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by

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ABSTRACT

Multi-plant organizations have trouble including both local and global information in their decisions. Outlets know local conditions but headquarters is able to coordinate outlets. In allocating decision-making power, firms must balance coordination and flexibility. I model this tradeoff, and show that the decentralized firm may standardize to avoid costs due to miscoordination. That is, increasingly variable local conditions cause decentralized choices to become less variable. Ex ante, decentralization is more profitable; neither form dominates ex post. Signals from outlets to headquarters improve the performance of the centralized firm, but one can always find conditions under which decentralization is preferred.

JEL Classifications: L23, D21

Key words: decentralization, information, multi-plant firms
1 Introduction

All organizations base decisions on local and global information, but when the organization consists of several plants, it often has trouble accounting for both sets of facts. Generally, each plant is better informed regarding conditions specific to its locality, while headquarters is better able to account for global issues affecting the coordination of outlets. Within the organization, decision-making power must be allocated, either to individual plants or to headquarters. This creates a tradeoff between using accurate local information and coordinating outlets. This paper describes and models the tradeoff between using local information and coordinating outlets.

Consider a firm producing several versions (brands) of the same product - automobiles, for example. Suppose that each brand is produced on a separate assembly line with unique characteristics, and that communication between lines, and between lines and headquarters is limited. These assumptions suggest that detailed knowledge of the characteristics of each brand deteriorates as it moves from that brand’s line to the firm’s other lines and to headquarters. The firm would like each line to exploit this detailed knowledge, but it recognizes that altering the characteristics or quantities produced of one brand might reduce sales of others, so that accounting for production conditions of one brand may have both a positive and a negative influence on revenue.

For example, automaker Saturn has recently introduced its L-Series sedan, in an attempt to retain customers trading in its popular (and smaller) S-Series autos. Its objective is to move existing Saturn owners up to a larger and more expensive auto, while attracting new customers for both types of cars it offers. There is a benefit (in terms of new customers attracted) to meeting customer demand for a larger, more comfortable automobile, but a

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potential cost to Saturn as well. If brand managers for the L-Series produce too many autos and drive down their price, the market for S-Series autos may be adversely affected. Coordination between production lines is needed to ensure that brands do not impinge on each other, but managers for each model need to be empowered to produce efficiently and to meet the demands of their customers. With the introduction of a second line of autos, Saturn has created a tradeoff between coordinating production lines and exploiting detailed knowledge of production and demand conditions.

The coordinating vs. exploiting location-specific information problem also arises in regulatory settings. Suppose, for example, that a region is considering the best way to abate pollution. Local authorities know the cost of abating pollution in their areas, while the central authority does not. The central authority is empowered to set pollution standards and make transfers between locations to reward (punish) abatement activities on the part of local authorities. In a centralized system, the regional authority is able to coordinate abatement activities between areas, while a decentralized system allows local governments to respond to specific abatement cost conditions in their areas. Yates (2000) uses this setting to show that when pollution dissipates rapidly or not at all, coordinating responses is most important, so that centralized leadership dominates. On the other hand, when pollution dissipates at a moderate pace, coordination is relatively less important, so that the flexibility available under decentralized leadership makes it the more profitable form.

The model presented in section 2 describes a firm which may be centralized in which case headquarters makes relevant production decisions, or decentralized in which case each outlet (plant, production line) makes its own production decisions. In the centralized organization, local information is unavailable, although the effect of i on its neighbors is accounted for. Each outlet in the decentralized organization takes its own local information into ac-
count, but not the information of other outlets. To model this, I assume no communication between outlets.\(^1\) Thus, the decentralized organization will not be perfectly coordinated, although its (partial) response to brand-specific (local) conditions will be more accurate.

In a first best world, headquarters would have enough information processing capacity to balance both local and global information in its decision making. In reality, the processing power needed to incorporate all information affecting various outlets can be impossibly large, so that headquarters usually leaves out some local information in making decisions (Vayanos (1999), Geanakoplos and Milgrom (1991)). Even when headquarters is able to receive and process all local information, incentive issues sometimes create reporting problems that make the firm less profitable than it could be. See, for example Laffont and Martimort (1998) (informational rent to outlets due to limits to communication and possible collusion by outlets against headquarters), McAfee and McMillan (1995) (informational rent to outlets due to padding of cost reports), Klibanoff and Poitevin (1996) (outlet misrepresentation of private information caused by inability of headquarters to commit to binding contracts), and Melumad, Mookherjee, and Reichelstein (1997) (cost to centralization due to loss of control over firm decisions).

Setting aside incentive problems, decentralized decision making implies that each outlet will exploit its particular local information. But then coordinating outlets to achieve the best global outcome, in the absence of a central decision maker, will be problematic. The effect of miscoordination in the decentralized organization is considered by Kollman, Miller,\(^1\)

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\(^1\)No communication captures the difficulty decentralized decision makers have in coordinating their activities. Limited communication raises the question of who talks to whom, which leads to a graph-theoretic problem with organizational complexity rising very quickly with the number of outlets. For models of inter- and intra-firm networks using graph theory, see Kranton and Minehart (1996), DeCanio, Watkins, Mitchell, Amir-Atefi, and Dibble (1998) and DeCanio and Watkins (1996). As long as communication is difficult under decentralization, the thought experiment of no communication should prove instructive.
and Page (1999) (search for optimal policy; decentralization may lead to local optimum instead of global optimum), and Chang and Harrington Jr. (1999) (outlets choose which type of consumer to serve - decentralized outlets may settle on less-profitable type).

The revelation principle demonstrates that as long as transmitting and processing information is costless, a firm with a single decision maker can imitate a firm with several centers of authority, so that centralization weakly dominates decentralization (Green and Laffont (1986), Mookherjee and Reichelstein (1990)). As noted in Laffont and Martimort (1998), transmitting information is not costless, which gives scope to organizational design and the possibility of decentralization. My model assumes imperfect communication between outlets and headquarters, so that decentralization will be preferred when a flexible response to local conditions is desirable. On the other hand, conflicts between decentralized decision makers sometimes arise, so that the coordinated actions dictated by headquarters may make centralization more profitable.

Aoki (1986) presents a model in which the firm centralizes as local conditions become increasingly uncertain. The model presented in this paper demonstrates that as an alternative to centralization, decentralized firms sometimes standardize in the face of increasingly uncertain local conditions. The standardization alternative allows the decentralized firm to maintain the flexibility gained from many decision makers, but achieve the coordination available to centralized organizations. In effect, outlets which are empowered to make their

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2 A large literature exists regarding the effects of costly information transmission. There are two types of costs, those due to delay and those due to message space requirements. Models containing the first cost include Bolton and Dewatripont (1994), Radner (1993), Van Zandt and Radner (1995). The second cost is considered in Marschak and Reichelstein (1998), Laffont and Martimort (1998), and Melumad et al. (1997). An elegant model of communication and decision making is presented by Carter (1995), who characterizes the value of different decision-making arrangements.

3 This result is demonstrated using a principal-agent framework in Baiman, Lurker, and Rajan (1995).

4 Because standardization is an option for the decentralized firm, it is straightforward to show that ex ante, decentralization weakly dominates centralization.
own decisions sometimes optimally ignore local conditions and behave as if they were being
directed by a less well-informed headquarters. Texas Instruments, for example, standardized
all production facilities of its DRAM chips. Individual facilities were probably more prof-
itable if each were customized to its local environment. TI chose to ignore local information,
because the gains from coordination offset the reduced flexibility.5

The model presented in section 2 generates Aoki's result that when the cost of
miscoordination is small, the firm will choose to decentralize. Going further, I show that
when local conditions ("emergent events") become more variable, miscoordination becomes
more costly, and predictability matters more. As noted above, when predictability matters,
outlets tend to "standardize" (limit and/or reduce their flexibility). As in Carter (1995),
allowing outlets to respond to privately available information improves profits. Finally, I
allow for the possibility of signals from outlets to headquarters, which enable the central
decision maker to respond (imperfectly) to local conditions. When signals are perfect the
firm will usually, although not always, centralize.

2 The Model

I will use team theory to model a multi-plant firm seeking to maximize profits. Because
strategic behavior has been extensively studied, I follow Van Zandt (1995) and Vayanos
(1999) and abstract from it in order to concentrate on other factors influencing the central-
ization/decentralization decision. Additionally, since I am modeling within-firm interactions,
the relationship between the agents in this model is assumed to continue into the (unmod-
eled) future, so that the threat of future punishment will enforce good (i.e. non-strategic)

5Evidently, even these gains from standardization did not improve profitability greatly, as Texas Instru-
ments sold its DRAM production facilities to Micron Technology, Inc. in 1998.
behavior during the period modeled here.

2.1 General Form

Each outlet's profit is given by $P - \lambda_i$, where $P = p(x_1, x_2, ..., x_n)$ represents the revenue the firm receives, which is affected by the firm's choice of the $x_i$'s. Each $x_i$ can be thought of as the amount $x$ of a particular type $i$ of good the firm chooses to produce and sell. Types are selected by the firm before the decisions modeled here are considered, so that for purposes of this model they are given exogenously. Saturn, for example, now offers two types of automobile, the S-series and the L-series. Each outlet produces and sells a single version of the product. The firm's problem is to choose how much of each type to sell, given that each of them affects the firm's revenue. For ease of exposition, I present a firm selling two types (models) of the same good (automobile), although the results generalize to more than two.

In choosing profit-maximizing quantities, the firm may take two forms. It can be centralized, in which case headquarters chooses production/sale amounts for both outlets and is able to coordinate perfectly between them, or it can decentralize and allow outlets to make their own decisions regarding amount to produce/sell. When the firm decentralizes, each outlet is able to respond to local conditions ($\lambda_i$) which the centralized firm cannot observe and respond to.

Local conditions $\lambda_i$ may represent demand conditions, such as the size of the prospective market. They may also represent cost conditions, in which case we may think of $\lambda_i$ as the marginal cost for each outlet. We assume that each production line knows its own marginal cost with certainty, but not the costs of the other line, and that headquarters does not know the marginal cost of either production line with certainty. Teece (1996) has pointed out that detailed knowledge of production conditions is tacit and therefore difficult
to transmit, so that assuming that outlet \( i \) has better knowledge of \( \lambda_i \) than outlet \( j \) and than headquarters seems reasonable.

Profit for each outlet is thus given by \( p(x_1, x_2)x_i - \lambda_ix_i \), and the firm's profit is given by \( p(x_1, x_2)(x_1 + x_2) - \lambda_1x_1 - \lambda_2x_2 \). The centralized firm maximizes profits from each outlet, taking into account the effect of each outlet's actions on the other but not the effect of (unknown) local conditions. The decentralized firm also maximizes profits at each outlet, but accounts for local conditions rather than the effect of decisions on other outlets. To capture this tradeoff, I assume that headquarters uses the expected value of local shocks \( (E\lambda_i) \) in the firm's objective function. Thus, the centralized firm's objective function is \( p(x_1, x_2)(x_1 + x_2) - x_1E\lambda_1 - x_2E\lambda_2 \). When the firm is decentralized, outlets produce and sell without knowing the other's choice, so that outlet 1 uses \( Ex_2 \), and outlet 2 uses \( Ex_1 \) in place of their true values. Thus, outlet one's objective function is \( p(x_1, Ex_2)(x_1 + Ex_2) - \lambda_1x_1 - E(\lambda_2x_2) \). For comparison, I list first best choices, when the firm is able to coordinate and respond to local conditions; i.e. when the firm is able to maximize \( p(x_1, x_2)(x_1 + x_2) - \lambda_1x_1 - \lambda_2x_2 \).

Maximizing the profit functions as given, and concentrating on the choice of \( x_1 \) (since \( x_2 \) can easily be obtained by switching subscripts) we obtain the following:

\[
x_1^d = \frac{\lambda_1 - p_1^d}{\frac{dp_1^d}{dx_1}} - Ex_2
\]

\[
x_1^c = \frac{E\lambda_1 - p^c - x_2\frac{dp^c}{dx_1} + \frac{dx_2}{dx_1}(E\lambda_2 - p^c - x_2\frac{dp^c}{dx_2})}{\frac{dp^c}{dx_1} + \frac{dx_2}{dx_1}\frac{dp^c}{dx_2}}
\]

and

\[
x_1^* = \frac{\lambda_1 - p^* - x_2\frac{dp^*}{dx_1} + \frac{dx_2}{dx_1}(\lambda_2 - p^* - x_2\frac{dp^*}{dx_2})}{\frac{dp^*}{dx_1} + \frac{dx_2}{dx_1}\frac{dp^*}{dx_2}}
\]

For notational convenience, define \( p^c = p(x_1^c, x_2^c) \), \( p^d = p(x_1^d, x_2^d) \), \( p_1^d = p(x_1^d, Ex_2^d) \), and
\[ p^* = p(x_1^*, x_2^*). \] From these choices, we see immediately that the decentralized firm is able to respond directly to local shocks \((\lambda_i)\). Headquarters, on the other hand, responds only indirectly through the effect of local shocks on the expected value of local conditions \((E\lambda_i)\). When flexibility is important, the firm should decentralize.

If we assume that \(p^c = p^* = p_1^d\), we can highlight the advantages and disadvantages of centralization and decentralization. In this case, it is easy to show that

\[ x_1^* - x_1^c = \frac{\lambda_1 - E\lambda_1 + \frac{d\lambda_2}{dx_1}(\lambda_2 - E\lambda_2)}{\frac{dp}{dx_1} + \frac{dp}{dx_2} \frac{d\lambda_2}{dx_1}} \]  

(1)

and

\[ x_1^* - x_1^d = \frac{1}{\frac{dp}{dx_1} + \frac{dp}{dx_2} \frac{d\lambda_2}{dx_1}} \left[ \frac{dp}{dx_1}(Ex_2 - x_2) - \frac{d\lambda_2}{dx_1}(p + x_2 \frac{dp}{dx_2} - \lambda_2) + \frac{d\lambda_2}{dx_1} \frac{dp}{dx_1}(p + \frac{dp}{dx_1}Ex_2 - \lambda_1) \right] \]  

(2)

Notice that the centralized choice is different from optimal only inasmuch as local conditions \((\lambda_1 \text{ and } \lambda_2)\) are different from their expected values. When local conditions vary little, headquarters can achieve choices that are quite close to optimal. This is not surprising, as headquarters’ approximate knowledge of local conditions is better, the closer are realized conditions to expectations.

The decentralized choice is different from optimal in three ways. First, outlet one is forced to use its expectation of outlet two’s production/sales, instead of its realized value. This difference is mediated by the effect that outlet one’s choice has on revenue, and is represented by the first term in equation 2, \(\frac{dp}{dx_1}(Ex_2 - x_2)\). Second, the optimal choice of production at outlet one directly affects the optimal choice made for outlet two. This cross-outlet effect is accounted for by inclusion of the term \(\frac{d\lambda_2}{dx_1}\) in the optimal choice for outlet one. Since the decentralized firm cannot take this cross-outlet effect into account, its choice will
be different from optimal by the second term given in equation 2, \( \frac{dx_2}{dx_1} (p + x_2 \frac{\partial p}{\partial x_2} - \lambda_2) \). Finally, note that outlet one's choice affects firm revenue which in turn helps determine outlet two's choice. This indirect effect (through firm revenue) is given by the third term, which includes the direct effect of \( x_1 \) on \( x_2, \frac{dx_2}{dx_1} \), and is mediated by the effect of outlet production/sales on price \( \frac{\partial p}{\partial x_2} \frac{dx_2}{dp} \).

The essence of the coordination advantage available to headquarters is that it is better able to exploit somewhat accurate information than are the outlets. If local conditions are not too variable (\( \lambda_1 \) and \( \lambda_2 \) are close to \( E\lambda_1 \) and \( E\lambda_2 \) respectively), centralized decision making will lead to choices that are close to optimal, since both \( x_1^e \) and \( x_2^e \) approach their optimal values. This is not true in the decentralized firm, as it has no way to coordinate outlets, and this problem does not disappear when local conditions stabilize around their expected values. While \( \lambda_1 \) is known with certainty by outlet one, it has no way to gain information on \( \lambda_2 \) and \( x_2^d \). This inability to coordinate makes outlet one respond incorrectly to conditions in the other market and to the choice made by outlet two. Thus, in some sense outlet one's response to its own local conditions is incorrect.

The cost of incorrect responses depends on the size of \( \frac{dp^d}{dx_1} \), the responsiveness of revenue to a change in the amount produced by outlet one. When \( \frac{dp^d}{dx_1} = k \) (a constant), it is straightforward to show that \( \text{var} x_1^d = \frac{1}{k^2} [\text{var} \lambda_1 + \text{var} p_1^d - 2\text{cov}(\lambda_1, p_1^d)] \). Thus, when \( k < 1 \), \( \text{var} x_1^d \) is likely larger than \( \text{var} \lambda_1 \), and increasingly variable local conditions (rising \( \text{var} \lambda_1 \)) lead to an increasingly variable choice of location by outlet one (rising \( \text{var} x_1^d \)). This condition, \( k < 1 \), suggests that revenue (as perceived by outlet one) is not very responsive to outlet one's production choice. When outlet one does not see its choice affecting revenue very much it is better off responding, and perhaps even over-responding to local conditions. On the other hand, if \( k > 1 \), revenue is greatly affected by outlet one's production choice,
and outlet 1’s action does not respond as flexibly to increasingly variable local conditions. That is, $\text{var} x_1^d$ may not rise even when $\text{var} \lambda_1$ increases greatly. When outlet one’s choice has a large effect on revenue, the range of high-revenue choices for outlet one are quite limited. The gains to a flexible response are offset by costly miscoordination, so that the firm is better off when outlet one stays within a narrow range of production choices.

Since the centralized firm does not respond directly to local conditions, decentralized choices are at least as variable as those made by the centralized firm. In the limit, the cost to miscoordination is infinitely large ($\left| \frac{dp_1}{dx_1} \right| \rightarrow \infty$), which narrows the range of high revenue output choices to a single amount. In this case, the decentralized firm does not respond to local conditions at all. When predictability matters, the firm appears centralized, even when it is not.

One might expect the variability of the decentralized location choice to fall as local conditions become more variable, especially when the gain in flexibility is outweighed by the cost of miscoordination (as measured through $\frac{dp_1}{dx_1}$). If the cost of miscoordination is not constant, the decentralized firm may indeed standardize as local conditions become more variable. Standardization occurs when, in the face of increasingly variable local conditions, the costliness of miscoordination rises more quickly than the gains from a more flexible response. If responding to changing demand conditions for L-series sedans adversely affects S-series sales, Saturn may not wish to respond to such conditions. In fact, if changing demand conditions for L-series sedans increase the likelihood of a miscoordinated response between the two models, Saturn may actually reduce the responsiveness of the L-series line to variable demand conditions.

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6 This result is ruled out when $k < 1$, that is when revenue is not very responsive to outlet one’s choice. For $k > 1$, it may or may not be true.
Result 1 As local conditions become more variable, the decentralized firm will standardize if the cost of miscoordination is larger than the gains to increased flexibility.

Proof: The cost of miscoordination is given by \( \frac{dp_i^d}{dx_1} \). Observe that \( \text{var}(x^d_1) = \text{var} \left( \frac{\lambda_1}{dp_i^d/dx_1} \right) + \text{var} \left( \frac{\lambda_1 p^d}{dp_i^d/dx_1} \right) - 2\text{cov} \left( \frac{\lambda_1}{dp_i^d/dx_1}, \frac{p^d}{dp_i^d/dx_1} \right) \) so that \( \text{var}(x^d_1) \) is negatively related to \( \text{var}(\lambda_1) \) when \( \text{var} \left( \frac{\lambda_1}{dp_i^d/dx_1} \right) \) falls as \( \text{var} \lambda_1 \) rises. When the variability of \( \frac{1}{dp_i^d/dx_1} \) rises faster than the variability of \( \lambda_1 \) we can conclude that outlet one reduces its responsiveness to local conditions as those conditions become more variable.

Q.E.D.

Earlier, we saw that when miscoordination is infinitely costly, the decentralized firm will not respond to local conditions. This result goes even further, and shows that even when miscoordination is not infinitely costly, the decentralized firm may reduce its responsiveness, since standardization is a way to reduce the risk of costly miscoordination. The production line for L-series cars, may be better off ignoring changes in demand conditions or the cost of production \( \lambda_i \), in order to maintain a coordinated strategy with the line producing S-series autos. In effect, the decentralized firm behaves as if it were centralized, even when it is not. As predictibility becomes more important, outlets with freedom to select their own actions may behave as if they were being told what to do.

2.2 A Linear Example

In order to obtain closed-form solutions to each outlet's problem, and to illustrate the paper's second main result, I posit the simplest demand structure possible, a linear demand curve, \( p = a - b(x_1 + x_2) \). Profits generated at outlet 1 are given by \( \pi_1 = (a - b(x_1 + x_2) - \lambda_1)x_1 \). This specific form of demand structure enables me to show that even under the best of circumstances, it is not possible to say that centralization (decentralization) is always preferrable. As noted above, and as will be true here, decentralization is ex ante preferrable,
since decentralized outlets always have the option of ignoring local conditions and behaving as
if they were directed by headquarters. Ex post, even when decentralized outlets are perfectly
able to coordinate their responses, centralization occasionally leads to higher profits.

Substituting in the expected value of local conditions $E\lambda_1$ for the centralized firm,
and the expected choice of outlet two $Ex_2$ for the decentralized firm, and maximizing the
resulting profit functions, we obtain

$$\begin{align*}
x_1^d &= \frac{1}{3b} \left[ a + E\lambda_2 - \frac{E\lambda_1}{2} - \frac{3\lambda_1}{2} \right] \\
x_1^c &= \frac{1}{3b} \left[ a + E\lambda_2 - 2E\lambda_1 \right]
\end{align*}$$

and$^7$

Since $Ex_1^d = x_1^c$, outlets choosing their own locations have the option to behave as if they
were being directed by a central coordinator. As above, the decentralized firm can imitate
the centralized firm, and is therefore ex ante more profitable.$^8$ As long as $dx_1^c/dx_2^c = 0$
at the optimum, the risk of miscoordinated responses in the decentralized firm does not offset
the advantage of increased flexibility. Since I am more interested in ex post profitability, and
since I assume that outlets have no way to coordinate their actions, outlet 1 may choose a
"centralized" position, while outlet 2 responds to its local conditions. Thus, decentralization
may be ex post less profitable than centralization.$^9$

Since $x_1^c$ contains only expected values, the centralized firm is completely predictable.

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$^7$I assume that $dx_1^c/dx_2^c = dx_2^c/dx_1^c = 0$ at equilibrium. If these terms are not zero at equilibrium, then

$$x_1^c = \left[ \frac{a-E\lambda_1(1+d_{x_1}/d_{x_2})+E\lambda_2-E\lambda_1}{b(3+d_{x_2}/d_{x_1}+d_{x_1}/d_{x_2}+(d_{x_1}/d_{x_2})(d_{x_2}/d_{x_1}))} \right]$$

$^8$Plugging in the optimal values to the profit functions, we see that $EI\Pi_d - EI\Pi_c = \frac{1}{b} \{ \text{var}(\lambda_1 - \lambda_2) \} > 0$.

$^9$Allowing even limited communication between outlets increases the chances of decentralization being ex
post preferred. In a decentralized system, the number of messages that must be exchanged rises rapidly as
the number of outlets rises, however, creating a different set of problems. See Radner (1993), Marschak and
Reichelstein (1998) for two approaches to the minimizing message costs problem.
An outside observer can predict the centralized firm's choices even before local conditions are realized. Inasmuch as predictability matters, centralization will be preferred.

The following facts are derived directly from the firm's optimal choices:

**Result 2**

1. *more costly miscoordination (larger $b$) makes the decentralized firm less responsive to both increased size and variability of local shocks.*

2. Outlet one's location is larger (smaller) under centralization when realized local conditions are larger (smaller) than expected. $x_{1}^{c} > (\langle x_{1}^{d} \rangle) \leftrightarrow \lambda_{1} > (\langle \lambda_{1} \rangle)$

3. The relationship between expected local conditions determines the relationship between centralized outlet positions. $x_{1}^{c} > (\langle x_{2}^{c} \rangle) \leftrightarrow E\lambda_{2} > (\langle \lambda_{1} \rangle)$

4. Decentralized outlet positions depend on relationships between both expected and realized local conditions. $x_{1}^{d} > (\langle x_{2}^{d} \rangle) \leftrightarrow E\lambda_{2} + \lambda_{2} > (\langle \lambda_{1} \rangle)E\lambda_{1} + \lambda_{1}$.

**Proof:**

1. $x_{1}^{d} - E x_{1}^{d} = \frac{1}{2b}(E\lambda_{1} - \lambda_{1})$, which proves that as $b$ (the cost of miscoordination) rises, decentralized choices are closer and closer to their expected values. $\text{var}x_{1}^{d} = \frac{1}{4b^{2}}\text{var}\lambda_{1}$, so that when $b > \frac{1}{2}$, variability of decentralized location choices rises by less than the increased variability of local shocks.

2. inspection of the optimal choices for the decentralized and centralized firms, plus a little algebra proves this result.

3. inspection of the optimal choices for the decentralized and centralized firms, plus a little algebra proves this result.
4. *inspection of the optimal choices for the decentralized and centralized firms, plus a little algebra proves this result.*

As in the general case, the decentralized firm responds to increasingly variable local conditions as long as miscoordination is not costly \((b < 1/2)\). As revenue becomes more responsive to an outlet’s choice \((b\) rises), miscoordination becomes more costly, causing the firm’s choices to become more and more predictable. In the limit the decentralized firm is entirely predictable and identical to the centralized firm.

Not surprisingly, knowing the relationships of \(EA_1\) to \(EA_2\) allows one to predict the output choices the centralized firm will make, but *not* the choices the decentralized firm will make. It is possible that we could see \(x_1^c > x_2^c\), but \(x_1^d < x_2^d\). When predictability in the output choices of outlets matters, the firm should centralize.

Next, we consider an alternative centralized organization, in which outlets send some signal to headquarters indicating the deviation of local conditions from expected. This should make centralization more profitable, both ex ante and ex post, as local conditions may now be (imperfectly) observed by headquarters. I assume that outlets send signal \(s_i = \lambda_i - E\lambda_i\) to headquarters. One can think of this as a daily report regarding equipment maintenance and input quality, or as a monthly demographic report on customers and economic conditions in an outlet’s sales area.

Unfortunately, since much knowledge regarding local conditions is tacit, all information regarding production conditions cannot be communicated in a finite report.\(^\text{10}\) The signal received by headquarters is given by \(s_i = \hat{s}_i + \varepsilon_i\), where \(\varepsilon_i\) is a normally distributed random variable with mean 0 and variance \(\sigma_i^2\). Will this communication make it ex-

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\(^{10}\)Transfer of knowledge within and between firms has been considered by several authors, especially as it relates to Japanese industrial structure. See, for example, Audretsch and Feldman (1996), Audretsch and Stephan (1996), Teece (1996), Hippel (1988), Granovetter (1985).
ante profitable to centralize? Perhaps. Calculating the difference in expected profits gives $E \Pi_d - E \Pi_c = \frac{1}{36b}(-7\text{var}(\lambda_1 - \lambda_2) - 4(\text{var} \lambda_1 + \text{var} \lambda_2) + 4(\sigma_1^2 + \sigma_2^2))$. When signal reception is perfect ($\sigma^2 = 0$), this difference is negative, so that centralization is indeed ex ante more profitable. By allowing signals, we increase headquarters' flexibility enough to allow it to emulate the decentralized firm. The coordination advantage of the centralized firm then causes it to dominate decentralization. Unfortunately, noisy signals (large $\sigma_i^2$) may cause the centralized firm to coordinate on the wrong output choices ($x_1, x_2$). Because the signal from outlet $i$ affects both $x_i$ and $x_j$, the centralized firm may miscue both outlets when it receives an inaccurate signal. Noisy signals may be costly enough that decentralization would be preferred ex ante.

Considering ex post profitability, one can show that in some cases centralization is preferred, while in others the decentralized firm is more profitable. However, even under the best of circumstances, neither organization will always be more profitable. I have considered two polar cases, when local conditions do not vary ($E \lambda_i = \lambda_i$ for both outlets), and when signal reception is perfect ($s_i = s_i$ for both outlets). In the first case, one would expect decentralization to be more profitable, since each outlet's prediction of the other's location choice will be perfect (i.e. the firm is perfectly able to coordinate and respond flexibly). Imperfect signals may get in the way for the centralized firm, so that one would expect centralization to be less profitable. In fact, centralization turns out to be less profitable as long as the signals received from each outlet are equally noisy. There are occasions, however, when a perfect signal from one outlet makes centralization more profitable ex post.

**Result 3** When local conditions do not vary ($\lambda_i = E \lambda_i$), and assuming similar reception from both outlets, decentralized profits will be larger.

**Proof:** $\Pi^d - \Pi^c = \frac{1}{96b}[(s_1 + s_2)(-a + s_1 + s_2) + s_1(5\lambda_2 - 4\lambda_1) + s_2(5\lambda_1 - 4\lambda_2)]$. When $s_1 = s_2 = 0,$
\( \Pi^d = \Pi^c \). Given our assumption that \( E\lambda_i = \lambda_i, s_i = 0 \) is a perfect signal, so that the firm can coordinate perfectly and respond to local conditions no matter who makes decisions. If reception from both outlets is similar, then \( s_1 \neq 0 \) and \( s_2 \neq 0 \). \( \frac{d(\Pi^d - \Pi^c)}{ds_1} = \frac{-\alpha + 2(s_1 + s_2) - 4\lambda_1 + 5\lambda_2}{9b} \)

and \( \frac{d(\Pi^d - \Pi^c)}{ds_2} = \frac{-\alpha + 2(s_1 + s_2) - 4\lambda_2 + 5\lambda_1}{9b} \). WLOG assume \( 4\lambda_1 - 5\lambda_2 \geq 0 \). Then \( 4\lambda_2 - 5\lambda_1 \leq 0 \), and \( \frac{d(\Pi^d - \Pi^c)}{ds_1} \leq \frac{-\alpha + 2(s_1 + s_2)}{9b} \leq \frac{d(\Pi^d - \Pi^c)}{ds_2} \). But this implies that \( \frac{d(\Pi^d - \Pi^c)}{ds_2} - \frac{d(\Pi^d - \Pi^c)}{ds_1} > 0 \). Even when the worsening of one of the signals reduces \( \Pi^d - \Pi^c \), the other more than offsets the reduction and \( \Pi^d - \Pi^c \) increases. Decentralization will eventually be more profitable. Q.E.D.

This result does not rule out the possibility that centralization can occasionally dominate decentralization. Because we do not know the signs of \( \frac{d(\Pi^d - \Pi^c)}{ds_1} \), when reception from one location (say \( s_1 \)) worsens while that of the other location (\( s_2 \)) does not change, centralization may become (for some realizations of local conditions and corresponding signals) more profitable.\(^{11}\) These accidental combinations of local conditions and signal quality that make centralization more profitable occur only rarely, but cannot be ruled out completely.

In the second case (perfect signal reception), the centralized firm should be more profitable, as it adds the ability to respond perfectly to local conditions to its coordinating skills. The following result proves this intuition (almost always) correct.

**Result 4** When the central decision maker’s reception of signals is perfect, the centralized firm will generally be more profitable.

**Proof:** If reception is perfect, then \( \varepsilon_1 = \varepsilon_2 = 0 \) and the signal received (\( s_i \)) is given by \( s_i = \lambda_i - E\lambda_i \). This makes

\[
\Pi^d - \Pi^c = \frac{1}{36b}[(2a - s_1 - s_2)(s_1 + s_2) - 10(s_1\lambda_1 + s_2\lambda_2) + 8(s_1\lambda_2 + s_2\lambda_1)]
\]

\(^{11}\)Because the signal received from both outlets affects \( x^*_1 \), a faulty signal from outlet two could have a large effect on the choice made by outlet one, and thus on centralized profits.
Using the second form, it is easy to show that when \( \lambda_1 = E\lambda_1 \), \( \Pi^d = \Pi^c \). Using the first form, we see that 

\[
\frac{d(\Pi^d - \Pi^c)}{d\lambda_1} = \frac{-s_1 + 4s_2}{18b} \quad \text{and} \quad \frac{d(\Pi^d - \Pi^c)}{d\lambda_2} = \frac{-s_2 + 4s_1}{18b}.
\]

WLOG assume \( s_1 \geq s_2 \). Then \( \frac{d(\Pi^d - \Pi^c)}{d\lambda_1} < 0 \), while the sign of \( \frac{d(\Pi^d - \Pi^c)}{d\lambda_2} \) is uncertain. Additionally, \( \min\left( \left| \frac{d(\Pi^d - \Pi^c)}{d\lambda_1} \right|, \left| \frac{d(\Pi^d - \Pi^c)}{d\lambda_2} \right| \right) = \min\left\{ \frac{s_1 - s_2}{2b}, \frac{s_1 + s_2}{18b} \right\} \geq 0 \). If \( \frac{d(\Pi^d - \Pi^c)}{d\lambda_2} < 0 \), \( \Pi^d - \Pi^c \) is decreasing no matter which of \( \lambda_1 \) or \( \lambda_2 \) varies from its expected value. When \( \frac{d(\Pi^d - \Pi^c)}{d\lambda_2} > 0 \), we are still assured that the positive effect of variable \( \lambda_2 \) is more than offset by the negative effect of variable \( \lambda_1 \). Assuming local conditions vary from expectations by approximately the same amount, the firm is always at least as well off centralized. 

Q.E.D.

As with the result regarding non-variable local conditions, one cannot guarantee that centralization is always more profitable than decentralization. In general, better signal reception makes centralization more profitable, but there may be cases, even when signals are perfect, when the firm could have done better if it were decentralized.

These two results demonstrate the role that externalities between outlets have in affecting firm profits. Even when problems of information are solved (by perfect signals or unchanging local conditions), decentralized outlets may impose negative (or positive) externalities on each other through the choice of output. Because decentralized outlets are assumed unable to communicate, these costs (benefits) cannot be eliminated through any form of perfect information. From these two results we can conclude that developing a system of communication between decentralized outlets would go a long way towards clarifying the
organization's optimal choice of form.\textsuperscript{12}

3 Conclusions and Suggestions for Further Research

This paper has demonstrated that when flexibility matters, decentralization can increase profitability. On the other hand, if predictability is important, the firm will rationally ignore local conditions. In this case, the ability to coordinate matters, and the firm is better off centralized. I have also shown that, given a large (constant) or rapidly increasing cost of miscoordination, the decentralized firm will standardize as local conditions become more variable. In the limit, the decentralized firm is completely standardized and behaves exactly as it would in the presence of a central coordinator. I have also demonstrated that even when signals from outlets to headquarters allow it to respond to local conditions, one cannot conclude that centralization is \textit{always} more profitable, since faulty signals may cause headquarters to coordinate on the wrong output levels.

There are several issues of decision making authority that were not considered in this paper. The model omitted all consideration of moral hazard, and the incentives problem a single decision maker might face. Other issues that arise in the multi-plant firm include economies of scale available to the centralized firm, and the information processing problem faced by a single (possibly overburdened) decision maker. This information overload often leads to "mixups" (giving the wrong instructions to an outlet).

Finally, I have considered only one possibility for solving problems that arise once the organizational form is set. For many organizations successful decentralization involves

\textsuperscript{12} One possibility would be to allow outlet 2 to see the selection made by outlet 1 before \( x_2 \) is chosen. Preliminary work suggests that this does not solve the externality problem. A second possibility is to allow outlets to make "tentative" choices which are communicated to the other outlet. This method of communication also does not appear to solve the externality problem.
coordinating the actions of interrelated outlets. How this is done remains an open question, one that becomes especially relevant when the standard solution to externalities (creating a market) is difficult. Finding alternative ways for centralized organizations to respond to local conditions is also important.

References


13 A potential classification scheme divides coordination mechanisms into “turn signals” - communication that allows outlets to signal their intentions and “stop signs” - guidelines which all outlets know and follow. In future research, I will explore the efficacy of these different coordinating methods.


One Boss or Many?
Decision Making and Coordination in the Multi-Plant Firm

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Abstract

Multi-plant organizations have trouble including both local and global information in their decisions. Outlets know local conditions but headquarters is able to coordinate outlets. In allocating decision-making power, firms must balance coordination and flexibility. I model this tradeoff, and show that the decentralized firm may standardize to avoid costs due to miscoordination. That is, increasingly variable local conditions cause decentralized choices to become less variable. Ex ante, decentralization is more profitable; neither form dominates ex post. Signals from outlets to headquarters improve the performance of the centralized firm, but one can always find conditions under which decentralization is preferred.

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1 Introduction

All organizations base decisions on local and global information, but when the organization consists of several plants, it often has trouble accounting for both sets of facts. Generally, each plant is better informed regarding conditions specific to its locality, while headquarters is better able to account for global issues affecting the coordination of outlets. Within the organization, decision-making power must be allocated, either to individual plants or to headquarters. This creates a tradeoff between using accurate local information and coordinating outlets. This paper describes and models the tradeoff between using local information and coordinating outlets.

Consider a firm producing several versions (brands) of the same product - automobiles, for example. Suppose that each brand is produced on a separate assembly line with unique characteristics, and that communication between lines, and between lines and headquarters is limited. These assumptions suggest that detailed knowledge of the characteristics of each brand deteriorates as it moves from that brand’s line to the firm’s other lines and to headquarters. The firm would like each line to exploit this detailed knowledge, but it recognizes that altering the characteristics or quantities produced of one brand might reduce sales of others, so that accounting for production conditions of one brand may have both a positive and a negative influence on revenue.

For example, automaker Saturn has recently introduced its L-Series sedan, in an attempt to retain customers trading in its popular (and smaller) S-Series autos. Its objective is to move existing Saturn owners up to a larger and more expensive auto, while attracting new customers for both types of cars it offers. There is a benefit (in terms of new customers attracted) to meeting customer demand for a larger, more comfortable automobile, but a