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Abstract

We investigate the incentives sales managers have to transmit information on demand conditions to headquarters under different organizational structures, and its subsequent impact on firm performance. When headquarters chooses quantities, their interests are aligned and reliable information is transmitted. When the choice of quantities is delegated to the sales manager, instead, he prefers not to transmit reliable information and as a consequence, headquarters set transfer prices having poor information about demand. We then see that, due to this difference in the quality of the information available to headquarters, the centralized organization frequently has the best performance.

Keywords: Organizational structure, transfer pricing, information transmission, internal accounting system.

JEL classification: D21, D81, M21

1 Introduction

Good information is key for any decision-maker in an organization and especially for those at the top of the hierarchy. Indeed, firms rely on internal accounting systems to provide headquarters and all relevant decision-makers with the most accurate and up-to-date information available.[1] Beyond the technical capabilities of the accounting system, however, division managers may affect the quality of the information received by headquarters (HQ

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[1]According to Zimmerman (2014), "An internal accounting system typically serves two purposes: decision management and decision control. Decision management refers to those aspects of the decision process in which the manager either initiates or implements a decision. Decision control refers to those aspects of the decision process whereby managers either ratify or monitor decisions." In this paper we thus focus on the role of an internal accounting system on decision management.

from now on). In particular, internal management reports combine the information generated by the internal accounting system with the discretion of the agent in charge of the report to accurately transmit it.[2] In this paper we study how the strategic incentives of managers on information transmission interact with the allocation of authority within the firm. We compare two commonly known and empirically widely observed organization structures that feature a different degree of decentralization of decisions (Acemoglu et al., 2007), namely more centralized firms in which divisions are organized as revenue centers versus more decentralized firms where divisions are profit centers. We show that centralization aligns the incentives of the division with those of the HQ and how this leads to better information transmission within the organization.

Below we analyze a firm, composed by the HQ and a sales division, that takes production decisions under uncertainty. The HQ is assumed to maximize the firm's profits (no agency problem between shareholders and the HQ exists) and possess general knowledge about market conditions. The sales division is run by a manager characterized by having a better knowledge of the market conditions but it is biased toward the performance of its own division. We will see that, when HQ organizes production activities in order to maximize firm's profits (delegate to a better informed but misaligned manager or centralize activities to a poorly informed agent) she is concerned about the impact of the organizational structure on sales managers incentives to transmit reliable information about market conditions.

The HQ can organize production activities in two basic ways. The contractual options for the HQ are incomplete and, as in Aghion and Tirole (1994), she only chooses the allocation of authority. The first possibility is a centralized type of organization in which the HQ takes all production decisions and the sales division becomes a revenue center: here the division has a low degree of decision-making. In the second possibility the HQ delegates production decisions to the manager. In this case, the HQ sets a transfer price at which divisions internally trade, and the sales division, which becomes a profit center, chooses which quantity to produce.[3] Under a centralized regime, the HQ sets the quantity to produce using only general information about market conditions: as a consequence, the firm cannot adapt quantities to the real demand conditions. Under the delegated regime, the HQ takes advantage of the precise knowledge of the manager and therefore production becomes contingent to the actual demand conditions. However, the transfer price only imperfectly reflects the real marginal cost since it is set by the HQ who has general information about demand conditions. The optimal degree of decentralization is driven by the degree of congruence of interests between the manager and the HQ (as in Aghion and Tirole, 1997), and by the relative steepness of marginal costs as compared to marginal revenues (as in Weitzman, 1976)

In the information transmission stage (prior to the production stage) the manager running the division reports the HQ about the demand conditions. The communication stage takes the form of Bayesian persuasion (Kamenica and Gentzkow, 2011): Given a

[2] Calvasina et al. (1995) provide examples of inaccurate internal management reports and argue in these cases they become of very little use for internal decision-making.

[3] In decentralized firms a transfer pricing mechanism consists of a internal transaction in which one division of the firm (e.g. the factory) provides an intermediate product or service to another (e.g. the seller division). The transfer price appears to be a revenue for the selling division and appears to be a cost for the buying division. Thus, divisions that are originally revenue or cost center become profit centers. Since managers tend to be evaluated on the performance of his division, transfer pricing becomes a powerful mechanims widely used to delegate decisions.

particular internal accounting system, the manager is free to choose the accuracy of the internal management report. We show that the choice of the organizational form has a great influence on the incentives of the manager to write an accurate report. Indeed, we find a bang-bang type of solution: when the division takes the form of a revenue center, the manager provides the most accurate report possible while under a profit center structure, a more decentralized structure, the report is highly inaccurate. Moreover, the incentives to provide information are unaffected by the degree of alignment between the manager and the HQ.

The impact of the organizational structure on the incentives to transmit accurate information goes as follows. When the division takes the form of a revenue center, the manager have no authority over production decisions. The only mechanism to influence the HQ is through the transmission of information. Because the manager cares about revenues, he becomes risk-averse to quantity missadjustment to demand conditions under this organizational structure, as a consequence, the manager becomes highly aligned with HQ's interests and provides the most accurate information possible. When the division takes the form of a profit center, the HQ delegates production decision to the manager (who has a better knowledge of the demand conditions) setting a transfer price to transmit information over costs. The manager becomes risk-lover under this organizational structure and hence prefers variability in production; as a consequence he dislikes to transmit accurate information.

We thus provide a rationale for firms to centralize production activities when there is transmission information both in centralized and delegated organizations. In previous research, transmission of information only occurs in centralized organizations. When the quality of information is exogenously given (as in Dessein, 2002) decentralization tends to be the optimal allocation of authority, especially if manager's biases are small. However, when the quality of information is endogenously chosen by the sales manager (as in Deimen and Szalai, 2019), centralized organizations leads to information of higher quality for the headquarters and, as a consequence, centralized organization emerges more often as an optimal type of organization. Thus we see that Deimen and Szalai results extend to the case in cases in which delegation also requires information transmission to HQ. Our analysis has also implications regarding the type of internal accounting systems: Organizing the sales division in profit centers is more advisable when the internal accounting system guarantees a minimum level of precision of the information transmitted to the HQ, whereas an internal accounting systems that is capable to produce highly accurate reports but requires management involvement to produce them should be better organized through revenue centers.

Our contribution to the literature can be summarized as follows. First, we connect two different literatures, the transfer pricing and the organizational economics literatures: In our model, the headquarters delegates decisions using a transfer pricing scheme. This is the most widely used mechanism by multinationals to coordinate units and decentralize decision making within an organization (see Ernst and Young, 2001, Tang, 2003, and Gox and Schiller 2007). Our paper adds to this transfer price literature that we analyze the impact on performance of the fact that the local manager influences the quality of information. On the other hand, there is a literature on organizational economics (since Dessein, 2002) that studies the optimal allocation of control when managers are biased and may communicate strategically (see also Rantakari, 2008, Alonso et al, 2015 for more recent theoretical analysis of this literature). We add to this literature the analysis of more explicit organizational structures (a more centralized one where headquarters set quantities versus another one where headquarters only set transfer prices) and a more realistic approach of the delegated organization, since in our analysis headquarters still retain a certain degree of control through the transfer price. We represent strategic information transmission through a simple version of the model developed in the literature of Bayesian persuasion (Gibbons, 2013, Kamenica and Gentzkow, 2011 and Deimen and Szalay 2019). Our paper also contributes to the accounting literature: By providing a formal analysis on how the performance of an internal accounting system depends in part on the ability of local managers to manipulate it, we can evaluate which is the optimal way to allocate decision rights between headquarters and local managers. Simon et al. (1954) is the first analysis of this issue we are aware of, but the existing literature is mostly empirical. A recent example is Indjejikian and Matějka (2012) who show that local managers may take advantage of more decentralized accounting systems.

The paper is organized as follows. The next section presents the main elements of the model. Section 3 shows the main result of the paper. To disentangle the effects, we first show the case where the report is exogenously given and secondly we study the case where the manager running the division chooses the accuracy of the report. Section 4 concludes. All proofs are left in an Appendix.

2 The model

We consider a firm with a revenue function $R(q;\theta) = \left(\widetilde{\theta} - \frac{q}{2}\right) q$, being $\widetilde{\theta}$ a random variable distributed according to $F(\theta)$ with mean μ and precision τ_θ (or variance $\sigma_\theta^2 = 1/\tau_\theta$) commonly known to all agents. Production costs are given by $C(q) = m\frac{q^2}{2}$; the steepness of the marginal cost function, $m > 0$, will be a crucial parameter in our analysis.[4] Firm's expected profits can be written as

$$E\Pi_{HQ} = E\left\{\left(\widetilde{\theta} - \frac{(1+m)\,q}{2}\right) q\right\}. \tag{1}$$

The firm can organize its divisions either as revenue or profit centers. As argued in Acemoglu et al. (2007), the firm delegates more authority on a more informed party, the division manager, when divisions are organized as profit centers: Under a revenue center organization, or simply R, HQ directly chooses quantities; when the sales division is a profit center, or simply P, the firm adopts a transfer price policy, HQ sets a transfer price p and then the sales division observes θ, the true demand conditions, and chooses quantities taking the internal price p as given.

The sales division is run by a manager whose utility is

$$U_m = \phi{\cdot}\Pi_{HQ} + (1-\phi)\cdot OF \tag{2}$$

where Π_{HQ} are profits of the whole firm and $OF \in \{R(q;\theta), \Pi_S\}$ is the objective function of the sales division, which depends on whether the division is a revenue center (and then

[4] In the analysis below we obtain qualitatively similar results if we consider a revenue function $R(q;\theta) = \left(\widetilde{\theta} - \frac{bq}{2}\right) q$ and a cost function $C(q) = a\frac{q^2}{2}$; then the relevant parameter, as in Weitzman (1974), is the ratio $m \equiv \frac{a}{b}$ of the relative steepness of the marginal cost function with respect to the marginal revenue function. Note also that we simplify Weitzman's analysis in that he considers both demand and cost uncertainty.

the sales manager gives weight $1-\phi$ in his objective function to revenues $R(q;\theta)$) or a profit center (in which case the division expected weights $1-\phi$ in his objective function) with expected profits

$$E\Pi_S = E\left\{\left(\widetilde{\theta} - \frac{q}{2}\right) q - pq\right\}. \tag{3}$$

The parameter ϕ takes values on $(0,1)$ and captures the degree to which the division manager internalizes the profits of the whole company; a large value $\phi \simeq 1$ means that the manager takes decisions almost as if he were the HQ while a low value $\phi \simeq 0$ suggests a manager strongly biased to consider only the profits of the division. In the analysis below, we take the value of the parameter ϕ as a given.[5]

In the information transmission stage the sales manager sends a report to the HQ about demand conditions. This report takes the form of an unbiased signal $s = \theta + \varepsilon_i$, where the error ε_i has zero mean, precision τ_ε and is uncorrelated with the true parameter θ, $E(\varepsilon\theta) = 0$. HQ aggregates all available information on demand conditions, both the initial information and the signal, before deciding on either quantities or transfer prices. We assume that HQ posterior mean about the demand parameter $E\theta|\, s$ is a convex combination of the prior mean μ and the signal according to their respective precision, $E\theta|\, s = (1-\tau)\mu + \tau s$ where $\tau = \frac{\tau_\varepsilon}{\tau_\varepsilon + \tau_\theta} \in (0,1)$ is the precision of the signal.[6]

Although we assume the report to be perfectly verifiable, the division manager can choose, before knowing θ's realization, the accuracy of the report (formally, the precision of the error term τ_ε, that leads to precision τ of the signal) in the interval $\tau \in [\underline{\tau}, \overline{\tau}]$, where $0 \leq \underline{\tau} < \overline{\tau} \leq 1$. Across firms, differences of these bounds might be explained by the internal accounting system implemented at each firm. In the first place, the quality of the internal accounting system would differ according to the level of previous investments on information systems. Moreover, differences in bounds may capture whether firms standardize their internal accounting systems or allow division managers to influence their design.[7]

We can summarize the strategic interaction between HQ and the sales manager as follows: First, HQ chooses whether the sales division is either a revenue or a profit center. Second, the sales manager sends a signal about demand conditions. Third, HQ update her beliefs on θ and production takes place: in a more centralized firm HQ chooses quantity q to maximize firm's expected profits while under more delegation of authority (when the division is a profit center), HQ chooses a transfer price p and then the sales manager chooses quantity q to maximize his objective function after observing demand conditions θ.

[5]The degree of internalization of the whole profits of the company may come from the incentive contract of the sales manager. In the most recent analysis of this issue we are aware of Crawford et al. (2018). In their study, they estimate a value $\phi = 0.79$ for division managers of firms in the multichannel television market, giving thus empirical support to an incomplete internalization of overall profits at the division level.

[6]Formally, for the signal s to be a sufficient statistic of θ with $E\theta|\, s = (1-\tau)\mu + \tau s$ we require the prior and the posterior distribution of θ to be conjugate distributions (DeGroot 1970, 2004 edition). More generally, a conjugate prior is convenient, because it provides form-closed expression for the posterior. See Fink (1997) for a compendium of conjugate priors.

[7]Indjejikian and Matějka (2011 p.287) offer anecdotical evidence on the degree of discretion division manager have in their reporting to HQ. A business group controller states the following: "Let everybody simply report in their own way, the way they think is most valuable to them, and if they think they have enough information, then it must be the case that a higher level also has enough information"

Therefore, the strategy of HQ includes the election of an organization structure in the first stage of the interaction and the choice of either a quantity or a transfer price in the third stage; and the strategy of the division manager includes the choice of the signal precision to maximize his expected utility and, if he is in charge of a profit center, the choice of a quantity once parameter θ is known. We solve the game backwards and we look for a perfect Bayesian equilibrium of the game.

3 Optimal organization structure

This Section presents the main result of the paper. To disentangle the different effects, we first study in Subsection 3.1. the optimal organization of the sales division when the signal is exogenous, namely, when the manager running the division cannot affect the precision of the signal. Then, in Subsection 3.2. we study the different incentives to provide accurate information depending on the organization and we evaluate its effects in terms of the optimal organization of the firm.

As a benchmark, assume the HQ have full knowledge over the true state of the demand parameter θ. In this case, the first best outcome can be achieved under both organizations and therefore how the firm is organized becomes irrelevant. Indeed, under a R organization the HQ chooses the quantity that maximizes firm's profit, i.e., $q^{FB}(\theta) = \frac{\theta}{1+m}$, whereas under a P organization a transfer price $p^{FB}(\theta) = \frac{m}{1+m}\theta$ leads the sales manager to choose a quantity $q(p,\theta) = \frac{\theta-(1-\phi)p}{1+m\phi}$ equal to the optimal one, $q(p^{FB}(\theta),\theta) = q^{FB}(\theta)$. In either case, for a given realization of the demand parameter θ the firm can achieve under both organizations the optimal level of profits $\frac{\theta^2}{2(1+m)}$ and expected profits yield[8]

$$E\Pi_{HQ}^{FB} = \frac{1}{2(1+m)}(\mu^2 + \frac{1}{\tau_\theta}) \tag{4}$$

3.1 Exogenous signal

Let us assume in this Section that at the information transmission stage, the manager cannot affect the quality of the report, that is, the manager sends a report with a given precision τ. Suppose first that the division is a revenue center and HQ chooses the level of production that maximizes expected profits after observing the realizations of both the exogenous signal and the public information. Thus, HQ maximizes $E\Pi_{HQ}^{R}\big|\, s = E\left\{\left(\widetilde{\theta} - \frac{(1+m)q}{2}\right) q \Big|\, s\right\}$; the optimal quantity is

$$q^R(s) = \frac{E\theta|\, s}{1+m} = \overline{q} + \frac{\tau}{1+m}(s-\mu).$$

This optimal quantity can be decomposed into two terms: The first one, $\overline{q} = \frac{\mu}{1+m}$, is the quantity the HQ would choose if only public information was available; the second element is an adjustment on quantity according to the additional information revealed by signal s, increasing production if the signal suggests positive demand conditions ($s > \mu$)

[8] Note that firm's profits are increasing in firm's volatility. When the firm is able to perfectly adapt to changes in demand conditions, the firm benefits from more demand volatility. This is due to the complementarity effect between the optimal quantity and the demand condition parameter θ. A formal argument is presented in Appendix B.

and decreasing it otherwise. The adjustment is larger, the more informative the signal is ($dq^R/d\tau > 0$). For a perfectly informative signal ($\tau = 1$ and then $s = \theta$) the optimal quantity would coincide with the optimal production level $q^{FB}(\theta)$; a completely uninformative signal ($\tau = 0$) leads to production $q^R = \overline{q}$. By substituting this optimal quantity on $E\Pi_{HQ}^R\big| s$, we obtain expected profits

$$E\Pi_{HQ}^R = \frac{1}{2(1+m)}\left\{\mu^2 + \frac{\tau}{\tau_\theta}\right\}$$

These profits compare to expected profits (4) as follows:

$$E\Pi_{HQ}^R = E\Pi_{HQ}^{FB} - l_R$$

where $l_R \equiv \frac{1}{2(1+m)}\frac{1-\tau}{\tau_\theta}$ is the expected profit loss due to the inaccuracy of the signal. As expected, a more precise signal reduces the profit loss.

Suppose now the firm delegates authority to the sales manager. Solving backwards, the sales manager observes the demand conditions θ and chooses q to maximize (2) for a given transfer price p. This leads to

$$q^P(\theta, p) = \frac{\theta - (1-\phi)\, p}{1+m\phi}$$

Note that if $\phi = 1$ the quantity chosen by the manager is independent of the transfer price and coincides with the efficient one, since in this case the manager internalizes firm's profits when choosing quantities. When $\phi < 1$ the manager is biased toward his division profits and transfer prices transmit relevant information on costs to influence his decision on quantities.

The HQ chooses the transfer price that maximizes firm's expected profits taking into account the manager behavior just mentioned and using HQ information over demand conditions. The optimal transfer price can be decomposed as

$$p(s) = \frac{m}{1+m}\, E\theta\big|\, s = \overline{p} + \frac{m}{1+m}\tau\,(s-\mu)\,.$$

In the absence of the signal, the optimal transfer price is $\overline{p} = \frac{m}{1+m}\mu$. Better information allows HQ to set a more precise transfer price. When the signal suggests high demand, $s > \mu$, HQ set $p(s) > \overline{p}$ since large production costs must be internalized by the sales manager. When the signal suggest dim demand conditions, HQ reduces the transfer price since production costs are expected to be lower.

Firm's expected profits under this more delegated organization structure are

$$E\Pi_{HQ}^P = \frac{1}{2\,(1+m)}\left(\mu^2 + \frac{\tau}{\tau_\theta} + \frac{1-\tau}{\tau_\theta}\frac{(1+2m\phi-m)\,(1+m)}{(1+\phi m)^2}\right)$$

and compared to expected profits in (4) we have

$$E\Pi_{HQ}^P = E\Pi_{HQ}^{FB} - l_P$$

where the expected profit loss is $l_P \equiv \frac{1}{2(1+m)}\frac{(1-\tau)}{\tau_\theta}\left(\frac{m(1-\phi)}{1+\phi m}\right)^2$.

Under decentralization, the expected profit loss also is decreasing on the precision of the signal τ, but the bias $1-\phi$ of the manager toward his own division profits increases the size of the loss. In our model, the manager uses two sources of information over costs when deciding what to produce, the information transmitted via the transfer price and the true costs of the company. How relevant is one information or the other in his decision process is measured by parameter ϕ. In the polar case $\phi = 0$, the manager only cares about his own division, and the only source of information over cost is the one transmitted (with some noise if $\tau < 1$) through the transfer price. On the other hand, if the sales manager interest are fully aligned with those of the firm ($\phi = 1$), he discards the information coming from the transfer price and he chooses the optimal level of production $q(\theta) = \frac{\theta}{1+m}$. As long as $\phi \in (0, 1)$ the manager uses both sources of information.

The following proposition compares the size of the expected profit losses under both organizational structures and states which is the best one when the signal is exogenous.

Proposition 1 *The optimal organization minimizes expected losses. A profit center is preferred to a revenue center if* $l_R > l_P$ *which holds whenever* $\phi \geq \widehat{\phi} = \max\left\{0, \frac{m-1}{2m}\right\}$*.*

Our result naturally extends the basic trade-off between prices and quantities in Weitzman (1974) by introducing managerial biases and the existence of a signal.

Indeed, if biases are maximum ($\phi = 0$) and no signal is available, Weitzman result directly emerges in our model: The use of prices or quantities depends on the relative steepness of the marginal revenue and the marginal cost. When HQ chooses a quantity $q^R = \overline{q} = \frac{\mu}{1+m}$ it is independent of market conditions, and is too low when demand conditions are favorable. When authority is delegated to the sales manager he adjusts quantities according to demand conditions. However, since the HQ picks the transfer price $\overline{p} = \frac{m}{1+m}\mu$ before uncertainty is revealed, transfer prices transmit imprecise information over marginal costs to the manager, and the manager asks for an inefficiently large quantity when demand conditions are favorable ($\theta > \mu$) and the opposite otherwise. Centralization of authority minimizes the loss when marginal costs are steeper than marginal revenues ($m > 1$) and delegation of authority reduces the loss in the opposite case. Figure 1 (a) graphically represents these effects.

Figure 1(a) Figure 1(b) here

Proposition 1 also shows that having an exogenous signal does not modify the optimal way of organizing production activities. Of course a more informative signal (higher τ) leads to better decision-making and the firm reduces the loss with respect to the efficient level ($\frac{\partial l_P}{\partial \tau} < 0$ and $\frac{\partial l_R}{\partial \tau} < 0$). However, the relative loss $\frac{l_P}{l_R} = \left(\frac{m(1-\phi)}{1+\phi m}\right)^2$ is independent of the signal precision τ.

The preference of one organization over the other is solely determined by firm's costs m (as argued above) and by the managerial bias ϕ (Figure 1(b) graphically represents the optimal organization structure as a function of these two parameters). Having a manager that better internalizes overall firm's profits leads to a more delegated organization: While under a profit center structure, a manager more concerned about the whole company (higher ϕ) makes better quantity decisions (putting more weight on the real costs of the company rather than on the imprecise information provided by the transfer price), the manager running a revenue center makes no production decisions and therefore his bias has no relevance.[9] A change of regime from a delegated to a more centralized type of organization may occur if the firm's marginal costs increases and the manager level of congruence is low enough ($\phi < \frac{1}{2}$). A change from a centralized to a more delegated type of organization is recommended if, given $m > 1$, the manager running the division becomes highly aligned with HQ's interests.

3.2 Endogenous precision

In this subsection, we study how the structure of the organization shapes the incentives of the manager to transmit accurate information to the HQ and the subsequent optimal organizational structure.

In the information transmission stage, the manager running the division decides the quality of the report, that is, he chooses the precision of the signal τ within the bounds $[\underline{\tau}, \overline{\tau}]$ imposed by the internal accounting system.[10] Proposition 2 shows the equilibrium precision under each organization structure.

Proposition 2 *If $\phi < 1$, the manager chooses maximum precision $\tau^R = \overline{\tau}$ when the division in a revenue center while choosing the minimum accuracy $\tau^P = \underline{\tau}$ when the division is a profit center.*

Proposition 2 shows that the organization of the sales division crucially affect the incentives to provide accurate information. As in Deimen and Szalai (2019), when the manager controls the quality of the information, a more hierarchical structure leads to a transmission of information of higher quality. Moreover, this effect is independent of the manager's level of alignment ϕ.

In order to better understand the incentives of the manager when choosing the precision of the signal τ, assume that the manager is fully biased toward its own division ($\phi = 0$):

- Under R, the manager wants to maximize the expected value of the revenue function $R(q;\theta) = \left(\theta - \frac{q}{2}\right) q$, which is a concave function of q; hence the manager is risk-averse in variations of q and thus clearly prefers less than more variation on quantities for a given value of parameter θ. This manager thus prefers less variation on Headquarters decisions, and this can be achieved with more precise information on demand conditions.

- Consider now the manager incentives on information quality under P: For a given transfer price p, the manager maximizes $R(q;\theta) - pq$, which leads to $q = \theta - p$ and division profits $\frac{q^2}{2}$. This is a convex function on q; hence the manager is risk-lover in q now. This has a direct and an indirect effect on his incentives when choosing the precision of the signal, and both effect go in the same direction: The first, direct effect, is that more precision of the signal leads to less variation on quantities, but a risk-lover manager do prefer more variation. The second, indirect effect, is that more precision of the signal leads to a better adjustment of transfer prices to demand conditions; but this implies higher transfer prices when demand is favorable (to internalize the impact of higher production on costs) and the opposite when demand is low; in other words, from the point of view of the manager

[9] This result goes in line with related papers regarding the decision to allocate authority in an organization. For instance, Dessein (2002) shows that, under exogenous information structures, the firm should delegate decisions to a more informed manager as long as the bias is not too large (i.e. as long as $(1 - \phi)$ is not too high)

[10] If $\underline{\tau} = \overline{\tau}$ the manager of the division have no choice of the precision of the signal and we are back to the exogenous precision case.

more information leads transfer price to work as an "insurance" that smooth quantities. But a risk-lover manager is against an insurance policy, and hence prefers less correlation of transfer prices to demand conditions.

If $\phi > 0$, any manager is partially aligned with the interest of the whole firm, and firm's profits increase with more accurate information no matter the organizational choice selected ($\frac{\partial l_P}{\partial \tau} < 0$ and $\frac{\partial l_R}{\partial \tau} < 0$), that is, more information allows the HQ to make better decisions. Proposition 2 states that, unsurprisingly, under R the manager chooses maximum precision. Anyway expected profits (4) are achieved by centralizing activities only if the signal can perfectly inform about demand conditions, $\overline{\tau} = 1$. Strikingly, however, under P the manager still prefers minimum accuracy for any $\phi > 0$. The intuition is that a manager that internalizes the profits on the whole company considers the real costs $C(q)$ instead of the transfer price p when choosing quantities; but the precision of the signal is irrelevant when the decision maker already observes θ. Hence, even if $\phi > 0$ (as long as $\phi < 1$) the only relevant aspect for the manager is the impact of the precision of the signal on the expected profits of the division. Expected profits (4) can only be achieved if the manager is fully aligned with the firm, $\phi = 1$.[11]

Similarly to Proposition 1, the decision to centralize or decentralize will depend on the organization that minimizes the losses with respect to the efficient allocation. According to Proposition 2, the loss under centralization is now $\widetilde{l}_R = \frac{1}{2(1+m)} \frac{(1-\overline{\tau})}{\tau_\theta} < l_R$ whereas the loss under decentralization is $\widetilde{l}_P = \frac{1}{2(1+m)} \frac{(1-\underline{\tau})}{\tau_\theta} \left(\frac{m(1-\phi)}{1+\phi m} \right)^2 > l_P$. Since more (less) reliable information exists under centralization (decentralization), losses are lower (higher) than in the exogenous case. Comparing the relative losses leads to the following result.

Proposition 3 *When precision is chosen by the division manager, a profit center is preferred to a revenue center if and only if expected losses are lower under a profit center,* $\widetilde{l}_R > \widetilde{l}_P$. *This happens when* $\phi \geq \phi^* = \max \left\{ 0, \frac{m - m^*(\underline{\tau}, \overline{\tau})}{m(1+m^*(\underline{\tau}, \overline{\tau}))} \right\}$, *where we define* $m^*(\underline{\tau}, \overline{\tau}) = \sqrt{\frac{1-\overline{\tau}}{1-\underline{\tau}}} \in [0, 1)$.

Proposition 3 extends the result obtained in Proposition 1 by taking into account the incentives from managers running the division to provide accurate information . Figure 2 shows the optimal organizational form as a function of the cost function parameter m and the degree of alignment ϕ both when the precision is exogenous (dashed line; threshold $\widehat{\phi}$) and when the precision is endogenous (solid line; threshold ϕ^*). Similarly to the exogenous case, higher marginal costs and a manager biased toward its own division push toward a centralized organization. Yet, under endogenous selection of precision, a centralized organization emerges more often as an optimal allocation of authority. The threshold ϕ^* that separates the two organizational regimes is now affected by the actual bounds of the firm's internal accounting system, $\underline{\tau}$ and $\overline{\tau}$, through $m^*(\underline{\tau}, \overline{\tau})$. Keeping the managerial bias ϕ fixed, the delegation region gets smaller when $m^*(\underline{\tau}, \overline{\tau})$ is closer to cero (and expands when $m^*(\underline{\tau}, \overline{\tau})$ is closer to 1). Besides, for lower values of $m^*(\underline{\tau}, \overline{\tau})$, organizing the firm as a profit center makes sense only if the manager's alignment increases ($d\phi^*/dm^* < 0$).

Notice that how to organize the sales division crucially depends on the threshold $m^*(\underline{\tau}, \overline{\tau})$ which is a function of the bounds $\underline{\tau}$ and $\overline{\tau}$ generated by the internal accounting system. Note that, as long as $\overline{\tau} < 1$, it is the difference between those bounds rather

[11] Note that at $\phi = 1$ the manager always chooses $q^P = q^{FB}$ irrespective of the quality of the information transmission.

than the actual value what determines this threshold and eventually affects the optimal way of organizing the sales division. Thus, standardized internal accounting systems that restrict the manager's ability to control the quality of internal management reports are more suitable in profit centers type of organizations. Instead, organizing the sales divisions as a revenue center is more compatible with internal accounting systems that give the manager of the division higher discretion to write internal management reports.

Also, Proposition 3 provides useful insights about the quality of the internal accounting systems: There is no a direct relationship between the quality of the internal accounting system and the organization of the sales division. To see this, Figure 2 (b) graphically represents the optimal decision to organize the sales division as a profit or a revenue center as a function of the bounds of the internal accounting system. The solid line depicted in the figure represents all possible combinations of these bounds such that the firm is indifferent between organizing the unit as a revenue or as a profit center. Note that firm's profits increase along this solid line but the indifference decision remains.[12] Finally, above (below) this solid line, the gap between bounds is larger (lower) and the firm should organize the firm as a revenue center (profit center).

Therefore investments affecting the quality of the internal accounting system (the bounds of the system) should be balanced with the organization of the sales division: investments that reduce (increase) the gap between bounds makes organizing sales division as a profit center (revenue center) more attractive. When the firm organizes its division as a revenue center, investments that improve the upper bound $\overline{\tau}$ are recommended without hesitation whereas those affecting the lower bound $\underline{\tau}$ make sense only if the improvement allows the firm to change regime and organize the firm as a profit center (an opposite argument works for the profit center case).

Figure 2(a) Figure 2(b) here

4 Conclusions and further research

The main goal of this paper has been to show the interplay between the manager's incentives to transmit reliable information to Headquarters and the organizational structure. When the quality of information is exogenous, the decision to delegate production decisions depends on the bias of the manager and on the relative steepness of marginal cost and marginal revenues. When in addition managers have control over the quality of information, in a centralized organization the manager interests are aligned with the headquarters and high quality of information is transmitted within the firm. Instead, under a decentralized organization we show that the manager is unwilling to transmit high quality information to headquarters. Thus, when taking into account that managers may control the quality of information, the optimal allocation of authority tends to shift toward more centralized hierarchies. Our analysis also suggests that internal accounting systems that constrain manager's discretion to affect the quality of the report may soften the delegation problem, and that those internal accounting systems that provide division managers with broad discretion only work correctly under more centralized production organizations.

[12] The solid line is $\overline{\tau} = 1 - \Gamma(m,\phi) + \Gamma(m,\phi)\underline{\tau}$ where $\Gamma(m,\phi) = \left(\frac{m(1-\phi)}{1+\phi m}\right)^2$ and $\phi > \widehat{\phi}$ holds. This implies that the bisector line is a case in which P is preferred to R and whenever $\overline{\tau} = 1$ R is preferred to P

A natural extension of our research would be to study the optimal allocation of authority when agents, in addition to controlling the quality of information, can communicate unverifiable information (cheap talk) and analyze the way those channels of communication interact each other (similarly to the analysis in Bertomeu and Marinovic, 2015 or Deimen and Szalay, 2019). Another relevant issue that has not been addressed in this paper is how analysis extends when several divisions are implied in the information transmission process instead of just one and issues of coordination among divisions (as in Rantakari (2008) and Alonso et al. (2015)) emerge.

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5 Appendix A

Proof of Proposition 1. In this proof, we first solve the problems for the centralized organization and the decentralized organization. Then we find the loss function l_R and l_P and compare them. (I) Under R, HQ solves

$$\max_{\{q\}} E\Pi_{HQ}|\, s = E\left\{\left(\theta - \frac{(1+m)\, q}{2}\right) q\right\}\Bigg|\, s$$

and the optimal quantity under R is obtained by solving the first order condition,

$$q^R = \frac{E\theta|\, s}{1+m} = \frac{1}{1+m}\left(\mu + \tau\left(s-\mu\right)\right)$$

Plugging q^R into $\Pi_{HQ}|\, s$ we obtain that

$$\begin{aligned}
E\Pi^R_{HQ}\left(q^R\right)\big|\, s &= E\left\{\left(\theta - \frac{\left(\mu + \tau\left(s-\mu\right)\right)}{2}\right)\frac{\left(\mu + \tau\left(s-\mu\right)\right)}{1+m}\right\} \\
&= \frac{1}{2\left(1+m\right)} E\left\{\left(2\theta - \left(\mu + \tau\left(s-\mu\right)\right)\right)\left(\mu + \tau\left(s-\mu\right)\right)\right\} \\
&= \frac{1}{2\left(1+m\right)} E\left\{\left(\left(2-\tau\right)\left(\theta-\mu\right) + \mu - \tau\varepsilon\right)\left(\mu + \tau\left(\theta-\mu\right) + \tau\varepsilon\right)\right\} \\
&= \frac{1}{2\left(1+m\right)}\left(\mu^2 + \left(2-\tau\right)\tau\frac{1}{\tau_\theta} - \tau^2\frac{1}{\tau_\varepsilon}\right) \\
&= \frac{1}{2\left(1+m\right)}\left(\mu^2 + 2\tau\frac{1}{\tau_\theta} - \tau^2\left(\frac{1}{\tau_\theta} + \frac{1}{\tau_\varepsilon}\right)\right)
\end{aligned}$$

$$
\begin{aligned}
E\Pi_{HQ}^{R}\left(q^{R}\right)\big|\, s &= \frac{1}{2(1+m)}\left\{\mu^{2}+\frac{\tau}{\tau_{\theta}}\right\} \\
&= \frac{1}{2(1+m)}\left\{\mu^{2}+\frac{1}{\tau_{\theta}}-\frac{(1-\tau)}{\tau_{\theta}}\right\} \\
&= \frac{1}{2(1+m)}\left\{\mu^{2}+\frac{1}{\tau_{\theta}}\right\}-\frac{1}{2(1+m)}\frac{(1-\tau)}{\tau_{\theta}} \\
&= E\Pi_{HQ}^{FB}-l_{R}
\end{aligned}
$$

(II) Under transfer pricing, the production stage is divided in two substages. First, the HQ announces a transfer price, and second the division chooses the quantity after observing the true demand conditions. Solving backwards, the division maximizes $U_m = \phi\Pi + (1-\phi)\,\Pi_S$, then the optimal quantity is the solution to maximize

$$
\phi\Pi+(1-\phi)\,\Pi_{S}=\phi\left(\left(\theta-\frac{1+m}{2}q\right)q\right)+(1-\phi)\left(\theta-\frac{1}{2}q-p\right)q
$$

the first order condition implies that

$$
\begin{aligned}
\frac{\partial\left(\phi\Pi+(1-\phi)\,\Pi_{S}\right)}{\partial q} &= 0 \Longleftrightarrow \phi\left(\theta-(1+m)\,q\right)+(1-\phi)\left(\theta-q-p\right)=0 \\
&\Longleftrightarrow \theta-(1-\phi)\,p-q\,(1+m\phi)=0 \\
&\Longleftrightarrow q=\frac{\theta-(1-\phi)\,p}{1+m\phi}=q^{P}\left(\theta,p\right)
\end{aligned}
$$

Given $q^{P}(\theta,p)$, the HQ chooses the transfer price p that maximizes firm's expected profits, that is,

$$
\max_{\{p\}} E\Pi_{HQ}=E\left\{\left(\theta-\frac{(1+m)\,q\,(p)}{2}\right)q\,(p)\right\}
$$

First order conditions

$$
\begin{aligned}
E\left\{\left(\theta q'(p)-(1+m)\,q\,(p)\,q'(p)\right)\right\} &= 0 \\
E\left\{\left(\theta\left(\frac{-(1-\phi)}{1+m\phi}\right)-(1+m)\left(\frac{\theta-(1-\phi)\,p}{1+m\phi}\right)\left(\frac{-(1-\phi)}{1+m\phi}\right)\right)\right\} &= 0 \\
\frac{(1-\phi)}{1+m\phi}E\left\{\left(-\theta+(1+m)\left(\frac{\theta-(1-\phi)\,p}{1+m\phi}\right)\right)\right\} &= 0 \\
\frac{1-\phi}{1+m\phi}E\left\{\left(\left(\frac{1-\phi}{1+m\phi}\right)m\theta-\left(\frac{1-\phi}{1+m\phi}\right)(1-\phi)\,p\right)\right\} &= 0 \\
\left(\frac{1-\phi}{1+m\phi}\right)^{2}E\left\{\left(m\theta-(1+m)\,p\right)\right\} &= 0
\end{aligned}
$$

leading to

$$
p\,(s)=\frac{m}{1+m}\;E\theta|\,s=\frac{m}{1+m}\left(\mu+\tau\,(s-\mu)\right)=\overline{p}+\frac{m}{1+m}\tau\,(s-\mu)
$$

Plugging this in firm's profit function it leads to

$$
\begin{aligned}
E\Pi_{HQ}^{P} &= \frac{1}{2(1+m)}\left(\mu^2+\frac{\tau}{\tau_\theta}+\frac{(1-\tau)}{\tau_\theta}\frac{(1+2m\phi-m)(1+m)}{(1+\phi m)^2}\right)\\
&= \frac{1}{2(1+m)}\left(\mu^2+\frac{1}{\tau_\theta}-\frac{(1-\tau)}{\tau_\theta}+\frac{(1-\tau)}{\tau_\theta}\frac{(1+2m\phi-m)(1+m)}{(1+\phi m)^2}\right)\\
&= \frac{1}{2(1+m)}\left(\mu^2+\frac{1}{\tau_\theta}\right)-\frac{1}{2(1+m)}\frac{(1-\tau)}{\tau_\theta}\left(1-\frac{(1+2m\phi-m)(1+m)}{(1+\phi m)^2}\right)\\
&= E\Pi_{HQ}^{FB}-\frac{1}{2(1+m)}\frac{(1-\tau)}{\tau_\theta}\left(\frac{m(1-\phi)}{(1+\phi m)}\right)^2\\
&= E\Pi_{HQ}^{FB}-l_P
\end{aligned}
$$

Now it is left to compare l_P and l_R. Note that $l_P=\frac{1}{2(1+m)}\frac{(1-\tau)}{\tau_\theta}\left(\frac{m(1-\phi)}{(1+\phi m)}\right)^2\leq l_R=\frac{1}{2(1+m)}\frac{(1-\tau)}{\tau_\theta}\iff\left(\frac{m(1-\phi)}{1+\phi m}\right)^2\leq 1\iff\phi\geq\frac{m-1}{2m}$. Since $\phi\geq 0$ the inequality holds for all $m<1$. Thus, $l_P\leq l_R\iff\phi\geq\widehat{\phi}=\max\left\{0,\frac{m-1}{2m}\right\}$ ■

Proof of Proposition 2. We have to show $\frac{\partial EU_m^R}{\partial\tau}=\frac{\partial E(\phi\Pi+(1-\phi)R)}{\partial\tau}>0$ and that $\frac{\partial EU_m^P}{\partial\tau}=\frac{\partial E(\phi\Pi+(1-\phi)\Pi_S)}{\partial\tau}<0$. Under R, the manager running the division chooses the level of precision that maximizes expected utility when $OF=R(q)=\left(\theta-\frac{q}{2}\right)q$. Given that $q^R=\frac{E\theta|s}{1+m}=\frac{1}{1+m}(\mu+\tau(s-\mu))$, expected revenues of the division can be expressed as a function of firm's expected profits in the following way, $ER=\gamma(m)E\Pi^C$ where $\gamma(m)=\frac{1+2m}{1+m}\in(1,2)$. Therefore, the expected utility of the manager running the division under R is simply

$$EU_m^R=\phi E\Pi_{HQ}^R\left(q^R\right)+(1-\phi)\gamma(m)E\Pi_{HQ}^R\left(q^R\right)=E\Pi_{HQ}^R(\phi+(1-\phi)\gamma(m))$$

Since $\frac{\partial E\Pi_{HQ}^R}{\partial\tau}>0$ the utility of the manager also increases with the precision of the signal, that is, $\frac{\partial EU_m^R}{\partial\tau}=\frac{\partial E(\phi\Pi+(1-\phi)R_{SD})}{\partial\tau}>0$.

Under P, the expected utility of the manager is

$$EU_m^P=\phi E\Pi_{HQ}+(1-\phi)E\Pi_{SD}$$

and noting that $q=\frac{\theta-(1-\phi)p}{1+m\phi}$ and $p(s)=\frac{m}{1+m}E\theta|s=\frac{m}{1+m}(\mu+\tau(s-\mu))$, and after some algebra, we can show that the first element of the former equation is

$$E\Pi_{HQ}=\left(\frac{\mu^2(1+\phi m)^2(1+m)+\frac{1}{\tau_\theta}(1+m)^2(1-m+2\phi m)+\frac{\tau}{\tau_\theta}m^2(1+m)(1-\phi)^2}{2(1+\phi m)^2(1+m)^2}\right)$$

and the second element can be rewritten as

$$
\begin{aligned}
E\Pi_S &= \left(\frac{\mu^2(1+\phi m)^2+\frac{1}{\tau_\theta}(1+m)^2(1+2\phi m)}{2(1+\phi m)^2(1+m)^2}\right)\\
&\quad-\left(\frac{\frac{\tau}{\tau_\theta}m(1+\phi m)(2+m+\phi m)+\frac{\tau}{\tau_\theta}m^2(1+m)(1-\phi)\phi}{2(1+\phi m)^2(1+m)^2}\right)
\end{aligned}
$$

It is clear that $\frac{\partial E\Pi_{HQ}}{\partial \tau} > 0$ and $\frac{\partial E\Pi_S}{\partial \tau} < 0$. Now it is left to show that $\frac{\partial U_m^D}{\partial \tau} < 0$. Noting that the last elements of the two equations cancel one another when there are weighted by ϕ and $(1-\phi)$ respectively, we get that

$$\begin{aligned} EU_m^D &= \phi E\Pi_{HQ} + (1-\phi) E\Pi_S \\ &= \phi \left(\frac{\mu^2 (1+\phi m)^2 (1+m) + \frac{1}{\tau_\theta} (1+m)^2 (1-m+2\phi m)}{2 (1+\phi m)^2 (1+m)^2} \right) \\ &\quad + (1-\phi) \left(\frac{\mu^2 (1+\phi m)^2 + \frac{1}{\tau_\theta} (1+m)^2 (1+2\phi m) - \frac{\tau}{\tau_\theta} m (1+\phi m) (2+m+\phi m)}{2 (1+\phi m)^2 (1+m)^2} \right) \end{aligned}$$

and this can be easily rewritten as

$$EU_m^D = \frac{1}{2(1+\phi m)} \left(\mu^2 \left(\frac{1+\phi m}{1+m} \right)^2 + \frac{1}{\tau_\theta} - \frac{\tau}{\tau_\theta} \frac{m}{(1+m)^2} (1-\phi)(2+m+\phi m) \right)$$

Now it is clear that $\frac{\partial EU_m^D}{\partial \tau} < 0$. ■

Proof of Proposition 3. The firm chooses a decentralized over a centralized structure when $l_P < l_R$ that is, whenever

$$\frac{1}{2(1+m)} \frac{(1-\tau^P)}{\tau_\theta} \left(\frac{m(1-\phi)}{1+\phi m} \right)^2 \leq \frac{1}{2(1+m)} \frac{(1-\tau^R)}{\tau_\theta}$$

Under endogenous choice of precision, $\tau^P = \underline{\tau}$ and $\tau^R = \overline{\tau}$

$$\frac{1}{2(1+m)} \frac{(1-\underline{\tau})}{\tau_\theta} \left(\frac{m(1-\phi)}{1+\phi m} \right)^2 \leq \frac{1}{2(1+m)} \frac{(1-\overline{\tau})}{\tau_\theta}$$

That is, whenever,

$$(1-\underline{\tau}) \left(\frac{m(1-\phi)}{1+\phi m} \right)^2 \leq (1-\overline{\tau})$$

let us define $m^* = \sqrt{\frac{(1-\overline{\tau})}{(1-\underline{\tau})}} < 1$ and solve for ϕ then

$$\left(\frac{m(1-\phi)}{1+\phi m} \right)^2 \leq (m^*)^2 \iff \frac{m(1-\phi)}{1+\phi m} \leq m^* \iff \phi \geq \frac{m-m^*}{m(1+m^*)}$$

and since $\phi \geq 0$ loss under delegation is lower than under centralization if $\phi \geq \phi^* = \max\left\{0, \frac{m-m^*(\underline{\tau},\overline{\tau})}{m(1+m^*(\underline{\tau},\overline{\tau}))}\right\}$. Note that it is immediate to check that $\phi^* \geq \widehat{\phi} \iff m^* < 1$. ■

6 Appendix B.

In this small comment, we show the complementarity between demand conditions θ and quantity decisions. Assume full knowledge of the demand intercept θ, then no organizational problems exists and the HQ aims to maximize firm's profits. Assume firm's profits can be expressed in the following way

$$R(\theta, q) - C(q)$$

Then, the quantity q^* that maximizes firm's profits solves the FOC

$$R_q(\theta, q) - C_q(q) = 0.$$

and by IFT

$$\frac{dq}{d\theta} = -\frac{R_{q\theta}}{R_{qq} - C_{qq}}$$

Note that $\frac{dq}{d\theta} \gtrless 0 \iff R_{q\theta} \gtrless 0$, that is, the firm should increase production under an increase of the demand condition θ if $R_{q\theta} > 0$ (and reduce it otherwise). Now, evaluating firm's profits at q^*, $R(\theta, q^*(\theta)) - C(q^*(\theta))$, and analyzing the behavior of this function (using the envelope theorem), the function is convex if

$$R_{\theta\theta}(\theta, q^*(\theta)) + R_{\theta q}\frac{dq}{d\theta} > 0$$

A necessary condition for the convexity of the profit function is $R_{\theta q} > 0$ and holds for the particular function used in this model since $R_{\theta\theta} = 0$ and $R_{\theta q}\frac{dq}{d\theta} = \frac{1}{1+m} > 0$.