarrow e_1^* = 0$ (we are minimizing). Moreover, [A1.4] shows that $\hat{S}_1$ cannot be optimal, as $\partial^2{}_{S_1}\{\mathrm{TC}\}\Big|_{\hat{S}_1} = \beta \frac{\partial T}{\partial S_1}\frac{\partial E_0 TC_1}{\partial S_1} + \beta T \frac{\partial^2 E_0 TC_1}{\partial S^2{}_1}\Bigg|_{\hat{S}_1} = \beta T \frac{\partial^2 E_0 TC_1}{\partial S^2{}_1} < 0$ which is the condition of a maximum. Thus, the solution of $\partial_{S_1}\{\mathrm{TC}\} = \beta T \frac{\partial E_0 TC_1}{\partial S_1} = 0$ cannot be $\frac{\partial E_0 TC_1}{\partial \hat{S}} = 0$ but $S_1^* = \overline{S}$ *that satisfies* $T(e_1 = 0, e^*{}_2, S_1 = \overline{S}, S_2 = \hat{S}) = 0$ which is a second-order polinomious [9]:

$$T(e_1 = 0, e_2^*, S_1 = \overline{S}, S_2 = \hat{S}) = \frac{Q}{c_f \Delta\varepsilon}\left(\frac{c_f(\overline{D} + \overline{\varepsilon})}{Q} + 2c_h\theta\frac{\overline{S}_1{}^2}{2Q} + 2c_r\theta\frac{(Q - \overline{S}_1)^2}{2Q} - \theta\frac{c_r c_h Q}{2(c_r + c_h)_1} + \frac{\alpha}{\beta} - TC_0 + Mk(e_2^* + e_0)\right)$$

Thus, by choosing the root of the previous polinomious with $\overline{S}_1 > \hat{S}_1$, we can ensure that

$$\partial^2{}_{S_1}\{\mathrm{TC}\}\Big|_{\overline{S}_1} = \beta\frac{\partial T}{\partial S_1}E_0 TC_1 + \beta T\frac{\partial^2 E_0 TC_1}{\partial S^2{}_1}\Bigg|_{\overline{S}_1} = \beta\frac{\partial T}{\partial S_1}E_0 TC_1\Bigg|_{\overline{S}_1} > 0$$

This is the condition of a minimum.

Finally, for $S_1 = \overline{S}_1$, $\partial_{e_1}\{\mathrm{TC}\}\Big|_{(e_1 = 0, \hat{S}_1)} = C'(e_1 = 0) = 0$ with $\partial^2{}_{e}\{\mathrm{TC}\}\Big|_{(e_1 = 0, \hat{S}_1)} = -M\beta k\frac{\partial T}{\partial e_1} + C'(e_1) > 0$.

Thus, $e_1^* = 0$ is the optimal effort combined with first-period inventory level $\overline{S}_1$.

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$$T(e_1 = 0, e_2^*, S_1 = \overline{S}, S_2 = \hat{S}) = \frac{Q}{c_f \Delta\varepsilon}\left(\frac{c_f(\overline{D} + \overline{\varepsilon})}{Q} + 2c_h\theta\frac{\overline{S}_1{}^2}{2Q} + 2c_r\theta\frac{(Q - \overline{S}_1)^2}{2Q} - \theta\frac{c_r c_h Q}{2(c_r + c_h)_1} + \frac{\alpha}{\beta} - TC_0 + Mk(e_2^* + e_0)\right) = 0$$

$$\Rightarrow \frac{c_f(\overline{D} - \varepsilon)}{Q} + \theta\frac{c_r c_h Q}{2(c_r + c_h)} - \frac{\alpha}{\beta} + TC_0 - Mk(e_2^* + e_0) = 2\frac{c_f \overline{D}}{Q} + 2c_h\theta\frac{\overline{S}_1{}^2}{2Q} + 2c_r\theta\frac{(Q - \overline{S}_1)^2}{2Q} \equiv 2E_0(TC_1[\hat{S}])$$

[9] This polinomiuos has always a real solution when $\hat{T} < 0$. This is the case because $\overline{T}(\overline{S}_1 = \hat{S}_1) = \hat{T}$ and $\overline{T}$ increases with $\overline{S}_1$ for $\overline{S}_1 > \hat{S}_1$. Thus there always will be a $\overline{S}_1 > \hat{S}_1$ such that $\overline{T} = 0$

If we use the definition of $\hat{T}$ in [9] and the fact that $E_0(TC_1[\hat{S}]) = \frac{c_f \overline{D}}{Q} + \theta \frac{c_r c_h Q}{2(c_r + c_h)}$, we can obtain:

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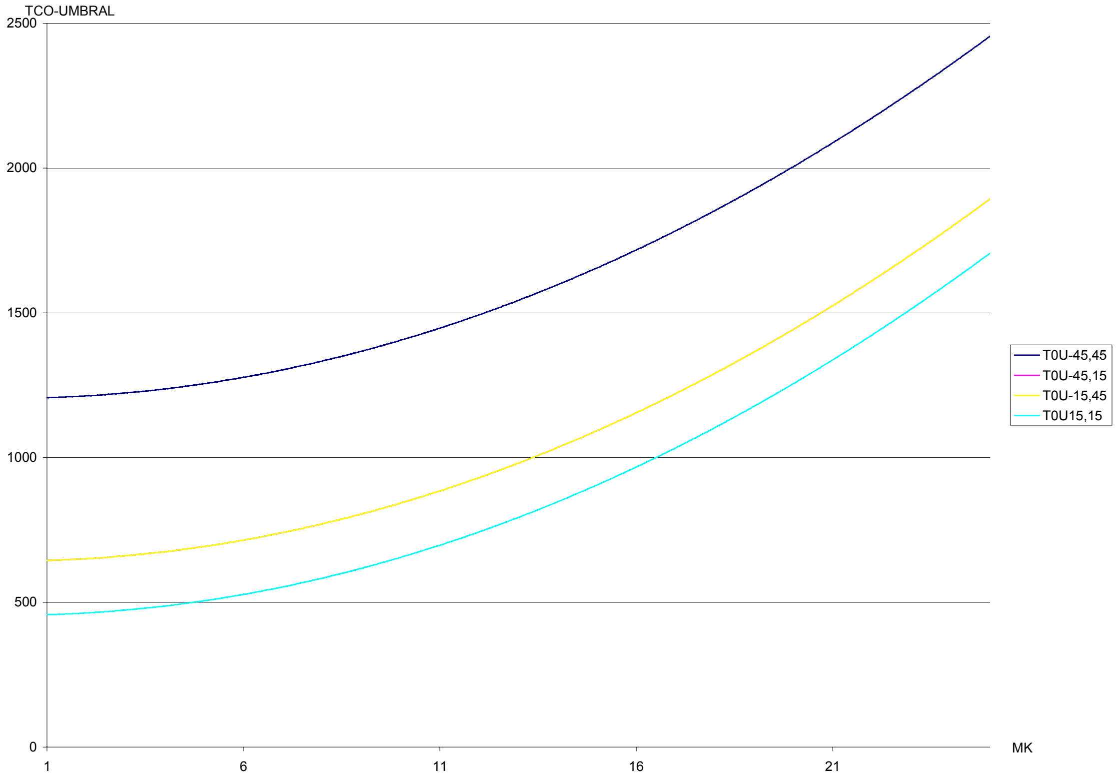
$$\hat{T} = \frac{Q}{c_f \Delta \overline{\varepsilon}} \left( 2 \frac{c_f (\overline{D})}{Q} + 2\theta \frac{c_r c_h Q}{2(c_r + c_h)_1} - \left( \frac{c_f (\overline{D} - \overline{\varepsilon})}{Q} + \theta \frac{c_r c_h Q}{2(c_r + c_h)_1} - \frac{\alpha}{\beta} + TC_0 - Mk(e_2^* + e_0) \right) \right) \Rightarrow$$

$$\Rightarrow \hat{T} = \frac{2Q}{c_f \Delta \overline{\varepsilon}} (E_0(TC_1[\hat{S}]) - E_0(TC_1[\overline{S}])$$

## Figure 1. Graphic of $\overline{TC}_0$ with regard to Mk



## TABLE 1

| **SCENARIOS** | $\overline{D}$ =5,000 ; $\varepsilon_1$=250 ; $\varepsilon_2$=250<br>$\overline{\varepsilon} = 500$ $\underline{\varepsilon} = -500$ $\theta = 1$ $e_0 = 0$<br>$\alpha$=30 $\beta$=1 $c_f$=1 Q=100 Mk=12.5 |
|---|---|
| Scenario 1: Perishable and competitive | $c_h$=45 ; $c_r$=45 |
| Scenario 2: Perennial and competitive | $c_h$=15 ; $c_r$=45 |
| Scenario 3: Perishable and low competitive | $c_h$=45 ; $c_r$=15 |
| Scenario 4: Perennial and low competitive | $c_h$=45 ; $c_r$=45 |

## Table 2

| Scenario 1 (45-45) ; TC2* = 1175 ; $\overline{TC}_0$=1366.25 (1210) ; S2*=50 | | | | | | |
|---|---|---|---|---|---|---|
| | TC0=1.3TC2* | | TC0=1.7TC2* | | TC0=1.9TC2* | |
| | MK>0 [1,2] | Mk=0 | MK>0 | Mk=0 | MK>0 | Mk=0 |
| (TC0-TC1)/TC0 (%) | 17,80 | 12,68 | 25,38 | 21,46 | 30,07 | 26,90 |
| (TC1-TC2*)/TC1 (%) | 6,42 | 11,90 | 21,17 | 25,10 | 31,91 | 34,86 |
| ***SD(%VS)*** [3] | 19,86 | 20,98 | 27,41 | 28,11 | 31,73 | 32,19 |
| **Scenario 2 (15-45) ; TC2*=612,5 ; $\overline{TC}_0$= 803,75 (647.50) ;S2*=75** | | | | | | |
| | TC0=1.3TC2* | | TC0=1.7TC2* | | TC0=1.9TC2* | |
| | MK>0 [1,2] | Mk=0 | MK>0 | Mk=0 | MK>0 | Mk=0 |
| (TC0-TC1)/TC0 (%) | 23,08 | 13,74 | 29,77 | 22,27 | 33,62 | 27,55 |
| (TC1-TC2*)/TC1 (%) | 0,00 | 10,83 | 16,24 | 24,32 | 28,26 | 34,27 |
| ***SD(%VS)*** [3] | 17,36 | 13,73 | 18,53 | 19,51 | 22,26 | 23,04 |
| **Scenario 3 (45-15) ; TC2*=612,5 ; $\overline{TC}_0$= 803,75 (647.50) ;S2*=25** | | | | | | |
| | TC0=1.3TC2* | | TC0=1.7TC2* | | TC0=1.9TC2* | |
| | MK>0 [1,2] | Mk=0 | MK>0 | Mk=0 | MK>0 | Mk=0 |
| (TC0-TC1)/TC0 (%) | 23,08 | 13,74 | 29,77 | 22,27 | 33,62 | 27,55 |
| (TC1-TC2*)/TC1 (%) | 0,00 | 10,83 | 16,24 | 24,32 | 28,26 | 34,27 |
| ***SD(%VS )*** [3] | 34,93 | 30,01 | 37,17 | 38,26 | 41,87 | 42,51 |
| **Scenario 4 (15-15) ; TC2*=425 ; $\overline{TC}_0$ = 616,25 (460) ; S2*=50** | | | | | | |
| | TC0=1.3TC2* | | TC0=1.7TC2* | | TC0=1.9TC2* | |
| | MK>0 [1,2] | Mk=0 | MK>0 | Mk=0 | MK>0 | Mk=0 |
| (TC0-TC1)/TC0 (%) | 23,08 | 14,71 | 33,82 | 23,01 | 36,90 | 28,15 |
| (TC1-TC2*)/TC1 (%) | 0,00 | 9,81 | 11,11 | 23,60 | 24,53 | 33,72 |
| ***SD(%VS)*** [3] | 25,72 | 20,88 | 27,13 | 28,47 | 31,59 | 32,71 |

[1] The dashed region represents the "good-type" of equilibrium

[2] Mk=25

[3] This is $\sqrt{(\frac{S_1 - S_0}{S_0})^2 + (\frac{S_2 - S_1}{S_1})^2}$