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Efficient Coordination By Optimal Allocation Of Decision Rights For Participants On Electronic Financial Services Markets

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For Participants On Electronic Financial Services Markets

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Efficient Coordination By Optimal Allocation Of Decision Rights For Participants On Electronic Financial Markets*

Abstract

Information technology (IT) is enabling large companies and particularly banking firms to create new forms of organizations. Both globalization of markets and stronger regulation throughout the world puts pressure on banking firms to either spend more money coordinating business activities in the traditional hierarchical ways or to employ new forms of organizations enabled by (lower costs of) IT. When facing uncertain demand in multiple horizontal markets, resource allocation problems occur. Accordingly, the location of decision authority in a multilevel hierarchical organization has profound impact on the performance of the firm. The firm has to design its coordination structure, which determines who makes the resource allocation decisions. Considering the tradeoff between pooling effects in the case of centralized decision-making and better assessment of local markets in the case of decentralized decision-making, the decision problem where to locate decision rights to maximize total profits has to be solved. In this paper we investigate for both independent and dependent demands the total profits for each of the possible coordination mechanisms: centralized decision-making, decentralized decision-making, and intermediate-level decision-making. It turns out that - depending on the crucial parameters of the firm - decentralized decision-making or centralized decision-making may be optimal. But in many relevant cases the optimal location of decision rights is at an intermediate level of the hierarchy. We illustrate the findings by considering the banking firm coordinating equity capital allocation

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by granting alternative decision rights to their employees as participants on electronic financial markets. Finally we discuss the generality of the approach and its applicability in other areas such as inventory management.

Keywords: coordination mechanisms, internal organization, internal resource allocation, organizational design, electronic markets, financial services markets, inventory management.

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1.Introduction

While globalization of worldwide financial services markets is continuing, the creation of a single market in financial services and the free access to domestic markets for all members of the European Union (EU) - with a variety of changes in the regulatory framework as well as new competitors - pressure European banks to increase their flexibility. Compared to many other countries in theory banks in the EU have long been free to engage EU-wide in the whole range of financial services and have started to do so in practice.[1] With the worldwide advent of Internet Banking and Brokering the business is quickly becoming global.

German universal banks[2] have long taken advantage of the opportunities to offer a wide range of products for reasons of risk diversification, bundling of services and cross-selling, and thus the German banking market is dominated by large banking firms. Recently, mergers have occurred to obtain economies of scale (e.g., the merger between Hypobank and Vereinsbank 1998) and economies of scope (e.g., the merger between Deutsche Bank and Bankers Trust 1999). Due to the large size and diversified nature of such banking firms there is a strong need for efficient coordination and controlling instruments with large-scale applicability.

To date, capital budgeting instruments are mainframe-based and hierarchically organized, and thus both expensive and inflexible. The recent developments in IT now allow for cheaper client/server- and network-based options helping to shape more flexible organizations. Since banking is a technology-driven business, there are shifts resulting from these developments.

1 The United States has restricted banks both geographically and functionally (separating commercial from investment banking).

2 A universal bank is a financial intermediary that performs services usually associated with commercial banks, investment banks, and insurance companies. In Germany however, banks can engage in insurance operations only through a subsidiary, see Greenbaum and Thakor (1995, p. 545 and 667).

Given the conditions sketched above, the inefficiencies of hierarchical coordination instruments and the corresponding system support used by major banks become apparent: volatility, permanent changes and heterogeneity of the markets reduce the efficiency of centralized business planning. We observe information losses within multi-stage hierarchies, agency problems, slow decision-making processes, and lack of flexibility[3]. E.g., the increased capital requirements result in increasing capital reserves held by the single subunits and hierarchy levels. Thus, an increasing amount of capital is withdrawn from productive use resulting in reduced competitiveness.

Thus in this paper we concentrate on the problem of (equity) capital reserves, i.e., precautionary capital held by decision units for reasons of uncertainty of future business volume and thus uncertainty w.r.t. equity capital resources needed for conducting the business[4]. If future resource demand is uncertain[5], to hold such precautionary capital makes sense no matter whether these decisions are centralized, decentralized, or made at an intermediate level.[6] However, the problems associated with that, are quite different: While centralized decisions (see Figure 1) suffer from insufficient knowledge of future business prospects due to agency and information processing problems and thus the quality of the relevant parameters for the central decision authority is worse, in the case of decentralized

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3 A main question our research group has addressed in a number of papers is under which conditions which forms of intra-bank electronic financial markets - due to IT development - compared to hierarchical solutions are becoming more competitive. Subquestions of interest have been and still are: Which suitable implementation of such markets will lead to a better allocation of scarce (equity) capital to autonomous business units with simultaneous observance of regulation principles, better market responsiveness by a stronger ability to reallocate financial resources dynamically, and improved use of local knowledge? For more details on these ideas see Sandbiller (1996), Klein and Hinrichs (1997), Hinrichs and Klein (1997), Sandbiller et al. (1997), Sandbiller (1998), Buhl and Will (1998), Dittmar and Horstmann (1999), Dittmar et al. (1999).

4 Due to regulation, equity capital is linked to different banking businesses via different factors; hence any business - depending on its volume and risk class - requires a certain amount of equity capital. Thus any business conducted today may reduce the opportunity to do (possibly more profitable) business tomorrow.

5 For example, uncertainty arises from the fact that the prospective utilization of committed loan limits or credit lines cannot be perfectly predicted by the bank.

6 In favor of hierarchical coordination we assume that in the whole hierarchy no more equity capital reserves are held than are optimal for the hierarchy as one perfect decision unit. *Hierarchical*

decision-making (Figure 2) the problem is somewhere else: The knowledge about customers and thus on parameters representing future business prospects at the decentralized level assumes maximum quality available in the company; but there is no knowledge about (and maybe no incentive to account for) relevant parameters of other decision units. In the case of holding precautionary equity capital, this implies that each unit optimizes locally and thus - due to foregone pooling advantages - in total we usually have a much higher level of precautionary capital than is optimal for the banking firm as a whole.

Centralized Decision-Making

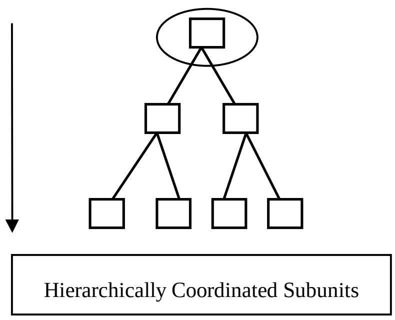

Figure 1: Hierarchical and Market Coordination

Decentralized Decision-Making

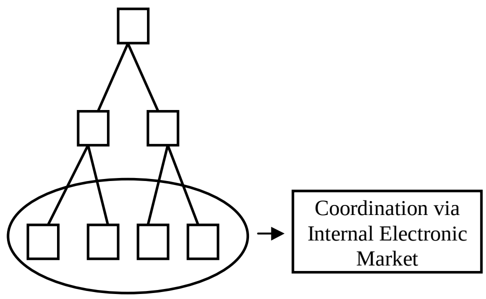

Figure 2: Market Coordination

If decisions are made at some intermediate level (see Figure 3) - implying that in our banking scenario we have participants being coordinated via the Internal Electronic Market and coordinating their subunits hierarchically - the problems arising constitute a mixture of the ones discussed above. Still, such an intermediate solution may be optimal for the bank if it constitutes a suitable tradeoff between (equity capital) pooling advantages and the losses from inefficiencies (e.g. due to lacking customer/market knowledge) in hierarchical coordination.

misallocations, reserves, etc. in the analysis will be covered by an (inefficiency) parameter to be

Decision-Making on an Intermediate Level

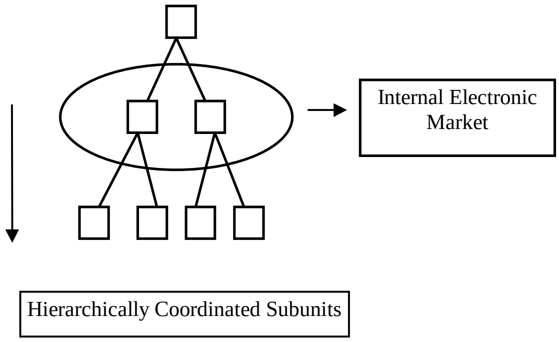

Figure 3: Intermediate Coordination

To be able to analyze such questions in more detail, we proceed as follows: In Section 2 - after presenting the notation and basic assumptions - we start out by illustrating a simple, but fairly general model for determining optimal precautionary capital due to Whalen (1966); this model is sufficiently general to be applicable for centralized, decentralized and intermediate-level decision-making. This enables us to apply the model in Section 3 to the case when (equity capital) resource demands are assumed to be random variables with strictly positive variance, but pairwise independent; thus the correlation between any two demands is zero implying a linear increase of variance in case of pooling and thus strong pooling advantages. In Section 4 we relax the independence assumption and allow for arbitrary correlation. In the worst case of perfectly correlated demands this implies a quadratic increase of variance and thus smaller, but still existing pooling advantages. In both sections these pooling advantages in case of hierarchical coordination are compared with the corresponding disadvantages (i.e., coordination costs and inefficiency losses). It turns out that - depending on the values of the

introduced in the next section.

relevant parameters - anything may be optimal, i.e.; totally decentralized participation on the Internal Electronic Financial Market without hierarchy coordination, central planning without making use of electronic market coordination, and intermediate solutions taking advantage of both, hierarchical and electronic market coordination. We provide formal conditions and indifference results for these alternative coordination schemes. A summary, a discussion of the generality of the results, and prospects for further research in Section 5 conclude the paper.

2. A Model For Determining Precautionary Equity Capital

The model contains the following assumptions:

(A1) *Equity Capital Resources*: The banking firm's decision unit is assumed to have equity capital resources R available. The demand D for these resources implied from conductible business is a random variable with a symmetric[7] density distribution[8] and strictly positive variance σ^2. The bank may decide to employ an amount $r < R$ for doing business implying that it holds precautionary equity capital $l = R - r$ for meeting uncertain future demands.

(A2) *Illiquidity Costs*: If l is not sufficiently large such that demand exceeds the precautionary capital and thus profitable business cannot be conducted any more, we assume that there exists a fixed[7] illiquidity cost $\alpha > 0$.

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[7] For sake of tractability in Section 3 and 4 we keep the model in this section straight forward by adding these simplifying assumptions. We get back to this point in Section 5.

[8] To simplify the analysis, in accordance with Whalen (1966) we let *E(D) = 0* , i.e., we only account for the demand exceeding the expected value explicitly in our analysis.

(A3) *Proceeds*: If the banking firm's decision unit decides to employ equity capital resources r for doing business, the corresponding proceeds are given by $ri\beta$, where $i > 0$ denotes the return rate[9] and $\beta \leq 1$ denotes a strictly positive efficiency parameter accounting for coordination costs and losses from inefficiency e.g., due to increasing market inefficiency or inefficient hierarchy coordination and the like.

(A4) *Objective Function*: The banking firm seeks to maximize a profit function[10] accounting for proceeds from employing equity capital resources r minus expected illiquidity costs depending on l.

(A5) *Worst-Case-Distribution*: Since we do not want to restrict the analysis to some specific demand distribution function, we work with the upper bound[7] of the Tschebyscheff-inequality.

Observing that the demand is a non-negative random variable, Tschebyscheff-inequality says that the probability of the demand exceeding[11] σ by some factor λ is *at most* $\frac{1}{2\lambda^2}$.

Letting $\lambda = \frac{1}{\sigma}$, we can determine an *upper bound* Max P on the probability of demand exceeding l:

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9 For the sake of simplicity it is assumed that the banking firm earns nothing on the precautionary equity capital, i.e. the rate for the riskless investment is zero. This is justified because a strictly positive interest rate less than *i* would not change the result of the maximization problem. The same holds for the inventory of goods where in most cases the firm does not earn money on the inventory stock (see Section 5).

10 In the case of decentralized decision-making our analysis assumes that decentralized decision units act as a team (Marschak 1955, Marschak and Radner 1972). This means that they have the same objective, i.e. maximizing the total profits of the firm. This assumes that all incentive problems, for example the ones recently addressed by Nault (1998) w.r.t. the investment decision authority, have been solved. Thus the focus of the analysis is not on the vertical moral hazard problem, but on the effects of pooling and the effective use of information.

11 Due to the footnote above we have $E(D) = 0$. Thus this states that demand exceeds the expected value by $\lambda\sigma$.

(1) $P(D>l)\leq MaxP(D>l)=\dfrac{\sigma^2}{2l^2}$.

If we multiply this probability with the fixed illiquidity costs α, we obtain the expected illiquidity costs for the Worst-Case-Distribution (A5). Thus, given Assumptions (A1) through (A5), the banking firm's / decision units' profit function can be specified in the following way:

(2) $P=ri\beta-\alpha\dfrac{\sigma^2}{2(R-r)^2}$,

where the first expression denotes proceeds from employing r, $0\leq r\leq R$, and the second one represents the corresponding expected illiquidity costs.

Maximizing Objective Function (2) w.r.t. r, such that $0\leq r\leq R$ we obtain from the first order condition (with the second order condition obviously satisfied)[12]

(3) $r^*=R-\sqrt[3]{\dfrac{\alpha\sigma^2}{i\beta}}$

and thus

(4) $l^*=R-r^*=\sqrt[3]{\dfrac{\alpha\sigma^2}{i\beta}}$.

Note that for positive illiquidity costs and variance of demand for the decision unit it is optimal to hold precautionary equity capital and thus not to employ total resources R. Plugging in the optimal value r^* in Objective Function (2) we obtain

(5) $P^*=Ri\beta-\dfrac{3}{2}\alpha^{\frac{1}{3}}(i\beta)^{\frac{2}{3}}\sigma^{\frac{2}{3}}$,

which for sufficiently large

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12 We assume that available capital resources are sufficiently large, such that $R>\sqrt[3]{\dfrac{\alpha\sigma^2}{i\beta}}$ holds. This implies that r* is positive. This inequality is not very restrictive. For instance, in Example 1 we have

(6) $$\beta > \left(\frac{3}{2} \frac{\alpha^{\frac{1}{3}} \sigma^{\frac{2}{3}}}{R i^{\frac{1}{3}}} \right)^3$$

is strictly positive. If β is equal to the right hand side of Inequality (6) or $\beta = 0$, we have optimal profits of zero; in between, they are negative.

In the next sections, we will apply this model to centralized, decentralized and intermediate-level decision-making.

3. Optimal Banking Operation For Independent Demands

Suppose the banking firm has n decentral units facing equity capital demands D_i, $i = 1, \ldots, n,$ for being able to conduct their business. For sake of simplicity we assume the following:

(A6) All these demands are identically distributed (pairwise) independent random variables with Assumptions (A1) through (A5) satisfied, i.e., all have (or can make) identical equity capital resources $R_i = R$ available.

Thus all demands D_i have an identical variance σ^2. From the independence assumption it follows that all (pairwise) covariances are zero and thus

(7) $$Var(\sum_{i=1}^{n} D_i) = \sum_{i=1}^{n} Var(D_i) = \sum_{i=1}^{n} \sigma^2 = n\sigma^2 \ .$$

Hence the zero covariance between any two demands implies a linear increase of total variance. Thus, the standard deviation increases with the square root of n.

$R = 100{,}000 > 472 \cong \sqrt[3]{105{,}263{,}158} = \sqrt[3]{\frac{\alpha\sigma^2}{i\beta}}$ for $\alpha = 4000$; $\sigma = 5000$; $i = 0.16$; $\beta = 0.95$. For these parameters Inequality (6) is also easily satisfied with $\beta = 0.95 > 0.00211 = \left(\frac{3}{2} \frac{\alpha^{\frac{1}{3}} \sigma^{\frac{2}{3}}}{R i^{\frac{1}{3}}} \right)^3$.

If decisions are made on a higher level of the hierarchy and subunits are coordinated hierarchically, we have coordination costs for hierarchy coordination and resulting inefficiencies such as information processing costs and losses from inferior local customer/market knowledge. It seems natural to assume, that these costs are increasing with the hierarchy level employed as decision unit. Especially local knowledge „like intuitions and expertise regarding market factors that are honed over time by local sales-force at a particular branch“ (Anand and Mendelson 1997) is difficult to communicate. Additionally, the losses of information will increase when information is passed through several hierarchical levels to the final decision maker. Thus we let our inefficiency parameter be given by $\hat{\beta}$**,** such that $\hat{\beta}=1$ in the case of decentralized decision-making and $\hat{\beta}<1$ in the case of centralized decision-making.

If all the decision units act independently of each other, each unit determines equity capital resources employed and precautionary capital according to Equations (3) and (4) from Section 2. Thus the banking firm's maximal total profit in case of decentralized decision-making, P_D^*, is given by the sum of the n decentralized units' total profit

(8) $$P_D^* = nRi - \frac{3n}{2}\alpha^{\frac{1}{3}} i^{\frac{2}{3}} \sigma^{\frac{2}{3}} \text{ .}$$

In case of pooling[13] n decentralized units (and thus deciding centrally) we have strong pooling advantages due to this section's independence assumption: Total variance of demands increases linearly with n and due to Equation (4) precautionary equity capital increases only with $n^{\frac{1}{3}}$. Thus maximal total profits for the case of pooling n units together are given by

13 We may view this pooling of demands as an application of the risk sharing principle as Milgrom and Roberts (1992, p. 211) put it: „The principle of risk sharing - that sharing independent risks reduce the aggregate costs of bearing them - is the basis of all financial insurance contracts“. The analysis in Section 4 will show that the cost reduction also holds for dependent and particularly for correlated demands.

(9) $$P_C^* = nRi\hat{\beta} - \frac{3}{2} n^{\frac{1}{3}} \alpha^{\frac{1}{3}} (i\hat{\beta})^{\frac{2}{3}} \sigma^{\frac{2}{3}}\ .$$[14]

Observe that for $\hat{\beta}$ sufficiently close to 1 decentralized decision-making is less profitable than pooling units together and deciding centrally. If $\hat{\beta}$ is sufficiently small, however, the pooling advantage is overcompensated by increasing inefficiency due to hierarchical coordination.

Notice that $P_C^* = P_D^* \Leftrightarrow$

(10) $$Ri^{\frac{1}{3}}\left(1-\hat{\beta}\right) = \frac{3}{2}\alpha^{\frac{1}{3}}\sigma^{\frac{2}{3}}\left(1-\left(\frac{\hat{\beta}}{n}\right)^{\frac{2}{3}}\right).$$

For $n = z^m$ and $\hat{\beta} = \beta^m$, where z is the span of control and m the depth of the hierarchy (see Assumption A (7) to be introduced on the next page) we obtain: $P_C^* = P_D^* \Leftrightarrow$

(11) $$Ri^{\frac{1}{3}}\left(1-\beta^m\right) = \frac{3}{2}\alpha^{\frac{1}{3}}\sigma^{\frac{2}{3}}\left(1-\left(\frac{\beta}{z}\right)^{\frac{2m}{3}}\right).$$

The indifference results (10) and (11) show under which conditions the aspects in favor of centralized and decentralized decision-making are balanced. In addition to the two alternatives of centralized or decentralized decision-making, the banking firm faces a third option to allocate decision rights w.r.t. equity capital resources. If decisions are made on some intermediate level (see Figure 3), this implies a mixed market/hierarchical banking operation with intermediate participants being coordinated via the Internal Electronic Market and coordinating their subunits hierarchically. Such an intermediate solution may be optimal for the bank if it constitutes a suitable tradeoff between (equity capital) pooling advantages and

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14 A completely different way to model the inefficiency from centralized decision-making is to assume that the center has less precise knowledge of demand so that the variance of distribution of demand is greater. If $\hat{\beta} = 1$ in Equation (9) we see from the analysis that instead of Equation (7) $Var\left(\sum D_i\right) > n^3\sigma^2$ would

the losses from inefficiencies (e.g., due to lacking customer/market knowledge) in hierarchical coordination.

To analyze this case, we introduce the following more special assumption to characterize the organizational structure of the banking firm considered.

(A7) If each decentralized unit of the banking firm is a decision unit acting independently of the other ones on the Internal Electronic Market without any hierarchical coordination, i.e., we say decisions are made on the lowest level m in the banking hierarchy, then we have a maximum number of market participants. For the case of a unique span of control z and a hierarchy depth of m the number of participants is then given by z^m. If decisions are made higher up in the hierarchy on level $k < m$ and subunits are coordinated hierarchically, the number of market participants z^k decreases resulting in increasing inefficiency of the Internal Electronic Market (see Weber (1995), Clemons and Weber (1996)). In addition we have coordination costs for hierarchical coordination and inefficiencies resulting from it such as agency and information processing costs and losses from inferior local customer/market knowledge. It seems natural to assume, that these costs are increasing with decreasing hierarchy level k employed as decision unit. Thus we let our inefficiency parameter be given by $\hat{\beta} = \beta^{m-k}$, such that $\hat{\beta} = 1$ in case of decentralized decision-making ($k = m$) and $\hat{\beta} < 1$ in the case of intermediate-level ($0 < k < m$) and centralized decision-making ($k = 0$).

Given these parameters, the maximum profit for each decision unit $j = 1, \ldots, z^k$ can be specified in the following way:

be necessary for $P_C^* > P_D^*$. If this approach is to be further elaborated, one would have to distinguish

(12) $$P_j^* = z^{m-k} Ri\beta^{m-k} - \frac{3}{2}(z^{m-k})^{\frac{1}{3}}\alpha^{\frac{1}{3}}(i\beta^{m-k})^{\frac{2}{3}}\sigma^{\frac{2}{3}} \quad , \quad j = 1,\dots,z^k \ .$$

Thus the banking firm's maximal total profit is given by the sum of the z^k decision units' maximal profit

(13) $$P_k^* = \sum_{j=1}^{z^k} P_j^* = z^m Ri\beta^{m-k} - \frac{3}{2} z^k (z^{m-k})^{\frac{1}{3}}\alpha^{\frac{1}{3}}(i\beta^{m-k})^{\frac{2}{3}}\sigma^{\frac{2}{3}} .$$

Notice that Equation (13) is quite general: Given the parameters from Assumption (A7), Equation (8) constitutes a special case for $k = m$ and Equation (9) does so for $k = 0$. Also observe that for β^{m-k} sufficiently close to 1 with a suitable choice of k decentralized decision-making is less profitable than pooling units and deciding (participate in the market) on an upper hierarchy level $k < m$. If m is sufficiently large and thus β^{m-k} is sufficiently small, however, the pooling advantage is overcompensated by increasing inefficiency due to hierarchical coordination. The following examples illustrate that in the optimal solution this tradeoff does (and usually will) result in decision-making on an intermediate hierarchy level.

Example 1: We consider a banking firm consisting of a headquarter (decision level k = 0) and two divisions (decision level k = 1). Each division consists of 2 branches operating in the customer market (decision level k = 2). Thus, the structure of the banking firm is given by Figures 1 - 3. For this case, the unique span of control is 2 ($z = 2$), the hierarchy depth m equals 2, and, hence, the total number of decentralized units is $z^m = 4$. Each decentralized unit i (i = 1,...,4) is assumed to have equity resources $R_i = R = 100{,}000$ Monetary Units (MU) available. The demands $D_i = D$ for these resources implied from conductible business are pairwise independent random variables with a symmetric density distribution and strictly positive standard deviations $\sigma = 5000$ MU. If demand exceeds the precautionary capital and thus profitable business cannot be conducted any more, the banking firm faces a fixed

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between the (positive) pooling effect and the (negative) knowledge effect in centralized decision-making.

illiquidity cost $\alpha = 4000$ MU. The rate of return on employed equity capital resources is $i = 16\% = 0.16$. The efficiency parameter β equals 0.95. In this setting, three alternatives of decision-making w.r.t. the employment of equity capital resources exist: totally decentralized participation on the Internal Electronic Market without hierarchical coordination ($k = 2$), central planning without making use of electronic market coordination (pooling all, $k = 0$), and one intermediate-level solution taking advantage of both hierarchical and electronic market coordination ($k = 1$). Applying Equation (13) we are able to compute the maximum profit for all three alternatives and find that the intermediate banking operation is the optimal solution with $P_1^* = 55{,}803$ MU. Applying pure hierarchical or market coordination yields lower maximum profits, namely $P_0^* = 54{,}718$ MU and $P_2^* = 55{,}792$ MU, respectively.

Finally, we can provide indifference results showing under which conditions the alternative decision structure implies identical values of the banking firm's objective function. Generally for $n = z^m$ and $\hat{\beta} = \beta^m$ for $k = 0$ (Assumption (A7)) we find that: $P_C^* = P_k^* \Leftrightarrow$

(14) $$Ri^{\frac{1}{3}}\left(\beta^{m-k} - \beta^m\right) = \frac{3}{2}\alpha^{\frac{1}{3}}\sigma^{\frac{2}{3}}\left(\left(\frac{\beta}{z}\right)^{\frac{2}{3}(m-k)} - \left(\frac{\beta}{z}\right)^{\frac{2}{3}m}\right)$$ [15]

Notice that under the same conditions we find $P_D^* = P_k^* \Leftrightarrow$

(15) $$Ri^{\frac{1}{3}}\left(1 - \beta^{m-k}\right) = \frac{3}{2}\alpha^{\frac{1}{3}}\sigma^{\frac{2}{3}}\left(1 - \left(\frac{\beta}{z}\right)^{\frac{2}{3}(m-k)}\right)$$ [16]

These indifference results illustrate that - depending on the crucial parameters of the banking firm - intermediate-level decision-making may be as good as centralized or decentralized decision-making. In many relevant cases, and particularly for larger values of *m*

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[15] For $k = 0$ both the left hand side and the right hand side of Equation (14) are zero, which is obvious because in this case $P_C^* = P_k^* = P_0^*$. For $k = m$ Equation (14) is reduced to Equation (11).

[16] For $k = m$ both the left hand side and the right hand side of Equation (15) are zero, which is obvious because of $P_D = P_k = P_m$. For $k = 0$ Equation (15) is reduced to Equation (11).

(the hierarchy depth), intermediate solutions will constitute an optimal tradeoff between the aspects in favor of centralized and decentralized decision-making. The next section extends the analysis to the case when demands are not independent.

4. Optimal Banking Operation If Demands Are Not Independent

We now relax the independence assumption (A6), but - for sake of simplicity - assume furtheron, that all demands are identically distributed random variables with Assumptions (A1) through (A5) satisfied, i.e., all demands D_i have an identical variance σ^2. From that it follows that the total variance is given by

$$(16) \qquad Var(\sum_{i=1}^{n} D_i) = \sum_{i=1}^{n} Var(D_i) + \sum_{i \neq j}\sum Cov(D_i, D_j)$$

$$= \sum_{i=1}^{n} Var(D_i) + \sum_{i \neq j}\sum \rho_{ij}\sigma_i\sigma_j$$

$$= n\sigma^2 + \sigma^2 \sum_{i \neq j}\sum \rho_{ij} \ ,$$

where the ρ_{ij}'s denote the (pairwise) correlation coefficients.

In the worst case of perfectly correlated demands ($\rho_{ij} = 1$ for all i, j) as an upper bound we obtain by observing that there are $n(n-1)$ correlation coefficients, each being at most equal to 1

$$(17) \qquad Var(\sum_{i=1}^{n} D_i) = n\sigma^2 + n(n-1)\sigma^2 = n^2\sigma^2 \ .$$

This implies a quadratic increase of variance and thus an at most linear increase of standard deviation.

For the case of decentralized decision units acting independently nothing changes compared to Section 3. For the banking firm as a whole we still obtain maximal total profits to be given by Equation (8) above.

In the case of pooling all n units together, however, the situation changes. Since total variance of demands increases quadratically with n^2 and thus due to Equation (4) precautionary equity capital increases now with $n^{\frac{2}{3}}$, pooling advantages are smaller than in Section 3, but still exist. Thus maximal total profit for the case of centralized decision-making (i.e. pooling n units) are in the worst case of perfect correlation given by

$$(18) \qquad P_C^* = nRi\hat{\beta} - \frac{3}{2} n^{\frac{2}{3}} \alpha^{\frac{1}{3}} (i\hat{\beta})^{\frac{2}{3}} \sigma^{\frac{2}{3}},$$

which checks with Equation (9) except for the exponent of n being now 2/3 instead of 1/3.

Note that in the case of all correlation coefficients being positive, n^2 constitutes an upper and n a lower bound for the increase of variance. Thus Equation (18) is a lower bound for the objective function and Equation (9) is an upper bound.

In the case of arbitrary correlation coefficients (i.e. some being sufficiently negative such that $\sum\sum\rho_{ij} = -n$) total variance (16) may become zero and thus the second term in the objective function (18) may vanish, i.e. we have $P_C^* = nRi\hat{\beta}$ for $\sum\sum\rho_{ij} = -n$.

Comparing Equations (18) and (8) we find that for the structure of Assumption (A7):

$$P_C^* \stackrel{>}{<} P_D^* \Leftrightarrow$$

$$(19) \qquad Ri^{\frac{1}{3}}\left(1-\beta^m\right) \stackrel{<}{>} \frac{3}{2} \alpha^{\frac{1}{3}} \sigma^{\frac{2}{3}} \left(1 - \left(\frac{\beta^2}{z}\right)^{\frac{m}{3}}\right).$$

By comparing Equations (11) and (19) it turns out that they differ only in the following: In the former we have $z^{-\frac{2m}{3}} = n^{-\frac{2}{3}}$ while in the latter we have $z^{-\frac{m}{3}} = n^{-\frac{1}{3}}$.

Similar to Section 3, we can now consider the intermediate-level case for $\rho_{ij} = 1$ and obtain for a decision unit *j* on level *k*

$$(20) \qquad P_j^* = z^{m-k} Ri\beta^{m-k} - \frac{3}{2}(z^{m-k})^{\frac{2}{3}} \alpha^{\frac{1}{3}} (i\beta^{m-k})^{\frac{2}{3}} \sigma^{\frac{2}{3}} \quad , \quad j = 1,\ldots,z^k .$$

Thus the banking firm's maximal total profit is given by the sum of the z^k decision units' maximal profit :

$$(21) \qquad P_k^* = \sum_{j=1}^{z^k} P_j^* = z^m Ri\beta^{m-k} - \frac{3}{2} z^k (z^{m-k})^{\frac{2}{3}} \alpha^{\frac{1}{3}} (i\beta^{m-k})^{\frac{2}{3}} \sigma^{\frac{2}{3}}$$

Comparing Equations (21) and (13) shows that they only differ in the exponent of z^{m-k} being 2/3 here and 1/3 in the former. Again notice that given the structure of Assumption (A7) Equation (21) contains Equation (8) and (18) as special cases for $k = m$ and $k = 0$, respectively. They assume identical values if and only if: $P_C^* = P_k^* \Leftrightarrow$

$$(22) \qquad Ri^{\frac{1}{3}}\left(\beta^{m-k} - \beta^m\right) = \frac{3}{2}\alpha^{\frac{1}{3}}\sigma^{\frac{2}{3}}\left(\left(\frac{\beta^2}{z}\right)^{\frac{1}{3}(m-k)} - \left(\frac{\beta^2}{z}\right)^{\frac{m}{3}}\right)$$[17]

Notice that under the same conditions we find $P_D^* = P_k^* \Leftrightarrow$

$$(23) \qquad Ri^{\frac{1}{3}}\left(1 - \beta^{m-k}\right) = \frac{3}{2}\alpha^{\frac{1}{3}}\sigma^{\frac{2}{3}}\left(1 - \left(\frac{\beta^2}{z}\right)^{\frac{1}{3}(m-k)}\right).$$[18]

Comparing Equations (22) with (14) and (23) with (15) shows that they only differ in the exponent of z being $-\frac{1}{3}(m-k)$ here instead of $-\frac{2}{3}(m-k)$ there.

The following example illustrates the results with the parameter values from Section 3.

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17 For $k = 0$ both the left hand side and the right hand side of Equation (22) are zero, which is obvious because in this case $P_C = P_k = P_0$. For $k = m$ Equation (22) is reduced to Equation (11).

18 For $k = m$ both the left hand side and the right hand side of Equation (23) are zero, which is obvious because in this case $P_D^* = P_k^* = P_m^*$. For $k = 0$ Equation (23) is reduced to Equation (11).

Example 2: We consider the banking firm of Example 1. The parameter values remain unchanged. But in contrast to Section 3 we now assume that the demands are not independent, but perfectly correlated. Thus, pooling advantages are smaller than in Section 3, but still exist.

In this setting, again three alternatives of decision-making w.r.t. the employment of equity capital resources exist: totally decentralized participation on the Internal Electronic Market without hierarchical coordination ($k = 2$), centralized planning without making use of electronic market coordination (pooling all, $k = 0$), and intermediate-level solutions taking advantage of both, hierarchical and electronic market coordination ($k = 1$). Applying Equation (21), we are able to compute the maximum profit for all three alternatives.

For the case of decentralized decision units acting independently nothing changes compared to Section 3. For the banking firm as a whole we still obtain total profits $P_2^* = 55{,}792$ MU. Due to decreasing pooling effects, however, applying pure hierarchical or intermediate-level decision-making yields lower maximum profits than for the case of independent demand, namely $P_0^* = 52{,}931$ MU and $P_1^* = 54{,}504$ MU, respectively. As a result, the optimal solution has shifted from intermediate-level to decentralized decision-making.

For sufficiently small positive correlation coefficients, the intermediate-level solution may become optimal again[19]; and for some correlation being sufficiently negative, the centralized alternative may be optimal.[20]

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19 An example for the case $\sum_{i \neq j} \sum \rho_{ij} \to 0$ has been given in Example 1.

20 Assume that $\sum \sum \rho_{ij} = -n$ implying $\sigma^2 = 0$, $l^* = 0$, $r^* = R$ at the central level. This implies $P_C^* = nRi\hat{\beta}$ and thus large pooling advantages without precautionary capital for centralized decision-making. The corresponding inefficiency is given by $(1-\beta)nRi$, while for decentralized decision-making we obtain as inefficiency: $-\frac{3n}{2}\alpha^{\frac{1}{3}} i^{\frac{2}{3}} \sigma^{\frac{2}{3}}$. For total variance on the central level of zero often P_C^* is much

5. Conclusions And Prospects For Further Research

We have shown that - depending on the values of the relevant parameters - anything may be optimal for the banking firm, i.e. totally decentralized participation on the Internal Electronic Market without hierarchical coordination, centralized planning without making use of electronic market coordination, and intermediate-level solutions taking advantage of both hierarchical and electronic market coordination. Our analysis may help to redesign existing hierarchical organizational allocation processes by showing which level should optimally be selected for investment authority and electronic market participation. Thus the analysis constitutes a tool for inventing more market oriented organizations; it is quite different, however, from the approach of Malone et al. (1999), where inheritance from computer science and coordination theory is used on higher levels of abstraction by considering similarities to also provide tools for inventing organizations. As key parameters favoring pooling demands and thus hierarchical coordination we have identified small correlation, small coordination inefficiency and flat hierarchies.[21] The opposite properties on the other hand are favoring Internal Electronic Market coordination and thus decentralized decision-making. Obviously, this applies particularly to large firms with strongly correlated businesses.

While development of IT for suitable designs may reduce coordination costs such as information processing costs (thus increasing $\hat{\beta}$) for electronic hierarchies and electronic markets, it is questionable whether this reduction is true to the same extent for both. As particularly questionable we consider the relation between agency costs in hierarchies and technological development. Inefficiency may also result from reducing the number of market

better than P_D^*; in Example 2 we obtain $P_C^* = P_0^* = 57{,}760$ and thus a much better result than participants in case of (partial) hierarchical coordination. As our analytical analysis indicates, such factors and developments usually neither imply a superiority or inferiority of pure market or pure hierarchy solutions, but rather influence whether decisions should be made higher or lower in the hierarchy (but neither at the top nor at the bottom).

Our analytical analysis has several limitations. One limitation is that we have assumed a certain level of coordination costs and inefficiency in case of hierarchical coordination via the factor $\hat{\beta}$, but have neither explained why it occurs nor differentiated between different sources of costs and inefficiency. The model for determining precautionary equity capital took into account only fixed, but no variable illiquidity costs, although in reality we usually will have both. Less severe seems to us the assumption of all units being equal w.r.t. demand and thus resources; if they are not, most of our results can still be deduced, but with much more analytical effort.

Of course our analysis is not restricted to the banking scenario outlined above. The model from Section 2 and most of the analysis and discussion in Sections 3 and 4 are directly applicable to other resource allocation problems such as multi-level inventory management. The tradeoff between pooling advantages in case of centralized stocking and less inefficiency (e.g. shorter lead-time and lower transportation costs) in case of decentralized stocking is common in inventory management.[22] There is a vast literature on sophisticated stochastic inventory models, but little application of them in practice, where to the best of my knowledge from a couple of years having worked in the field mainly quite simple models are employed. One reason for this seems to be that the quality of data is often insufficient for application of

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$P_1^* = 54{,}504$ and $P_D^* = P_2^* = 55{,}792$.

21 This is particularly the case, if correlation with adverse signs lead to zero total variance.

22 At this point we want to draw the reader's attention away from the traditional inventory management literature to approaches at the interface to other areas, where - as the author's experience indicates - often more potential for practical improvement is given. E.g. Milgrom and Roberts (1989) analyze the IT-related substitution effects between inventory and communication with customers. Lee and Lee (1999) address the (in practice often poorly solved) coordination between production and marketing decisions.

the sophisticated approaches. In our analysis it turned out that the knowledge of the correlation coefficients is key to the results. While in the financial services field - for reasons of regulation and risk management - correlation data of appropriate quality can usually be obtained, I doubt whether the same is true in most areas of inventory management. This may limit the applicability of the results presented here to this and other resource allocation fields. If appropriate correlation data are (or can be made) available, however, the results are general enough to be applied in these areas as well.

In future research we see a particular need for an improved understanding of the sources of inefficiency in both (electronic) hierarchies and electronic markets (e.g. Reimers (1996)). While analytical modeling may help in understanding which factors are key and which are of minor importance, a lot of experimental and empirical work in these areas needs to be done to understand which costs and inefficiencies vanish due to technological development, which ones can be reduced or even avoided by suitable designs, and which ones resist (or are even fueled by) IT development.

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