Information Management with Specific Investments and Cost-Based Transfer Prices

Steffen Hinss, University of Ulm*

Alexis H. Kunz, University of Lausanne†

Thomas Pfeiffer, University of Vienna‡

Forthcoming in: The European Accounting Review

Abstract

We analyse information flows in a profit-centre organisation with internal trade between two risk-neutral divisions. Prior to production, the divisions make unverifiable investments in intrafirm synergies. After investments are made, the selling division announces a cost-based transfer price which includes a mark-up on variable costs. The buying division then decides what quantity to purchase at that unit cost. From the head office’s perspective, the key issues are to influence both, divisional investments and the seller’s manipulation of the mark-up. To do so, the head office can fund a pre-decision information system before divisional investments are made. The system produces forward-looking information that can be used to improve the divisions’ investments decisions, but which cannot be used in evaluating their performance. Our analytical framework allows us to identify cost and revenue structures for which pre-decision information either supports or destroys intrafirm synergies by motivating or discouraging divisional investments, thereby resulting in an increase in, decrease in, or in no impact whatsoever on, firm profit. Among our most interesting findings is the counterintuitive result that pre-decision information can undermine the incentives of risk-neutral agents to invest specifically. Our results add to earlier agency models that found different, albeit equally dysfunctional effects of pre-decision information. Contrary to these studies, our findings are not driven by either risk aversion or rent extraction.

* University of Ulm, Faculty of Mathematics and Economics, Institute for Business Administration, Helmholtzstrasse 18, D-89069 Ulm/Germany.
† University of Lausanne, HEC, Internef 523, CH-1015 Lausanne/Switzerland, E-Mail: alexis.kunz@unil.ch.
‡ University of Vienna, Institute of Accounting and Control, Bruenner Strasse 72, A-1210 Vienna/Austria, E-Mail: thomas.pfeiffer@uniwie.ac.at
1 Motivation

In recent years, many firms have made substantial investments in information systems to improve the quality of information available to decision-makers. Large investments in information technologies are generally justified by the argument that better and cheaper information leads to improved profits. However, empirical investigation has yielded inconclusive or even contradictory results regarding this commonly-held claim (Hackett, 1997; Strassmann, 1997). Researchers have proposed several explanations for these seemingly contradictory and paradoxical findings, such as methodological deficiencies, data selection problems, lags due to learning and adjustment behaviour, or implementation failures (Barua et al., 1997). Surprisingly, to date, little work has been done to identify the conditions under which investments in information systems contribute to firm productivity (Thatcher and Oliver, 2001). The purpose of this study is to provide new insights into the linkage between information systems and firm-value, while advocating an incentive-oriented explanation why information systems may fail in practice. Our findings suggest that there exist cost and revenue structures for which pre-decision information systems are disadvantageous, even when implementation failures can be ruled out with certainty.

Our study analyses costs and benefits of pre-decision information in a framework in which a head office regulates intrafirm trade between two risk-neutral divisions. Empirical studies show that, in practice, transfer prices are usually cost-oriented (Emmanuel and Mehaffi, 1994; Schiller, 1999). We account for that fact by basing intrafirm trade on standard cost transfer prices. Prior to engaging in production, the divisions must make unverifiable, firm-specific investments in intrafirm synergies to increase firm profit in the long run. Two problems complicate divisional investments. First, investments are risky so that from an ex post perspective, resources may be allocated inefficiently. Secondly, since investments are unverifiable and specific, contractual complexity prevents that the divisions are fully compensated for their investments’ positive externalities. As a consequence, production suffers from underinvestment. We enrich this standard incentive problem by endowing the head office with an option to fund a pre-decision information system to resolve the investment risk. Information systems typically provide detailed information to lower levels of the organization, while only a summary of this information is made available to top management. Consequently, a large part of the information remains private to lower levels of the organization (Baiman/Sivaramakrishnan, 1991). Furthermore, forward-looking information is typically soft information, because variables and cause-and-effect-chains are inherently difficult to specify in an unambiguous manner (Stein, 2002). Since the information is not verifiable, it cannot be used for performance evaluation. Note that a contract that conditions variables on such soft information is not enforceable in court. Therefore, when deciding whether to fund the information system, the question arises whether to give divisional management access to detailed information on which it can base its decisions, when such (detailed) information cannot be used in evaluating its performance (Baiman/Sivaramakrishnan, 1991, p. 747). We investigate this issue by examining the conditions under which it may (or may not) be valuable for the firm to fund
the pre-decision information system.

Clearly, the head office’s information policy influences divisional incentives to make specific investments. To study the economic consequences of different information policies, we investigate how the information system affects divisional investment behaviour and firm profit. Our analytical framework allows us to identify cost and revenue structures for which pre-decision information either supports or destroys intrafirm synergies by motivating or discouraging firm-specific investments, thus resulting in an increase in, decrease in, or in no impact whatsoever on, the overall firm profit. Among our most interesting findings is the counterintuitive result that pre-decision information systems can be detrimental to firm value because they may discourage firm-specific investments. Hence, contrary to common intuition, it may not always be in the owners’ best interest to install an information system in the first place. From a practical point of view, we therefore suggest that the externalities of pre-decision information on divisional investment incentives and intrafirm synergies should be carefully taken into account before a firm decides whether or not to install an information system.

We are not the first to investigate the possible negative effects of pre-decision information. Several agency-theoretical studies show that pre-decision information may discourage agents if they are risk-averse (Bushman et al., 2000; Datar, 2000; Christensen, 1981; Baiman and Sivaramakrishnan, 1991; Penno, 1984, 1990 and Baiman and Evans, 1983). Our model differs from these studies in two respects. First, from a methodological point of view, we focus on problems of firm-specific investments in a world of incomplete contracts and not on a standard principal-agent problem. Secondly, our results are not driven by the agents’ risk aversion. Instead, we argue that pre-decision information may be detrimental because it can destroy investments incentives of risk-neutral agents.

Studies on information systems are typically categorised according to whether they analyse pre- or post-decision information (Baiman/Evans, 1983; Sivaramakrishnan, 1991). Pre-decision information is information on which individuals can base their decisions. Conversely, post-decision information cannot be used for decision making because it arrives after the decision has been implemented (Baiman/Sivaramakrishnan, 1991, p. 747). Several papers employ an incomplete contracting approach to show that incremental post-decision information may aggravate commitment problems (e.g. Cremer, 1995; Arya et al., 2000). Post-decision information typically enables a principal ex post, to extract a higher surplus from the agent than without the information. Since the agent anticipates the rent extraction and since the principal cannot credibly commit to refrain from so doing, the agent reduces his actions. In such a setting, blocking post-decision information serves as a credible commitment device for the principal not to engage in rent extraction. Our model differs from this branch of the literature in three respects. First, we analyse pre-decision and not post-decision information. Whereas models of post-decision information focus on how information influences surplus division, we investigate how pre-decision information influences both the quality of managerial decision-making and the division of the surplus. Second, information systems in our study are not dysfunctional because they facilitate rent
extraction, but because they may discourage firm-specific investments. Third, in contrast to the post-decision literature, agents in our model cannot condition their actions upon information that becomes available after the decision is implemented.

In our model, intrafirm trade borrows several features from the incomplete transfer pricing literature (Edlin and Reichelstein, 1995; Baldenius et al., 1999). Baldenius et al., 1999, analyse the comparative advantage of negotiated versus cost-based transfer prices to reduce intrafirm hold-up problems and production inefficiencies. Nevertheless, the influence of information systems on intrafirm trade is not an issue in their study. Schiller, 1999, investigates the value of post-decision information in a standard agency model with cost-based transfer prices. In his model, the head office has the option to disclose revenue information in order to influence intrafirm trade between a selling and a buying division. Since such information is prone to strategic exploitation by the selling division, disclosing it can be harmful to the firm. Our study differs from Schiller’s model in three respects. Firstly, our analysis focuses on pre-decision and not on post-decision information. Secondly, in our model, contracts are incomplete so that the revelation principle on which Schiller’s analysis is based on does not apply. Thirdly, in our analysis negative consequences of information do not stem from strategic rent extraction, but from dysfunctional investment incentives generated by the information system.

The work that is related most closely to our study is that of Pfeiffer, 2004. He analyses the impact of pre-decision information and intrafirm hold-up problems in a model in which two divisions bargain over a jointly-produced surplus. The study identifies conditions under which a pre-decision information system can either be beneficial or harmful for the head office. Intrafirm trade in Pfeiffer’s analysis is limited to a binary strategy of either to trade or not to trade the widget at all. This simple binary description of the trading process makes it impossible to perform a thorough analysis of the impact of pre-decision information on cost-based transfer prices and state-contingent quantities choices. Our model differs from Pfeiffer, 2004, in the following respects: surplus division in our model is based on cost-based transfer prices and not subject to negotiations. Hence, whereas production is ex-post efficient in Pfeiffer’s analysis, quantity decisions in our model suffer from the well-known double marginalisation problem. Due to this fact, our model analyses pre-decision information systems, which may strengthen (or weaken) a division’s relative bargaining power. Hence, we study information systems that directly influence the magnitude and the division of the surplus. In Pfeiffer’s study, the division (but not the magnitude) of the surplus remains unaffected by the information system. Furthermore, we explicitly account for the practical necessity to vary production quantities when the states of the world are more or less attractive.

The remainder of the article is organised as follows. Section two presents the model. In Section three, the analytical results are derived and discussed. Section four concludes the article with a brief summary on the findings.
2 The Model

2.1 Production Process and Intrafirm Trade

Consider a multidivisional firm consisting of a head office \( H \), a production division \( P \), and a marketing division \( M \). The firm develops, manufactures, and sells a widget in a two-tiered process that involves a development and a production stage. During the development stage, both divisions incur unverifiable firm-specific investments \( I := (I_M, I_P) \in \mathbb{R}_+^2 \) to increase the firm-profit in the long run. Investments by the production division \( P \) reduce production costs \( C(\cdot) \), whereas investments by the marketing division \( M \) increase revenues \( R(\cdot) \). Specific investments come with costs \( w(\cdot) \) that are monotonically increasing and convex in the investment level

\[
w_i(I_i) = \frac{1}{2} I_i^2 \quad \text{(for } i = P, M).\]

Due to contractual complexity, investment costs must be borne entirely by the investing party. After investments are made, both divisions enter the production stage. During this stage, division \( P \) produces an intermediate good which is neither available nor tradable on the outside market and that, therefore, must be progressed internally. Intrafirm trade is based on standard cost transfer prices.\(^4\) This captures the common notion that actual unit costs become known at a later stage and that even then they will not be (entirely) verifiable to the head office (Sahay, 2003). Borrowing from Baldenius et al., 1999 and Schiller, 1999, we model standard cost transfer pricing as follows. First, the production division \( P \) issues an unverifiable cost report \( v \). The marketing division \( M \) then decides what quantity \( q \in \mathbb{R}_+ \) of the good it wants to purchase at that unit cost, which then serves as the transfer price. After internal trade has taken place, division \( M \) completes the good and sells it on the external market.

A crucial factor in our model is that profits vary contingent upon the state of nature. In particular, we assume that nature consist of two states \( \theta \in \{\theta_1, \theta_2\} \) of which each one will be realised with probability \( p_\theta \). To capture the notion that a firm’s cost and revenue structure is largely influenced by variations in its environment, we assume that each state is paired with different cost and revenue functions \( C(\theta, \cdot) \) and \( R(\theta, \cdot) \). However, costs and revenues are also influenced critically by the produced quantity \( q \) and the level of divisional investments \( I \). For simplicity, we assume that the cost and revenue functions have the

\(^4\) In what follows, we exclude two-part transfer pricing from our analysis. As will become evident below, such a scheme would be optimal only in the case of one-sided investment by the producer, whereas it would be ambiguous if investments were to be made by both divisions or by the marketer only. Two-tariff transfer pricing is tantamount to a negotiated transfer pricing scheme in which the producer holds all the bargaining power (see Baldenius et al. 1999, p. 81). Since in this case, the two-tariff transfer pricing system is just a special application of Pfeiffer’s 2004 study on information and negotiated transfer prices, we omit this scheme in our analysis.
form (for $a_\theta$, $b_\theta$, $c_\theta > 0$)

$$R(q, \theta, I_M) := \left( a_\theta - \frac{1}{2} b_\theta \cdot q + I_M \right) \cdot q \quad \text{and} \quad C(q, \theta, I_P) := (c_\theta - I_P) \cdot q.$$  

State-contingent revenues $R(\cdot)$ are strictly monotonically increasing and concave in the intermediate product’s quantity $q$. Likewise, they are linearly increasing in the marketing division’s investment level $I_M$. On the other hand, state-contingent costs $C(\cdot)$ are strictly linearly increasing in the produced quantity $q$. Furthermore, they are strictly monotonic and linearly degressive in the production division’s investment level $I_P$.

The head office’s objective is to maximise the firm’s state-contingent profit margin after investment costs

$$\Pi(q, \theta, I_M, I_P) := M(q, \theta, I_M, I_P) - \sum_{i=M,P} w_i(I_i)$$

$$:= R(q, \theta, I_M) - C(q, \theta, I_P) - \sum_{i=M,P} w_i(I_i).$$

Both divisions are managed by risk-neutral managers who maximise their divisional profit.\(^5\)

Before being able to observe the state $\theta$, both managers must simultaneously choose their level of investment $I_i$ (for $i = P, M$). After investments are made but before production takes place, both managers learn the true state $\theta$ and the overall level of investment $I$. Hence, whereas investments have to be made under imperfect information about the state, production takes place under certainty.

### 2.2 The Information System

The head office can resolve the investment risk by funding a pre-decision information system that will be operated by the division managers. For simplicity, we assume that investments in the information system are negligible. The information system collects and structures prospective information and communicates this information via a soft signal about the future state. Generally, the set of all feasible information systems consists of a continuum of prospective signals that is bounded by the two extreme types of a perfectly informative system $\mathcal{P}$ and a completely non-informative system $\mathcal{N}$. Before the signal is issued, both divisions share homogeneous expectations about the cost and revenue functions in each state and about their corresponding a priori probabilities. In accord with Baiman/Sivaramakrishnan, 1991, we assume that the signal remains private information to the division managers and, therefore, cannot be used for performance evaluation or contracting.\(^6\)

If the information system is implemented, the signal initiates a Bayesian learning process during which the divisions (but not the head office) can revise their

\(^5\) See, for instance, Edlin and Reicheinstein, 1995, p. 279, Baldenius et al., 1999, p. 70, for the same assumption about managerial behaviour.

\(^6\) There is ample reason as to why this might be plausible in practice: First, information systems typically provide detailed information to lower levels of the organization, while only a summary of this information
expectations about the future state. To avoid tedious case distinctions, we restrict the head office’s decision to either (i) fund a perfect information system (PeIS) or (ii) not to fund an information system at all (NoIS). Hence, the head office has the option to either allow the divisions to perfectly observe the future state or not let them learn it at all. Henceforth, we denote the first option to employ a perfect information policy $\mathcal{P}$ and the latter option to employ a no-information policy $\mathcal{N}$.

Figure 1 provides an overview of the model’s time sequence and information structure.

![Figure 1: Time Sequence](image)

The model’s time sequence can be summarised as follows. At the outset ($t = 1$), all parties share symmetric information about the cost and revenue functions $C(\cdot)$ and $R(\cdot)$ in each state $\theta$ and about the a priori probabilities $p_\theta$ that a particular state will be realised. Moreover, all parties know that trade will be based on standard cost transfer prices. At $t = 2$ the head office decides whether or not to fund the information system. If the system is funded, it produces in $t = 3$ a soft signal $S$, which both divisions use to revise their expectations. Since the signal remains private to the managers, the head office cannot use the signal to update its expectations. If no information system has been installed, then no division can revise its expectations. At $t = 4$ both divisions have to choose their level of

is furnished to top management (Baiman/Sivaramakrishnan, 1991). Secondly, tasks are delegated because managers are more specialized than the head office. Central to specialization is superior knowledge and expertise, which endows a person with a higher absorptive capacity when it comes to interpret and act on new information. Therefore, the head office may lack the specialisation and the necessary expertise to understand and adequately interpret the signal (Hart and Moore, 1988 and Hart, 1995). Thirdly, forward-looking information is typically soft information, because variables and cause-and-effect-chains are inherently difficult to specify in an unambiguous manner (Stein, 2002). Suppose, for instance, that the information system of a biotech firm reveals that a new drug component successfully passed all required tests. What does this mean for the division’s costs and revenues? Clearly, the division manager possesses superior knowledge regarding these factors and thus is more capable of planning on the division’s behalf than is the head office. Since soft information is not verifiable, it cannot be used for performance evaluation. A contract that conditions variables on such soft information would not be enforceable in court (Hart, 1995). Another reason might be that the head office may simply be too busy to re-run the whole planning process once the signal is made available. Besides its inferior absorptive capacity due to the lack of specialization, a large control span prevents the head office from devoting as much time and effort to re-running a division’s planning process as its associate division could. This argument is supported by empirical evidence showing that the head offices of large corporations may supervise up to several hundred organizational units.
specific investment $I_M$ and $I_P$. At $t = 5$, after investments are made, both divisions can observe the realised state and the overall level of specific investments with certainty. At $t = 6$ the producer quotes the transfer price $v$. At $t = 7$ the marketing division orders the quantity $q$ of the intermediate good. At $t = 8$ the marketing division completes the good and sells it on the outside market; divisional income and the firm-wide profit are realised.

3 Pre-Decision-Information and Firm Value

In this section, we analyse under what conditions it might be valuable for the head office to fund the information system. We investigate this for the three different investment scenarios that investments are either (i) two-sided by both divisions ($I = (I_M, I_P)$) or one-sided by (ii.a) the producer ($I = I_P$) or (ii.b) the marketer ($I = I_M$). To avoid tedious case distinctions, our explanations will focus on the case of one-sided investments by the producer ($I = I_P$). However, the detailed results for all three cases are presented in the appendix. Our analysis proceeds as follows. In section 3.1, we derive the benchmark case of the first-best solution in which all investment decisions are made by the head office. In section 3.2 we then analyse the decentralised setting in which investments and quantity decisions remain subject to divisional authority.

3.1 The First-best Solution

If information is distributed symmetrically, the head office can trivially enforce optimal investments. When it decides on what quantity to produce in $t = 7$, it will already have learned the realised state $\theta$ and the level of specific investments $I = I_P$. Hence, the head office’s quantity decision will always be ex post efficient. Consequently, the pre-decision information system does not affect production in terms of conditionally efficient quantity choices, but with respect to efficient investments. To derive the optimal investment and production plan, we work backwards, i.e. we first solve for the optimal quantity $q(\theta, I)$ in $t = 7$. Given $q(\theta, I)$, we then solve for the optimal investment level $I$ in $t = 4$.

In $t = 7$ the head office maximises the state-contingent profit margin (for $a_\theta - c_\theta, b_\theta > 0$)

$$q(\theta, I) \in \arg \max_{q \in \mathbb{R}_+} \left\{ R(q, \theta) - C(q, \theta, I) \right\} = \left\{ \frac{a_\theta - c_\theta + I}{b_\theta} \right\}. \tag{1}$$

It follows immediately that the efficient quantity $q(\theta, I)$ strictly increases in the producer’s investment level $I$. Since the optimal investment level is a function of the investment’s anticipated profitability, the information system influences the incentives to invest specifically.

(i) If the head office funds the information system, it can perfectly anticipate the state
\[ \theta. \] Therefore, its optimisation problem in \( t = 4 \) is to choose the investment level that maximises the state-contingent firm profit

\[
I_{\theta}^{B_P} \in \arg \max_{I \in \mathbb{R}_+} \{ M(q(\theta, I), \theta, I) - w_P(I) \}. \tag{2}
\]

(ii) If the head office does not fund the information system, no learning process is possible and it remains ignorant about the realised state. In this case, it chooses an investment level to maximise the expected firm profit based on the a priori probabilities

\[
I_{\theta}^{N} \in \arg \max_{I \in \mathbb{R}_+} \{ E [M(q(\theta, I), \theta, I)] - w_P(I) \}. \tag{3}
\]

The optimisation problems (2) and (3) coincide for the special case that one state will be realised with certainty. Obviously, in such a scenario pre-decision information has no impact on the head office’s investment decision.

Table I summarises the solution of the programmes (2) and (3) (proof in the appendix).

Two aspects of Table I are worth discussing in more detail. At the optimum, marginal investment costs equal the expected marginal quantity of the intermediate good. Thus, the more the head office expects to sell on the external market \textit{ex post}, the more it is willing to invest \textit{ex ante}. If the firm has access to the information system, it can discriminate between the states. In this case, the head office always chooses the optimal state-contingent investment level. If, on the other hand, there is no prospective information available, such adaptation processes are impossible and the investment decision must be based on a priori probabilities. In this case, the optimal investment level is an expected value, i.e. the head office weights the optimal investment levels of all feasible states with their corresponding a priori probabilities. To evaluate the merits of the information system, we compare the firm’s expected profit margins for the two cases that the head office employs either an information or a no-information policy. Proposition 1 summarises the findings for the first-best scenario (proof in the appendix).

\textbf{Proposition 1} \textit{In the first-best case, funding the information system is always beneficial for the head office, no matter whether specific investments are (i) two-sided or one-sided by either (ii.a) the producer or (ii.b) the marketer. In all three cases, funding the information system increases the firm’s expected profit.}

Proposition 1 is based on the well-known Blackwell Theorem (1951), which states that incremental information c.p. never proves to be harmful to a rational decision maker as
long as the costs of acquiring and processing this information are negligible. The intuition behind the theorem is simple. If additional information is both credible and valuable, exploiting this information allows learning by revising expectations and strategies. Therefore, additional information may be seen as an option that provides more flexibility for controlling a decision. This holds even if the newly acquired information is useless. Since in such a case the information can simply be ignored, it can never be harmful. Hence, in a first-best scenario, the information policy always strictly dominates the no-information policy as long as the costs of installing and maintaining it are excluded from the analysis.

3.2 The Decentralised Scenario

Next, we investigate whether the firm may still unreservedly benefit from the information system if the investment decisions are subject to divisional authority. Therefore, we derive the producer’s optimal investment and production plan in the decentralised setting. As before, our analysis follows the case of one-sided investment by the producer. The findings for the two other cases are detailed in the appendix.

Under a regime of cost-based transfer prices, the producer quotes in \( t = 5 \) an unverifiable cost report \( v \), which then becomes the good’s per unit transfer price. Knowing the transfer price \( v \), the marketer will then place his quantity order. At this point, both divisions will already know the state \( \theta \) and the producer’s level of firm-specific investments \( I \). Therefore, the optimal transfer price will be represented by the state-contingent linear function \( v(\cdot)q(\cdot) \). Applying backward induction again, we first solve for the optimal quantity choice. In a second step, we then solve for the producer’s optimal investment, provided the quantity is exchanged at \( t = 7 \).

In \( t = 7 \) the marketer maximises his divisional profit subject to the transfer price \( v \)

\[
q(\theta, v) \in \arg \max_{q \in \mathbb{R}_+} \{ R(q, \theta) - vq \} = \left\{ \frac{a_\theta - v}{b_\theta} \right\}. \tag{4}
\]

The marketer’s optimal reaction function to the transfer price is very intuitive. The higher the producer sets the transfer price, the less the marketer will buy from him. The producer, on the other hand, quotes a transfer price that maximises his divisional profit, subject to the marketer’s reaction function

\[
v(\theta, I) \in \arg \max_{v \in \mathbb{R}_+} \{ vq(\theta, v) - C(q(\theta, v), \theta, I) \} = \left\{ \frac{a_\theta + c_\theta - I}{2} \right\}. \tag{5}
\]

Interestingly, the transfer price \( v(\theta, I_p) \) is a decreasing function of the producer’s investment \( I \). Thus, the more the producer invests, the lower he sets the transfer price to motivate the marketer to order larger quantities of the intermediate good. To derive the optimal quantity of the intermediate good, we insert equation (5) in equation (4) and find

\[
q(\theta, I) = \frac{a_\theta - c_\theta + I}{2b_\theta}. \tag{6}
\]
Comparing equation (1) to (6), it follows immediately that trade in the decentralised scenario amounts to only half of the first-best quantity. Hence, the firm suffers from a productivity loss due to the double marginalisation. Moreover, equation (6) shows that firm productivity is a linear function of the producer’s investments. Next, we investigate how the information system influences the producer’s investment incentives.

In \( t = 4 \), the producer maximises his divisional income net of investment costs, subject to his information set and subject to the marketer’s reaction function towards the transfer price.

(i) If the information system is funded, the producer can discriminate between the different states. Since he knows which state will be realised, he invests at the optimal state-contingent level \( I^P_\theta \) to maximise his divisional profit

\[
I^P_\theta \in \arg \max_{I \in \mathbb{R}_+} \{ v(\theta, I)q(\theta, I) - c(q(\theta, I), \theta, I) - w_P(I) \}.
\]

According to the first-order condition, marginal investment costs must equal the marketer’s quantity order, i.e. \( w_P(I^P_\theta) = I^P_\theta = q(I^P_\theta, \theta) \).

(ii) On the other hand, if the producer has no access to the information system, he maximises his expected divisional profit based on the a priori probabilities \( p_\theta \)

\[
I^N \in \arg \max_{I \in \mathbb{R}_+} \{ E[v(\theta, I)q(\theta, I) - c(q(\theta, I), \theta, I)] - w_P(I) \}.
\]

Thus, he accounts for the marketer’s expected quantity order by deciding upon the investment level according to the following first-order condition: \( w'_{P}(I^N) = I^N = E[q(I^N, \theta)] \).

Table II summarises the solution for the decentralised scenario (proof in the appendix).

- Please insert Table II here -

Table II shows that the head office suffers from underinvestment in the decentralised scenario. This can be best understood when recalling that the produced quantity in the decentralised scenario equals only half of the first-best quantity. Any reduction in the produced quantity reduces the division’s surplus. It is easy to see that the producer has stronger investment incentives \textit{ex ante} if he expects to earn a higher surplus \textit{ex post}. Therefore, any (expected) drop in the produced quantity reduces his incentives to invest and thus results in underinvestment. Moreover, inspection of Table II reveals that the information system is now not unambiguously beneficial for the firm, but may even decrease the firm’s profit. Before we turn to a general characterisation of this problem, we first demonstrate such negative effects of pre-decision information in a simple numerical example.
3.2.1 Detrimental Effects of Pre-Decision Information: A Numerical Example

To show that pre-decision information can be disadvantageous for the firm, we assume that the state-contingent cost and revenue functions are of the form

\[ C(q, \theta, I) = \begin{cases} (1 - I) \cdot q & \text{for } \theta_1 \\ (2 - I) \cdot q & \text{for } \theta_2 \end{cases} \quad \text{and} \quad R(q, \theta) = \begin{cases} (5 - \frac{1}{2} \cdot 2q) \cdot q & \text{for } \theta_1 \\ (9 - \frac{1}{2} \cdot 3q) \cdot q & \text{for } \theta_2. \end{cases} \]

All the relevant data of the example are summarised in Table III: Columns 1 and 2 depict the two cases in which the head office either funds, or abstains from funding, the information system. The impact of the information system on the transfer price and the production quantity are exhibited in rows 1 to 3. Its influence on specific investments, divisional income and firm profit are depicted in rows 4, 5 and 6. The merits of the information system, measured by the differences in profit with and without information, are exhibited in rows 7 and 8. To ease comparisons between the results, all values of Table III were multiplied by the common denominator, which is 1 299 600. To economise on notation, we employed the following simplifications

\[ v_P^i := v_P(\theta_i, I_P^i), v_N^i := v_N(\theta_i, I_N^i), \]
\[ q_P^i := q_P(\theta_i, I_P^i), q_N^i := q_N(\theta_i, I_P^i) \quad (\text{for } i = 1, 2). \]

Table III shows that installing an information system under the example’s assumption is detrimental to firm value. If endowed with the information system, the producer always invests at the optimal state-contingent level of

\[ I_P^1 = 1732800 \text{ or } I_P^2 = 1819440 \text{ respectively.} \]

If not equipped with the information system, the producer remains ignorant about the realised state. In this case, he chooses an investment level which maximises his expected divisional income, net of investments costs. As shown in Table III, expected investments are strictly lower under the prospective information policy than under the no-information policy

\[ E[I_P^1] = 1776120 < E[I_N^1] = I_N = 1778400. \]

Interestingly, a no-information policy has an incentive effect on the producer, motivating him to enhance expected investments. Since increased producer investments reduce expected production costs, the producer lowers the expected transfer price from 4 635 600 with information to 4 634 100 without information. This, in turn, boosts internal trade from 3 552 240 units with information to 3 556 800 units without information. This is so because the marketer profits from the lower transfer price by ordering a larger quantity.\(^7\) As shown in Table III, these measures result in disparate value consequences for the firm.

\(^7\) Remember that both states are equally probable, therefore, \( E[q_P^1] = \frac{1}{2} \cdot [q_{P1}^1 + q_{P2}^1] = \frac{1}{2} \cdot [3 465 600 + 3 638 880] = 3 552 240. \) Likewise, \( E[q_N^1] = \frac{1}{2} \cdot [q_{N1}^1 + q_{N2}^1] = \frac{1}{2} \cdot [3 488 400 + 3 625 200] = 3 556 800. \)
and the divisions: whereas a no-information policy increases the expected firm profit by +343 (from 7 982 432 with information to 7 982 775 without information), it simultaneously reduces the producer’s profit by −570 (from 4 916 820 with information to 4 916 250 without information).

Installing the information system is always beneficial for the investing division. This is so because ignoring the information results in the same investment and transfer pricing decision as without the information. Nevertheless, as shown, pre-decision information can be detrimental to the noninvesting division and the overall firm. This is so because blocking information motivates the manager to expand expected firm-specific investments. Since this reinforces intrafirm synergies, the no-information policy generates a higher expected firm profit than under perfect information. Therefore, a first, important conclusion of our analysis is that, under certain conditions, not funding the information system may constitute a subtle way of protecting firm-specific investments. In our model, as in Christensen (1981), pre-decision information can undermine an agent’s incentives to contribute to firm value. Nevertheless, contrary to Christensen (1981), negative incentive effects in our model are not attributable to the agent’s risk aversion. In our model, pre-decision information is detrimental because it undermines the incentives of risk-neutral agents to make firm-specific investments. We return to this point more thoroughly in the next section when we discuss the driving forces behind the detrimental effects of pre-decision information.

3.2.2 Discussion of Pre-Decision Information on Firm Value

Next, we provide some intuition as to how pre-decision information influences firm value. Proposition 1 shows that the producer always benefits from the information system. Therefore, the producer’s expected profit margin is always higher with the information system than without it. Yet what about the marketer? We know that the more the producer invests, the lower he sets the transfer price and therefore, the larger the quantity that the marketer orders from the producer. To analyse the synergy between the two divisions, we insert equations (5) and (6) into the marketer’s profit margin function

\[ R(q(\theta, I), \theta) - v(\theta, I)q(\theta, I) = \frac{1}{2}b_\theta \left( \frac{d_\theta + I}{2b_\theta} \right)^2. \]  

It is straightforward to see that the marketer’s profit margin is strictly increasing in the producer’s investment \( I \). Hence, the marketer always prefers higher investments to lower ones, since this unambiguously increases his profit.

From the previous section we know that if the producer has access to pre-decision information, he can discriminate between the states. Since he knows that he is facing \( q(\theta, \cdot) \), he invests at the optimal state-contingent level \( I^P_{\theta} \) while satisfying the first-order condition

\[ v(\cdot) = (a_\theta - c_\theta + I)/2b_\theta \quad \text{and} \quad q(\cdot) = (d_\theta + I)/2b_\theta. \]

This follows immediately from the equations (5) and (6), i.e. \( v(\cdot) = (a_\theta - c_\theta + I)/2b_\theta \) and \( q(\cdot) = (d_\theta + I)/2b_\theta. \)
$w'_p(I^p_\theta) = I^p_\theta = q(\theta, I^p_\theta)$. If the producer has no access to the information system, he cannot discriminate between the different states. Therefore, he invests $I^N$ while satisfying the first-order condition for the expected quantity: $w'_p(I^N) = I^N = E[q(\theta, I^N)]$. Clearly, the resulting level of $I^N$ depends heavily on the states’ a priori probabilities. Trivially, if one state is realised with certainty, investment with and without information coincide, i.e. $I^p_\theta = I^N$ for $p_\theta = 1$. On the other hand, if the two states are realised with disparate probabilities, the investment levels with and without information diverge. Henceforth, we assume without loss of generality that the investment $I^p_\theta$ strictly exceeds $I^p_1$. Clearly, investment $I^N$ must then lie between the optimal state-contingent investment levels, i.e. $I^p_1 \leq I^N \leq I^p_2$. Hence, when comparing the information policy with the no-information policy, we find the following effects (see also graph I):

(i) In (the bad) state 1, the producer invests more in the no information case that in the information case ($I^p_\theta < I^N$). Since the investments cannot be partitioned on the realised state, this always reduces the producer’s profit (Proposition 1). By contrast, larger investments in intrafirm synergies simultaneously result in an increase of the marketer’s profit (see equation (7)). Consequently, in (the bad) state 1, a no-information policy increases the marketer’s profit, but reduces the profit of the producer.

(ii) In (the good) state 2, the producer invests less in the no information case than in the information case ($I^N < I^p_2$). Again, unambiguously reduces the producer’s profit because the investments cannot be partitioned on the realised state (Proposition 1). Since the producer reduces his investments in intrafirm synergies, this also decreases the marketer’s profit (see equation (7)). Consequently, in (the good) state 2, a no-information policy unambiguously reduces the profit of both the producer and the marketer.

--- Please insert Graph I here ---

Therefore, we find the following: The information system is always beneficial for the producer, irrespective of the realised state. By contrast, the information system turns out to be beneficial for the marketing division only in state 1, while being disadvantageous for it in state 2. Consequently, a no-information policy proves to be valuable for the firm only if the marketer’s expected profit gain in state 1strictly outweighs the sum of (i) the marketer’s expected loss in state 2 and (ii) the expected loss of the producer in the states 1 and 2. Note that contrary to Schiller, 1999 and Arya et al. 2000, the information system is not dysfunctional because it facilitates strategic rent extraction, but because it discourages specific investments. The precise technical conditions under which this is the case are characterised in the next section.
3.3 The Value of Pre-Decision Information: A General Characterisation

Next, we are interested in the conditions under which pre-decision information systems are either beneficial, detrimental, or have no value implications at all. We proceed as follows. First, we derive the results for the case of one-sided investments by the producer (see Lemma 1). Then, we generalise this result in Proposition 2 to all three cases. The results for the case of one-sided investment by the producer are summarised in Lemma 1.

Lemma 1 If firm-specific investments are one-sided by the production division, there are critical threshold values (for \( d_\theta := a_\theta - c_\theta \))

\[
T_1 := \frac{d_1(2b_2 - 1)}{2b_1 - 1}, \quad T_2 := \frac{d_1[(16b_1 - 2p_1)b_2^2 + 3(p_2b_1 + p_1b_2) + (2p_1 - 14)b_1b_2]}{16b_1b_2 - (2p_1 - 12)b_1b_2 + 3(p_1b_2 + p_2b_1) - 2p_2b_1^2}
\]

and

\[
T_3 := \frac{2b_1^2 - 2b_1b_2 - b_1 + b_2}{(2b_1b_2 - p_1b_2 - p_2b_1)(2b_1 - 1)(2b_2 - 1)}
\]

of the firm’s profit margin function, so that funding the information system

(i) is always detrimental for the firm, resulting in a reduction of both the expected level of firm-specific investment and the expected firm profit iff \( (d_2 - T_1) \cdot (d_2 - T_2) \cdot T_3 < 0 \) is satisfied;

(ii) always proves to be beneficial for the firm, resulting in an increase of both the expected level of firm-specific investment and the expected firm profit iff \( (d_2 - T_1) \cdot (d_2 - T_2) \cdot T_3 > 0 \) is satisfied;

(iii) has no impact whatsoever on firm value iff \( (d_2 - T_1) \cdot (d_2 - T_2) \cdot T_3 = 0 \) is satisfied.

Lemma 1 shows that the value of the pre-decision information systems is a function of the firm’s cost and revenue structure. Moreover, it provides a complete characterisation of the conditions under which information systems are either beneficial, detrimental or indifferent to firm value. The main contribution of Lemma 1 is the counterintuitive finding that there exist conditions under which pre-decision information is always disadvantageous. Note that in our model, information is not deleterious because it enables strategic rent extraction between divisions, as in Schiller, 1999. Rather, it is detrimental because a no-information policy would force a risk-neutral agent to expand specific investments as a reaction to the state risk. Since, in such a case, uninformed agents would invest more
in intrafirm synergy than would informed ones, blocking information acts as a coarse incentive scheme to foster specific investments. Under such conditions, granting agents access to the information system wrecks their incentives to invest and thereby destroys intrafirm synergies. In particular, Lemma 1 reveals that a necessary, but not sufficient, condition for pre-decision information to be harmful is

$$E[I^P_\theta] \leq I^N.$$ 

There exist similar conditions for the cases of one-sided investment by the marketer (see Lemma 2 in the appendix) and two-sided investments by both divisions (see Lemma 3 in the appendix) under which a pre-decision information system is either beneficial, detrimental or indifferent to firm value. Proposition 2 summarises this result.

**Proposition 2** In the decentralised setting, funding the information system comes with ambiguous consequences for firm value, no matter whether firm-specific investments are (i) two-sided or one-sided by either (ii.a) the producer or (ii.b) the marketer. In all three cases, there exist conditions concerning the structure of the cost and revenue functions under which funding the information system increases, reduces, or has no impact on the expected firm profit.

The detailed conditions under which the information system mitigates, exacerbates, or has no effect on firm profit are discussed in the appendix. Inspection of Lemma 1 to 3 reveals that all three cases share the same technical structure, but, due to the different investments scenarios, differ in the level of the various threshold values. Overall, Proposition 2 shows that pre-decision information can also be harmful for the cases of one-sided investments by the marketer and two-sided investments by both divisions.

### 4 Conclusion

The purpose of this study is to provide new insights into the linkage between information systems and firm value, while advocating an incentive-oriented explanation why information systems may fail in practice. Our analysis studies costs and benefits of pre-decision information in a model of intrafirm trade between two risk-neutral divisions. Prior to engaging in production, the divisions must make unverifiable, specific investments in intrafirm synergies to increase the firm profit in the long run. Two problems complicate divisional investments. First, divisional investments have to be made under uncertainty about their outcome, with the consequence that production suffers from allocational distortions. Second, due to contractual complexity, divisions invest less in intrafirm synergies.
than would be desirable from a firm perspective, thus leaving the head office with an underinvestment problem. We enrich this standard incentive problem by endowing the head office with an option to fund a pre-decision information system that resolves the investment risk. We then investigate under what conditions this option may be valuable for the firm. Our analytical framework allows us to identify cost and revenue structures for which pre-decision information either supports or destroys intrafirm synergies by motivating or discouraging divisional investments, thereby resulting in an increase in, decrease in, or in no impact on firm profit. We derive this result for the three different investments scenarios of (i) one-sided investments by the producer (Lemma 1), (ii) one-sided investments by the marketer (Lemma 2), and (iii) two-sided investments by both divisions (Lemma 3). One of our main findings is the counterintuitive result that pre-decision information systems may be disadvantageous even if implementation failures can be ruled out with certainty. Pre-decision information is detrimental because a no-information policy would force risk-neutral agents for certain cost and revenue structures to expand their investments as a reaction to state risk. Since, in such a case, uninformed agents invest more in intrafirm synergy than informed ones, blocking information acts as a coarse incentive scheme to foster specific investments. Our study shows that the conditions under which this holds depend heavily on the firm’s cost and revenue structure. From a practical point of view, we therefore suggest that the externalities of pre-decision information on divisional investment incentives and intrafirm synergies should be carefully taken into account before a firm decides whether or not to install an information system.

5 References


6 Mathematical Appendix

6.1 First-Best Solution

First-best solution for the two-state case.

According to Section 3.1, by backward induction we find the first-order conditions $q(\theta, I) = (d_\theta + I)/b_\theta$ and $w_p(I^{fbN}) = E[q(\theta, I^{fbN})]$. For the NoIS-case, the producer invests

$$I^{fbN} = E[q^N(\theta, I^{fbN})] = E\left[\frac{d_\theta + I^{fbN}}{b_\theta}\right] = \frac{p_2d_2b_1 + p_1d_1b_2}{b_1b_2 - p_1b_2 - p_2b_1}.$$  

Setting $q^N(\theta, I^{fbN}) = (d_\theta + I^{fbN})/b_\theta$ leads to the solution of Table I. The solution for the case of the perfect system $P$ can be found by inserting the boundary values $(p_1, p_2) = (1, 0)$ and $(p_1, p_2) = (0, 1)$ into the solution of the NoIS-case. This leads to the solution of Table I. ∎

Proof of Proposition 1 is a straightforward application of Blackwell’s Theorem for all three cases (i), (ii.a) and (ii.b). ∎

6.2 Investments by the Production Division

Solution of the decentralised setting with asymmetric information. According to Section 3.2, by backward induction we find the first-order condition $q(\theta, I) = (d_\theta + I)/2b_\theta$. We find further

$$w_p(I^N) = -E\left[\frac{\partial(v(q(\theta, I^N), \theta) - C(q(\theta, I^N), \theta, I^N))}{\partial I}\right] = E[q(\theta, I^N)].$$

For the NoIS-case, the producer invests

$$I^N = E[q(\theta, I^N)] = E\left[\frac{d_\theta + I^N}{2b_\theta}\right] \quad \text{or} \quad I^N = \frac{p_2d_2b_1 + p_1d_1b_2}{2b_1b_2 - p_1b_2 - p_2b_1} \quad \text{respectively.}$$

Setting $q(\theta, I^N) = (d_\theta + I^N)/2b_\theta$ leads to the solution of Table II. The solution for the case of the perfect system $P$ can be found by inserting the boundary values $(p_1, p_2) = (1, 0)$ and $(p_1, p_2) = (0, 1)$ into the solution of the NoIS-case. This leads to the solution of Table II. ∎

Proof of Lemma 1. Installing an information system is beneficial (or harmful) if the difference $V$ of the expected firm profit $\Pi^P$ with information and the expected firm profit
\( \Pi^N \) without information is larger (or smaller) than zero \( (V := \Pi^P - \Pi^N \geq 0, \text{ or } V \leq 0) \). Obviously, both functions \( \Pi^P = \Pi^P(p_1) \) and \( \Pi^N = \Pi^N(p_1) \) depend on the a priori probability \( p_1 \). For the boundary values, we find

\[
V(0) := \Pi^P(0) - \Pi^N(0) = 0 \quad \text{and} \quad V(1) := \Pi^P(1) - \Pi^N(1),
\]

since once a state is realised with certainty, information is pointless. According to the definition, if the difference function \( V \) is concave (or convex), then the difference function must be larger than zero

\[
V(p_1) = V(p_1 \cdot 1 + (1 - p_1) \cdot 0) \geq (\text{or } \leq) \ p_1 V(1) + (1 - p_1)V(0) = 0.
\]

Concavity or convexity can be checked by analysing second-order derivatives. The function \( \Pi^P(\cdot) \) is linear in \( p_1 \), resulting in \( \partial^2 \Pi^P(\cdot)/\partial^2 p_1 = 0 \). Therefore, for the second-order derivative, we find

\[
\frac{\partial^2 V(p_1)}{\partial^2 p_1} = \frac{Y_1(p_1Y_2 - 3p_2b_1(d_1 - d_2) - 2d_2(1 - 8b_2)b_1^2 + Y_1((14d_1 - 12d_2)b_2 - 16b_2^2d_1)b_1)}{4(2b_1b_2 - p_1b_2 - p_2b_1)^4}
\]

with \( Y_1 = b_1b_2(d_1(1-2b_2)+d_2(2b_1-1)) \) and \( Y_2 = 2b_1^2d_2 - 2b_1b_2(d_1 + d_2) + 2b_2^2d_1 - 3b_2(d_1 - d_2) \).

The second order derivative has the following properties: (i) the denominator is positive \((4(2b_1b_2 - p_1b_2 - p_2b_1)^4 > 0)\), and (ii) the nominator possesses the zero points \( T_1 \) and \( T_2 \). Comparing algebraic signs of the second order derivative completes the proof. \( \square \)

### 6.3 Investments by Both Divisions

**Lemma 2** If firm-specific investments are two-sided, there are critical threshold values

\[
T_1 := \frac{d_1(4b_2 - 3)}{4b_1 - 3}, \quad T_2 := \frac{d_1[12b_2^2p_1 - 208b_1b_2^2 - 81(p_1b_2 + 81p_2b_1)] + b_1b_2(264 - 12p_1)}{12p_1b_1b_2 - 208b_1^2b_2 + 252b_1b_2 + 12p_2b_1^2 - 81(p_1b_2 + p_2b_1)}
\]

and

\[
T_3 := \frac{4(b_1^2 - b_1b_2) + 3(b_2 - b_1)}{(4b_1b_2 - 3(p_1b_2 - p_2b_1))(4b_1 - 3)(4b_2 - 3)}
\]

of the firm’s profit margin function, such that installing the information system

(i) is always detrimental for the firm, resulting in a decrease of both the expected level of firm-specific investment and the expected profit if \( (d_2 - T_1) \cdot (d_2 - T_2) \cdot T_3 < 0 \) is satisfied,

(ii) always proves to be beneficial for the firm, resulting in an increase of both the expected level of firm-specific investment and the expected profit if \( (d_2 - T_1) \cdot (d_2 - T_2) \cdot T_3 > 0 \) is satisfied,
(iii) has no impact whatsoever on firm value iff \((d_2 - T_1) \cdot (d_2 - T_2) \cdot T_3 = 0\) is satisfied.

**Proof of Lemma 2.** In analogy to Section 3.2, we find the first-order conditions: 
\[ v(\theta, I) = d_\theta + I_M - I_P, \quad q(\theta, I) = (d_\theta + I_P + I_M)/(2b_\theta), \quad w_p'(I_N^N) = -E \left[ \partial(C(q(\theta, I_N^N), \theta, I_{M}^N)/\partial I_P) \right] = E[q(\theta, I)] \quad \text{and} \quad w_M'(I_N^N) = E \left[ \partial \left( R(q(\theta, I_N^N), \theta, I_{M}^N) - v(\theta, I_N^N) \right) / \partial I_M \right] = E[1/2 \cdot q(\theta, I_N^N)]. \]

This leads to the following quantities for the NoIS-case \((i = 1, 2, i \neq j)\)

\[
I_P^N = \frac{2(p_2d_2b_1 + p_1d_1b_2)}{4b_1b_2 - 3(p_1b_2 + p_2b_1)}, \quad I_M^N = \frac{p_2d_2b_1 + p_1d_1b_2}{4b_1b_2 - 3(p_1b_2 + p_2b_1)}
\]

and

\[
q_N^N(\theta, I_N^N) = \frac{4d_d b_j + 3p_d(d_j - d_i)}{4b_1b_2 - 3(p_1b_2 + p_2b_1)}
\]

and for the case of the perfect system \((s = 1, 2)\)

\[
I_P^s = \frac{2d_s}{4b_s - 3}, \quad I_M^s = \frac{d_s}{4b_s - 3} \quad \text{and} \quad q_P^s(\theta, I_s^P) = \frac{4d_s}{4b_s - 3}.
\]

Again, we get the case of a prospective system by inserting the boundary values \((p_1, p_2) = (1, 0)\) and \((p_1, p_2) = (0, 1)\) into the solution of the nonprospective system. The rest of the proof follows the argumentation used in the proof of Lemma 2. The second-order derivative of \(V(p_1)\) is

\[
\frac{\partial^2 V(p_1)}{\partial^2 p_1} = \frac{Y_1(Y_2 - 81p_2b_1(d_1 - d_2) - 12p_2b_1^2d_2)}{4(4b_1b_2 - 3p_1b_2 - 3p_2b_1)^4} + \frac{Y_1(208b_1^2b_2d_2 + ((264d_1 - 252d_2)b_2 - 208b_2^2d_1)b_1)}{4(4b_1b_2 - 3p_1b_2 - 3p_2b_1)^4}
\]

with \(Y_1 = b_1b_2(d_1(3 - 4b_2) + d_2(4b_1 - 3))\) and \(Y_2 = p_1(12b_2^3d_1 - 12b_1b_2(d_1 + d_2) - 81b_2(d_1 - d_2))\).

The second-order derivative has the following properties (i) the denominator is positive \(((b_1b_2 - p_1b_2 - p_2b_1)^4 > 0)\), (ii) the nominator possesses the zero points \(T_1\) and \(T_2\). Comparing algebraic signs of the second-order derivative completes the proof. \(\square\)

### 6.4 Investments by the Marketing Division

**Lemma 3** If firm-specific investments are one-sided by the marketing division, there are critical threshold values

\[
T_1 := \frac{d_1(4b_2 - 1)}{4b_1 - 1}, \quad T_2 := \frac{d_1[(4p_1 + 80b_1)b_2^2 + 3(p_2b_1 + 3p_1b_2) - b_1b_2(4p_1 + 32)]}{4p_1b_1b_2 + (80b_1^2 - 36b_1)b_2 + 3(p_1b_2 + p_2b_1) + 4p_2b_1^2}
\]

and

\[
T_3 := \frac{4b_1^2 - 4b_1b_2 - b_1 + b_2}{(4b_1b_2 - p_1b_2 - p_2b_1)(4b_1 - 1)(4b_2 - 1)}.
\]
of the firm’s profit margin function, such that installing the information system

(i) is always detrimental for the firm, resulting in a decrease of both the expected level of firm-specific investment and the expected firm-profit if-and-only if \((d_2 - T_1) \cdot (d_2 - T_2) \cdot T_3 < 0\) is satisfied,

(ii) always proves to be beneficial for the firm, resulting in an increase in the expected level of firm-specific investment and the expected firm profit iff \((d_2 - T_1) \cdot (d_2 - T_2) \cdot T_3 > 0\) is satisfied,

(iii) has no impact on firm value iff \((d_2 - T_1) \cdot (d_2 - T_2) \cdot T_3 = 0\) is satisfied.

**Proof of Lemma 3.** By backward induction we find the first-order conditions \(v(\theta, I) = (d_0 + I) / 2\), \(q(\theta, I) = (d_0 + I) / 2b_0\) and \(w'_M(I^N) = E [\partial (R(q(\theta, I^N), \theta, I^N) - v(\theta, I^N)) / \partial I] = E[1/2 \cdot q(\theta, I^N)]\). This leads to the following quantities and investments for the NoIS-case \((i = 1, 2, i \neq j)\)

\[
I^N = \frac{p_1b_2d_1 + p_2b_1d_2}{4b_1b_2 - p_1b_2 - p_2b_1} \quad \text{and} \quad q^N(\theta, I^N) = \frac{4d_4b_j + p_2(d_j - d_i)}{4b_1b_2 - p_1b_2 + p_2b_2}
\]

and for the case of the perfect system \((S = 1, 2)\)

\[
I^P_s = \frac{d_s}{4b_s - 1} \quad \text{and} \quad q^P(\theta, I^P_s) = \frac{4d_s}{4b_s - 1}.
\]

Again, we find the case of a perfect system by inserting the boundary values \((p_1, p_2) = (1, 0)\) and \((p_1, p_2) = (0, 1)\) into the solution of the noninformative system. The rest of the proof follows the same argumentation used in the proof of Lemma 2. The second-order derivative of \(V(p_1)\) is

\[
\frac{\partial^2 V(p_1)}{\partial p_1^2} = \frac{Y_1(p_1Y_2 + 3p_2b_1(d_1 - d_2) - 4(d_2 + 20d_2b_2)b_1^2 + Y_1(80b_2^2d_1 - (32d_1 - 36d_2)b_2)b_1)}{4(4b_1b_2 - p_1b_2 - p_2b_1)^4}
\]

with \(Y_1 = b_1b_2(d_1(4b_2 - 1) + d_2(1 - 4b_1))\) and \(Y_2 = 4b_1^2d_2 - 4b_1b_2(d_1 + d_2) + 4b_2^2d_1 + 3b_2(d_1 - d_2)\). The second-order derivative has the following properties (i) the denominator is positive \(4(4b_1b_2 - p_1b_2 - p_2b_1)^4 > 0\), (ii) the nominator possesses the zero points \(T_1\) and \(T_2\). Comparing algebraic signs of the second-order derivative completes the proof. □
# TABLES

First-best Solution

## TABLE I

FIRST-BEST SOLUTION WITH AND WITHOUT THE INFORMATION SYSTEM

<table>
<thead>
<tr>
<th>First-order conditions ((d_\theta := a_\theta - c_\theta))</th>
<th>(q(\theta, I) := \frac{d_\theta + I}{b_\theta})</th>
<th>(w'(I) := E[q(\theta, I)])</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimal quantity</td>
<td>(q(\theta, I) := \frac{d_\theta + I}{b_\theta})</td>
<td>(w'(I) := E[q(\theta, I)])</td>
</tr>
<tr>
<td>Optimal investment</td>
<td>(w'(I) := E[q(\theta, I)])</td>
<td>(w'(I) := E[q(\theta, I)])</td>
</tr>
</tbody>
</table>

Two-states case \(\theta \in \{\theta_1, \theta_2\}\)

<table>
<thead>
<tr>
<th>Perfect Information</th>
<th>(\eta^P(\theta, I^{\text{fbP}}) := \frac{d_\theta}{b_\theta - 1})</th>
<th>(I^{\text{fbP}} := \frac{d_\theta}{b_\theta - 1})</th>
<th>(\Pi^{\text{P max}} := E\left[\frac{1}{2} b_\theta q^P(\theta, I^{\text{fbP}})^2 - \frac{1}{2} \left(I^{\text{fbP}}\right)^2\right])</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimal quantity</td>
<td>(\eta^P(\theta, I^{\text{fbP}}) := \frac{d_\theta}{b_\theta - 1})</td>
<td>(I^{\text{fbP}} := \frac{d_\theta}{b_\theta - 1})</td>
<td>(\Pi^{\text{P max}} := E\left[\frac{1}{2} b_\theta q^P(\theta, I^{\text{fbP}})^2 - \frac{1}{2} \left(I^{\text{fbP}}\right)^2\right])</td>
</tr>
<tr>
<td>Optimal investment</td>
<td>(\eta^P(\theta, I^{\text{fbP}}) := \frac{d_\theta}{b_\theta - 1})</td>
<td>(I^{\text{fbP}} := \frac{d_\theta}{b_\theta - 1})</td>
<td>(\Pi^{\text{P max}} := E\left[\frac{1}{2} b_\theta q^P(\theta, I^{\text{fbP}})^2 - \frac{1}{2} \left(I^{\text{fbP}}\right)^2\right])</td>
</tr>
<tr>
<td>No Information</td>
<td>(\eta^N(\theta, I^{\text{fbP}}) := \frac{d_i b_j + p_j (d_i - d_j)}{b_i b_j - p_1 b_2 - p_2 b_1})</td>
<td>(I^{\text{fbN}} := \frac{p_2 d_2 b_1 + p_1 d_1 b_2}{b_i b_j - p_1 b_2 - p_2 b_1})</td>
<td>(\Pi^{\text{N max}} := E\left[\frac{1}{2} b_\theta q^N(\theta, I^{\text{fbN}})^2\right] - \frac{1}{2} \left(I^{\text{fbN}}\right)^2)</td>
</tr>
</tbody>
</table>

| Expected firm profit | \(\Pi^{\text{P max}} := E\left[\frac{1}{2} b_\theta q^P(\theta, I^{\text{fbP}})^2 - \frac{1}{2} \left(I^{\text{fbP}}\right)^2\right]\) | \(\Pi^{\text{N max}} := E\left[\frac{1}{2} b_\theta q^N(\theta, I^{\text{fbN}})^2\right] - \frac{1}{2} \left(I^{\text{fbN}}\right)^2\) |
Decentralised Setting

<table>
<thead>
<tr>
<th>DECENTRALISED SCENARIO WITH AND WITHOUT THE INFORMATION SYSTEM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>First-order conditions</strong> ((d_\theta := a_\theta - c_\theta))</td>
</tr>
<tr>
<td>Optimal quantity (q(\theta, I) = \frac{d_\theta + I}{2b_\theta})</td>
</tr>
<tr>
<td>Optimal investment (w'(I) = E[q(\theta, I)])</td>
</tr>
</tbody>
</table>

**Two-states case** \(\theta \in \{\theta_1, \theta_2\}\)

<table>
<thead>
<tr>
<th><strong>Perfect Information</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimal quantity (q^P(\theta, I^P_\theta) = \frac{d_\theta}{2b_\theta - 1})</td>
</tr>
<tr>
<td>Optimal investment (I^P_\theta = \frac{d_\theta}{2b_\theta - 1})</td>
</tr>
<tr>
<td>Expected firm profit (\Pi^{P\text{max}} = E\left[\frac{3}{8} b_\theta q^P(\theta, I^P_\theta)^2 - \frac{4}{8} (I^P_\theta)^2\right])</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>No Information</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimal quantity (q^N(\theta_1, I^N) = \frac{2d_j b_j + p_j(d_j - d_i)}{2b_1 b_2 - p_1 b_2 - p_2 b_1}) ((i, j = 1, 2, i \neq j))</td>
</tr>
<tr>
<td>Optimal investment (I^N = \frac{p_1 d_1 b_2 + p_2 d_2 b_1}{2b_1 b_2 - p_1 b_2 - p_2 b_1})</td>
</tr>
<tr>
<td>Expected firm profit (\Pi^{N\text{max}} = E\left[\frac{3}{8} b_\theta q^N(\theta, I^N)^2\right] - \frac{4}{8} (I^N)^2)</td>
</tr>
</tbody>
</table>
Graph I: Investment decisions in the decentralised setting