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Capital Allocation and Information Processing - A Comparison between Hierarchical and Electronic Market Coordination Mechanisms

by

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Capital Allocation and Information Processing

A Comparison between Hierarchical and Electronic Market Coordination Mechanisms.[+]

Stefan P. Klein and Jens-W. Hinrichs [*]

Abstract

Recent research has dealt with questions of efficient coordination of economic activities. The considered alternatives range from (perfect) markets to (perfect) hierarchies with some hybrid forms in between. One of the main results of this research, especially of transaction cost theory, is that each alternative could be efficient, depending on certain characteristics of transactions and situations. This implies that each activity has to be examined for the appropriate coordination mechanism to choose. The choice of mechanisms has to be reconsidered periodically to avoid inefficient results caused by changing conditions. In our setting we address the problems large international corporations face when operating in a complex and dynamic business environment, trying to allocate investment capital to their decentralized units. The paper investigates whether the incorporation of an internal electronic market into an existing hierarchy can lead to an allocation of the scarce resource which is superior to the allocation resulting from a conventional hierarchical decision process. The underlying model is based on a situation with information asymmetries between the corporate headquarters and the operating units. We compare the capital allocation process with respect to its ability to allocate investment capital efficiently and to the costs of the process. The analysis shows that under certain conditions an internal electronic market is advantageous compared to a conventional hierarchical allocation.

1 Introduction

In an increasingly competitive business environment the efficient identification and evaluation of investment opportunities becomes more and more important for large globally operating firms. Prospective investment projects need to be evaluated quickly for being able to cope with the rapidly changing market conditions. This is especially the case in time-to-market sensitive fields like the computer and communications industry. In these industries the sharp decrease in prices over a relatively short period of time asks for an extremely fast response to new customers needs. Only being the first on the market allows an amortization of the highly specific investments. Additionally, the trend towards globalization creates the need for most companies to evaluate a growing number of investment opportunities, which become even more complex in a diversifying business environment. In order to be able to react to these challenges firms have to organize the capital allocation process in a way that scarce investment capital is efficiently allocated, thus to select the most promising investment opportunities.

Our analysis bases on the classical organizational form of large firms operating in different strategic business fields. The organization identifies, evaluates and decides about investment

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projects in its different areas of activity. Depending on the size and complexity of the projects, this requires manpower and other resources. Over time, the organizational structure is influenced by environmental (market dynamics, globalization) as well as internal factors (growth of the firm, diversification, competence).

This paper analyzes different capital allocation processes with respect to their ability to determine the optimal investment program and with respect to their ability to cope with the changing organizational conditions. We focus on two forms of mechanisms: First, a hierarchical approach, where the information about all investment opportunities is passed up and processed by the hierarchy levels. The decision about the implementation of projects is made at the highest level by a central authority. As an alternative for the allocation of the scarce resources an internal market is considered (for other possible alternatives see Ochsenbauer, 1989). So far market mechanisms were considered to be too expensive because of high transaction costs. With the availability of modern information technology (IT) those information processing and communication costs can be lowered substantially. Under certain conditions electronic market mechanisms become feasible. This is sometimes referred to as the Electronic Market Hypothesis (Malone et al., 1987). Most of the literature in this field investigates the prerequisites for and the use of hierarchical structures, markets and hybrid forms *between* organizations, as inter-organizational institutions (see e.g. Holland/Lockett, 1994). The idea of this paper is to complement a single hierarchical organization with an *internal* market mechanism in order to be able to take advantage of the effects on motivation and efficiency which can be observed in external markets. The results of the internal market allocation are compared to the hierarchical approach to answer the question whether the use of a market inside the hierarchy can cope with the described dynamics and the complexity of the business environment. It is asked, whether the market improves the allocation situation and/or whether it can lower the costs of the allocation process.

For the successful implementation of an internal market an additional problem has to be addressed: participants on external markets usually act in their individual interest. In the given setting an internal market will be embedded in the organization. The goals and restriction of the organization are represented by the central authority but the profit centers have presumably their own objectives. The market situation potentially causes problems if the objectives of both parties are conflicting. Therefore the market has to be enhanced by a mechanism which guarantees that the decentralized units act in accordance to central goals.

As a result we can show, that in the a hierarchy efficient capital allocation is only reached with a certain probability, but not systematically. This due to the information asymmetries which can not be overcome by the hierarchical mechanism, although the costs for information processing are fairly high. If the coordination is supported by an internal electronic market the first-best-solution can be realized systematically. Under certain circumstances the costs of this mechanism are lower then in the hierarchical setting. In a business environment, which is characterized by dynamic changes in market conditions, a trend towards globalization and the growth of the company the market shows a tendency to be superior to the hierarchy as the complexity of the situation rises.

The remainder of this paper is organized as follows: Section 2.1 describes the setting under which the analysis takes place. It is followed by Section 2.2 which presents the desired properties of the allocation mechanism and the criteria we use to evaluate the mechanism. As a reference for the comparison a first-best-solution is developed in Section 3. In Sections 4 and 5 we analyze the two mechanisms for resource allocation with respect to their allocation efficiency and their information processing costs. In Section 6 a first comparison of the differing allocation mechanisms for a static environment is presented. Section 7 analyzes the impact of changes in the business environment on organizational variables and investigates the consequences of change for both mechanisms. We summerize our findings in Section 8 and conclude the paper in Section 9 by looking at the limitations of our analysis and some prospects for further research.

2 Model Settings

2.1 Assumptions

The comparison is based on the following assumptions:

(A1) We consider an organization consisting of H levels of hierarchy with $h = 1, ..., H$ with a central authority on the top level (h=H), referred to as headquarters (HQ) and with I profit centers PC_i with $i = 1, ..., I$ on the lowest level (h=1).

(A2) Every profit center PC_i is able to identify N_i possible investment projects IP_{in_i} with $n_i = 1,..., N_i$.[1] The total number of investment projects sums up to $N = \Sigma_i N_i$. For the sake of simplicity the investment opportunities are assumed to have one cash outflow $c^0 < 0$ at t = 0 and positive cash inflows $c^t_{in_i} > 0$ in the periods thereafter (t > 0). All cash flows are assumed to be deterministic and the initial investment amount c^0 is assumed to be identical for all projects.

(A3) Investment decisions are made on the basis of net present value (NPV). The discount rate r represents the opportunity costs of capital at the external market and is assumed to be identical for the headquarter and all departments. Each project has a unique NPV and only investment projects with positive NPVs are being considered.

(A4) The headquarter has a limited amount C of free capital resources available which it intends either to put at the profit center's disposal for investment or to invest at the external capital market. The profit centers have no access to the external capital market. Given c^0, with the amount C exactly m (with $m < \Sigma_i N_i$) projects can be completely implemented, i.e. $C = m \times c^0$.

(A5) Each unit in the hierarchy has a span of control of s.[2] Units in the intermediate hierarchy levels are able to manage s subordinate units. On the lowest level, each profit center PC_i is able to implement s projects. For the implementation of all m projects $I = m/s$ profit centers will be necessary. Given s, for each number m of investment projects the number of hierarchy levels H can be determined from the relationship $m = s_{(0)} \cdot s_{(1)} \cdot ... \cdot s_{(H)} = s^H$ as

$$H(m,s) = \left\lceil \frac{\ln m}{\ln s} \right\rceil .$$[3]

(A6) Because of information asymmetries the headquarter has no reliable information about the possible investment projects. The departments have complete information about their own projects, but do not possess knowledge about the projects of other units.

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[1] Since the number of identified investment opportunities will differ for each of the profit centers, the variable N has to carry the subscript i to identify the profit center it is belonging to.

[2] The span of contol usually denotes the number of subordinates managed by a higher level manager (Krüger, 1994, p.62 f.).

[3] To take into account that a hierarchy has integer number of hierarchy levels, the result of ln m/ln s is rounded up to the next higher integer number.

(A7) The investment projects are assumed to be independent of each other.[4]

(A8) All investment projects are assumed to be executable in fractions $f \in [0,1]$.

2.2 Desired Properties of Allocation Mechanisms: Efficiency at Minimal Costs

In the following comparison of capital allocation mechanisms we address two key questions:

1. How good is the mechanism in solving its allocation task, i.e. does it lead to an efficient allocation?

Under the assumptions given, allocational efficiency can be understood as a state in which no reallocation of the scarce resource capital increases the sum of NPVs of the implemented investment projects. To determine an efficient allocation the following general algorithm can be applied:

Let ***p*** denote the set of all possible investment projects IP_{in_i}. To achieve an optimal allocation it is necessary to identify the set of optimal projects ***o*** out of the possible projects ***p***.[5] An optimal selection of projects for the existing resources can be reached in two steps:

> 1) Rank the possible projects with respect to their NPV in descending order with $NPV_1(IP_{in_i}) > NPV_2(IP_{in_i}) > ... > NPV_N(IP_{in_i})$. This yields the set of *ranked* possible projects ***r***.
>
> 2) Select the *m* best projects, starting from $NPV_1(IP_{in_i})$. This results in the set of optimal projects ***o***.

2. How much does it cost to apply an allocation mechanism?

Our analysis focuses on two types of costs: Misallocation costs and information processing costs.

Misallocation Costs

If a mechanism fails to select the *m* optimal projects, only a suboptimal solution of the allocation problem occurs. Such a solution could be denoted as ***s*** and the respective loss can be quantified as

$$MC = \Sigma_{i=1,...,m}(\boldsymbol{o_i} - \boldsymbol{s_i}).$$

In this equation the NPVs of the projects selected in the suboptimal solution are being compared to the ones of the optimal solution. MC is the loss in NPV which is caused by the misallocation. This value can be used as a measure for the efficiency of the respective mechanism.

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[4] This avoids side effects of the investment projects, like technological externalities, e.g. existing economies of scale or scope.

[5] The dimension of ***p*** is *N*, which is the total number of projects of all business units (with $N = \Sigma_i N_i$) The dimension of ***o*** is only *m*, which represents the number of feasible projects with the given resources (with $m = C / c^0$).

Information Processing Costs

In order to come to a useful investment decision information about each project has to be processed. The specialized profit centers have faster and cheaper access to market information than the headquarter or other levels in the hierarchy. In addition the information is usually specific and each profit center has specialized information processing capacity (experience, trained staff ...) so that project evaluation can be done faster, better and with less detailed information by the specialized unit, than by any other unit. If the information could be used for a investment decision on the lowest level (h=1) of the hierarchy the information processing costs would be

$$k^{+} = k^{+}(1).$$

If the decision about the investment project is made on higher levels, the information about the projects has to be processed in a certain way. The above hierarchy level, which is usually the supplier of the investment capital has less or even no expertise in the respective market to which the capital requiring projects belong. Thus, a detailed description of the project is needed. This description has to allow a consistent inter-subjective comparison between projects which belong to heterogeneous markets. Additionally the Information has to be standardized in order to enable an interpretation and a comparison of the projects. Higher levels will have to aggregate the information, to be able to handle the growing number of projects. Each of these activities is costly. Thus, the total information processing costs per project depends on the number of processing steps, i.e. hierarchy levels

$$k^{+} = k^{+}(H) .$$

The costs will increase with each additional hierarchy level because on each level additional information processing (especially aggregation) is necessary.

An optimal allocation mechanism minimizes the sum of both types of costs, misallocation costs and the costs of the capital allocation process. In the next sections we analyze the allocational efficiency and the costs of two mechanisms: a classical hierarchical decision process and the allocation via an internal electronic market. A first-best-solution will serve as reference with respect to the other solutions.

3 First Best Solution

This section’s objective is to construct a measure which allows an assessment of the quality of the capital allocation processes. We skip Assumption (A6) and suppose that the headquarter has no disadvantage compared to the departments concerning its access to information. It is assumed to be able to collect and process all information about the projects itself. The information can be processed at no cost. In this framework profit centers are only needed for operational purposes and for efficient execution of central investment decisions. The objective of the headquarter is to maximize the sum of NPVs (NPV^{HQ}) by selecting those investment projects with the (ranked) largest NPV^{IP} up to the limiting financial restriction.

The allocation problem can be stated as follows:

$$NPV^{HQ} = \sum_{i=1}^{I} \sum_{n_i=1}^{N_i} x_{\mathrm{in}_i} \cdot NPV_{in_i}^{IP} \rightarrow \max!$$

$$s.t.$$

$$\sum_{i=1}^{I} \sum_{n_i=1}^{N_i} x_{in_i} \cdot (-c^0_{in_i}) \leq C$$

$$0 \leq x_{ini} \leq 1$$

$$\forall i, \forall n_i$$

3.1 Allocation Efficiency and Misallocation Costs

As stated in Assumption (A4) the given amount *C* finances exactly *m* projects, each with an investment volume of c^0. Since each project has a unique NPV it will be either fully realized or not implemented at all. This is due to the fact that if two different projects were realized in fractions only, shifting the capital to the project with the higher NPV would always increase the value of the objective function. As a result, the x_{in} which are potentially $\in$ [0, 1] will in fact be exactly equal to one (for the *m* "good" projects) or zero (indicating the *N-m* "bad" projects) maximizing the objective function. The selected projects constitute the set ***s*** described above. Since the linear programming algorithm is the mathematically exact mechanism to select a maximizing combination under the given constraints, ***s*** will be equal to ***o*** and thus the misallocation costs will equal zero. In this case, when all projects are known to the decision maker, an efficient allocation of investment capital will be achieved and no misallocation costs will occur, thus

$$MC^{first} = \Sigma_{i=1,\dots,m}(\boldsymbol{o}_i - \boldsymbol{s}_i) = 0.$$

3.2 Information Processing Costs

Since the cash flows of the investment projects can be determined at no cost, the information processing costs are zero.

IPC = 0

This solution of the allocation problem is of course hypothetical. Still, it can serve as an idealistic reference with respect to the quality of the solution caused by the more realistic mechanisms. Their allocation efficiency and their ability to process information can be compared to this first best solution in order to identify the second best mechanism.

4 Hierarchical Allocation

In reality the headquarter does not have all necessary information especially when the investment projects stem from heterogeneous markets. In addition, the headquarter does not have unlimited information processing capacity. This is why the project information is gathered and aggregated by the different levels below the headquarter like it is described in Section 2.2. Since on every hierarchy level information is aggregated and condensed, only a fraction of the original information arrives at the headquarter. This is true for the quality as well as for the quantity of the information. With this reduced information the headquarter will determine the NPV of an investment opportunity. Since it is not acting on the complete set of information the NPV might differ from the actual NPV that would be calculated with full information. The estimation of a NPV can be understood as taken from a normal distribution with

$$\tilde{NPV} \sim N(NPV, \sigma).$$

$\tilde{NPV}$ has an expected value of the actual NPV and a standard deviation of σ. Because on each level of the hierarchy the information is aggregated the estimation of $\tilde{NPV}$ is becoming less precise with growing *H*. Thus, the standard deviation of the estimation is strictly increasing with the number of hierarchy levels

$$\sigma = \sigma(H) .$$

The formal description of the allocation problem for the hierarchy remains almost unchanged from the problem description of the first-best-solution. But there is a difference with respect to the NPVs. The linear program is now based on the estimated values $\tilde{NPV}_{in_i}{}^{IP}$.

$$\tilde{NPV}^{HQ} = \sum_{i=1}^{I} \sum_{n_i=1}^{N_i} x_{in_i} \cdot \tilde{NPV}_{in_i}{}^{IP} \rightarrow \max!$$

$$s.t.$$

$$\sum_{i=1}^{I} \sum_{n_i=1}^{N_i} x_{in_i} \cdot (-c_{in_i}^0) \leq C$$

$$0 \leq x_{in_i} \leq 1$$

$$\forall i, \forall n_i$$

4.1 Allocation Efficiency and Misallocation Costs

The linear program now selects the projects with the best $\tilde{NPV}s$. Since their expected values are equal to the actual NPVs, the set of selected projects ***s*** will in most cases be corresponding to the optimal selection ***o***. In these cases the misallocation costs are zero. With a positive probability though, the estimates of some $\tilde{NPV}s$ will be incorrect, since they are drawn from normal distribution with σ > 0. For sufficiently large *H* and thus σ(*H*) these incorrect estimations can lead to a solution, where projects that should be carried out are dropped in the favor of projects with in fact lower NPVs. Such a selection causes misallocation costs. Since there is a certain probability that this will occur, the expected value of the misallocation costs is positive

$$E(\mathrm{MC}^{\mathrm{H}}) > 0,$$

$$E(S_{i=1,\ldots,m} (\boldsymbol{o}_i - \boldsymbol{s}_i)) > 0.$$

The probability for a suboptimal selection of projects is increasing with σ(H). This is due to the fact that with a growing distance to the source of information the estimation error for each project is growing. Thus, the probability is rising that a lower NPV project is selected instead of a higher NPV project because of wrong estimations. For a growing σ the distribution functions of the estimated NPVs will be increasingly overlapping. Thus, the probability is rising that additional projects will be subject to an incorrect selection due to estimation errors. An increasing number of hierarchy levels thus leads to an increase in the expected value of misallocation costs.

4.2 Information Processing Costs

In the hierarchical setting each identified project will be evaluated. Thus, the costs of information processing depend on N, the total number of investment projects, with

$$N = \Sigma_i N_i .$$

Like stated above, the information processing costs per project depend on the number of hierarchy levels in the way

$$k^+ = k^+(H) ,$$

since additional information processing is necessary on each level. This leads to total costs of the information processing activities inside the hierarchy. These costs are given by the product of the total number of projects and the information processing costs per project, depending on the hierarchy level:

$$IPC^H = k^+(H) \cdot N.$$

Following Assumption (A5) the cost function has to be modified in the following way:

$$k^+(H) = k^+\left(\left\lceil \frac{\ln m}{\ln s} \right\rceil\right)$$

which results in information processing costs of

$$IPC^H = k^+\left(\left\lceil \frac{\ln m}{\ln s} \right\rceil\right) \cdot N .$$

As a result we can state, that a hierarchical mechanism may allocate the scarce investment capital efficiently. But compared to the first best solution misallocation costs have to be expected with a certain probability. Those misallocation costs tend to be higher with a growing number of hierarchy levels. Additionally, the information processing itself is costly and depends on the structure of the hierarchy and the number of identified investment projects.

5 Internal Market Allocation

In this section we are going to consider a market approach, where the local knowledge of the profit centers will be used locally, thus avoiding the high costs of information processing for the units on the above hierarchy levels. In addition, the information about the overall investment situation and the scarcity of investment capital will be implicitly incorporated into the profit center's calculation. We install an internal market and investigate its effects on misallocation and information processing costs. It can be shown that a market mechanism can facilitate a reallocation, which systematically substitutes "good" for "bad" projects. This mechanism will lead to an efficient allocation, with usually lower information processing costs than in the case of a hierarchical allocation.

5.1 Incentive Compatible Compensation Schemes

In the case of an internal market investment decision rights are assigned to the profit centers.[6] The competence of the headquarter is then restricted to strategic issues and financial control. Given this autonomy the decentral units are able to pursue their own objectives. Under asymmetric information their behavior cannot be monitored by the central authority. This creates a problem if the decentral goals conflict with the headquarters objective function. In this case the departments may increase their own utility to the detriment of the headquarter's objectives. Thus, a mechanism has to be found which avoids this behavior and leads the profit centers to act in accordance to the central goal. The common (hierarchical) approach to cope with this problem is that profit centers are committed to objectives and behavioral rules imposed by the headquarter. Additionally, control and threats are necessary to assure that profit centers actually act in accordance with the rules and objectives. Obviously means like control and punishment are likely to have negative motivational effects on decision makers in the profit centers. Thus, a differing approach is the harmonization of the headquarter's and profit centers' objectives by using incentives. In this concept a so called "incentive compatible compensation scheme" is created in order to give the profit centers a strong incentive to act directly in the interest of the headquarter and (in our case) to avoid inefficient allocations because of differing individual goals. A compensation scheme is called incentive compatible, if each decision, which improves the welfare position of the decentral decision maker also improves the welfare position of the delegating central authority (Laux, 1995).

Example:

Given all investment opportunities, the HQ aims to maximize the residual NPV after compensation of decision makers. In this situation incentive compatibility can be achieved by tying the decision makers compensation to the NPV of the projects. Formally spoken, the compensation scheme has to be a strictly monotonically growing function of the residual NPV. In the special case of a linear function, this can be formally described as follows:[7]

$$S_t (1 + r)^{-t} \times P_t = a \times S_t (1 + r)^{-t} \times (C_t - P_t), \quad \text{with } a > 0$$

$$\Leftrightarrow \quad S_t (1 + r)^{-t} \times P_t = a/(1 + a) \times S_t (1 + r)^{-t} \times C_t$$

In the remainder of this paper we will assume that decision makers' (incentive compatible) compensation is linearly related to the NPVs of the investment projects. Thus, they are incited to select investment projects with the highest NPVs. An existing incentive compatible compensation scheme gives the opportunity to neglect the explicit consideration of decision makers' goals and to focus the illustration on the NPVs alone without loss of generality.

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[6] The special case of decentralization of investment decisions is often refered to as investment center concept.

[7] $S_t (1 + r)^{-t} \times P_t$ denotes the NPV of compensation (payment) and $S_t (1 + r)^{-t} \times C^t_{in}$ denotes NPV of project cash flows.

Given this compensation scheme, each profit center is encouraged to participate in the internal market with its projects. This is due to the fact that because the internal market gives the opportunity to increase the sum of net present value of the compensation payments for market participants. This is achieved by a sharing rule, which is applied when a market transaction takes place: In each transaction the amount c^0 is exchanged between buyer and seller. This gives the buying profit center the opportunity to carry out a project, which would not be executable without the additional capital. With this new project the unit will thus receive an additional payback depending on the project's NPV. Since the profit center aims to maximize the net present value of its compensation payments, it will be willing to pay a price to obtain the capital for this marginal project. The unit will be interested in buying the additional amount of capital as long as the price is lower than the additional compensation it obtains. The same applies for the seller: a profit center will give up a project (and with it the compensation) if it can participate in the compensation of the buying profit center. Of course this new compensation must be higher than the compensation resulting from the original project. The compensations stemming from the seller's and the buyer's marginal project constitute an interval. If the market sharing rule determines an actual "price" in between the limits of this interval, both units take advantage of the market transaction and hence will engage in the market transaction.[8] Since the compensation scheme is a strictly increasing function of the project-NPV, all market transactions are also in the interest of the central authority.

5.2 The Market Mechanism

For the allocation of the scarce capital an internal market is now established. All profit centers are able to participate in the transactions of this internal market. The investment capital is allocated heuristically by the headquarter and each profit center receives a certain amount. This allocation of investment capital will only by chance be efficient, in most cases it will be sub-optimal. Given this situation and the incentive compatible compensation scheme above, the profit-centers know that individual improvements are possible via a market-based reallocation. This reallocation process consists of four steps which are specified as follows:

1. In a first step each profit center obtains one or more portions c^0 of investment capital. Under the assumptions given the initial distribution of the capital over the profit centers is irrelevant for the efficiency of the final allocation (Coase, 1960).
2. Then each profit center ranks its investment projects according to the respective NPVs.
3. Given the capital budget the profit centers can identify two "marginal" projects: MPR[9] is the project with the smallest NPV still being carried out. The project MPNR is the first project which cannot be realized because of the financial constraint.
4. In a fourth step each profit center formulates its demand and supply strategy. The profit center demands capital for the project MPNR and thus gives a ***limited bid-order*** into the market, with the limit set to the NPV of the project MPNR. The unit also acts as a supplier for its capital otherwise tied to project MPR and formulates a ***limited ask-order*** with the NPV of its project's MPR.
5. In the fifth step, the market mechanism matches supply and demand in order to determine the market price. This mechanism works as follows: Since the I profit centers specify

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[8] For example, the price could always be determined exactly in the middle of the intervall. Thus both units would be participating equally in the improvement in NPV.

[9] MPR is short for the marginal project which is still realized under the given budget constraint, whereas MPNR is short for the marginal project which is not realized.

supply for one MPR and demand for one MPNR there are exactly *I* ask-prices and *I* bid-prices in the market. The profit center with the highest bid-price and the one with the lowest ask-price (with bid-price > ask-price) are determined to exchange the investment amount c^0.[10] After the transaction these two participants have to evaluate one new marginal project. The marginal projects of the other units are left unchanged.

Steps three to five are being repeated until no further transaction occurs. This marks the end of the reallocation process.

5.3 Allocation Efficiency and Misallocation Costs

The market mechanism is designed in such a way, that the exchange of the capital portion c^0 is always directed from the least best still executed project to the best not executed project. This results in the maximum reduction of misallocation costs in each market iteration. An efficient allocation will be achieved after a maximum of *m* iterations: Each profit center *i* is able to specify its m_i projects that can be carried out with the given capital budget and the N_i-m_i projects which can not be realized. The potentially realizable projects of all profit centers can be ranked by NPV, which results in the set ***r***. The other projects, which will not be realized under the given capital allocation can be ranked into the set ***r’*** . The market mechanism leads to an exchange between these two sets in a way, that in every iteration the least best project in ***r*** is substituted by the best project in ***r’***. Since the set ***r*** has the dimension *m* it follows, that the maximum number of market transactions is limited to *m*. This maximum of market transactions will occur in the situation, when all *m* projects have to be exchanged. This is the case, when the set of elements of set ***r*** is perfectly disjunctive from the set of elements of ***o***, the set of optimal projects. In this case all *m* "bad" projects have to be substituted by "good" projects, which takes exactly *m* iterations. Because every profit center has an incentive to perform market transactions it will evaluate new projects and take them to the market. Thus, the reallocation process will not stop as long as a project from ***r’*** can be exchanged by one of ***r***, increasing the sum of NPVs. It follows that

$$MC^{IEM} = \Sigma_{i=1,\dots,m}(\boldsymbol{o}_i - \boldsymbol{s}_i) = 0.$$

5.4 Information Processing Costs

An internal market mechanism that supports a companywide reallocation of resources must be supported by appropriate IT. An electronic marketplace must be provided which facilitates trading from all locations, where the company is doing business. The results of the trading process must be traced and trades must be settled. Thus the costs of development and installation of such an IT infrastructure are quite high. Once the infrastructure is implemented though the variable costs borne out of the use of the market place are neglectable. Thus the costs of the infrastructure can be assumed fix. With the decrease in prices in the IT sector it is likely that these costs are decreasing over time (t). Thus, for the installation of the internal market the infrastructure costs are assumed to be

$$IS = IS(t).$$

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[10] We take this specialized market mechanisms for simplicity of illustration. It can be shown, that the allocational efficiency is reached even if different market mechanisms are implemented (e.g. double auction, auction markets).

In order to be able to specify capital demand and supply the investment projects needs to be evaluated by the profit center that identified the project, like described in Section 2.2. This results in costs of $k^{+}(1)$ per project which takes part in the market process. The total sum of costs is determined by the number of projects that go into the market clearing process as capital demand and supply.

Supposing that the initial allocation is optimal no market transaction occurs and the process terminates. In this case at least each of the *I* profit centers had to evaluate two projects and the costs are restricted to the *minimum* costs:

$$IPC^{IEM} = IS + 2 \cdot I \cdot k^{+}(1)$$

If the initial allocation was not efficient, reallocation over the internal market will start. The number of reallocation steps to reach an efficient allocation depends on the initial allocation and on the distribution of the investment projects over the profit centers. As it has been shown above, the maximum number of market transactions is limited to *m*. After each market transaction one new project has to be evaluated and described on each side of the transaction. So the *maximum* costs are:

$$IPC^{IEM} = IS + 2 \cdot (I + m - 1) \cdot k^{+}(1)$$

The situation, where ***r*** is perfectly disjunctive from ***o***, is extremely unlikely. For this to happen, the distribution of investment capital over the profit centers must be in such a way, that no project of the globally optimal solution can be executed with the given budgets. With the exception of this case, the evaluation costs for the market transactions are always much lower. Thus, for the internal market mechanism we can state that it will lead to an efficient allocation and reach the first best solution. The costs of this mechanism stem from the initial infrastructure investment and from the necessary information processing activities, depending on the number of profit centers and the number of feasible projects.

6 Comparison in a Static Environment

In a first step the capital allocation mechanisms considered are being compared with respect to the information processing costs. Both mechanisms process information about the *N* identified investment projects and come to a decision whether a project should be implemented or not. Since the information processing associated with the investment decision is costly the question has to be addressed which mechanism causes lower costs for a given *N*. The costs of the hierarchical mechanism are increasing with *N*, the costs of the market mechanism are independent of it. Thus, there should be a critical number of projects N* for which the superiority of the mechanism switches from the hierarchy to the market solution.

The critical value of N* can be determined by equating the information processing costs for both mechanisms:

$$k^{+}\left(\left\lceil \frac{\ln m}{\ln s} \right\rceil\right) \cdot N = IS(t) + 2 \cdot (m/s + m - 1) \cdot k^{+}(1)$$

$$\Leftrightarrow \qquad N^*_{max} = \frac{IS(t) + (2(m/s + m - 1) \cdot k^{+}(1)}{k^{+}\left(\left\lceil \frac{\ln m}{\ln s} \right\rceil\right)}$$

Thus, N* is a function of t, m, s and $k^{+}()$. Depending on these parameters the value N* represents the number of investment projects, where a switch from one mechanism to the other takes place.

As it was shown in Section 5.4 the costs of the market allocation process depend on the initial allocation of investment capital. This effect is not modeled explicitly but can be taken into account by using the minimum and the maximum cost function described in Section 5.4 as numerator in the above equation. This leads to two values of N*: N^*_{min} will be determined if the minimum cost function is used. N^*_{max} results for the maximum cost function, as it is shown in the equation above. In situations where the number of potential investment opportunities is smaller than N^*_{min} it is cheaper to allocate the capital hierarchically. If *N* exceeds N^*_{max} an internal market is cheaper than a hierarchical allocation. In a situation where $N^*_{min} < N < N^*_{max}$ the optimal choice of the mechanism depends on the ex ante distribution of the investment capital.

Figure 1 illustrates this relationship. In the diagram the two horizontal lines represent the upper and the lower bound of the information processing costs of the internal market. The line with the positive slope represents the information processing costs of the hierarchical mechanism:[11]

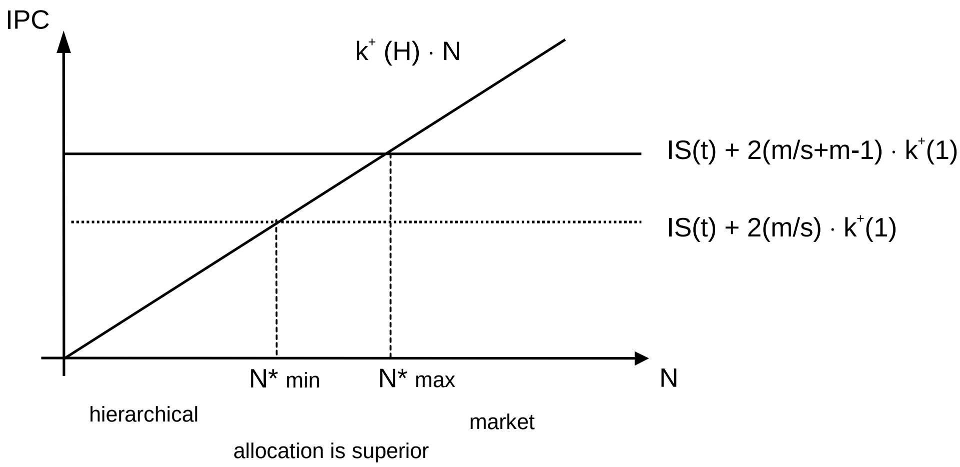

Figure 1) The critical values N^*_{min} and N^*_{max}.

In a second step the analysis is now extended with respect to misallocation costs. As shown in Section 5.3 the misallocation costs of the internal market are zero. This is due to the fact that the market mechanism will reallocate the capital until no improvement is possible anymore. Thus, an internal market mechanism causes only information processing costs. The analysis

[11] Although the cost function is not continuous in N, because N is $\in \mathbb{N}$, it is strictly increasing with respect to consecutive discrete values N. For sake of simplicity, we illustrate the cost function continuously.

for the misallocation costs in the hierarchy is not that straightforward. We can state, that there is a positive probability that misallocation costs occur in a static environment, as argued in Section 4.1. The level of these costs has not been calculated analytically. Merely the maximum of these costs can be determined. It is reached if, due to massive distortion of information, the *m* worst projects are being selected from the ranked set of possible projects. The maximum misallocation costs can be added to the information processing costs in order to calculate the maximum of total costs of the hierarchical allocation mechanism. These maximum costs (max TC) are represented by the dotted line in Figure 5. The actual value will, with a positive probability, be somewhere in between the maximum and the simple information processing costs.

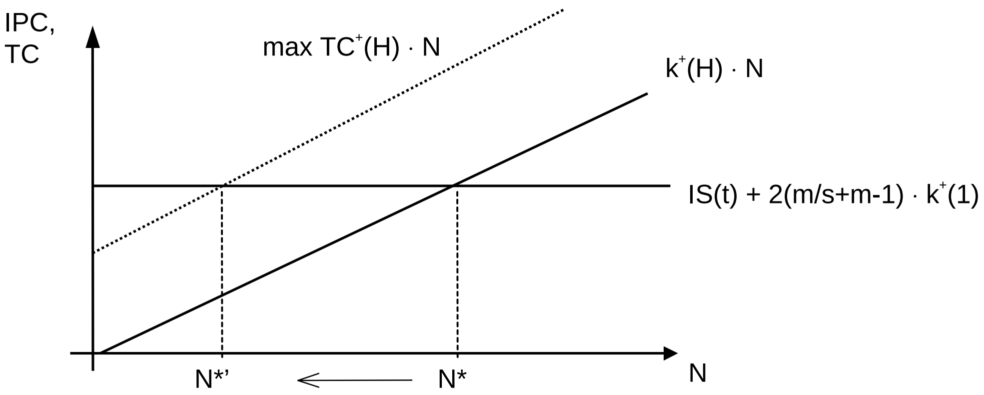

Figure 2) Effect of misallocation costs.

Although the misallocation costs are not determined analytically, we can state that the these costs cause a shift of N* to the left, no matter how large the actual value really is. Thus, the implementation of an internal market becomes attractive already for a lower number of projects.

7 Comparison in a Dynamic Environment

So far we have analyzed the capital allocation process in a stable environment. Since usually the business environment is changing in manifold ways, the analysis has to be extended for being able to draw conclusion about the performance of the allocation mechanism with respect to efficiency and cost aspects.

Three main drivers that determine the complexity of investment decisions can be identified:

a) dynamics of market and product changes (a)
b) the growth of the firm (b)
c) the globalization and diversification of activities of the firm (g)

These parameters have an impact on the organizational structure of the firm and cause changes in the variables of our model in the following way.

An organizational answer to the growing dynamics of the business environment is to reduce the span of control. This is due to increasing complexity of the business environment on the one hand and on the other hand due to the pressure towards innovation in products and processes (Krüger, 1994, p.62 f.). Thus we can propagate the following relationship

(A9) $s = s(\alpha)$, where s is decreasing in α.

The growth of the firm enables it to realize more investment projects. This relationship results in

(A10) $m = m(\beta)$, hence an increase in β leads to an increase in m.

To be able to handle a growing number of projects with a smaller span of control, the firms have to create more and more diversified profit centers and additional hierarchy levels. The relationship between the number of hierarchy levels H and both, the span of control s and the number of projects m was

$$H = \left\lceil \frac{\ln m}{\ln s} \right\rceil.$$

Given that function, the number of hierarchy levels H is strictly increasing in m and decreasing in s. The growing dynamics in the business environment and the growth of the firm itself will thus lead to an increase in the number of hierarchy levels, because of Assumptions (A9) and (A10).

The third factor, globalization and diversification of the activities of the firm leads to an increase in N, the number of possible investment projects

(A11) $N = N(\gamma)$, where N is increasing in γ.

For this factor we have shown that a critical value N* exists, for which the decision for a certain mechanism switches. Thus, with increasing N (c.p.) a change from a formerly hierarchical allocation mechanism to a market allocation will become more and advantageous. But the increase in complexity and number of potential investment projects has also an impact on the capital allocation process. It leads to problems in the allocation of scarce investment capital which concern

a) the costs of information processing inside the firm and
b) the efficiency of the capital allocation mechanism.

We will now take a look at the consequences of these developments. First we focus on the information processing costs for both, hierarchy and market.

In a first step an isolated increase or decrease in the number of hierarchy levels is considered. Such a change could stem from strategic or operational decisions implying a reorganization of the firm. The equation for N* can be simplified to:

$$N^*(h) = \frac{IS(t) + 2(m/s + m - 1) \cdot k^+(1)}{k^+(H)}$$

In the case of an isolated increase in the number of hierarchy levels the value of N* will be decreasing. This is because for any *H'* > *H* for the information processing costs it holds that $k^+(H') > k^+(H)$. The denominator of the above expression is larger for *H'* whereas the numerator remains constant. Thus, the resulting N*' will be smaller than N*.[12] The following figure illustrates this relationship.

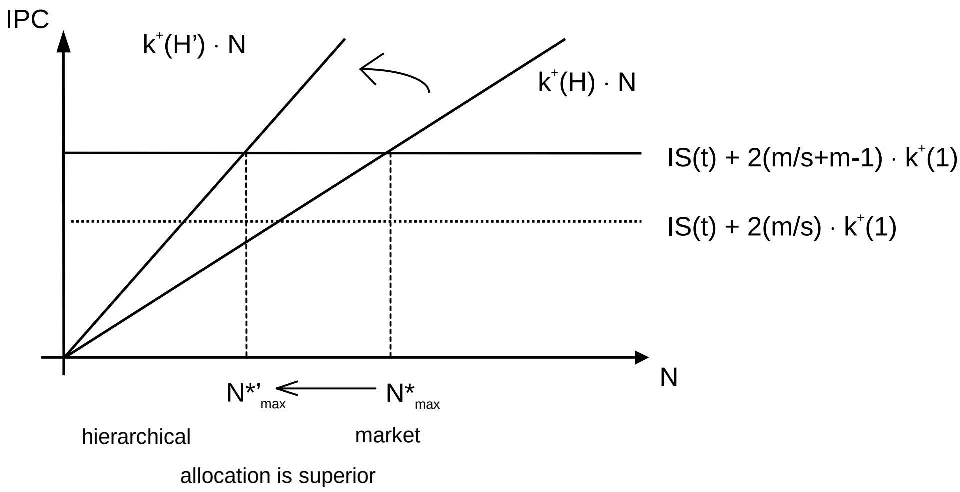

Figure 3) Effect of an increase in *H* on N*.

As a result we can state, that with an increasing number of hierarchy levels a hierarchical mechanism can evaluate less projects than a market mechanism at the same costs. The investment into the IT infrastructure for an internal market mechanism makes sense already for lower numbers of identified projects. It also follows, that companies which, for operational reasons, have to work with a fairly large number of hierarchy levels should consider a decentralization of allocation and coordination tasks. Coordination activity may be cheaper using an internal market mechanism.

The analogous consideration of course applies in the case of a decreasing number of hierarchy levels: for each H' < H the corresponding N*' will be larger than N*. Thus, in cases of a flat hierarchical structure the infrastructure and information processing costs of a market might exceed the costs of the hierarchical setting.

[12] Investigating the development of N* for *H* => ¥ results in an infinite growth of the hierarchical information processing costs and thus N* approaches zero.

If the company is growing the financial basis *C* for investment projects is presumably growing too. Since *m* equals C/c^0, the firm is able to implement a growing number of investment projects. An increase in *m* has two opposite effects on N*. On the one hand, for a given span of control, the hierarchy has to grow in order to handle the additional projects. But with a growing number of hierarchy levels the information processing costs are increasing. N* will be lowered, as shown above. On the other hand each additional project will also increase the maximum and minimum costs of the information processing using the internal market. This leads to an increase in N*. To determine the aggregate effect, the influence of an increase in *m* on numerator and denominator has to be investigated in more detail.

The maximum information processing costs using the internal market were

$$IPC^{IEM} = IS(t) + 2(m/s + m - 1) \cdot k^{+}(1) .$$

These costs are linearly increasing with each additional project by the factor $k^{+}(1) \times (2/s + 1)$.

The information processing costs in the hierarchy were

$$k^{+}(H) = k^{+}\left(\left\lceil \frac{\ln m}{\ln s} \right\rceil\right).$$

In this equation additional projects cause higher costs only, if the hierarchy has to be extended by another level. Thus, the information processing costs in the hierarchy remain usually stable while *m* is increasing. It follows, that with a linear growth in the numerator and a constant denominator the effect on N* is positive. This is represented in Figure 4 by a shift from N* to N*'.

In the critical case, where because of an additional project an additional hierarchy level has to be implemented the cost curve turns to the left, resulting in a higher slope. Whether N* is decreased or increased depends on the actual cost function $k^{+}(H)$. If the additional information processing costs caused by the new hierarchy level are extremely high, they may compensate the increase in the costs of the market, leading to a decrease in N*. If they are moderate, the aggregated effect on N* is still positive. This case is illustrated by Figure 4 where N*' shifts to N*".

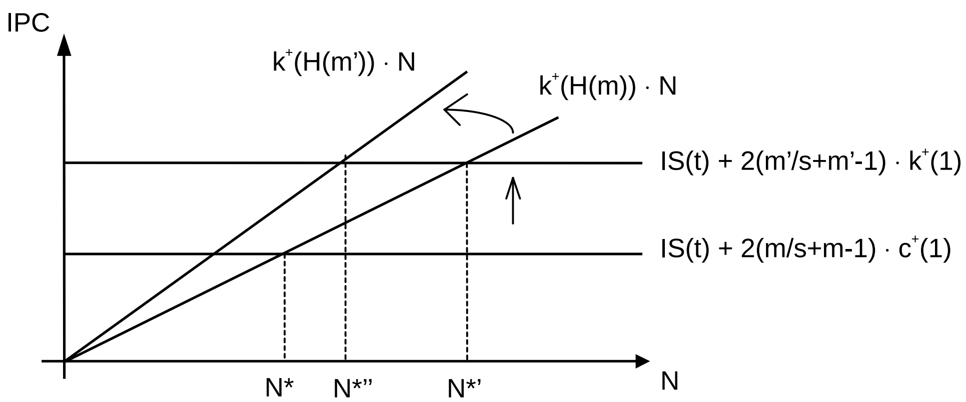

Figure 4) Effect of an increase in *m* on N*.

The last effect we consider is the general tendency towards sinking IT costs. In our setting sinking IT costs imply sinking fixed costs for the implementation of the market infrastructure. This leads to a parallel shift of the cost curve of the market information processing costs. Since the installation of an internal market is now cheaper, the use of the market mechanism makes sense already for a lower number of investment projects. Thus, N* is decreasing.

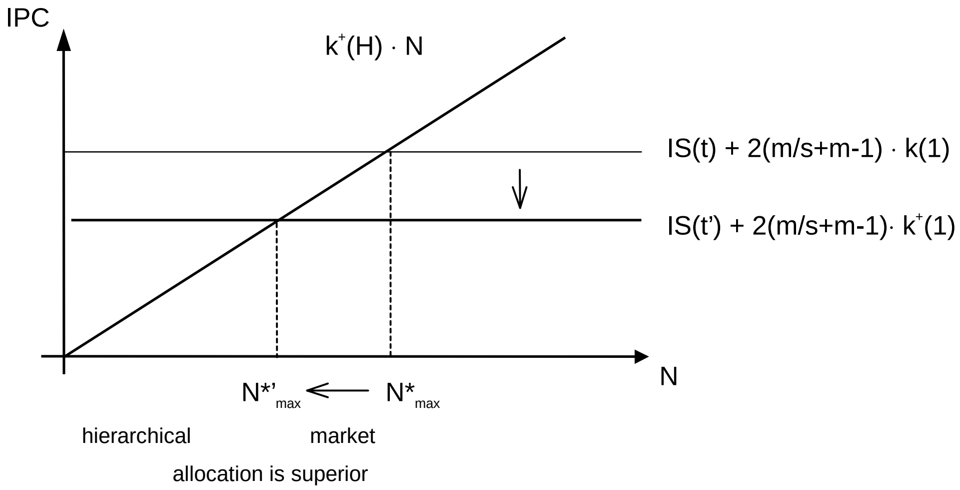

Figure 5) Effect of sinking IT costs on N*.

For the misallocation costs in a dynamic environment we can state the following: the market mechanism in this setting will reach an efficient allocation. This result will be achieved independently of the dynamics of the environment. Thus, no misallocation costs occur, the market again causes only information processing costs.

The misallocation costs in the hierarchy are influenced by the number of hierarchy levels because the standard deviation σ is increasing with *H*. The probability of higher misallocation costs increases as the hierarchy grows. We have not shown analytically to which extent this increase happens. Still, we can state that misallocation costs occur with a positive probability and the total costs of the mechanism will be higher than the simple information processing costs. The maximum of the misallocation costs however is not influenced by the number of hierarchy levels.

8 Summary

In order to allocate scarce investment capital information about the multitude of investment opportunities has to be processed efficiently in order to come to an optimal investment decision. For that reason mechanisms have to be developed that guarantee allocational efficiency of the investment decision at low costs of information processing. In a classical hierarchical setting we compared two mechanisms with respect to their ability to solve this task: a conventional approach to overcome information asymmetries by information passing from low level profit centers to the headquarter with investment decisions remaining on the central level. And a new and innovative approach with an implementation of an internal electronic capital markets that allows reallocation of investment capital driven by individual interest of decentral decision makers. To select the appropriate mechanism the costs of applying these mechanisms had to be taken into account. We concentrated our analysis on two types of costs: the costs that stem from a non-optimal allocation of the investment capital and the costs of the information processing activity caused by the mechanism. As a result we were able to show, that depending on the situation in the business environment and the situation inside the firm one mechanism can be identified to work at lower costs and thus, to be superior to the other.

9 Limitations and Prospects for Further Research

There are of course a number of limitations to our analysis. One is that the initial investment amount is equal for all projects These assumptions are justifiable for reasons of simplicity of illustration, but seem not to be very realistic. A market mechanism that handles differing investment amounts would have to allow for coalitions of small projects on the supply side in order to finance larger ones. Another limitation is that the project cash flows are deterministic. An approach, which takes risk and uncertainty explicitly into account, has to deal with different individual risk attitudes and different individual expectations about the future. The determination of the misallocation costs in the hierarchical setting remained somewhat fuzzy. Although the basic idea behind the source of these costs was described, a thorough probabilistic modeling would give a more precise insight in the dimension of the actual cost development. Extending the model in those respects is subject to our ongoing research.

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