Insider Trading: Should It Be Prohibited?

by

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March 1990
RESEARCH PROGRAM IN FINANCE AT THE
WALTER A. HAAS SCHOOL OF BUSINESS,
UNIVERSITY OF CALIFORNIA, BERKELEY

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March 9, 1990

Finance Working Paper #195

* The author thanks the Laboratoire d'Econometrie for support during this research, and particularly thanks Isabelle Bajeux and Patrick Bolton for their generous help. Gerard Gennette, Pete Kyle, and Ailsa Roell also provided important insights. I retain credit for all mistakes.
Abstract

Insider trading occurs when a subset of investors have privileged information about a stock's future value. We examine whether investors should be allowed to trade on the basis of such information. Investors have rational expectations, and the impact of insider trading on real investment decisions is explicitly considered. We show that, when insider trading is permitted:

- Stock prices are more efficient (better reflect information), and will be higher on average.
- Expected real investment is larger.
- Markets are less liquid.
- Owners of investment projects and insiders will benefit.
- Outside investors and liquidity traders will be hurt.
- Welfare may increase or decrease from insider trading, depending on the economic environment. In our "base case" with no production flexibility, insider trading decreases welfare.
- The welfare advantage to prohibiting insider trading is larger as liquidity trading increases, future price variability is larger, and real investment is relatively inflexible to changes in current stock price.
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I. Introduction

Is insider trading good for financial markets?

In 1934, the U.S. Congress decided "no", and insider trading in the United States has been regulated by the SEC since that time. Not all countries have followed the U.S. example. And the debate continues: some countries without regulation are now considering it, whereas in academic circles, the benefits of regulating insider trading are still being contested.¹

The merits of insider trading have been debated on two levels:

(i) Is it "fair" to have trading when individuals are differentially informed?

(ii) Is it economically efficient to allow insider trading?

The Securities Exchange Act of 1934 justifies the regulation of insider trading on the presumption that such activity is "unfair"

¹ See, for example, Manne [1966], Carlton and Fischel [1983], Easterbrook [1985], Glosten [1988], Bajeux and Rochet [1989], and Manove [1989].
to outside investors. Critics point out that trading is always unfair whenever one investor is better informed than another. Yet no one has advocated that all trading based on private information should (or could) be restricted. The line between what information is fair, and what information is unfair, has been the subject of considerable legal argument. Recent U.S. cases have emphasized breach of fiduciary duty by employees using privileged information, rather than unfairness.

Because there is no commonly accepted definition of "unfair", we do not directly address this aspect of insider trading. But the second aspect of insider trading, its impact on economic efficiency and welfare, is more susceptible to economic analysis. We can show which parties gain, which lose, and how much. When the sum of monetary gains and losses can be associated with economic welfare, our analysis also provides a measure of the net benefits (or costs) which result from prohibiting insider trading.

Before plunging into a formal model of markets with asymmetric information, it is useful to review the common arguments cited pro and con insider trading:

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2 See, for example, Brudney [1979].

3 If transfer payments are possible between parties, then the environment in which the sum of monetary benefits is greater will be will be Pareto superior to any alternative.
Pro:

> Insider trading will bring new and useful information into asset prices. Decision makers--both portfolio managers and firms making real investment decisions--can reduce risk and improve performance when prices reflect better information.

> Because of reduced risk, asset prices will be higher and more real investment will occur.

Con:

> Outside investors will invest less because of the market is "unfair". Asset prices will be lower and less real investment will occur.

> Market liquidity will be reduced, thereby disadvantaging traders who must trade for life-cycle or other reasons not related to information.

> Insider trading makes current stock prices more volatile, further hurting traders with liquidity needs.

Note that all these points can be true simultaneously--with one exception. The pro-insiders argue that asset prices will rise when insider trading is permitted, while the anti-insiders maintain that asset prices will fall.
Elements of a reasonable model to analyze these concerns should include the following:

(i) Insiders, who by virtue of their privileged position have more precise information about future stock price than outside investors. It seems reasonable to presume that insiders will recognize the impact of their purchases on the current stock price.

(ii) Outsiders, who have less precise information about future stock price. Such investors recognize that current price may reflect (at least partially) the information of insiders. Outsiders are risk averse and, being numerous, behave as perfect competitors.

(iii) Liquidity traders who trade for exogenous reasons, such as intertemporal smoothing of income flows.

(iv) Real investment, financed by a supply of new shares, which depends upon the issuing price per share. A higher current stock price will lead to the issuance of a larger number of shares and to greater real investment.

We develop a model which contains these elements in as simple a form as possible. Our objective is to assess the validity of the arguments pro and con insider trading. We consider equilibrium prices and welfare in comparable markets where insider trading is
either permitted or restricted. We assume that if insider trading is prohibited, the inside information will not be reflected in prices or decisions.

Our analysis begins with a model which includes differentially informed investors. In recognizing the monopoly power of the inside trader, the model is similar in spirit to Grinblatt and Ross [1985] and Kyle [1985]. However, there are important differences which permit a more appropriate analysis of insider trading.

First, the number of shares issued (and real investment) is endogenously determined. Without endogenous investment, it would be difficult to study the welfare impact of increased price efficiency. Second, we explicitly consider the welfare impact which results from insider trading accelerating the resolution of uncertainty. While insider trading may reduce the uncertainty of future prices, it correspondingly increases the uncertainty of current prices. It also affects the allocation of risks and the liquidity of the market. These implications must be recognized in drawing welfare conclusions.

Our model can be contrasted with other recent work addressing questions of insider trading. First, we focus directly on the welfare of the various participants, rather than on the degree to which prices reflect information. The latter is simply an element affecting welfare through its influence upon production and portfolio decisions.
Glosten [1988] and Bajeux and Rochet [1989] have examined welfare in markets with insider trading but without production. They show that insider trading hurts liquidity traders. Their models, following Kyle [1985], assume that prices are set by risk-neutral market-makers. But this assumption precludes consideration of an important aspect of insider trading: the impact of reduced future price volatility on the level of current asset prices. And they do not examine the potentially positive impact of insider trading on the efficiency of investment.

Manove [1989] examines insider trading where all participants are risk neutral. Manove's description of markets seems somewhat bizarre: when information is favorable, rationing by lottery rather than price is assumed. Fishman and Hagerty [1989] have examined a model in which all investors are risk neutral but recognize their influence on prices. They focus on the extent to which prices reflect information. In their model, insider trading is harmful only if it induces outsiders to gather less information, which in turn will be the case only if outsiders behave noncompetitively.

In contrast, our results suggest that insider trading may be undesirable even when investment is flexible, and risk-averse outsiders behave competitively and cannot alter their information. Our results confirm that many of the arguments both pro and con insider trading are correct:
Stock prices will more fully reflect information when insider trading is permitted. Average stock price will rise, firms' average profits from financing new real investment will be higher and the level of real investment may increase. However, this alone does not guarantee that welfare will increase.

Insider trading decreases both the expected return and risk to outsiders' investment. Under some circumstances, outside investors will demand more shares on average when insider trading is permitted. Nonetheless, we find that outside investors' welfare will always be lower—even when their average demand increases.

Liquidity of markets will be reduced when insider trading is permitted, and liquidity traders will suffer welfare losses.

Total welfare may increase or decrease with insider trading. Welfare will tend to increase when the amount of investment is highly responsive to current stock price. In this case the gains from greater investment efficiency more than offset the costs to outside investors and liquidity traders. If investment is inflexible to current stock price, net welfare tends to be lower when insider trading is permitted.

Finally, we show that asymmetric information is likely to impose greater welfare costs when the better informed are employees of the firm itself, rather than external investors. This distinction has escaped other economic models of insider trading.
II. Markets with Insiders and Endogenous Supply: An Overview

Investors choose a portfolio consisting of a risk-free asset (with interest rate normalized to zero) and a shares of a risky asset. Investors maximize expected utility of future wealth, conditional on the information they possess when they make their choice.

Future price per share $p$ is given by

$$ p = p^* + e, $$

where $p^*$ is the mean future price which is common knowledge, and $e$ is a random variable whose unconditional distribution is normal with mean zero and variance $sp$.

Current price is $p_0$ is determined by supply and demand for shares. Demand for shares comes from three sources: insiders, outsiders, and liquidity traders.

(i) Insiders observe $e$ precisely, and thus know future price exactly at the time they choose their portfolio.\(^4\) However, their purchases or sales $d_i$ will be tempered by the recognition that these activities will affect price. Insiders also observe the current price $p_0$.

\(^4\) We could extend the model to include imperfect observation by insiders. This would reduce both the benefits and costs associated with insider trading, but the nature of the effects we examine would not be affected.
(ii) Outsiders cannot observe $e$. They can observe current price $p_0$, and therefore can determine the net supply from this price. However, they cannot exactly infer $e$ from insider trading since net supply depends on liquidity trading as well as insider trading. Thus current price is a noisy signal of future price, and outsiders will use this information to condition their expectations.

(iii) Liquidity traders demand a random amount $v$ which is independent of price. No market participants observe $v$ directly. But insiders will be able to impute $v$ from observing the current market price $p_0$. So it does not matter whether we allow them to observe $v$ directly or not.

Supply come from entrepreneurs or firms issuing shares:

(iv) Firms offer an endogenously-determined number of shares $q$, each share providing a random future value $p$. The cost of providing such shares, $C(q)$, is increasing and strictly convex. The firm chooses the number of shares issued to maximize its profit $II$ from this activity, where

$$II = p_0q - C(q).$$

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5 A more complex model would allow liquidity traders to reduce their activities as the cost of such trading rises. This would moderate the costs that insider trading imposes on liquidity traders, affecting the magnitude but not the nature of our results.

6 For example, consider an entrepreneur or firm which can produce a good in a competitive market with constant returns to scale (exclusive of the costs of installing capacity). Let $q$ denote the number of units the firm chooses to produce, and also the number of shares issued. The future profit per unit of production, and therefore per share, is random and equals $p$. The current price per share is $p_0$, implying total revenue from issuing shares is $p_0q$. The cost
We presume the firm behaves competitively and takes \( p_0 \) as given.\(^7\) We also presume that whatever special information the firm might have with respect to future price \( p \) does not affect its decision to issue shares \( q \): current (nonrandom) profit II uniquely determines the share issuance decision. This assumption is relaxed in Section VII below.

A rational expectations equilibrium (REE) is a price function with the following properties:

(i) It is a price function in which insider information enters only through insiders' demand. Since other participants cannot distinguish liquidity demand \( v \) from insider demand \( d_i \), the price function must be of a form

\[
p_0 = f(v + d_i, w)
\]

where \( w \) is the vector of all other commonly observed (or directly inferrable) parameters.\(^8\)

\(7\) In fact, the firm's choice of \( q \) will have a small impact on \( p_0 \) via the REE price equilibrium. A change in \( q \) will have a much smaller impact on price than an unobserved change in supply \( d_i \) (or \( v \)), since the choice of \( q \) (unlike \( d_i \)) is known not to contain inside information. In the linear model examined subsequently, we can easily incorporate a firm's choice of \( q \) affecting price, through an appropriate decrease in the variable \( z \) introduced below, which determines the sensitivity of supply \( q \) to a change in current price.

\(8\) We can think of our market as follows. Outside investors have a "willingness to pay" (inverse demand) function which depends only on the net amount that they purchase and not (separately) on the random [contd. next pg.]
(ii) Given the REE price function (1), \( d_i \) is chosen to maximize net insider wealth

\[
W_i = (p + e - p_o) * d_i.
\]

Insiders behave as monopolists: they recognize that \( p_o \) depends upon \( d_i \) through (1).

(iii) Given the REE price function, outsiders choose to purchase a number of shares \( d_o \) which maximizes expected utility of future wealth, conditional upon the price \( p_o \). Thus \( p_o \) serves two roles for outsiders: determining the cost of each share, and influencing their expectations about future stock price \( p + e \).

(iv) Firms choose to issue a number of shares \( q \) which maximizes the net proceeds to original shareholders, \( p_o * q - C(q) \), where \( p_o \) is the REE price.

(v) The REE price function equates supply and demand for every possible value of the random variables \( e \) and \( v \).

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variables \( v \) or \( e \). In the REE model developed below, this willingness to pay function is of the form \( p_o = s + tX \), where \( X \) is the net amount they purchase. The amount they purchase must clear the market, i.e. \( X = q - v - d_i \). \( q \) is a linear, deterministic function of \( p_o \) in our model. Substituting that for \( X \) and rearranging terms gives \( p_o = a + c^*(v + d_i) \). By requiring that price be measurable with respect to outsiders' demand, this approach restricts the set of insiders' equilibrium strategies relative to those considered in Grinblatt and Ross [1985] and Laffont and Maskin [1989], who consider price functions where \( e \) can enter the REE price function independent of insider demand \( d_i \).
III. Markets With Inside Traders and Production:

A Mean-Variance Rational Expectations Model

We construct a simple model with mean-variance preferences along the lines suggested above. The modelling draws from Grossman [1976], Grossman and Stiglitz [1980], and Hellwig [1980], but with a monopolistic sector as in Grinblatt and Ross [1985]. Ex ante distributions of future price shock $e$ and liquidity demand $v$ are given by

$$
e: \quad N(0, sp)$$
$$v: \quad N(0, sv)$$
$$e, v \text{ are independent.}$$

We postulate a linear REE price function of the form (1) above:

$$(3) \quad p_0 = a + c(v + d_i).$$

We shall show that for appropriate choices of $a$ and $c$, (3) will indeed satisfy our earlier definition of a REE price function.

i. Demand

We assume a single inside investor (or cartel of investors),
negligible in number relative to outside investors. Inside investor(s) observe \( e \) precisely, and thus have no uncertainty about future price \( p = p + e \). They will chose \( d_i \) to maximize their final wealth, recognizing that their demand affects price through the equilibrium relationship (3).\(^9\) Thus insiders choose \( d_i^* \) to

\[
\text{(4) } \quad \text{maximize } W_i = (p + e - p_0)^*d_i
\]

\[
= (p + e - [a + c*(v + d_i)])^*d_i.
\]

using (3).\(^{10}\) This implies

\[
\text{(5) } \quad d_i^* = \frac{(p - a)/(2*c) + [1/(2*c)]}*e - (1/2)*v.
\]

Observe that \( d_i^* \) (which hereafter we denote \( d_i \)) depends upon both the inside information \( e \), and the liquidity demand \( v \). Although \( v \) cannot be observed directly, the insider can impute \( v \) directly from observing \( p_0 \) and knowing the REE function (3).\(^{11}\)

\(^9\) Despite being few in number, insiders will have substantial investment demand because they face no risk and therefore act "risk neutrally".

\(^{10}\) Final wealth is given by \( W_i = W_i + p^*d_i + y^*(1+r) \), where \( W_i \) is initial wealth, \( y \) is the holding of the riskfree asset paying interest rate \( r \), and the budget constraint is \( p_0^*d_i + y = W_i \). Normalizing \( W_i = 0 \) and \( r = 0 \) gives (4).

\(^{11}\) Alternatively, we could postulate that the monopolist observes neither \( v \) nor \( p_0 \) at the time he makes his demand decision \( d_i \). In this case, if the monopolist is risk neutral, it is easy to show \( d_i = [p + e - a]/[2*c] \) and \( p_0 = A + B*e + C*v \), where \( A = (a + p)/2 \), \( B = 0.5 \), and \( C = c \). (Compare with equation (3'), in which the only difference is \( C = .5*c \). The nature of our results will be little affected by the choice of what the monopolist observes.
Substituting for \( d_i \) from (5) into (3) gives

\[
(3') \quad p_0 = A + B*e + C*v,
\]

where \( A = (a + p)/2; \ B = 1/2; \) and \( C = (c/2). \) We can also rewrite the insiders' demand for stock (5) as

\[
(6) \quad d_i = [(p - A)/(2*C)] + [1/(4*C)]*e - (1/2)*v.
\]

Note that insider demand does not depend upon risk aversion, since by assumption there is no risk at the time when insiders choose \( d_i. \) While clearly an exaggeration, our assumption of perfect observability reflects the notion that insiders have a "sure thing" when they trade.

Outsiders can predict the insider's pricing rule (6), and therefore recognize that (3') as well as (3) describes the REE price function. Outsiders do not observe \( e \) but can use (3') to form a probabilistic estimate for \( e \) given \( p_0, \) which in turn allows them to compute the conditional expectation and variance of future price \( p \) given \( p_0: \)
(7) \[ E(p|p_0) = p + \frac{\text{cov}(p,p_0)}{\text{Var}(p_0)}[p_0 - E(p_0)] \]

\[ = p + \frac{K/B}{p_0 - A}; \]

\[ \text{Var}(p|p_0) = sp*(1 - K), \]


Outsiders have mean-variance preferences over ending wealth \( W_o. \)¹²

For any current price \( p_0, \) outsiders choose between investing in the stock or a riskfree asset so as to maximize the certainty equivalent of \( W_o, \)

(8) \[ U(W_0|p_0) = E(W_0|p_0) - (ra/2)*\text{Var}(W_0|p_0). \]

where \[ W_o = W + (p - p_0)*d_o, \]

\( d_o \) is outsiders' share purchase of the risky stock and \( W \) is the outsiders' initial wealth which we subsequently normalize to zero.¹³

Maximizing (8) with respect to \( d_o \) yields

(9) \[ d_o^* = \frac{[E(p|p_0) - p_0]/[ra*\text{Var}(p|p_0)]}. \]

¹² There are a large number of outside investors. We substitute a single "representative" investor with appropriately normalized risk aversion parameter.

¹³ \( W \) might be random (say as the result of other investments). If \( W \) is independently distributed from \( p \) and \( p_0, \) similar results will follow.
Using (7), we can rewrite (9) as

\[ d_0 = \frac{p + (K/B)(p_0 - A) - p_0)}{[ra*sp*(1 - K)].} \]

\[ = m + n*p_0, \]

where

\[ m = \frac{p - K*A/B}{[ra*sp*(1 - K)]} \]

\[ n = \frac{[K/B - 1]}{[ra*sp*(1 - K)].}. \]

Liquidity traders provide a third source of demand. While it is possible to endogenize aspects of their decisions, we take the simplest possible route and assume they demand a random amount \( v \), which is independent of \( e \) and is normally distributed with zero mean and variance \( sv \).

Summing the three sources of demand (6), (10), and \( v \) gives total demand as a function of the exogenous variables and the coefficients \( A, B \) and \( C \) of the hypothesized REE price function (3'):

\[ D = \frac{[(p - A)/(2*C)] + [1/(4*C)]*e + (1/2)*v}{[ra*sp*(1 - K)].} \]

\[ + \frac{[p + (K/B)(p_0 - A) - p_0)}{[ra*sp*(1 - K)].}. \]

We turn now to the supply of securities.
(ii) Supply

The firm (or entrepreneur) issues an endogenously determined number of shares \( q \) to the market. These shares promise an identical future value \( p \) per share, independent of the number of shares \( q \) which are offered. The cost of providing shares represents the real investment required to provide the returns to the \( q \) shares. We assume a convex cost function for providing additional shares, given by

\[
C(q) = \begin{cases} 
0, & 0 \leq q \leq Q \\
= c_0 + c_1 q + .5 c_2 q^2, & q > Q,
\end{cases}
\]

where \( Q = -c_1/c_2 \) and \( c_0 = .5 c_1^2/c_2 \).

This functional form has the following properties. Shares can be created without cost up to a level given by \( Q \). This guarantees a strictly positive minimum supply of shares \( Q \). Thereafter, marginal costs rise from zero with a speed which depends on the magnitude of \( c_2 \). The condition determining \( c_0 \) assures that the cost function is continuous at \( q = Q \).

The firm must decide how many shares to supply. It can sell shares for \( p_0 \) per share, where \( p_0 \) is the equilibrium price. It issues
shares to maximize profit (for its original shareowners)

\[ II = p_0^*q - C(q). \]

\[ = p_0^*q - c_0 - c_1^*q - (c_2/2)^2q^2. \]

implying an optimal share issuance (supply) of

\[ (12) \quad q = z^*p_0 + Q, \]

where \( z = 1/c_2. \)\(^{13}\) Because the cost of providing shares is zero up to \( q = Q, \) the firm will always provide this level no matter how rapidly marginal cost increases beyond \( Q. \) Note that the special case where production is inflexible corresponds to the limiting case where \( z \rightarrow 0 \) and \( q^* = Q. \)

(iii) The REE Price Function

Recall that an REE price function must equate supply and demand for each possible resolution of the random variables \( e \) and \( v. \) That

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\(^{13}\) We presume that the firm does not possess inside information (knowledge of future price \( e \)) when it makes its share issuance decision. Nonetheless, \( e \) does affect investment through the REE price function \( p_0. \) For a discussion of how the model changes when firms do possess inside information at the time shares are issued, see Section VII below.
is, total demand from (11) must equal total supply from (12), or

\[
\begin{align*}
(14) \quad \left[ (p - A)/(2*C) \right] + \left[ 1/(4*C) \right] * e + (1/2) * v \\
+ \left[ p + (K/B) * (p_0 - A) - p_0 \right] / [ra*sp*(1 - K)] \\
- [z*p_0 + Q] &= 0,
\end{align*}
\]

for all \((e, v)\). This equation can be solved for \(p_0\), and the resulting constant term and coefficients of \(e\) and \(v\) must equal the coefficients \(A, B,\) and \(C\) of the postulated REE function \((3')\). We can now show the following

**Theorem:** A linear REE exists in our model with

\[
(15) \quad p_0 = A + B*e + C*v,
\]

where

\[
\begin{align*}
B &= 1/2 \\
C &= 1/(2*M) \\
A &= \frac{p*(z + 2*g) - Q}{2*(z + g)} \\
\end{align*}
\]

with

\[
M = (ra*sv/2)*\left(-1 + \left[ 1 + 4*(z + g)/(ra*sv) \right]^{0.5} \right)
\]

and

\[
g = 1/(ra*sp).
\]

**Proof:** See the Appendix.
Several conclusions can be drawn about prices in our REE setting:

(i) The sensitivity of prices to inside information $B$ is always the same. Half of the future above-average value will be reflected in present prices, regardless of liquidity supply volatility $sv$ or future price uncertainty $sp$. This constancy reflects the nature the insiders' response to observations of $e$ and $v$.

(ii) The ex ante expected current price, $A$, is independent of the supply volatility $sv$. It can readily be verified that expected current price is decreasing in risk aversion $ra$ and in future price volatility $sp$.

(iii) The liquidity of the market (as measured by the inverse of $C$, the price impact of a liquidity trade) increases as production becomes more sensitive to price ($z$ increases), and decreases as the volatility of future price ($sp$) increases. For reasonable ranges of parameters, liquidity also increases with the volatility of liquidity trading $sv$.

IV. Comparison of REE Prices: Markets with and without Insider Trading

We wish to compare the REE price function with insider trading, as described in Theorem I, with the REE price function in a similar market which prohibits insider trading. Insiders now behave as
outsiders, but since they are of negligible mass their trading, now limited by risk aversion, will be negligible.

Demand from the outside investors is given by

\[
(10') \quad d_o' = \frac{[p - p_0]}{(r^2 s p)}
\]

\[= m' + n' p_0,\]

where

\[m' = p/(r^2 s p)\]

\[n' = -1/(r^2 s p)\]

It can readily be verified that the REE price function in the absence of insider trading is of the form

\[
(16) \quad p_0' = A' + C' s v,
\]

where

\[A' = \frac{[p s - Q]}{[z + g]};\]

\[C' = 1/[z + g]\]

Comparing this price function with (15), we find:

1. The average stock price will be higher when insider trading is permitted. This can be seen immediately from
A - A' = \[p\times z + Q]/[2\times (z + g)] > 0.

This resolves the controversy of how insider trading affects the level of stock prices: they will rise.

2. The average amount of real investment (or equivalently, shares q issued) will be higher with insider trading. This follows immediately from (12) and the fact that the average stock price will be higher.

3. For "reasonable" parameter levels, the liquidity of the market is reduced by insider trading. Liquidity is greater when a liquidity trade has a lesser impact on price, i.e. when the magnitude of C, the coefficient of v, is smaller. It can be shown that C exceeds C' (implying lower liquidity with insider trading) whenever

\[(17) \quad (z + g) > 2\times ra\times sv.\]

This will be the most difficult to satisfy when z = 0 (no flexibility of production), in which case (17) reduces to

\[(18) \quad 1 > 2\times ra^2\times sv\times sp.\]

Realistically, it is unlikely that the risk aversion factor ra will exceed 6, the volatility (standard deviation) of the liquidity supply will exceed 20% of total supply, or the volatility of prices
will exceed 50%\textsuperscript{14}. For such extremes, the r.h.s. of (18) is 0.72, and the inequality is satisfied. We conclude that, under reasonable parameter specifications, $C > C'$ and insider trading reduces market liquidity.

4. For reasonable parameter levels, current prices will be more volatile when insider trading is permitted. Note that

$$\text{Var}(p_0) = B^2sp + C^2sv > (C')^2sv = \text{Var}(p_0')$$

This follows directly from the lower liquidity levels for reasonable parameters ($C > C'$) and the sensitivity of $p_0$ to $e$ ($B > 0$) in the equilibrium with insider trading.

5. Future price volatility given current prices $[\text{Var}(p|p_0)]$ will be lower when insider trading is permitted. Note that

$$\text{Var}(p|p_0) = sp[1 - B^2sp/(B^2sp + C^2sv)].$$

Since $B = 0$ when there is no insider trading, the result follows immediately.

These last two results show a key aspect of insider trading: it

\textsuperscript{14} Ibbotson and Sinquefield suggest that the S&P 500 return has averaged about 6 to 8 percent higher than the riskfree return, with standard deviation about 20%. The certainty equivalent of such a return would be consistent with an $r_a$ of 1.5 to 2 in our model. Gennette and Leland [1989] examine market liquidity in the context of differentially informed investors. They conclude that asymmetry reduces liquidity, with fewer insiders leading to less liquidity.
accelerates the resolution of uncertainty from the terminal period to the present period. A related consequence is

6. Current prices will be more highly correlated with future prices when insider trading is permitted. The actual correlation \( r \) is given by

\[
    r = \frac{B \cdot s_p}{\sqrt{B^2 \cdot s_p^2 + C^2 \cdot s_p \cdot s_v}}
\]

Without insider trading, the correlation is zero. For reasonable parameter values (see our example in Section VI), the correlation of current and future prices in the presence of insider trading will be on the order of 0.7.

This aspect of insider trading is beneficial. Decisions (including investment and consumption) made with better information will in general be better decisions. But other considerations are also important. The introduction of insider trading will not necessarily make participants better off, despite the greater efficiency of investment. We turn now to welfare comparisons of the two equilibria.

V. Welfare

We look at the welfare of each class of participants in the rational expectations equilibrium developed above. The question
of welfare must be posed **ex ante** any knowledge of the random variables \(e\) or \(v\). That is, we ask the following question: before knowing the actual information that insiders will receive, are participants better or worse off with insider trading? We assume that all classes of participants have mean-variance preferences of the form

\[
U(W) = E(W) - (ra/2)\cdot Var(W).
\]

Note that utility \(U\) can be interpreted as certainty equivalent wealth.

(i) **Inside Investors**

At the time they make their decisions \(d_i\) insiders can observe both \(e\) and \(p_0\) (implying knowledge of \(v\)). Their wealth given these observations is

\[
W_i = (p + e - p_0)\cdot d_i
\]

\[
= (p + e - p_0)\cdot [(p - A)/(2\times C) + e/(2\times C) - .5\times v]
\]

using (6). Substituting for \(p_0\) from (15) allows us to express insider wealth (**ex post**) as

\[
W_i = w_1 + w_2\cdot e + w_3\cdot v + w_4\cdot e^2 + w_5\cdot v^2 + w_6\cdot e\cdot v,
\]

26
where

\[
\begin{align*}
w_1 &= \frac{(p - A)^2}{2C} \\
w_2 &= \frac{(p - A)(3-2B)}{4C} \\
w_3 &= -(p - A) \\
w_4 &= \frac{(1 - B)}{4C} \\
w_5 &= \frac{C}{2} \\
w_6 &= \frac{3 - 2B}{4}
\end{align*}
\]

While insider profits $W_i$ are certain \textit{ex post}, they are uncertain \textit{ex ante}. From (19), we can immediately derive the \textit{ex ante} mean and variance of insider wealth:

\[
E(W_i) = w_1 + w_4sp + w_5sv
\]

\[
\text{Var}(W_i) = w_2^2sp + w_3^2sv + 2w_4^2sp^2 + 2w_5^2sv^2 + w_6^2sp^2sv
\]

The certainty equivalent of \textit{ex ante} random insider wealth is given by

\[
U(W_i) = E(W_i) - (ra/2)\text{Var}(W_i).
\]

(ii) Outsiders

Outsiders choose a risky investment $d_o$ to maximize risk-adjusted final wealth, given that they observe $p_0$. Their final wealth will
be

$$W_0 = W + (p - p_0)\hat{a}_o$$

where $W$ is exogenous initial wealth and $\hat{a}_o$ is given by (10).

Recalling

$$p - p_0 = [p + e - (A + B*e + C*v)]$$

allows us to write (after tedious calculations)

\[(20) \quad W_0 = s_1 + s_2*e + s_3*v + s_4*e^2 + s_5*v^2 + s_6*e*v\]

where

$$s_1 = (p - A)*(m + n*A)$$
$$s_2 = B*n*(p - A) + (1 - B)*(m + n*A)$$
$$s_3 = C*[n*(p - A) - (m + n*A)]$$
$$s_4 = n*B*(1 - B)$$
$$s_5 = -n*C^2$$
$$s_6 = n*C*(1 - 2*B)$$

and where $m$ and $n$ are defined in (10) when insider trading is permitted, and in (10') when insider trading is not permitted.\(^{15}\)

From (20) we derive the \textit{ex ante} mean and variance of $W$:

\(^{15}\) In the special case where $z = 0$, it can be shown that $n = -1/(2*C)$ and $n' = -1/C$. The terms for the weights $s_j$ simplify accordingly.
(21) \[ E(W_o) = s_1 + s_4^*sp + s_5^*sv \]

\[ \text{Var}(W_o) = s_2^2sp + s_3^2sv + 2*s_4^2sp^2 + 2*s_5^2sv^2 + s_6^2sp*sv \]

with certainty equivalent value

(22) \[ U(W_o) = E(W_o) - (ra/2)*\text{Var}(W_o) \].

(iii) Liquidity Traders

Liquidity traders trade an amount \( v \) which is random \textit{ex ante}. On average, liquidity traders expect neither to buy nor to sell: \( E(v) = 0 \). But when they do buy, it will tend to be at a price greater than average. When they sell, it will tend to be at a price lower than average. This creates both an expected cost and a volatility of cost.

Straightforward calculations yield:

(23) \[ \text{Cost} = -p_0^*v \]

\[ = -[(A + B*e + C*v)*v] \]

\[ = m_1 + m_2^*e + m_3^*v + m_4^*e^2 + m_5^*v^2 + m_6^*e*v, \]

where
\[ m_1 = m_2 = m_4 = 0 \]
\[ m_3 = -A \]
\[ m_5 = -C \]
\[ m_6 = -B \]

It follows immediately that

\[ E(\text{Cost}) = m_1 + m_4*sp + m_5*sv = -C*sv \]

\[ \text{Var}(\text{Cost}) = m_2^2*sp + m_3^2*sv + 2*m_4^2*sp^2 + 2*m_5^2*sv^2 + m_6^2*sp*sv \]

\[ = A^2*sv + 2*C^2*sv^2 + B^2*sp*sv \]

\[ U(\text{Cost}) = E(\text{Cost}) - (ra/2)*\text{Var}(\text{Cost}) \]

\[ = [-C - (ra/2)*(A^2 + B^2*sp + 2*C^2*sv)]*sv \]

Note that costs are incurred in the first period. We assume the same risk aversion coefficient \( ra \) here, although alternative formulations are possible.\(^{16} \)

\(^{16}\) Risk aversion to current wealth might be less than risk aversion to future wealth, because consumption choice is more flexible when risks are revealed early. Such a distinction would alter the magnitude of our results in favor of insider trading. Our approach is consistent with the liquidity investor carrying his costs forward to the second period, using the risk-free asset. This would allow us to assess expected cost and variance in the second period, and therefore to use the same \( ra \) as the investors who realized their wealth in the second period.
(iv) Stock Issuers: the Firm or Entrepreneur.

The model considers equilibrium with an endogenous supply of new shares. The returns to the shares are created by real investment. A scenario consistent with this approach is an entrepreneur financing a new firm by selling equity. The amount he realizes as an entrepreneurial profit is \( II = p_0q - C(q) \).

Alternatively, one can think of the project being undertaken by a firm with shares currently outstanding, but financing the new venture as a separate firm with its own equity financing. In this case it is the shareholders of the original firm who realize the increase in value \( II \). This alternative becomes important if the shareholders of the new venture overlap with the shareholders of the original firm. We discuss this in Section VII below. Here, we assume no overlap of ownership.

We can readily compute the expected profit and variance of profit to the original owner(s):

\[
(25) \quad II = p_0q - C(q)
\]

\[
= p_0(zp_0 + Q) - c_0 - c_1(zp_0 + Q) - (c_2/2)(zp_0 + Q)^2
\]

\[
= r_1 + r_2e + r_3v + r_4e^2 + r_5v^2 + r_6e^v
\]

where
\[ r_1 = zA^2/2 + A*Q \]
\[ r_2 = zA*B + B*Q \]
\[ r_3 = zA*C + C*Q \]
\[ r_4 = zB^2/2 \]
\[ r_5 = zC^2/2 \]
\[ r_6 = zB*C. \]

It follows directly that

\[(26)\quad E(II) = r_1 + r_4*sp + r_5*sv\]

\[ \text{Var}(II) = r_2^2*sp + r_3^2*sv + 2*r_4^2*sp^2 + 2*r_5^2*sv^2 + r_6^2*sp*sv \]

\[(27)\quad U(II) = E(II) - (ra/2)*\text{Var}(II)\]

We have now assessed the welfare of the four different agents. Note that our formulas also hold for the expected utility of agents when inside trading is prohibited, providing we substitute \( m', n', A', B' \) and \( C' \) for \( m, n, A, B, \) and \( C \).

VI. Welfare Compared: Insider vs. No Insider Trading

The complexity of the various expressions for utility of the four classes of agents precludes simple analytical results relating welfare with and without insider trading as a function of the exogenous parameters.
Nonetheless, we can use numerical analysis to examine welfare effects. We start with a "base case" with parameters chosen to reflect average market data. The parameters chosen are given in Table 1. We first consider agents' welfare as a function of flexibility of production to price (the parameter $z$).

(i) No Production Flexibility ($z = 0$)

In this case, $Q = 1$ is supplied to the market regardless of price $p_0$. Equilibrium values of expected demand, expected supply, and ex ante welfare are

**With No Inside Trading:**

$$p_0 = A' + C'v$$

$$= .9200 + .0800v$$

**With Inside Trading:**

$$p_0 = A + B*e + C*v$$

$$= .9600 + .500*e + 1.020*v$$

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where the upper line refers to equilibrium without insider trading, and the lower line to equilibrium with insiders.

Averages refer to the case where $e = v = E(e) = E(v) = 0$. 

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**TABLE 1**

**Base Case:**

**Ex Ante** price volatility (variance sp): 0.04

This is consistent with an annual standard deviation of the stock price of 20%.

Volatility of liquidity supply (variance sv): 0.01

This is consistent with an annual standard deviation of liquidity supply equal to about 10% of total supply.

Risk Aversion parameter (ra): 2

This implies a return premium to stocks equal to twice the future price volatility given current price (in our example, a risk premium of 8% over the risk-free rate when supply is normalized to 1).

Costless Supply (Q): 1

If production is inflexible to price (z = 0) then the production supply is normalized to 1.
As implied by our earlier proposition, average price is higher with insider trading. Supply is identical, since by assumption supply is invariant to price.

Insider trading increases the welfare of insiders—quite naturally, since they are excluded in the other case. More interestingly, the outsiders' utility (certainty equivalent) falls by more than half. While both expected returns and risk to outsiders falls, demand contracts only fractionally despite the substantial drop in their welfare.

Expected profit to original owners issuing the securities rises from 0.92 to 0.96. However, the increased riskiness of the issuing price in the case of insider trading reduces expected utility of profits to 0.93959. Profits to original owners when insider trading is prohibited are not very volatile, and their expected utility is .91994.

Because current prices are much more sensitive to random liquidity trades—i.e. markets are less liquid—the expected utility of liquidity traders drops from -.00927 to -.01973 when insider trading is permitted. That is, the certainty equivalent cost to liquidity traders more than doubles in the presence of insider trading. This is consistent with Hirschleifer's [1971] observation that early information resolution may not always benefit market participants.
Total utility (or certainty equivalence) declines slightly, from .95081 to .95010 when insider trading is permitted. For the base case, with no production flexibility, insider trading decreases welfare.

We varied the base-case parameters separately, with a range of ex ante price volatility from .01 to .08, volatility of liquidity supply from .001 to .10, and risk aversion from 1 to 4.

In all cases, insider trading continued to diminish total utility, as well as to increase the welfare of insiders and original owners, and to decrease the welfare of outsiders and liquidity traders.

The welfare advantage (increase in total certainty equivalent wealth) from prohibiting insider trading increases as

> Risk aversion increases
> Liquidity trading is more volatile
> Volatility of future price increases

over the range of parameters examined.

A bit more insight into these results can be obtained in the case where \( z = 0 \). Considerable algebraic manipulation shows that

\[
\begin{align*}
    s_4 + r_4 + m_4 + w_4 &= 0 \\
    s_5 + r_5 + m_5 + w_5 &= 0
\end{align*}
\]
both with and without insider trading. Furthermore, it can be shown that, when $z = 0$,

$$s_1 + r_1 + m_1 + w_1 = p^* Q,$$

regardless of whether insider trading is permitted or not.\(^{17}\)

Thus the total expected wealth (before risk adjustment) is invariant to the presence of insider trading when production is inflexible to price. This result implies that \textit{ex ante} total welfare decreases in the presence of insider trading because of risk effects: The distribution of total risks is less favorable with insider trading.

\[ \text{ii. Production is Flexible (} z = 1 \text{)} \]

We now consider the case where supply expands with price ($z = 1$). All other parameters remain at their base value.

Equilibrium values of expected demand, expected supply, and \textit{ex ante} welfare are

\(^{17}\) The comparison requires $w_1 = w_4 = w_5 = 0$ when insiders are prohibited, since their utility is presumed to be zero when prohibited.
With No Inside Trading:

\[ p_0 = A' + C'v \]

\[ = .8519 + .0740v \]

With Inside Trading:

\[ p_0 = A + B'e + C'v \]

\[ = .9259 + .500e + 0.981v \]

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As before, the second line describes equilibrium with insiders.

In contrast with our earlier result, we see that although each separate class of agents' welfare increases or decreases in the direction previously observed, the total welfare now increases rather than decreases. This result continues to hold for the range of parameters studied earlier.

Indeed, we find that the when production flexibility z exceeds about .06, welfare in the base case will increase when insider trading is allowed. A relatively small amount of production flexibility will lead to insider trading helping welfare. Of course welfare would be further improved if information were released to all investors before insiders acted upon it—-but we are not explicitly considering this alternative in our choice set.
Our results do suggest that certain kinds of better information might be more damaging to welfare than others. Information which affects price but not production decisions will in general have a more negative effect than information which affects production.

For example, consider a situation where inside information exists about the possibility of a takeover, but a change in stock price will not affect the firm's investment decisions. This example implies \( z = 0 \), and welfare would be negatively affected by insider trading. Contrast this with a situation where an external investor knows that a firm's potential investment has a very high payoff. Permitting him to trade on this information will raise share price and lead to cheaper (and therefore greater) financing. Welfare may be positively affected.

VII. Alternative Formulations and Interpretations

Our results rest on a number of assumptions. In this section we consider some alternative formulations and their impact on our conclusions.

i). Welfare weights

Our methodology has weighted (certainty equivalent) dollars equally, no matter how they are distributed. This is reasonable when winners compensate losers. When such transfers cannot be
effected, it is less clear that social welfare should be associated with total certainty equivalent wealth. Since insiders are relatively few in number, an argument could be made that their benefits should be accorded less weight. Clearly the case for prohibiting insider trading would be stronger in this situation.

ii) The Firm Possesses Insiders' Information

Our model presumes that insiders know future price \( p \), but the firm issuing shares does not (or does not act on this knowledge at the time of issuance). What if the firm also possesses the insiders' knowledge? Two technical problems exist in this case. First, if the firm's share issuance is observed, as we suppose, then an uninformed investor could perfectly impute the inside information about future price \( p \) by observing \( q \). Imperfect revelation would require either that share issuance is unobserved, or that the firm has random marginal cost (e.g. the cost parameter \( c \) is random) so that share issuance would be a noisy signal of future price \( p \).

If the firm could observe \( c \) as well as \( p \), implying the future value of shares and their issuance costs are known, a second problem must be faced: what is the issuing firm's objective? Let us assume it would choose share issuance \( q \) to maximize the investment's (sure) future value,

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18 The author thanks Isabelle Bajeux for pointing out this possibility, and for discussions on the subject.
\[ II = pq - C(q). \]  

Note that share issuance in this case would be independent of \( p_0 \), the initial price. Share issuance would also be the same whether insiders were permitted to trade for their own accounts or not. This corresponds to our "\( z = 0 \)" case studied above, since permitting insiders to trade on their own account--which will affect \( p_0 \)--would have no additional influence on production decisions. Insider trading is harmful in this case.  

In sum, if the firm possesses the same information as insiders, and acts on this in determining investment, there will most likely be welfare costs when insiders are allowed to trade for their own investment accounts. Insider trading will not affect production decisions, but will negatively affect welfare.

This suggests that it is not only legally appropriate, but also economically useful, to distinguish an employee who has better

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19 Even this is not obvious. If the firm's estimate of (sure) future profit from share issuance is less than current profit \( p_0 q - C(q) \), why would it issue fewer shares? If its estimate is greater than current profit, why should it pass this along to new shareholders? The firm might choose to use debt financing in this latter case--which in turn becomes another signal for uninformed investors to consider in forming their future price expectations. Modelling the appropriate choice of a firm with superior information remains a complex problem.

20 Given that optimal share issuance depends positively on both current and future (expected) price, we argue heuristically that issuance will always be less sensitive to current price when the firm already possesses the inside information--for any objective the firm might have. Current price affects issuance for two potential reasons: its positive direct impact, and its positive indirect impact via providing information on expected future price. But if the firm already possesses the inside information, it will ignore the (noisy) information in current price, reducing the second impact to zero.
information from an unaffiliated investor who has better information. The former should be prohibited from trading, whereas the latter may bring benefits via his effect on production decisions.

iii). Outside Investors Are Firm's Original Owners

We have separated outside investors from original owners. Original owners sell shares at a random price in the first period. This randomness reduces the certainty equivalent value of their shares. Similarly, outside investors purchase shares (from the original owners) at an \textit{ex ante} random price, also affecting their risk. An alternative formulation would allow outside investors to coincide with original owners. If outside investors purchased all issued shares, all \textit{ex ante} price risk associated with \( p_0 \) would disappear. Even when outsiders purchase only a fraction of issued shares, considerable price risk can be avoided.

This can easily be handled on our model by aggregating original owners and outside investors into a single entity, with \textit{ex ante} sensitivity to exogeneous parameters given by

\[
\begin{align*}
t_1 & = s_1 + r_1 \\
t_2 & = s_2 + r_2 \\
\vdots \\
t_6 & = s_6 + r_6.
\end{align*}
\]
Mean, variance, and expected utility of the aggregated class will be given by

$$E[W_a] = t_1 + t_4*sp + t_5*sv$$

$$\text{Var}[W_a] = t_2^2*sp + t_3^2*sv + 2*t_4^2*sp^2 + 2*t_5^2*sv^2 + t_6^2*sp*sv$$

$$U[W_a] = E[W_a] - (ra/2)*\text{Var}[W_a].$$

This expression then replaces $U[W_0]$ and $U[II]$ in our previous analysis.

Because the effect of risky current price $p_0$ is reduced in this alternative, we find that welfare effects of insider trading are positive for the base case. The original owner/outside investor is slightly better off when insider trading is permitted: Gains as an original owner more than offset losses as an outside investor.

Insider trading does not benefit total welfare for all parameter levels, however. For example, if the standard deviation of liquidity demand in our base case rises from 10% to 16% (or more), insider trading again lowers welfare when $z = 0$.

(iv) Outsiders Can Gather Information

When outsiders have the possibility of acquiring information, as
in Fishman and Hagerty (1989), insider trading may affect this decision. We have seen that outsiders' expected utility suffers when inside trading is permitted. Following Fishman and Hagerty, assume that this may reduce the amount of information outsiders gather, which in turn increases their \textit{ex ante} future price volatility. But we have shown greater volatility of future prices implies a greater loss from insider trading. We conclude that, when outsiders can gather information, there is further reason to restrict insider trading.

\textbf{VIII. Conclusions}

Our analysis suggests that insider trading may help or hurt markets, depending upon the characteristics of those markets. This should not be surprising: the fact that controversy still exists on the issue suggests that there is no single "best" answer regardless of circumstances.

Our analysis \textit{does} indicate who gains, and who loses. It also identifies the characteristics of those markets which are likely to gain from insider trading, and those which are likely to lose.

Liquidity traders are major losers when insider trading is permitted. Markets become less liquid when insiders trade: prices move more in response to unobserved random supply shocks, because investors believe price movements might be coming from informed investor activity. If liquidity traders had a way to inform
markets that their trades were indeed information-free, they would be less harmed. However, liquidity traders who couldn't inform markets would suffer more, since market liquidity decreases as $sv$ becomes smaller.

Outside investors also are hurt when insider trading is permitted. Their expected return is reduced. Because they are trading against better-informed investors, they own more shares when expected returns are low, and fewer shares when expected returns are high. But outside investors also have reduced risks: Because some risks are revealed through prices, the remaining risks are less. Both the mean and variance of outsiders' returns are reduced by insider trading. Outsiders' demand for stock may increase, but their welfare always decreases.

Gainers from insider trading of course include the insiders themselves. But we also show that owners of firms issuing shares will in general benefit from insider trading. The average issuing price will be higher. And there are additional benefits from the fact that investment level will be sensitive to future prospects, as reflected (when insider trading is permitted) in current price.  

\footnote{The existence of basket securities could help (well-diversified) liquidity traders, to the extent that trading a basket minimizes the likelihood that an investor has firm-specific information. See, for example, Gorton and Pennacchi [1989].}

\footnote{Note we focus on producer surplus (from profit), but do not explicitly examine consumer surplus related to the output of the good being produced. Any possible increase in consumer surplus would favor insider trading.}
The net impact of these separate consequences of insider trading can be positive or negative. Our studies suggested that insider trading is less desirable as:

- Production flexibility decreases
- Investor risk aversion increases
- Liquidity trading is more volatile
- Future price volatility increases.

The single most important factor is the sensitivity of production—real investment—to current price. If sensitivity is great, insider trading is likely to be beneficial. This follows because insider trading will bring better information into prices, and (if investment is sensitive to price) into real investment.

When firms themselves possess inside information, allowing insider trading for personal profit is likely to have negative effects. Firms will pay less attention to current market price if they already possess information superior to that price. Because the sensitivity of investment to current price is less, the negative aspects of insider trading will tend to dominate the positive aspects. This may well explain why regulation has focused on prohibiting trading based on superior information emanating from inside the firm, as contrasted with superior information generated

\[23\] Of course one could argue that the firm will generate inside information only if insiders can profit by trading for their personal account. But firms which act in the interests of their shareholders would have (at least some) motivation to gather better information.
externally.

Typically, insider trading has been more tolerated in less-developed financial markets. This is somewhat puzzling in light of the above results, if less developed markets are associated with greater future price volatility, and perhaps greater investor risk aversion as well.

There are a number of possible explanations. First, liquidity trading may be much more important in highly developed capital markets. Insider trading is particularly harmful to liquidity traders. Second, it is possible (although not obvious) that less-developed financial markets have a greater fraction of superior information that is generated outside the firm. Thus investment level would be more sensitive to stock market price. Third, and more likely, less-developed markets may be equally harmed by insider trading, but restrictions are simply impossible to enforce.

Our model captures many of the key ingredients of the insider trading controversy. But it should be extended to multiple time periods. We have shown that insider trading "moves up" the resolution of uncertainty. This one-time benefit may be relatively more important in a two-period model than in a multi-period model. If so, we overestimate the benefits of insider trading. But we must await the development of multi-period rational expectations models to answer this question definitively.
APPENDIX

Proof of Theorem I:

From (14), we can group terms into coefficients

- G of the future price surprise e;
- H of liquidity trading v;
- F of a constant; and
- M of price p₀, as follows:

\[(A.1) \quad Mp₀ = F + G*e + H*v\]

where

\[M = (z - [g/(1 - K)]*(K/B - 1))\]

\[F = ((p-A)/(2*C) + [p-A*K/B]*g/(1-K) - Q)\]

\[G = 1/(4*C)\]

\[H = 1/2\]

with \[g = 1/(ra*sp)\]

and \[K = sp/[sp + (C/B)^2*sv]\]

For (A.1) to be consistent with (15) for every possible e and v, it must be the case that

\[(A.2) \quad A = F/M\]

\[(A.3) \quad B = G/M\]

\[(A.4) \quad C = H/M.\]
This yields three nonlinear equations in the unknowns A, B, and C. From (A.4), \( M \times C = H = 1/2 \) implying \( M = 1/(2 \times C) \).

Substituting for G from (A.1) and for M from above into (A.3) gives

\[
B = 1/2.
\]

Since \( B = H = 1/2 \), it follows immediately from (A.4) that \( (C/B) = 1/M \), implying \( (C/B)^2 = 1/M^2 \) and \( K = M^2 \times sp/[M^2 \times sp + sv] \). Substituting for K and B into the equation for M in (A.1) yields a quadratic equation with positive solution

\[
M = \left( ra \times sv/2 \right) \times (-1 + \left[ 1 + 4 \times (z + g)/(ra \times sv) \right]^{0.5})
\]

We may now solve immediately for

\[
C = 1/(2 \times M)
\]

from (A.4) and the above expression for M, and for

\[
A = \left[ p \times (z + 2 \times g) - Q \right]/\left[ 2 \times (z + g) \right]
\]

from (A1), (A.2), and the variables B, C, and K. <<
REFERENCES

Bajeux, I., and Rochet, J-C. [1989], "Operations d'initiatives: une analyse de surplus," Finance, 10, 7-19.


