On the effectiveness of enforcement of insider trading laws

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Abstract: Empirical research has found significant effects of enforcement of insider trading laws on cost of equity. The reduction in cost of equity is expected when the adverse selection problem (i.e. the degree of insider trading) decreases. In this paper we model the game between a supervisor enforcing insider trading legislation and a trader possibly trading on inside information. The resulting equilibrium strategies illustrate when enforcement is indeed effective or, equivalently, when insiders are sometimes deterred from using their inside information and how further reduction in insider trading can be achieved. We discuss legal and economic implications as well as implications for empirical research. It appears that equilibrium strategies exist with enforcement but where all insider information is still used. This may be important for empirical research. We also find situations where improvements in the quality of the risk analysis system of the supervisor make the degree of insider trading increase. Furthermore, we find that reducing the amount of inside information for example by tighter disclosure requirements not necessarily leads to less insider trading since this effect may be offset by a more frequent use of inside information so that the degree of insider trading does not change.

Keywords: Insider Trading, Regulation, Game Theory, Enforcement, Cost of Equity

JEL-codes: C72, G18, K22, K42, D82
1. Introduction

In this paper we study the issue of compliance with respect to insider trading laws in a game theoretic setting. When evaluating supervisors, questions may arise whether enforcement of insider trading laws is effective and whether for example the audit frequency is high enough. This study wants to investigate what means or tools (e.g. increased penalties, better risk analysis system, higher audit efficiency) are efficient in deterring insiders from trading on inside information in different circumstances and what optimal audit frequencies are. In order to answer these questions we model a game between the supervisor and a trader, where the trader may get inside information and decides whether or not to use it. As in the practice of supervision and enforcement, the supervisor on the other hand has a risk analysis system in place, indicating suspicious trades with a certain probability. It has to set audit strategies dependent on the signals it receives.

The focus in this paper is on enforcement of insider trading regulation. DeMarzo et al. (1998) are the first to study the optimal investigation strategy of the regulator and the corresponding trading strategy of the traders with inside information. Compared to the study of DeMarzo et al. (1998) our approach takes another view on the problem the regulator faces with respect to some important aspects. The main reasons are that we want to answer different questions, such as: in which settings is the degree of insider trading (and thereby cost of equity) actually reduced by enforcement and how can the structure of the legal system and the efficiency and effectiveness of the supervisor contribute to this reduction. The main differences with DeMarzo et al (1998) are on five aspects. First, whereas DeMarzo et al. (1998) formulate the objective of the regulator as to maximize the expected utility of the uninformed traders, we model the regulator as optimizing its own objective. Of course, the benefits of uninformed traders are part of this objective, but we allow for other benefits and objectives as well. The approach of DeMarzo et al., (1998) is more in line with the ‘public interest theory’ of regulation. Our approach is more in line with the ‘interest group theory’ (see e.g. Posner, 1974).

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1 This is also done for example in Glaeser et al. (2001) in their model of enforcement incentives. They acknowledge motivation by e.g. ‘politics’ or short run career concerns.
Second, the optimization problem of DeMarzo et al. (1998) is from the point of view of the regulator facing a budget constraint. The regulator has to maximize the benefits of uninformed traders by auditing transactions given a budget constraint. As a consequence, benefits that could be materialized by more investigation, but that do not yield additional financing (penalties and taxes are taken into account in the budget constraint), will not be materialized if the budget constraint is binding. Reduction in cost of equity is an example of benefits that may result, but do not directly contribute to the financing of the regulator. We allow for higher costs of auditing if these are offset by more benefits. We therefore incorporate the cost of auditing in the objective function. In this way, our model is more comparable to the tax compliance literature (see e.g. Graetz et al., 1986, Beck and Jung, 1989, Sansing, 1993, and De Waegenaere et al., 2006). In insider trading a compliance problem exists with respect to following or violating the rules, as in tax compliance issues.

Third, DeMarzo et al. (1998) incorporate in one probability whether an investigation is done, the probability of getting caught and the probability of getting convicted. We separate these three elements in order to explicitly study the sensitivity to the effectiveness of the supervisor and the legal system. We therefore have to model separately the probability of getting caught, the risk analysis system of the supervisor and the probability of getting prosecuted and convicted.

Fourth, as a result of the separate modeling of a risk analysis system, we are able to study the effects of such a system with the supervisor. Although it is generally assumed that a better signal on whether a trade was based on inside information is preferable, this appears not to hold in all situations.

Finally, DeMarzo et al. (1998) already mention that they do not take into account whether the threat of auditing is credible or not. Given the objective of maximizing utility of uninformed traders, they had to assume that the regulator can commit to an investigation policy. In our paper we explicitly look at sustainable equilibrium strategies given that the regulator has its own objectives. As we will see, there is an equilibrium in which the regulator cannot credibly threat to audit because of relatively high audit costs although auditing could be socially optimal.

As a result, our model looks completely different from the model in DeMarzo et al. (1998). Of course, social benefits are included in the objective and are potentially huge. The benefits due to reduction in cost of equity however depend on the actual reduction in insider trading. We make some concessions.
too. To explicitly model the compliance issue, we do not explicitly build in uncertainty in prices with risk aversion for the trader.

Using a simple game-theoretic model, this paper presents the different equilibrium strategies that can result. We analyze how the different parameters (such as design of the legal system or the law) influence the resulting trading strategy of the insider and investigation policy of the supervisor. More specifically, we find five equilibria. First, there is a situation where audit costs are relatively high compared to direct benefits. In this case, there is no enforcement and all inside information for traders is used. In this equilibrium, the regulator cannot credibly threat to audit. In the second and third equilibrium, expected penalties are not sufficiently high to prevent the trader from using its inside information, but the audit process of the regulator is cost-efficient compared to direct benefits for the supervisor. In this case, there is a lot of enforcement, but the eventual effect measured as the reduction of insider trading is zero. The difference between the two equilibria is whether all trades are audited or only those signaled by the risk analysis system as high risk. When audit costs are very low, the supervisor may even prefer to audit trades that are not signaled as suspicious. These two equilibria might explain that indeed enforcement as such may not always reduce cost of equity. In this case there is enforcement and accompanying social costs, without the real social benefits of reduced insider trading resulting in lower cost of equity. The fourth equilibrium is the situation that benefits are sufficiently high to have a credible threat to audit, expected penalties are sufficiently high to deter insiders from always trading but the risk analysis system of the supervisor is not that reliable that only positive signals have to be audited. Traders are deterred from always using inside information (and thereby cost of equity is reduced) in this equilibrium. Equilibrium five is similar, but here the risk analysis system of the supervisor is of high quality, so transactions based on inside information are detected more easily. Here the reduction in the degree of insider trading due to enforcement and therefore the reduction in cost of equity is the highest. The enforcement rate is however low compared to the earlier equilibrium strategies with enforcement.

We study how these strategies depend on several parameters in the model. One obvious and important parameter is the conviction rate. In the European Union, legislation generally requires inside
information to be precise in order to be found guilty on insider trading (see e.g. Maug, 2002). This may result in many cases where information is private, but cannot be classified as inside information. This results in a possibly low effective conviction rate (convictions compared to investigations of the regulator) which increases the probability of ending up in equilibria with a low reduction in insider trading.

We also find that a better risk analysis system of the regulator is not always preferable. When the quality is not that good, so that trades not being signaled as high risk by the system also have to be audited with positive probability, marginal improvements in the quality of the system make the degree of insider trading increase. Therefore in order to have insider trading decrease, improvements should be made such that the resulting system is that reliable that only trades with positive signals have to be audited. In this case insiders will know that the probability of being signaled is high. A final result we mention is the effect of prevention, e.g. due to tighter disclosure rules to reduce the amount of inside information in the market. As may be expected, we show that this reduces the effectiveness of enforcement. Combined with less inside information, this reduced amount of inside information reduces the amount of insider trading in cases where enforcement is ineffective. However, when enforcement is effective (efficient audits and deterring penalties), a reduction in the amount of inside information does not affect the overall amount of insider trading. So when repression (enforcement) is effective, more prevention (disclosure) is offset by the loss in effectiveness of repression, since enforcement becomes more like searching for a needle in the haystack.

Apart from the insights in how to structure the legal system of insider trading laws and enforcement, our paper contributes to empirical research by explaining theoretically some current observations as well as by hinting at possible directions for future studies. The existence of an equilibrium where enforcement has no effect on the amount of insider trading could partially explain the weaker relation between enforcement and functioning of the capital markets as found in La Porta et al. (2006). We also show that lower enforcement rates may very well be linked with a low degree of insider trading in cases where the threat of an audit is credible and expected penalties are high. Furthermore, regarding the tradeoff between disclosure and enforcement, our model suggests that disclosure mediates the effect of enforcement on the cost of equity. Our model provides possible
directions to find more empirical evidence on the relation between cost of equity and enforcement of insider trading. In short, distinguishing between the equilibrium strategies found may yield new insights and empirical evidence. All empirical studies referred to are very carefully deducted, and do capture many effects and yield valuable insights. But whereas current research focuses on whether there is enforcement or not, our model suggests that cost of equity is also not reduced in situations with enforcement but with low expected penalties. The independent variable related to enforcement when explaining cost of equity should not be whether there is enforcement, but whether there is effective enforcement. Some more concrete suggestions are provided in Section 4.3.

The remainder of this paper is organized as follows. In the next section, we provide a short overview of related research. Section 3 describes the model. In Section 4 the resulting optimal equilibrium strategies presented. Section 5 deals with the analysis of the results. We discuss the sensitivity analysis of the parameters, some special situations of the model, the empirical implications and the economic and legal implications. Section 6 concludes.

2. Related literature

There is an extensive literature on insider trading in the areas of law, economics, finance and politics. An exhaustive overview of literature is by no means pursued here, but we will highlight some streams of research and results by mentioning the most related papers published in a wide variety of journals. We will focus on the more recent literature and refer to Bainbridge (1999) for a more detailed overview, especially of earlier research.

The first stream of research is about economic consequences of insider trading, insider trading laws and enforcement. These studies present economic theories relating to whether insider trading should be prohibited. One of the first theories was presented by Manne (1966), who argues that insider trading is efficient, since shareholders can benefit from insider trading by lowering the compensation costs. Later theories present opposite conclusions, especially by analyzing the effects of insider trading on the cost of capital (and thereby on investment decisions). Examples are Fishman and Hagerty
(1992) and Bebchuk and Fershtman (1994). An interesting conclusion found by Ausubel (1990) is that insider trading laws can be pareto-optimal. ‘Insiders are made better off if they can precommit not to trade on their privileged information; government regulation accomplishes exactly this’. Another economic consequence has been studied by Maug (2002). He studied the effects of insider trading legislation on corporate governance. It is shown that insider trading legislation can imply full disclosure whereas in the absence of insider trading legislation, managers may collude with a dominant shareholder at the expense of small shareholders. Other papers focus more explicitly on the agency costs associated with insider trading and agency costs associated with regulation and enforcement, such as Padilla (2002). Still, there are arguments in favor of insider trading laws and enforcement as well as arguments against it. This also holds for the stream of empirical research regarding the value of investor protection and the benefits of the existence of insider trading laws and enforcement.

Let us now mention some results from this stream of empirical research on the value of investor protection and insider trading laws. Theories supporting the prevention of insider trading are mostly based on showing that a reduction in insider trading can increase the efficiency of capital allocation and reduce the cost of equity. As mentioned, Ausubel (1990) adds an argument that insider trading laws can be the tool to enforce a more socially optimal cooperative equilibrium that cannot be enhanced without the enforcement of insider trading laws. Empirically however, the focus is on the cost of capital. The theory suggests that less insider trading reduces the adverse selection problem that arises from information asymmetry. This results in reduced estimation risk and therefore a lower cost of capital due to reduced uncertainty. Wurgler (2000) for example shows that the efficiency of capital allocation is positively correlated with the legal protection of minority investors (which may be accomplished by insider trading regulation). Easley and O’Hara (2004) show that investors demand a higher return to hold stocks with greater private information resulting in higher cost of capital. On the contrary, Bris (2000) finds by studying acquisitions, that laws that prosecute insider trading fail to eliminate profits made by insiders and make acquisitions more expensive. Bris (2000) argues that insider trading laws increase the market reaction to an acquisition increasing the possible payoffs from violating insider trading laws. Recent studies on the stock price effects in different countries with
different insider trading laws and regimes show however a significant value from enforcement of these laws. First, Bhattacharya and Daouk (2002) show that the cost of equity in a country decreases significantly after the first prosecution with respect to the insider trading law. They also show that the introduction of these laws as such does not reduce the cost of equity. Enforcement of the law is necessary to obtain the benefits in reduced cost of equity. Beny (2005) extends this study and also investigates whether differences in specific legal elements of the countries’ insider trading laws result in differences in structure and performance of the stock markets. More insider trading law variables are included as well as different enforcement variables (as also discussed in La Porta et al., 2006). Beny (2005) then shows that ‘countries with more prohibitive insider trading laws have more diffuse equity ownership, more accurate stock prices, and more liquid stock markets’. La Porta et al. (2006) investigate the effectiveness of different attributes in securities laws by studying IPO’s. They find little evidence that enforcement benefits stock markets but strong evidence that laws mandating disclosure and facilitating private enforcement (through liability rules) benefit stock markets. The compliance game in our paper does indeed show that there are situations with much enforcement of insider trading laws, but with no real benefits for the stock markets. This equilibrium may contribute to the explanation of the result observed in La Porta et al. (2006). Furthermore, we show that more disclosure may reduce the effectiveness of enforcement.

A third stream of research focuses on the behavior of informed traders. This started with Kyle (1985). This study has been extended in several ways. Recently Yung (2005) e.g. studies the behavior of a manager with inside information whose actions also influence firm value. Other papers extended the results of Kyle (1985) by incorporating real as well as financial sectors in their models (e.g. Leland, 1992) and the relationship between real and financial effects of insider trading (e.g. Jain and Mirman, 2000). Daher and Mirman (2006) extend this to a competitive environment.

Apart from these streams of research, there are still many other issues related to insider trading that are investigated. Without going into detail, we finally mention the questions about who should enforce a particular public law and how is it optimally enforced. Some papers on this subject are Glaeser et al. (2001), and Polinsky and Shavell (2000). Polinsky and Shavell (2000) study the economic theory of enforcement in a general setting and focus on questions like ‘how much resources
should be spent to detecting act violations?’, ‘should the sanction be a fine or imprisonment?’, ‘what levels should the sanctions be set?’’. Glaeser et al. (2001) compare the design of laws and regulation of the securities regulation in Poland and the Czech Republic. These transition economies had to design financial regulation essentially from scratch making it possible to compare and analyze the consequences of the implemented strategies that were almost opposite. Also the empirical papers of La Porta et al. (2006) and Beny (2005) take up the issue on public versus private enforcement to some extent. DeMarzo et al. (1998) model optimal enforcement of insider trading, and is thereby closely related to the setting of our paper.

3. The model

The game between trader and supervisor can be described in a simple model. The two players are a trader (T) and a supervisor (S). The trader actively trades and gets insider knowledge with probability $q$. T consequently has to decide whether or not to use this knowledge in his buy and sell orders. This decision is modelled with parameter $\alpha$. $\alpha=1$ means that he uses the information, and $\alpha=0$ means that he does not. Of course, whether or not T has insider knowledge is private information for T and not known by S. The probability that $T$ has inside information ($q$) is common knowledge. S observes many transactions, and has to decide for all these transactions whether or not to start an audit. In order to detect suspicious trades more easily, a risk analysis system is in place. The risk analysis system gives a private signal $s$ equal to one or zero for a trade. The signal equals one if a trade is labelled as high risk on insider trading and zero if it is labelled as low risk. The quality of the risk analysis system is indicated with $v$. The probability that $s=1$ if $q \cdot \alpha=1$ equals $v$; similarly, the probability that $s=1$ if $q \cdot \alpha =0$ equals $1-v$. Based on this system, S can update its beliefs on the trading strategy of T. Given a trading strategy $\alpha^e$ of $T$, the supervisor can determine a posterior probability based on the signal. These posterior probabilities are as follows:
Pr\{q \cdot \alpha = 1 \mid s = 1\} = \frac{v q \alpha^*}{(1-v)(1-q \alpha^*) + v q \alpha^*}
Pr\{q \cdot \alpha = 0 \mid s = 1\} = \frac{v}{(1-v)(1-q \alpha^*) + v q \alpha^*}
Pr\{q \cdot \alpha = 1 \mid s = 0\} = \frac{v q \alpha^*}{v(1-q \alpha^*) + (1-v) q \alpha^*}
Pr\{q \cdot \alpha = 0 \mid s = 0\} = \frac{1}{v(1-q \alpha^*) + (1-v) q \alpha^*}

It follows immediately that $v=1/2$ implies that the signal is useless, since the probability on insider trading then equals $q \alpha^*$. This is equivalent to the situation where no risk analysis system is in place. Finally note that the probability $q$ may just as well be interpreted as a kind of risk adjusted probability.

In this case, it is the probability that $T$ received inside information as assumed (or assigned) by $S$. The signal is private information for $S$; the quality of the system ($v$) is common knowledge. The decision whether to audit a transaction is indicated with $\beta$. Here $\beta_i = 1$ ($i = 0, 1$) means an audit is done if the system gives a signal $i$; $\beta_i = 0$ means no audit takes place. An audit brings along cost equal to $K$ and reveals to the supervisor whether or not the transaction was based on insider knowledge with probability $r$. This however does not imply that it can be proven easily. The supervisor however does always report this insider trading (if detected) to the public prosecutor. The prosecutor prosecutes and wins with probability $p$. In $1-p$ cases, the prosecutor either decides not to prosecute or loses the case in court.

So, to summarize, the sequence of the game is as follows:

1. $T$ gets inside information with probability $q$
2. If $T$ has private info, he decides whether or not to use it in his advantage
3. $S$ gets a signal with quality $v$
4. $S$ decides whether to audit the transaction
5. If audited, it is detected whether the transaction was based on inside information with probability $r$
6. If insider trading is detected, $S$ reports the trade to the public prosecutor and
7. a prosecution game is played with a resulting probability of conviction equal to $p$.

Payoffs
Using the private information will yield an additional (expected) profit for $T$ equal to $g$. When however the transaction is audited and insider trading is detected, so that the supervisor does report the trade to the prosecutor as insider trading, the penalty equals $\pi(p)$. We assume $\pi(p)$ is strictly increasing in the conviction rate $p$, $p \in [0,1]$. Furthermore we assume that $\pi(1) > g$, which implies that a conviction in court will yield more damage than the possible gain from insider trading. When the additional gain $g$ has to be repaid for example, this is already realized. Without this condition, the penalties will be too low compared to the incentives to prevent insider trading in any case. This case $\pi(1) < g$ is therefore not analyzed furthermore since it is straightforward.

Example: An example for a penalty function is $\pi_1 + p \pi_2$. There may be some loss independent of the conviction if the supervisor reports a trade to the prosecutor (one might think of damage because of shredded reputation, a report to a superior in the company et cetera) equal to $\pi_1$. If the trader is convicted the additional loss on top of this is, including for example the fine, is $\pi_2$.

As mentioned, the supervisor faces costs $K$ when an audit is done. The direct benefits, that we denote $B(p)$, are a function of the conviction rate $p$. One might think of the penalties incurred, which are a function of the conviction rate, but also of politics, trust in the supervisor, career concerns et cetera. As with the penalties, we assume that $B'(p) > 0$.

Example: An example of a benefit function $B(p)$ is $b_1 + p b_2$. The supervisor materializes benefits when reporting a trade to the prosecutor equal to $b_1$. These benefits are expected to be quite low. It may relate to a social benefit of increased trust in the supervisor but can also be attributed to benefits experienced by the supervisor itself. An example is a benefit for the supervisor since it contributes to the perception of power. Alternatively, it may be important for career concerns or ‘politics’ to show stakeholders that trades are investigated and reported. It may even be the case that the output (reported trades) is part of the evaluation of the functioning of the supervisor. Only when a conviction in court follows, higher benefits equal to $b_2$ are materialized. One might think of social value attributed to an equitable distribution of income and the value of the penalties imposed.
The most important economic benefit is the reduction in cost of equity due to an increase in confidence in the functioning of the financial markets (see e.g. Bhattacharya & Daouk, 2002). Although empirically related to the presence of enforcement, we explicitly model this as dependent on the actual degree of insider trading. If traders are not deterred from using inside information in some situations, the adverse selection problem does not decrease, resulting in the same information asymmetry implying no effect on cost of capital. Therefore, we incorporate social benefits dependent on the resulting strategy of T, since this partly determines the degree of insider trading. This can be modelled as \( b(qa) \), where \( b(0) \) is the maximal benefit that can result from the reduction in cost of equity. Furthermore \( b'(q) < 0 \) and without loss of generality we assume \( b(q) = 0 \). These requirements on \( b(.) \) imply that less insider trading is associated with higher benefits due to reduced cost of equity and the possible reduction in cost of equity is fully realized when there is no insider trading anymore \((qa=0)\). A simple example of such a function is \( b(x) = q - x \).

So T has to decide whether or not to use its inside information and S whether or not to audit a transaction given the signal it receives. Before determining and analyzing the optimal strategies of the players, the payoffs in different situations are presented in Table 1.

<table>
<thead>
<tr>
<th>Situation</th>
<th>Decision T</th>
<th>Decision S</th>
<th>Payoff T</th>
<th>Payoff S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insider knowledge present</td>
<td>( \alpha = 0 )</td>
<td>( \beta_i = 0 )</td>
<td>0</td>
<td>( b(\alpha) )</td>
</tr>
<tr>
<td></td>
<td>( \beta_i = 1 )</td>
<td>0</td>
<td>- ( K + b(\alpha) )</td>
<td></td>
</tr>
<tr>
<td>Insider knowledge present</td>
<td>( \alpha = 1 )</td>
<td>( \beta_i = 0 )</td>
<td>( g )</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>( \beta_i = 1 )</td>
<td>( g - r\pi(p) )</td>
<td>- ( K + rB(p) )</td>
<td></td>
</tr>
<tr>
<td>Insider knowledge not present</td>
<td>Given a strategy ( \alpha ) for cases where T has inside information</td>
<td>( \beta_i = 0 )</td>
<td>0</td>
<td>0 + ( b(qa) )</td>
</tr>
<tr>
<td></td>
<td>( \beta_i = 1 )</td>
<td>0</td>
<td>- ( K + b(qa) )</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Payoffs of S and T dependent on situation and decision.

The expected payoff for the supervisor when it receives signal i therefore equals:
\[
    P_{si} = \beta_i \left[ -K + \Pr\{ q \alpha = 1 \mid s = i \} \cdot r \cdot B(p) \right] + b(q \alpha), \quad i=0,1
\]  
and the trader’s expected payoff, given he has inside information, is:
\[
    P_T = \alpha \left[ g - v \beta_i r \cdot \pi(p) - (1 - v) \beta_0 r \cdot \pi(p) \right].
\]  
In cases where the trader has no insider information, there is a payoff equal to 0 for \( T \). Note that \( v \) equals the probability that \( S \) gets a signal equal to 1, so \( v = \Pr\{ s=1 \mid q \alpha=1 \} \) and similarly \( 1-v = \Pr\{ s=0 \mid q \alpha=1 \} \).

In the next section, the Nash-equilibria of this game are derived and the resulting equilibrium strategies discussed. If possible without confusion, the dependence of the functions \( B \) and \( \pi \) on \( p \) is suppressed.

4. **Optimal strategies**

A Nash-equilibrium is a set of strategies such that both players have the optimal answer to the other player’s strategy. Five possible equilibria result in this game. The following propositions formalize the equilibrium strategies. Proposition 1 presents the pure strategy equilibrium strategies. All proofs are in the Appendix.

**Proposition 1**

I. For \( K > K_A := \frac{vq}{(1-v)(1-q)+vq} rB(p) \), the equilibrium strategies are \( \alpha=1, \beta_0=0 \) and \( \beta_1=0 \).

II. For \( K_A < K \geq K_B := \frac{q(1-v)}{v(1-q)+q(1-v)} rB(p) \) and \( g > v \cdot r \pi(p) \) the Nash equilibrium strategies are \( \alpha=1, \beta_0=0 \) and \( \beta_1=1 \).

III. For \( K < K_B \) and \( g > r \pi(p) \) the Nash equilibrium strategies are \( \alpha=1, \beta_0=1 \) and \( \beta_1=1 \).
In the sequel we will refer to the equilibrium strategies of Propositions 1 as equilibrium I, II and III respectively. The first situation \((K > K_A)\) deals with the situation in which audit cost \((K)\) are high compared to expected direct benefits resulting from supervision even when auditing a suspicious trade signalled by the risk analysis system (these direct benefits equal \(\frac{vq - R(p)}{(1-v)(1-q)+vq}\)). As a result it is never optimal for the supervisor to audit, which implies that the traders always use all available inside information. Note that this can be due to the fact that the conviction rate is low and not necessarily implies that audits are inefficient. In this equilibrium, the supervisor will benefit from a lower \(\alpha\) due to the reduced cost of equity, but cannot convincingly threat to play a high audit rate. Suppose \(S\) threatens to play a high audit rate. This could lead to a lower \(\alpha\) yielding additional benefits. It is however not an equilibrium, since the supervisor can then marginally improve its objective by decreasing the audit rate. So although potentially socially optimal, a higher audit rate is not a sustainable equilibrium. In order to avoid equilibrium I, the supervisor needs to have an efficient audit process, compared to the expected direct benefits (i.e. benefits excluding the reduction in cost of equity).

In equilibrium II and III auditing and litigation yield benefits, but still this investigation strategy does not result in less insider trading. This implies that the reduction in cost of equity is *not* realized. The only benefits are maybe a fair distribution of income (and the social well-being associated with it), the value of the penalties imposed on the trader and possibly other benefits perceived by the supervisor such as pleasing stakeholders. This situation results if the expected penalty given an audit is less than the expected gain \(g\). The expected penalty given an audit depends on whether auditing trades signalled as ‘low risk’ still yields benefits in excess of audit costs. If audit cost are below the critical level \(K_B\), then the auditor also has a credible threat to audit trades with a signal \(s=0\). The expected penalty is then equal to \(r \pi(p)\). If audit costs are higher, there is no credible threat to audit trades signalled as non-suspicious (low risk), so the expected penalty then equals \(v r \pi(p)\). The trader will then always use inside information if gains exceed this level of expected penalties.

In these settings it is impossible to deter the trader from using its inside information. This can be due to either low penalties compared to the possible gains, a low conviction rate \((p)\) or ineffective audits of \(S\) (low \(r\)). Note that the penalties given conviction may therefore still be high.
The next proposition deals with the cases in which audit costs are relatively low and penalties are relatively higher compared to gains. For these cases mixed strategy equilibria result.

**Proposition 2**

**IV.** For \( K \leq K_B \) and \( vr \pi \leq g \leq r \pi \) the equilibrium strategies are \( \alpha = \alpha_0, \beta_0 = \beta_0, \beta_1 = 1 \).

**V.** For \( K \leq K_A \) and \( g \leq vr \pi \) the equilibrium strategies are \( \alpha = \alpha_i, \beta_0 = 0, \beta_1 = \beta_1 \).

with \( \bar{\alpha}_0 = \frac{Kv}{q[rB \cdot (1-v) + K(2v-1)]} \), \( \bar{\alpha}_i = \frac{K(1-v)}{q[rB \cdot v - K(2v-1)]} \), \( \bar{\beta}_0 = \frac{g - vr \pi}{(1-v)r \pi} \) and \( \bar{\beta}_1 = \frac{g}{vr \pi} \), so that \( 0 \leq \bar{\alpha}_0, \bar{\beta}_0, \bar{\alpha}_i, \bar{\beta}_1 \leq 1 \).

In the sequel we will refer to the equilibrium strategies of Propositions 2 as equilibria IV and V respectively. In the mixed strategy equilibria IV and V insiders are in some cases deterred from trading based on inside information and therefore the economic benefit of reduction in cost of equity is realized to some extent. In this case, the threat of conviction is sufficiently high (compared to the benefits of insider trading) in order to reduce the degree of insider trading, so that the ultimate goal (a lower degree of insider trading and thereby reduction of the cost of equity) is realized. Equilibrium IV is an equilibrium with high audit frequency. All positive signals and some negative signals generated by the risk analysis system are audited. Compared to equilibrium V, this equilibrium results if the quality of the risk analysis system is poor (low \( v \)). When the quality is high (\( v \) high), equilibrium strategy V is more likely to result. Here the signal is of good quality, making it possible to deter insiders from trading based on their inside information even when only auditing ‘high risk’ trades. The following proposition states that insider trading in equilibrium V, with high risk-analysis quality, is less likely than in equilibrium IV (the equilibrium with a lower quality of the signal).

**Proposition 3**

If \( v > 1/2 \) (\( v=1/2 \)) then \( \bar{\alpha}_i < \bar{\alpha}_0 \) (\( \bar{\alpha}_i = \bar{\alpha}_0 \))
Figure 1 illustrates the five possible equilibria as a function of audit cost $K$ and probability of conviction $p$, for linear penalty and benefit functions (in $p$).

Equilibrium strategies for different values of $p$ and $K$

![Equilibrium strategies graph](image)

*Figure 1*: Equilibrium strategies for different values of $p$ and $K$. This graph follows from parameter values $q = 0.04; r = 0.9; B(p)=100 + 1000p; \pi(p) =5 + 30p; g = 15; \text{and } v = 0.6.$

The next section gives an analysis of the effects of the different parameters on these equilibria. This results in implications for the supervisor and the legal system. We also formulate implications for empirical research.

5. **Analysis and implications**

Before discussing several situations in more detail, we first illustrate the strategies of the players in Figure 2. Figure 2 illustrates that the degree of insider trading decreases as soon as the supervisor can credibly threat to audit and the expected penalty for the trader when being audited is higher than the
possible gain (equilibria IV and V). From that critical value of $p$, the frequency of insider trading drops to a much lower level yielding a reduction in the adverse selection problem implying lower total cost of equity in the market. We will now consecutively discuss the sensitivity of some important parameters, some different cases that can be distinguished, relation with and implications for empirical research and finally legal and economic implications.

![Strategies as a function of $p$](image)

**Figure 2:** Strategies of S and T for different values of $p$. This graph follows from parameter values as used in Figure 1 and $K=7$. The different equilibrium strategies are indicated below the graph.

### 5.1 Sensitivity with respect to efficiency and penalties

First we will now study the sensitivity of the strategies with respect to the efficiency and effectiveness of the supervisor and the legal system. We will therefore look at the effects of the parameters $K$, $v$, $r$, $p$, $q$, $g$ and the functions $\pi(p)$ and $B(p)$. We will look at the effect on which equilibrium will result, as well as the effect on the strategies within an equilibrium in case of a mixed strategy. The effect of $p$ is illustrated in Figures 1 and 2. As $p$ increases, the direct benefits increase, making equilibrium I less
likely. Furthermore, it becomes more likely to end up in a ‘better’ equilibrium, i.e. an equilibrium with less insider trading. Within the mixed strategy equilibria, the trader’s rates of using information as well as the audit frequencies decrease with $p$. This is formalized in the following proposition.

**Proposition 4**

- The critical cost levels $K_A$ and $K_B$ increase with the conviction rate $p$.
- Furthermore, increases in the conviction rate $p$ make region IV increase at the expense of III, i.e. $\frac{\partial r\pi(p)}{\partial p} > 0$.
- Similarly increases in $p$ make region V increase at the expense of regions II and IV, i.e. $\frac{\partial v\pi(p)}{\partial p} > 0$.
- Within equilibria IV and V, trading and audit frequencies decrease with $p$.

The parameter $p$ measures the fraction of actual convictions resulting from all cases in which the supervisor detected insider trading. This can be influenced by the ‘quality’ of the prosecutor, but also by the definition of the law. The burden to prove guilt can be high if the definition of inside information is very precise. It follows from proposition 4 that increasing $p$ is almost always effective in reducing insider trading.

In order to summarize the effects of other parameters, we introduce the following notation:

- $p_1 = B^{-1} \left( \frac{K_v[1+(1-q)(1-v)+vq]}{rq} \right)$ the critical value of $p$ that separates equilibrium I from II and V,
- $p_2 = B^{-1} \left( \frac{K_v(1-q)+q(1-v)}{rq(1-v)} \right)$ the critical value of $p$ that separates equilibrium II from III and IV,
- $p_{23} = \pi^{-1} \left( \frac{v}{r} \right)$, the critical value of $p$ that separates equilibrium III from IV and
- $p_{34} = \pi^{-1} \left( \frac{v}{v} \right)$, the critical value of $p$ that separates equilibrium IV from V.

The sensitivity of these critical values to changes in the parameters indicates the relative likelihood of the equilibria indicated. The following proposition presents the sensitivity analysis.
Proposition 5

The signs of the sensitivity of the functions in the left column with respect to changes in the parameters or shifts in functions in the upper row are as follows:

<table>
<thead>
<tr>
<th>Deriv\wrt</th>
<th>∂K</th>
<th>∂r</th>
<th>∂v</th>
<th>∆π</th>
<th>∆B</th>
<th>∆q</th>
<th>∆g</th>
<th>Deals with:</th>
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<td>Region of equilibrium I versus II and V</td>
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<td>Region of equilibrium II versus III and IV</td>
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<td>Region of equilibrium III versus IV</td>
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<td>∂p₄₅</td>
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<td>Region of equilibrium IV versus V</td>
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<td>Degree of insider trading in equilibrium IV</td>
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<td>Degree of insider trading in equilibrium V</td>
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<tr>
<td>∂β₀</td>
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<td>Audit frequency in equilibrium IV</td>
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<td>+</td>
<td></td>
<td>Audit frequency in equilibrium V</td>
</tr>
</tbody>
</table>

For changes with respect to the functions B and π, ∆B (∆π) indicates a shift in the function B (π) so that

\[ B(p) + ∆B(p) > B(p) (π(p) + ∆π(p) > π(p)) \] for all \( p \).

We will now shortly discuss the results for some of these parameters. The effect of \( K \) is straightforward. A reduction in audit costs implies that equilibrium I becomes less likely. Equilibria III till V become more likely. However, if costs are already low compared to direct benefits of the regulator, changes do not affect whether equilibrium III, IV or V is played. As long as expected penalties are relatively low, i.e. \( rπ(p) < g \), changes in audit costs have no effect on the degree of insider trading. If the expected penalties when audited are relatively high compared to the gains, i.e. \( rπ(p) > g \), further increases in supervisor efficiency (reductions of \( K \)), may reduce the degree of insider trading. So when the objective is to reduce insider trading, increased efficiency may help, but only if the legal system is such that expected penalties given an audit are relatively high compared to the possible gains.

The effectiveness of the supervisor in detecting insider trading when an audit at cost \( K \) is performed, is measured with \( r \). As with costs, when audits become more effective the probability that equilibrium I results decreases. Contrary to decreases in \( K \), however, improvements in \( r \) do make equilibrium IV more likely compared to III and equilibrium V more likely compared to IV. Increases
in $r$ raise the expected penalty given an audit, since it is more likely that insider trading is detected.

Within equilibrium IV and V, increases in $r$ make both the audit frequency as the trading frequency decrease. As with $p$, the effectiveness of the regulator ($r$) is clearly important to invest in. A driver of this effectiveness may for example be the quality of supervisors (experts).

The quality of the risk analysis system (the quality of the signal indicating insider trading) does however not always contribute to reducing the degree of insider trading. It is even possible that a better quality of the signal increases the degree of insider trading. An increase in the quality of the risk analysis system decreases the likelihood on equilibrium I, III and IV. It increases the likelihood of equilibrium II at the expense of I, III and IV. Especially increasing II at the expense of IV may be undesirable since in equilibrium IV the degree of insider trading is lower than in equilibrium II.

Increases in the quality of the system do increase the area of equilibrium V at the expense of IV and II which is good measured in audit costs (less audits) and in the degree of insider trading (see Proposition 5). However, within equilibrium IV, increases in $v$ result in more insider trading. So if the supervisor audits all positive signals of insider trading and also some other cases, an improvement in the quality of the risk analysis system increases the degree of insider trading. The intuition is as follows. The trader knows the probability $v$ that he is audited for sure and $(1-v)$ that he is audited with probability $\tilde{\beta}_0$ which is less than 1. The gains of insider trading with a certain audit in case of a positive signal are still larger than the costs ($g > vr\pi$), so the strategy for what happens with probability $v$ does not have to be changed. However, the residual part (with probability $1-v$) makes the trader indifferent between using and not using his insider information. $S$ decreases its audit frequency for ‘low risk’ signals since otherwise total audits would increase, which implies that $T$ can increase its use of information to make $S$ indifferent. Note that this only holds as long as $g > vr\pi$. If $v$ is increased as much that this does not hold anymore, equilibrium V is played resulting in a reduction in insider trading. Therefore, marginal improvements in the risk analysis system are bad in equilibrium IV. Improvements should be such that equilibrium V becomes much more likely in many cases. Practically, improvements should be such that the system is so reliable that only positive (i.e. high risk) signals are being audited.
The penalties are only relevant for the equilibrium strategies if audit costs are relatively low (so equilibrium I does not result). Increases in penalties make the region of equilibrium III smaller at the expense of equilibrium IV, and IV smaller at the expense of V. When however insider trading is already prevented in some cases (equilibrium IV and V), increases in penalties do not decrease the frequency that traders use inside information within those equilibria, but do decrease the audit frequency of the supervisor. Given equilibrium V is played, increases in the penalties do not decrease the cost of equity, but improve social welfare only by reducing the cost of the supervisor due to fewer audits.

We finally look at the effect of tighter disclosure rules. If more information has to be made public, and if this has to be done faster, the probability on getting inside information decreases. In our model this yields a reduction in \( q \). As we see in proposition 4, a reduced probability on inside information increases the frequency of the use of this information. This increase can be explained by the fact that detecting insider trading is harder for the supervisor, since detecting insider trading will be more like searching for the needle in the haystack. As a consequence, it is attractive to use the information more often being a trader. This however does not mean that tighter disclosure rules are bad. Disclosure has a focus on prevention and enforcement on repression. In order to study the overall effect of tighter disclosure regulation, we should look at the total effect on insider trader, i.e. the effect on \( q \cdot \alpha \). The overall effect on insider trading is given in the following proposition.

**Proposition 6**

Within equilibrium I, II and III, an increased probability on inside information results in more insider trading: \( \frac{\partial q \cdot \alpha}{\partial q} > 0 \). Within equilibrium IV and V changes in the probability on inside information have no effect on the degree of insider trading: \( \frac{\partial q \cdot \alpha_0}{\partial q} = 0, \frac{\partial q \cdot \alpha_i}{\partial q} = 0 \).

So when enforcement is effective in reducing the degree of insider trading, tighter disclosure rules do not decrease the amount of insider trading and thereby do not decrease cost of equity. From
proposition 5 it follows that the audit frequency (and thereby audit costs) are also not affected by changes in $q$, so that audit costs are not reduced. It can therefore be concluded that in these cases (IV and V) a reduction in the degree of insider trading is not likely a viable argument for tighter disclosure requirements. When tighter disclosure requirements make enforcement unnecessary (in terms of the model when the decrease in $q$ makes that equilibrium II or I results instead of IV or V), it may indeed lower the overall degree of insider trading, but enforcement is then ineffective since all insider knowledge is used.

### 5.2 Trading volumes and reputation

The model is quite straightforward, and a possible extension could take account of differentiation of the trader with respect to the trade-size. Such a model would ask for a strategy in which $T$ chooses the total trade value ($w$) for example given a budget constraint. This will impact some parameters. At least the gain $g$ and the penalty from conviction $\pi$ will increase with the trade-size, and in these cases penalties are expected to have a fixed and a variable component, respectively for reputation and money. Furthermore, it is likely that the probability of getting caught will increase with the trade-size, so $v$ (and possibly $r$) will be an increasing function of $w$. Instead of solving this more complex model with specific functions developed for these dependencies, we analyze the logic of different cases in the general setting. We believe that this will yield the same level of intuition and understanding of the problem. Let us discuss the situations with low and high trade-size as well as situations with low and high possible loss due to shredded reputation.

For situations with low trade-sizes, the possible gains and penalties will be relatively low. As argued above, for low trade sizes it will be harder to detect insider trading, hinting at a case with low $v$ and possibly low $r$. In a situation with low $r$ it is more likely that equilibrium I results. DeMarzo et al. (1998) already find that for the benefit of uninformed traders, the supervisor does not focus on low trade-sizes if the supervisor has to choose because of the budget constraint. Our model also suggest that it is hard to deter insider trading with low volumes and low gains because of low $r$, since equilibria I till III where inside information is always traded upon, become more likely. Enforcement
can however result (equilibrium II, III) if the supervisor for example tries to establish a strong position, therefore yielding other benefits as those for uninformed traders (reduced cost of equity). Insider trading with high volume is however expected to be more easily detected by the supervisor. This would result in a high $v$ and $r$, making equilibrium V more likely compared to IV, II and I. If however the penalty resulting from conviction ($\pi$) is linearly increasing with volume at the same rate as gains ($g$), a further increase in trade-size will make equilibrium II more likely, even for high $r$. The intuition is that for the cost benefit analysis of the trader the expected value is taken which implies that the probability of not being caught and convicted is accounted for in the expected penalty increase. Furthermore, a possible fixed cost due to shredded reputation will remain constant making the trade relatively more attractive.

Let us now elaborate on cases with low and high possible cost of shredded reputation for the trader. Typically high-level managers have more access to inside information. They however face more costs if being caught with insider trading. This is for example studied in a different setting by Srinivasan (2005), who studies the penalties for outside directors when their companies experience accounting restatements. In this study, it is shown that although penalties following from lawsuits and imposed by the SEC are limited, the directors experience significant labor market penalties. Also in cases of insider trading it may therefore be expected that the shredded reputation may imply losses since it may be harder to get equivalent jobs, and the trader may be deterred from many potentially interesting supervisory functions. Furthermore, the case will be all over the newspapers. Naming and shaming will also cause immaterial damage. Examples are the cases of Martha Stewart in the US and Cor Boonstra in the Netherlands. On top of these higher penalties when being caught, there may be additional benefits for the supervisor. Reporting insider trading of well-known people may result in much free publicity. It may help in profiling the supervisor as a powerful institute. Famous people will therefore face higher penalties (reputation), but the benefits $B$ of the supervisor may also be higher.

What does this imply? First, although the supervisor may have an inefficient audit process for cases without free publicity, due to higher benefits in these high spin-off cases, it may be optimal to start an audit. So in terms of equilibrium strategies, II, III, IV and V are more likely to occur. The high costs of shredded reputation make that equilibrium III is less likely to result compared to IV and that equilibria
II and IV are less likely compared to equilibrium V. So the supervisor is more likely to audit high-level managers and these are on their turn more likely to be deterred from trading based on inside information. Insider trading is therefore expected to be reduced especially for those people that are more dependent on their reputation.

5.3 Implications for empirical research

The model might shed some light on findings in empirical research and indicate some possibilities to further investigate the relation between insider trading and cost of equity. As already stated in the introduction, most empirical research indicates that enforcement of insider trading laws improves the functioning of financial markets (see e.g. Bhattacharya and Daouk, 2002 and Beny, 2005). The recent study of La Porta et al. (2006) focuses also on disclosure requirements with respect to information and on liability rules especially in cases of IPO’s, and shows that private enforcement may be more powerful than public enforcement. A possible contribution to the explanation is the existence of equilibrium strategies II and III in our model. These equilibria show situations with high public enforcement but low effectiveness on capital markets since the low expected penalties do not deter traders to use inside information. More strict disclosure requirements however are effective in these equilibria. An alternative explanation is that tighter disclosure requirements imply that there is less inside information. In our model this implies that $q$ decreases. As a result, the contribution of public enforcement to reducing the cost of equity is much lower. First, equilibrium I is made more likely than equilibrium strategies II till V due to a lower $q$. Second, in equilibria I, II and III, tighter disclosure rules indeed decrease the amount of insider trading. Third, in equilibria IV and V, tighter disclosure requirements do not affect the overall degree of insider trading, but the contribution of enforcement to reaching this degree of insider trading decreases as $q$ increases (since the use of inside information increases).

The effect of enforcement on cost of equity thus depends on the disclosure requirements, since tighter disclosure requirements do decrease the degree of insider trading in equilibria I, II and III but
not in equilibria IV and V. For empirical research, this implies that it is expected that disclosure requirements mediate the effect of enforcement on cost of equity.

Some of the variables defined in our model are already taken into account to some extend in the model of Beny (2005) as an extension of Bhattacharya and Daouk (2002). However, a regression analysis assumes one sign for the different variables. Our model shows that this sign may only be valid on part of the ranges. Increases in $p$ for example will first lead to more enforcement without changing the functioning of the financial markets; later on enforcement reduces with $p$. The increases in $p$ will only improve functioning of the financial markets when due to the increase equilibrium IV or V results. So whereas current research, based on ‘enforcement Y/N’, separates equilibrium I from equilibrium II till V, our model suggests that the relevance of enforcement for cost of equity might be better explained by separating equilibrium I, II and III from equilibrium IV and V. Furthermore, within equilibrium IV and V, higher enforcement levels may be associated with less reduction in insider trading and therefore higher cost of equity. It may therefore be interesting to make an approximation for which equilibrium is expected most often and see whether the results are significantly different for these different subsets. Separating the data in sets with high expected penalties and with low expected penalties compared to the possible gains, might give an indication whether indeed equilibrium IV and V are more likely. As an indicator for expected penalties one can use penalties imposed on convictions compared to the gains made (see e.g. Meulbroek, 1992), especially in combination with approximations of $p$ and $r$. A critical value is $p$, which may be approximated by the number of convictions divided by the number of cases the supervisor hands over to the prosecutor. The parameter $r$ can be estimated by the number of cases handed to the prosecutor divided by the number of investigations started by the supervisor. The penalties and the parameter $p$ will definitely be influenced by the legal system. One might expect that $p$ is relatively low in the European Union since the legal system requires inside information to be precise (see Maug, 2002). The absence of private enforcement might also reduce expected penalties.

In conclusion, differentiating equilibrium IV and V from the rest by making an estimate for the relation between possible gains and expected penalties may improve empirical evidence on whether
and in which cases enforcement of insider trading laws contributes to the functioning of the financial markets.

Apart from this separation based on expected penalties, it may be interesting to study the relation between enforcement activity and cost of equity. Apart from equilibrium I, more enforcement (more audits) tends to be associated with more insider trading and therefore higher cost of equity. This may especially be interesting in those settings where indeed expected penalties are high so that traders are sometimes deterred from using their inside information (eq. IV and V).

Finally, including estimates for the parameters as used in our model might yield new insights and empirical evidence on the relative importance of different parameters such as penalty-level, effectiveness of the supervisor and effectiveness of the prosecution when evaluating the functioning of the insider trading laws, supervision and enforcement.

5.4 Legal and economic implications

Apart from applications in empirical research, lessons can be learned from this model regarding the legal system. There is an extensive literature on enforcement and defining fines from a more general perspective than from the insider trading point of view. We refer to the seminal work of Becker (1968) and the more recent research of Polinsky and Shavell (2000) and Garoupa (2001). In this section we will therefore shortly highlight some issues that follow from our model, knowing that much more has to be said on these issues from different perspectives to come to final conclusions.

From economic point of view, equilibrium V is preferred to equilibrium IV which in turn is preferred to equilibria I, II and III because of the reduction in cost of equity. It is however questionable whether I is preferred to II or vice versa. Let us assume that the purpose of insider trading laws is to reduce insider trading. This implies that some prerequisites exist to make supervision an interesting game in the sense that traders are sometimes deterred from using inside information.

First of all the supervisor must have expected direct benefits higher than costs or in terms of the model: \( K \leq K_A \). This has some practical implications. The effectiveness of the audit process (\( r \))
must be sufficiently high. It may therefore be important to hire high-quality experts. This may also increase costs $K$, but these two should be carefully weighted. Too strict rules regarding payment structures may harm the quality of people hired and therefore the effectiveness. Another internal issue for the supervisor is the performance measurement. It is important to measure outcome instead of output (such as number of investigations). This will result in higher $r$ and lower $K$. Alternatively to the effectiveness and efficiency, the benefits the supervisor experiences are important and need to be sufficiently high. An easy way to combine these elements is to make the penalties imposed after conviction part of the financing of the supervisor. The condition on $K$ also shows that when prevention is of high quality ($q$ low), enforcement might not be effective anymore.

A second prerequisite is that the expected penalties given an audit exceed the possible gains:

$r\pi(p) > g$ (or even $r\pi(p) > g$ if $K > K_B$). Again, the effectiveness of the supervisor ($r$) is important. Another important parameter is the conviction rate ($p$). The effectiveness of the legal system is crucial in deterring the trader from using its inside information. One should therefore carefully think about the definition of inside information and the necessities to prove this. Furthermore, high penalties might help in deterring trading on inside information. Polinsky and Shavell (2000) also indicate the possible deterrence that high penalties bring especially when detection (in our model detection and conviction) is at a lower level. If $p$ is low, an alternative is to give the supervisor the possibility to impose some penalties. Although definite convictions cannot be decided upon by the supervisor, giving the supervisor more freedom in making cases public for example, might increase the expected part of the penalty which is not subject to $p$. Penalties imposed by the supervisor are more effective in deterring insider trading than penalties imposed after conviction in court. Certainly, there are many other aspects important in deciding on these institutional settings, but it is also important to see and judge the relative effectiveness of means with respect to their ultimate goal being the reduction of the adverse selection problem: the reduction in the degree of insider trading.

A third implication has to deal with the risk analysis system of the regulator. Once the prerequisites mentioned above are satisfied, investing in such a system should be done carefully. As long as the system yield signals of trades that should be audited for sure, but apart from these dubious
trades some ‘low risk’ trades are also audited, improvements in the quality of the system make the
degree of insider trading increase. A high quality system can however contribute a lot to reducing
insider trading, but the quality must then be improved such that the most likely trades with inside
information are signaled so that only (part of) these have to be audited and trades not signaled as
suspicious need no auditing.

Furthermore it is important to notice that if enforcement is effective (i.e. it deters insiders from
always using inside information), further reductions in insider trading are realized by improving the
effectiveness and efficiency of the supervisor and legal system. Further increases in penalties do only
reduce supervisory cost, but not the degree of insider trading.

Finally, as already mentioned in the previous subsection, it is important to realize that more
disclosure requirements reduce the relative effectiveness of enforcement. Having the supervisor
investigating trades might even become suboptimal. Furthermore, in cases with effective enforcement,
less inside information is offset by more use of inside information. This implies that these two means
must be evaluated simultaneously, and that relative costs and effectiveness of these means must be
compared and weighted. More disclosure implies a higher accent on prevention, whereas enforcement
of insider trading focuses on repression. When enforcement is ineffective (equilibria I, II and III), all
attention may be given to prevention (lowering the amount of inside information); when enforcement
is effective, a reduction in insider trading is not a viable argument for tighter disclosure requirements,
and increasing disclosure might even be suboptimal dependent on the additional costs. The optimal
balance between prevention and repression is however beyond the scope of this paper, also since other
reasons than insider trading may be important in determining the disclosure requirements.

6. Conclusion

In this paper, we present a simple game-theoretic approach on the issue of insider trading. The model
yields insights in how to structure the legal system of insider trading laws and enforcement.
Furthermore, it can contribute to hypothesis formulation and the explanation of results in empirical research regarding insider trading.

We show in which cases the supervisor can deter traders from trading on inside information and in which cases this is not possible. Critical is on the one hand the effectiveness and efficiency of the supervisor in order to be able to credibly threat to audit, and on the other hand the expected penalties for the trader compared to the possible gains. The latter depends on the severity of the penalties and also on the effectiveness of the legal system (e.g. the probability of getting caught and convicted). We show that there exist cases in which the supervisor is always auditing but insider trading is not reduced. In this case, the real benefits of lower cost of equity due to less insider trading are not obtained despite the existence and enforcement of insider trading laws. Furthermore, we show that, when insiders are deterred from trading in some situations, lower enforcement levels are often associated with lower cost of equity. This is because lower enforcement levels may very well be due to a more effective legal system. These results might help in explaining empirical results and yield suggestions for further empirical research to explain the reduction in cost of equity dependent on insider trading laws and enforcement. More specifically, whereas current research separates data based on whether there is enforcement or not, we illustrate that another separation (based on expected penalties) might be preferable, since this better reflects the relation with the actual reduction in the adverse selection problem and therefore with cost of equity. The model also illustrates that more prevention (reduction in the degree of insider trading due to e.g. tighter disclosure rules) will make it harder to obtain reductions in cost of equity due to enforcement and can make enforcement (repression) suboptimal. We also show that a reduction in the amount of inside information does not affect the degree of insider trading when enforcement is effective, i.e. when enforcement deters traders from always using inside information. Reducing inside information may then not be a viable reason for increasing disclosure. Finally, our model illustrates that improvements in the risk analysis system of the supervisor (i.e. a better signaling of insider trading) may result in an increase in the use of inside information. This is the case if the quality is not so high that also some low risk trades have to be audited. Improvements should therefore be made such that the system allows to audit only high risk trades. An elaborate analysis of the implications is given in section 4.
For future research it may be interesting to expand the model of this paper e.g. to incorporate the pricing process and the uncertainty this brings with respect to the gains of the trader possibly in combination with a risk averse trader. It may also be interesting to expand the model more explicitly with the disclosure requirements and associated costs to obtain more specific insights in the relative effectiveness of disclosure (prevention) versus enforcement of insider trading (repression) and more importantly the optimal balance between these two means taking into account the relative costs. Furthermore, as indicated, the results give possible directions for further empirical research on the relation between enforcement of insider trading laws and the cost of equity thereby yielding insight in the costs and benefits of supervisors in different countries.

References


Appendix

Proof of Proposition 1.

Given \( K > K_A \), (1) implies that for all \( \alpha \in [0,1] \), \( P_s \) is minimized in \( \beta_0 = \beta_1 = 0 \). The optimal strategy for \( T \) is to maximize \( P_T \) (see equation (2)), given \( \beta_0 = \beta_1 = 0 \). This results in an equilibrium \( \alpha=1, \beta_0 = \beta_1 = 0 \).

For \( K_A \geq K > K_B \), (1) implies that for all \( \alpha \in [0,1] \), \( P_{s0} \) is minimized in \( \beta_0 = 0 \). Now if \( g > vr\pi(p) \), \( P_T \) is maximized in \( \alpha=1 \) for all \( \beta_0, \beta_1 \in [0,1] \), and \( \beta_I = 1 \) is optimal given \( \alpha=1 \) and \( K \leq K_A \).

For \( K \leq K_B \), there is also a credible threat to audit trades with signal \( s=0 \). When \( g > r\pi(p) \), \( P_T \) is maximized in \( \alpha=1 \), for all \( \beta_0, \beta_1 \in [0,1] \). Given \( \alpha=1 \), \( P_{si} \) is maximal in \( \beta_i = 1 \), for \( K \leq K_B \). This results in an equilibrium \( \alpha=1, \beta_0 = \beta_1 = 1 \). □

Proof of Proposition 2.

First notice that \( K \leq K_A \) implies that \( K[(1-v)(1-q) + vq] \leq vqrB \) so that for \( \frac{1}{2} \leq v \leq 1 \), it can be easily verified that \( \tilde{\alpha}_0 = \frac{Kv}{q[(rB-K)(1-v) + Kv]} \in [0,1] \). Similarly, it follows from \( K \leq K_B \) that \( \tilde{\alpha}_i = \frac{K(1-v)}{q[(rB-K)v + K(1-v)]} \in [0,1] \). Furthermore, notice that \( \tilde{\alpha}_0 - \tilde{\alpha}_i = \frac{K(K-rB)(2v-1)}{q[rBv-K(2v-1)][rB(1-v) + K(2v-1)]} \), so that \( \tilde{\alpha}_0 - \tilde{\alpha}_i > 0 \) (=0) if \( v > \frac{1}{2} \) (= \( \frac{1}{2} \)).

For all \( \alpha < \tilde{\alpha}_0 \) and \( K > K_A \), the optimal answer of the regulator is to have \( \beta_0 = 0 \). Similarly, for \( \alpha < \tilde{\alpha}_i \) it is optimal to apply the strategy \( \beta_1 = 0 \). On the opposite, the regulator optimizes benefits by having \( \beta_I = 1 \), for all \( \alpha > \tilde{\alpha}_i \). The regulator is indifferent between auditing and not-auditing when equality holds. Now when \( K \leq K_B \) for all \( vr\pi \leq g \leq r\pi \) the trader maximizes its payoffs given the audit strategy of the regulator by choosing \( \alpha = \tilde{\alpha}_0 \), which is an equilibrium if the regulator sets
Indeed $\beta_1 = 1$ is optimal since $\alpha > \tilde{\alpha}_i$. Similarly, optimizing the traders payoff for

$$g \leq vr\pi \text{ yields } \alpha = \tilde{\alpha}_i \text{ and } \beta_1 = \tilde{\beta}_i \text{ and } \beta_0 = 0 \text{ for all } K \leq K_A.$$  

**Proof of proposition 3.**

Follows from the proof of proposition 2.

**Proof of Proposition 4.**

Follows from straightforward calculations combined with the conditions for an equilibrium to hold;

the last item follows from \(\frac{\partial \tilde{\alpha}_0}{\partial p} < 0, \frac{\partial \tilde{\alpha}_1}{\partial p} < 0, \frac{\partial \tilde{\beta}_0}{\partial p} < 0, \frac{\partial \tilde{\beta}_0}{\partial p} < 0\)

**Proof of Proposition 5.**

Straightforward. Let us illustrate the derivatives of $\tilde{\alpha}_0$ and $\tilde{\alpha}_i$ with respect to $v$.

$$\frac{\partial \tilde{\alpha}_0}{\partial v} = \frac{Kq[(rB - K)(1 - v) + Kv] - (2K - rB)qKv}{q^2[(rB - K)(1 - v) + Kv]^2} = \frac{K(rB - K)}{q[(qrB - K)(1 - v) + Kv]^2} > 0$$

$$\frac{\partial \tilde{\alpha}_i}{\partial v} = -\frac{Kq[rBv - K(2v - 1)] + (2K - rB)qK(1 - v)}{q^2[rBv - K(2v - 1)]^2} = -\frac{K(rB - K)}{q[rBv - K(2v - 1)]^2} < 0.$$  

**Proof of Proposition 6.**

In equilibria I, II and III, the result is trivial since $\alpha = 1$ in these equilibrium strategies. Furthermore, for equilibria IV and V we find that $q\tilde{\alpha}_0$ and $q\tilde{\alpha}_i$ do not depend on $q$.