Chapter 3
Selling information

Outline

- Investment banks are generally regarded as being informed. They can use the information themselves to generate profits, or they could sell the information to other market participants.
- This model investigates the incentives for investment banks to sell their information.
- A complication arises in that information cannot be verified prior to its purchase, hence an investment bank could sell information it does not hold.
- We will consider how purchasers of information will assess that an investment bank actually holds the information it sells.

Outline

- We will firstly look in more detail at the specific setting of the model and the assumptions that are required.
- Subsequently we will then look at the implications of uniformed investment banks selling information they do not hold.
- This will then be contrasted against those investment banks that are holding the information. At this point we will also derive conditions under which only investment banks holding the information will actually sell it.
- Of course, for a sale of information to occur, it must be purchased and we will look at conditions such that the information is valuable to a purchaser.

- We will be looking at a situation where investment banks are seeking to sell information.
- We will see that a problem arises from the fact that information is not verifiable by purchasers.
- We will see how banks address this problem and what the implications are for the sale of information.

Opportunity to sell information

→ Information is usually valuable and investment banks can make use of this information, one way of using information is to sell it.

► As already mentioned, it is common to assume in many situations that investment banks are better informed than their clients. They might be more informed about specific securities or the market in general.

► Investment bank can use their informational advantage to generate profits by conducting their own investments, for example purchasing or selling the securities on which they hold information.

► In addition, or instead, they could sell the information to clients. When selling information, they directly benefit from the revenue, increasing their profits.

► A problem is though that information cannot be verified at the time of purchase, nor retrospectively in many cases; investment banks might have an incentive to sell information they do not hold. Purchasers of the information would like to have an assurance that they information they are sold actually exists and we will look at developing a verification mechanism to this effect.

→ The need to verify information actually exists will be at the heart of this model; the verification mechanism will restrict the ability to sell information, but it also ensures that the information has actual value to the purchaser.

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Signals

→ Investment banks will rely on information on the return or value of a security; such information is often referred to as a signal.

▶ Signals (information) will generally not be perfect, but have some degree of error. This is commonly modelled through an error term, which will capture all aspects that the signal does not include. The true return will then be given by the signal the investment bank receives, plus this error term.

▶ *Formula*

▶ If an investment bank has no information, it can not observe the signal and it would expect the signal they could obtain if they were informed to show the unconditional mean of the return. We also assume that the variance of the signal is known by all investment banks and their clients.

▶ We assume the error term to be unbiased such that the signal is, on average, correct. The variance of the error term is also known by all market participants.

▶ If we assume that the signal and error term are uncorrelated, the variance of the return can be given as the sum of variance of the signal and the error term. The resulting variance of the return is the risk that an uninformed investment bank faces.

→ Uninformed investment banks will not be able to use signals, while informed investment banks will use the signal as information on their expected returns and it will also reduce the variance as they are only exposed to the variance of the error term, having obtained the signal.

Problem and assumptions
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Uninformed banks
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Informed banks
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Purchase of information
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Summary
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Investments

→ We can now look into the investments that investment banks are making and how the information they hold will affect their decisions. Of interest will be the total value of this investment after one time period.

▶
- Investment banks will choose between government securities, investing the amount G, which yield the risk-free rate r
- and a risky asset, investing V and obtaining an uncertain return R. It is this risky asset that the investment bank obtains information about.

▶ *Formula*. We can now use that the total investment W_0 consists of the government bond G and risky asset V, hence $W_0 = G + V$ and eliminate the government bonds from the equation.

▶ Rather than looking at the value of the investment, we will consider the utility a bank obtains from their investment. This allows us to include the return of their investment, but also the risk. We assume that investment banks are risk-averse with risk aversion z. As the outcome of the investment is uncertain due to the risky asset, we use the expected utility investment banks obtain. The expected utility can be approximated as a the utility of the expected value less the variance, scaled by the risk aversion; the factor $\frac{1}{2}$ emerges for mathematical reasons. It is common to omit the utility itself as it is monotonously increasing, it will not affect any optimisation outcome.

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Problem and model assumptions

Uninformed investment banks

Informed investment banks

Purchase of information

Summary

- We will first consider the investment decisions of uninformed investment banks, that is those investment banks that have not obtained a signal on the return of the risky asset.
- We will afterwards then look at informed investment banks and compare their investment decisions.
- As we consider investment banks that might sell information, we will have to take into account the impact such a sale has on their expected utility.

Optimal investment without selling information

Optimal investment without selling information

→ We will seek to obtain the optimal investment of investment banks, but initially without them selling any information.

▶ Investment banks that are uninformed do not observe a signal and therefore their assessment of the return and risk of the risky asset will be based on public information.

  - This public information stipulates that the expected return of the risky asset is μ
  - and its variance is σ_R^2. The government bond is risk-free and we assume that the risk-free rate r is known and the variance of the government bond will be zero. We do not consider any interest rate risk in our assessment.

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  - We can now determine the expected value of the investment by taking expectations, using the formula on the previous slide $(W_1 = (1 + r) W_0 + (R - r) V)$.
  - Similarly we can obtain the variance of the investment.

▶ These expressions we can now insert into the expected utility $U_B = E[W_1] - \frac{1}{2} z Var[W_1]$ and as we seek the optimal investment into the risky asset, we maximize with respect to its value. The investment into government bonds is then given as the remainder of the total investment banks make. The first order condition for a maximum is that the first derivative of the expected utility is set equal to zero.

▶ This expression is solved for the optimal investment into the risky asset. We see that this investment is increasing in the excess return over the alternative investment into government securities, $\mu - r$, but decreasing in the risk and the risk aversion. The more risky an asset is, the less a risk-averse investor will like it and hence investment less into it. Similarly, for a higher risk aversion investment into the risky asset will be reduced.

▶ We can now insert this solution for the optimal investment into the risky asset, V^* into the expected utility. We obtain the expected utility for future reference.

→ We have obtained the optimal investment into the risky asset, and hence into government securities, in the case that investment banks are not informed and they do not seek to sell any information.

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▶ This expression is solved for the optimal investment into the risky asset. We see that this investment is increasing in the excess return over the alternative investment into government securities, $\mu - r$, but decreasing in the risk and the risk aversion. The more risky an asset is, the less a risk-averse investor will like it and hence investment less into it. Similarly, for a higher risk aversion investment into the risky asset will be reduced.

▶ We can now insert this solution for the optimal investment into the risky asset, V^* into the expected utility. We obtain the expected utility for future reference.

→ We have obtained the optimal investment into the risky asset, and hence into government securities, in the case that investment banks are not informed and they do not seek to sell any information.

Problem and assumptions
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Uninformed banks
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Informed banks
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Purchase of information
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Summary
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Optimal investment without selling information

▶ If investment banks are uninformed, they observe no signal
▶ Then $E[R] = \mu$

Optimal investment without selling information

→ We will seek to obtain the optimal investment of investment banks, but initially without them selling any information.

▶ Investment banks that are uninformed do not observe a signal and therefore their assessment of the return and risk of the risky asset will be based on public information.

▶
- This public information stipulates that the expected return of the risky asset is μ
- and its variance is σ_R^2. The government bond is risk-free and we assume that the risk-free rate r is known and the variance of the government bond will be zero. We do not consider any interest rate risk in our assessment.

▶
- We can now determine the expected value of the investment by taking expectations, using the formula on the previous slide $(W_1 = (1 + r) W_0 + (R - r) V)$.
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Problem and assumptions
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Informed banks
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Purchase of information
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Summary
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Optimal investment without selling information

▶ If investment banks are uninformed, they observe no signal
▶ Then $E[R] = \mu$ and $Var[R] = \sigma_R^2$

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Optimal investment without selling information

▶ If investment banks are uninformed, they observe no signal

▶ Then $E[R] = \mu$ and $Var[R] = \sigma_R^2$

▶ This gives $E[W_1] = (1+r)W_0 + (\mu - r)V$

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Informed banks
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Optimal investment without selling information

▶ If investment banks are uninformed, they observe no signal

▶ Then $E\left[R\right] = \mu$ and $Var\left[R\right] = \sigma_R^2$

▶ This gives $E\left[W_1\right] = \left(1 + r\right) W_0 + \left(\mu - r\right) V$ and $Var\left[W_1\right] = \sigma_R^2 V^2$

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Purchase of information
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Optimal investment without selling information

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▶ Maximizing expected utility for the optimal investment V we get
$\frac{\partial U_B}{\partial V} = (\mu - r) - z\sigma_R^2 V = 0$

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Problem and assumptions
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Purchase of information
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Summary
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Optimal investment without selling information

- If investment banks are uninformed, they observe no signal
- Then $E[R] = \mu$ and $Var[R] = \sigma_R^2$
- This gives $E[W_1] = (1+r)W_0 + (\mu - r)V$ and $Var[W_1] = \sigma_R^2 V^2$
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- Solving for $V^* = \frac{\mu - r}{z\sigma_R^2}$

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Problem and assumptions
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Uninformed banks
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Informed banks
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Purchase of information
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Summary
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Optimal investment without selling information

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▶ Expected utility is then $U_B^* = (1 + r)W_0 + \frac{(\mu - r)^2}{2z\sigma_R^2}$

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Problem and assumptions
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Uninformed banks
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Informed banks
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Purchase of information
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Summary
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Optimal investment without selling information

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Preventing uninformed selling of information

$\rightarrow$ We now look at the case that investment banks sell information.
▶
- As information is no physical good, an investment bank could claim that it holds the information it seeks to sell.
- This claim does not have to be true as it is not verifiable whether they actually hold the information.

▶
- Investment banks will charge a price P for providing this information. As investment banks charge a fixed price, there is no risk associated with selling information.
- They can still make investments, so will obtain the utility from this.

▶ *Formula*
▶ They will still make investments, but these can change as there is additional revenue from selling information that needs to be taken into account.
▶ At this point we do not seek to determine this optimal investment, but instead look at the condition such that the investment bank does not want to sell information. If their expected utility if selling information, $\hat{U}_B$ is lower than if not selling information U_B^*, they will refrain from doing so. The utility if not selling information we have obtained on the previous slide.
▶ We insert for the expected utility for not selling information, U_B^*, and solve for the maximum price that investment banks can charge and not be better off selling information. We see that this maximum price will depend on the investment into the risky asset, V.
$\rightarrow$ Investors know that and investment banks charging a price higher than P^* has an incentive to sell information, even if they do not hold this information; this might dissuade them from purchasing information that is priced too highly. We will now analyse this incentive of an investment bank to sell information it does not own in more detail.

Problem and assumptions
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Purchase of information
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Summary
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Preventing uninformed selling of information

▶ Investment banks can claim they have received a signal

$\rightarrow$ We now look at the case that investment banks sell information.

- • As information is no physical good, an investment bank could claim that it holds the information it seeks to sell.
  - • This claim does not have to be true as it is not verifiable whether they actually hold the information.

- • Investment banks will charge a price P for providing this information. As investment banks charge a fixed price, there is no risk associated with selling information.
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Preventing uninformed selling of information

▶ Investment banks can claim they have received a signal , even if this is not true

→ We now look at the case that investment banks sell information.
▶
  - As information is no physical good, an investment bank could claim that it holds the information it seeks to sell.
  - This claim does not have to be true as it is not verifiable whether they actually hold the information.
▶
  - Investment banks will charge a price P for providing this information. As investment banks charge a fixed price, there is no risk associated with selling information.
  - They can still make investments, so will obtain the utility from this.
▶ *Formula*
▶ They will still make investments, but these can change as there is additional revenue from selling information that needs to be taken into account.
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Problem and assumptions
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Informed banks
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Purchase of information
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Summary
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Preventing uninformed selling of information

▶ Investment banks can claim they have received a signal , even if this is not true

▶ Investment banks will charge a price for this information

▶ $\hat{U}_B = \qquad\qquad\qquad + P$

$\rightarrow$ We now look at the case that investment banks sell information.

- As information is no physical good, an investment bank could claim that it holds the information it seeks to sell.
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Preventing uninformed selling of information

▶ Investment banks can claim they have received a signal , even if this is not true

▶ Investment banks will charge a price for this information and obtain this revenue in addition to the utility from investment

▶ $\hat{U}_B = \left(1 + r\right) W_0 + \left(\mu - r\right) V + P - \frac{1}{2} z \sigma_R^2 V^2$

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Preventing uninformed selling of information

- Investment banks can claim they have received a signal , even if this is not true
- Investment banks will charge a price for this information and obtain this revenue in addition to the utility from investment
- $\hat{U}_B = (1 + r) W_0 + (\mu - r) V + P - \frac{1}{2} z \sigma_R^2 V^2$
- Investment into the risky asset might change if selling information

$\rightarrow$ We now look at the case that investment banks sell information.
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▶ At this point we do not seek to determine this optimal investment, but instead look at the condition such that the investment bank does not want to sell information. If their expected utility if selling information, $\hat{U}_B$ is lower than if not selling information U_B^*, they will refrain from doing so. The utility if not selling information we have obtained on the previous slide.

▶ We insert for the expected utility for not selling information, U_B^*, and solve for the maximum price that investment banks can charge and not be better off selling information. We see that this maximum price will depend on the investment into the risky asset, V.

$\rightarrow$ Investors know that and investment banks charging a price higher than P^* has an incentive to sell information, even if they do not hold this information; this might dissuade them from purchasing information that is priced too highly. We will now analyse this incentive of an investment bank to sell information it does not own in more detail.

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Summary
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Preventing uninformed selling of information

▶ Investment banks can claim they have received a signal , even if this is not true

▶ Investment banks will charge a price for this information and obtain this revenue in addition to the utility from investment

▶ $\hat{U}_B = (1 + r) W_0 + (\mu - r) V + P - \frac{1}{2} z \sigma_R^2 V^2$

▶ Investment into the risky asset might change if selling information

▶ The investment bank will refrain from selling information it does not hold if $\hat{U}_B \leq U_B^*$

$\rightarrow$ We now look at the case that investment banks sell information.
- • As information is no physical good, an investment bank could claim that it holds the information it seeks to sell.
  • This claim does not have to be true as it is not verifiable whether they actually hold the information.

- • Investment banks will charge a price P for providing this information. As investment banks charge a fixed price, there is no risk associated with selling information.
  • They can still make investments, so will obtain the utility from this.

- *Formula*
- They will still make investments, but these can change as there is additional revenue from selling information that needs to be taken into account.
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Summary
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Preventing uninformed selling of information

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- ▶ Investment banks will charge a price for this information and obtain this revenue in addition to the utility from investment
- ▶ $\hat{U}_B = (1 + r) W_0 + (\mu - r) V + P - \frac{1}{2} z \sigma_R^2 V^2$
- ▶ Investment into the risky asset might change if selling information
- ▶ The investment bank will refrain from selling information it does not hold if $\hat{U}_B \leq U_B^*$
- ▶ This solves for $P \leq P^* = \frac{(\mu - r)^2}{2 z \sigma_R^2} - (\mu - r) V + \frac{1}{2} z \sigma_R^2 V^2$

Preventing uninformed selling of information

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Selling news for long positions ($V > 0$)

→ For our analysis of the incentives of investment banks selling information it does not hold, we will first consider the case where investment bank take a long position in the risky asset. This is usually associated with a situation in which the expected return of the risky asset exceeds that of the risk-free asset.

▶ While it is generally acknowledged that individuals are risk averse, it is difficult to know the risk aversion. We therefore assume here that investors do not know the risk aversion of investment banks. If they do not know the risk aversion of banks, the condition for not selling information they do no own, P^*, this condition has to hold for any risk aversion

▶ We need to determine the smallest possible value of the price threshold, so will have to minimize its value.

▶ Solving the first order condition gives us that this value is minimized at this risk aversion.

▶ It is reasonable to assume that the expected return of the risky asset is higher than the risk-free rate, then we can take solve for the risk aversion by simply taking the square root.

▶ We can insert this risk aversion into the threshold P^* and we find that the maximum price that could be charged is zero

▶ As a price cannot be negative, this then implies that if investment banks hold a long position, they would always sell information, at any price. This is because the information they sell increases their profits without affecting their investments.

→ As long as investment banks invest positive amounts into the risky assets, they always have an incentive to sell information, even if they do not hold such information. Hence investors observing an investment bank selling information and making such investments in the asset, cannot be sure the information exists.

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Selling news for long positions ($V > 0$)

▶ The risk aversion of investment banks is unknown, so the constraint on P must hold for all values

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Selling news for long positions ($V > 0$)

▶ The risk aversion of investment banks is unknown, so the constraint on P must hold for all values

▶ The smallest possible price P is given from $\frac{\partial P^*}{\partial z} = -\frac{(\mu-r)^2}{2z^2\sigma_R^2} + \frac{1}{2}\sigma_R^2 V^2 = 0$

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Selling news for long positions ($V > 0$)

▶ The risk aversion of investment banks is unknown, so the constraint on P must hold for all values

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▶ Giving $z^2 = \frac{(\mu-r)^2}{\sigma_R^4 V^2}$

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▶ It is reasonable to assume that the expected return of the risky asset is higher than the risk-free rate, then we can take solve for the risk aversion by simply taking the square root.

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→ As long as investment banks invest positive amounts into the risky assets, they always have an incentive to sell information, even if they do not hold such information. Hence investors observing an investment bank selling information and making such investments into the asset, cannot be sure the information exists.

Selling news for short positions ($V < 0$)

→   Let us now consider the case of the investment bank having a short position in the risky asset. The main considerations of the investment bank are the same, as well as the threshold price at which they sell information they do not have.

▶   • If we again determine the risk aversion at which the threshold price P^* is smallest, we have to change the sign when taking the square root from the expression for the squared risk aversion, $z^2 = \frac{(\mu - r)^2}{\sigma_R^4 V^2}$

   • Inserting this risk aversion into the price threshold gives us a positive value due to the value of the investment into the risk asset, V, being negative. It is thus that the minimum price must be positive if investment banks hold short positions in the risky asset.
   • The investment bank would only want to sell information if the price is sufficiently high.

▶   Of course, banks will always charge the maximum possible price, neglecting any constraints coming from the demand for information. The price demanded by informed investment banks would seek to ensure that uninformed investment banks have no incentive to sell information and hence would choose a price marginally below the threshold for uninformed investment banks.

▶   • We can now insert the maximum price P^* into the expected utility of uninformed investment banks.
   • As the threshold price depends on the investment into the risky asset, V, we can now determine the optimal investment by maximizing the expected utility.

▶   Solving the first order condition, we get the optimal investment, which will be negative as required.

▶   We can now insert this optimal investment into the risky asset, V^*, back into the threshold price P^* and obtain the price that can be charged for information without inducing uninformed investment banks to sell information they do not have.

→   If investment banks have a short position in the risky asset, a sufficiently low price for information will prevent them from selling information they do not own.

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Selling news for short positions ($V < 0$)

► If $V < 0$, then $z = -\frac{\mu - r}{\sigma_R^2 V}$

→ Let us now consider the case of the investment bank having a short position in the risky asset. The main considerations of the investment bank are the same, as well as the threshold price at which they sell information they do not have.

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- If we again determine the risk aversion at which the threshold price P^* is smallest, we have to change the sign when taking the square root from the expression for the squared risk aversion, $z^2 = \frac{(\mu - r)^2}{\sigma_R^4 V^2}$.

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→ If investment banks have a short position in the risky asset, a sufficiently low price for information will prevent them from selling information they do not own.

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Selling news for short positions ($V < 0$)

- If $V < 0$, then $z = -\frac{\mu - r}{\sigma_R^2 V}$ and $P^* = -2\left(\mu - r\right)V > 0$

→ Let us now consider the case of the investment bank having a short position in the risky asset. The main considerations of the investment bank are the same, as well as the threshold price at which they sell information they do not have.

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- If we again determine the risk aversion at which the threshold price P^* is smallest, we have to change the sign when taking the square root from the expression for the squared risk aversion, $z^2 = \frac{(\mu - r)^2}{\sigma_R^4 V^2}$

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Problem and assumptions
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Summary
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Selling news for short positions ($V < 0$)

▶ If $V < 0$, then $z = -\frac{\mu - r}{\sigma_R^2 V}$ and $P^* = -2(\mu - r)V > 0$ and the investment bank would want to sell the information if the price is high enough

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  • We can now insert the maximum price P^* into the expected utility of uninformed investment banks.
  • As the threshold price depends on the investment into the risky asset, V, we can now determine the optimal investment by maximizing the expected utility.

▶ Solving the first order condition, we get the optimal investment, which will be negative as required.
▶ We can now insert this optimal investment into the risky asset, V^*, back into the threshold price P^* and obtain the price that can be charged for information without inducing uninformed investment banks to sell information they do not have.
→ If investment banks have a short position in the risky asset, a sufficiently low price for information will prevent them from selling information they do not own.

Problem and assumptions
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Uninformed banks
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Informed banks
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Summary
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Selling news for short positions ($V < 0$)

▶ If $V < 0$, then $z = -\frac{\mu - r}{\sigma_R^2 V}$ and $P^* = -2\left(\mu - r\right)V > 0$ and the investment bank would want to sell the information if the price is high enough

▶ As banks seek to maximize their utility they will sell information at the highest price P^*

→ Let us now consider the case of the investment bank having a short position in the risky asset. The main considerations of the investment bank are the same, as well as the threshold price at which they sell information they do not have.

▶
- If we again determine the risk aversion at which the threshold price P^* is smallest, we have to change the sign when taking the square root from the expression for the squared risk aversion, $z^2 = \frac{(\mu - r)^2}{\sigma_R^4 V^2}$
- Inserting this risk aversion into the price threshold gives us a positive value due to the value of the investment into the risk asset, V, being negative. It is thus that the minimum price must be positive if investment banks hold short positions in the risky asset.
- The investment bank would only want to sell information if the price is sufficiently high.

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▶ As banks seek to maximize their utility they will sell information at the highest price P^*

▶ Inserting this into the expected utility $\hat{U}_B$

→ Let us now consider the case of the investment bank having a short position in the risky asset. The main considerations of the investment bank are the same, as well as the threshold price at which they sell information they do not have.

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Summary
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▶ This then gives $P^* = 2 \frac{(\mu - r)^2}{z \sigma_R^2}$

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Preventing the sale of information that does not exist

Preventing the sale of information that does not exist

$\rightarrow$ We can now summarize our results so far on the sale of information by uninformed investment banks.

► We have seen that if uninformed investment banks hold long positions in the risky asset they seek to sell information about, they will do so at any price. Hence in such a situation, no information should be sold, it could come from uninformed investment banks that do not hold any information. For a potential buyer, there is no value in this information, although he might be unaware of this.

► In contrast, if uninformed investment banks hold short positions in the risky asset they seek to sell information about, they would only sell information if the price is sufficiently high. Thus, if information is sold at a price below the threshold, the information must come from an informed investment bank. Selling information above the price threshold does not allow a buyer to know whether the information they purchase is held by the investment bank or not.

$\rightarrow$ We have thus seen that uninformed investment banks have an incentive to sell information, if holding short positions in the risky asset only if the price they can obtain is sufficiently high. Thus to ensure that information is actually held, it needs to be sold at a sufficiently low price. We will now explore whether informed investment bank, those actually holding the information, have an incentive to sell their information at all.

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Uninformed banks
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Preventing the sale of information that does not exist

▶ If $V > 0$ for an uninformed investment bank, information should not be sold as it can be from informed or uninformed investment banks

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Preventing the sale of information that does not exist

▶ If $V > 0$ for an uninformed investment bank, information should not be sold as it can be from informed or uninformed investment banks

▶ If $V < 0$ for an uninformed investment bank, information may be sold if the price is below P^* as in this case it is from the informed investment bank

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Problem and assumptions
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Summary
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Preventing the sale of information that does not exist

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▶ If $V < 0$ for an uninformed investment bank, information may be sold if the price is below P^* as in this case it is from the informed investment bank

Preventing the sale of information that does not exist

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■ Problem and model assumptions

■ Uninformed investment banks

■ **Informed investment banks**

■ Purchase of information

■ Summary

- We have looked at the incentives for uniformed investment banks to sell information they do not own and found that if investment banks hold long position in the risky asset, they will always seek to sell information.
- If they hold short positions, they will only sell information if the price is sufficiently high.
- We will now see whether investment banks are willing to sell information at a sufficiently low price such that uninformed investment banks do not sell information.

Optimal investment without selling information

$\rightarrow$ We first look at the utility of an investment bank not selling any information but instead using their information to make better investments than uninformed investment banks

► Informed investment banks observe the signal s, which is their information about the return of the risky asset.
  • Using this information, the expected return of the risky asset will be given by the signal, given that the error term was assumed to have a mean of zero.
  • The variance of the return will be the residual variance arising from the fact that information is not perfect and can have errors.
  • We can use these expected returns and variances now to determine the expected value of the investment
  • as well as its risk.

► The utility function of informed investment banks is identical to that of uninformed investment banks, the only difference are only wether they have information or not. We can therefore insert the expected investment value and its variance into the expected utility, which we then maximize over the optimal investment into the risky asset. From this we need to solve the first order condition.

► The first order condition can be solved for the optimal investment into the risky asset. It will depend on the signal received as well as the variance of the error term, that is the remaining uncertainty after receiving the signal. This uncertainty will be smaller than for uninformed investment banks, implying a larger investment due to the lower risk. However, the signal will also affect the amount invested.

► Using the optimal amount to invest into the risky asset, we can then obtain the expected utility of the informed investment bank.

$\rightarrow$ Informed investment banks will in general make different investments into the risky asset, depending on their information. We will now see how these decisions are affected when selling their information.

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Optimal investment without selling information

▶ If investment banks are informed, they observe their signal

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Problem and assumptions
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Uninformed banks
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Summary
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Optimal investment without selling information

▶ If investment banks are informed, they observe their signal
▶ Then $E[R] = s$

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Summary
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Optimal investment without selling information

▶ If investment banks are informed, they observe their signal
▶ Then $E[R] = s$ and $Var[R] = \sigma_\varepsilon^2$

→ We first look at the utility of an investment bank not selling any information but instead using their information to make better investments than uninformed investment banks

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Optimal investment without selling information

▶ If investment banks are informed, they observe their signal
▶ Then $E[R] = s$ and $Var[R] = \sigma_{\varepsilon}^2$
▶ This gives $E[W_1|s] = (1+r)W_0 + (s-r)V$

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Optimal investment without selling information

- ▶ If investment banks are informed, they observe their signal
- ▶ Then $E[R] = s$ and $Var[R] = \sigma_\varepsilon^2$
- ▶ This gives $E[W_1|s] = (1+r)W_0 + (s-r)V$ and $Var[W_1|s] = \sigma_\varepsilon^2 V^2$

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▶ The first order condition can be solved for the optimal investment into the risky asset. It will depend on the signal received as well as the variance of the error term, that is the remaining uncertainty after receiving the signal. This uncertainty will be smaller than for uninformed investment banks, implying a larger investment due to the lower risk. However, the signal will also affect the amount invested.

▶ Using the optimal amount to invest into the risky asset, we can then obtain the expected utility of the informed investment bank.

→ Informed investment banks will in general make different investments into the risky asset, depending on their information. We will now see how these decisions are affected when selling their information.

Problem and assumptions
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Uninformed banks
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Informed banks
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Purchase of information
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Summary
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Optimal investment without selling information

▶ If investment banks are informed, they observe their signal
▶ Then $E[R] = s$ and $Var[R] = \sigma_\varepsilon^2$
▶ This gives $E[W_1|s] = (1+r)W_0 + (s-r)V$ and $Var[W_1|s] = \sigma_\varepsilon^2 V^2$
▶ Maximizing expected utility for the optimal investment V we get
$\frac{\partial U_B}{\partial V} = (s-r) - z\sigma_\varepsilon^2 V = 0$

→ We first look at the utility of an investment bank not selling any information but instead using their information to make better investments than uninformed investment banks

▶ Informed investment banks observe the signal s, which is their information about the return of the risky asset.
  - Using this information, the expected return of the risky asset will be given by the signal, given that the error term was assumed to have a mean of zero.
  - The variance of the return will be the residual variance arising from the fact that information is not perfect and can have errors.

  - We can use these expected returns and variances now to determine the expected value of the investment
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Selling information

→ Informed investment bank can use their information to make investment decisions, but they can also sell their information. We assume here implicitly that selling information does not derogate its value to the investment bank itself. Thus they might sell information and this doe snot affect their investment outcomes. Such a situation might be realistic if we assume that investment banks will already have obtained their investments before selling information and it will therefore not affect them.

▶ When selling information at a price, this will increase the profits of the investment bank as they obtain additional revenue but by assumption have no additional costs.

▶ The maximum price, the threshold P^*, does not depend on the investment made by the informed investment bank, it was only affected by the investment of the uninformed investment bank. Here the price is independent of the investment of the informed investment bank. Informed investment banks will charge a price at the threshold, where they prevent uninformed investment banks selling information they do not have. This increases the value of information to potential buyers as they know the information has been sold by an informed investment bank.

▶ Informed investment banks do not need to be prevented from selling information, they are always increasing their profits, hence they are always willing to sell such information.

▶ However, if their investment is positive, uninformed investment banks are also willing to sell information at any price; they can exclude uninformed investment banks from selling information only if investments are negative (short sales). If we assume that the investments of investment banks are observable, information can only be ensured to be from informed investment banks if the investment is negative.

▶ Requiring that V^{**} is negative, requires that the signal is below the risk-free rate.

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→ In order to distinguish themselves from uninformed investment banks, informed investment banks only sell information if it is sufficiently negative. For less negative or positive information, uniformed investment banks would also sell information, which would reduce its value to buyers.

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Selling information

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- ▶ The price does not depend on the investment V, this includes the maximum price P^*

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▶ The price does not depend on the investment V, this includes the maximum price P^*

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Selling information

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- The price does not depend on the investment V, this includes the maximum price P^*
- Informed investment banks would always sell their information
- To distinguish themselves from uninformed investment banks, they would sell only if $V^{**} < 0$

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Reasons for only selling negative information

Reasons for only selling negative information

→ We have seen that only negative information can be sold if we want to prevent uninformed investment banks to sell information they do not hold.

▶
- Positive information makes a long position of the risky asset optimal for informed investment banks; uninformed investment banks would always prefer a long position as we had assumed that $\mu > r$.
- Hence with positive information, both types of investment banks, informed and uninformed, would hold similar positions and the buyer of information will not be able to ascertain who he is buying the information from and therefore whether he purchases information that actually exists.

▶
- With negative information, informed investment banks take a short position, but uninformed investment banks do not hold this information and will therefore still invest into a long position. We assume here that uninformed investment banks cannot purchase information from informed investment banks and then sell the information on.
- As the investment banks now take different positions, potential buyers of the information can distinguish them. A short position means that the investment bank is informed, while a long position could be either an uninformed investment bank or, if information is positive, either an informed or uninformed investment bank.

▶ Uninformed investment banks in principle could copy informed investment banks and thereby appear to be informed. This is however not optimal as the adjustment of the investment is too large to make it profitable, given that the price they can obtain for the information is low. It was set this low in order to prevent uninformed investment banks from making such adjustments to their investments.

▶ Looking at the investments of investment banks, buyers of information can distinguish between informed and uninformed investment banks. This, however, only works if the information is negative. For positive information, the costs of adjustment for uninformed investment banks are small and the types of banks cannot be distinguished.

→ We use the investment decisions in the risky asset as an indicator for the presence of information and buyers of information can easily distinguish investment banks, but only for negative information. The sale of positive information is not possible in this model.

Reasons for only selling negative information

▶ Positive information makes a long position optimal for informed and uninformed banks

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Reasons for only selling negative information

▶ Positive information makes a long position optimal for informed and uninformed banks, this means they cannot be distinguished well

Reasons for only selling negative information

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▶ Looking at the investments of investment banks, buyers of information can distinguish between informed and uninformed investment banks. This, however, only works if the information is negative. For positive information, the costs of adjustment for uninformed investment banks are small and the types of banks cannot be distinguished.
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Problem and assumptions
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Uninformed banks
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Informed banks
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Purchase of information
oooo

Summary
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Reasons for only selling negative information

▶ Positive information makes a long position optimal for informed and uninformed banks, this means they cannot be distinguished well

▶ Negative information makes a short position optimal for informed and a long position for uninformed banks

Reasons for only selling negative information

→ We have seen that only negative information can be sold if we want to prevent uninformed investment banks to sell information they do not hold.
- • Positive information makes a long position of the risky asset optimal for informed investment banks; uninformed investment banks would always prefer a long position as we had assumed that $\mu > r$.
  - • Hence with positive information, both types of investment banks, informed and uninformed, would hold similar positions and the buyer of information will not be able to ascertain who he is buying the information from and therefore whether he purchases information that actually exists.

- • With negative information, informed investment banks take a short position, but uninformed investment banks do not hold this information and will therefore still invest into a long position. We assume here that uninformed investment banks cannot purchase information from informed investment banks and then sell the information on.
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▶ Negative information makes a short position optimal for informed and a long position for uninformed banks, this means they can be easily distinguished

▶ Adjustment of security holding for the uninformed investment bank is too large to sell negative information they do not hold

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Problem and model assumptions

Uninformed investment banks

Informed investment banks

Purchase of information

Summary

- We have thus far been concerned with the sale of information and how purchasers can ensure they obtain this information from an informed investment bank.
- We will now look at the decision to purchase information.

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Uninformed banks
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Informed banks
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Purchase of information
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Summary
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Investor decisions

→ Investors are purchasing information with the aim of making investment decisions. We will thus have to assess the benefits of purchasing information by comparing investment decisions with and without acquiring information.

▶ The considerations for investments into the risky asset are identical for investment banks and other investors. Then investors not purchasing the information are similar to uninformed banks not selling information.

▶ An investor not purchasing information will make the same decisions as an unformed bank as they have the same information, hence their expected utilities will be identical.

▶ Investors purchasing the information from an informed investment bank will have the same information as the informed investment bank itself and therefore they are very similar.

- Investors purchasing the information will therefore make the same decisions as an informed investment bank and obtain the same utility.
- However, their utility will be reduced by the price they pay for the information

▶ Investment banks sell information typically not to a single investor only, but to many investors. The price we established as the threshold for preventing uninformed investment banks selling information was representing the revenue from all information sales. If we assume that information is sold to multiple investors, each pays its fraction of the total revenue the investment bank obtains.

→ With investors being identical to investment banks, with the only difference being the purchase of information, we can now evaluate under which conditions investors will purchase information.

Investor decisions

▶ **Uninformed investors** are similar to uninformed banks

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Uninformed banks
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Purchase of information
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Summary
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Investor decisions

▶ Uninformed investors are similar to uninformed banks
▶ Their expected utility is given by $U_D^* = (1+r) W_0 + \frac{(\mu-r)^2}{2z\sigma_R^2}$

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Uninformed banks
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Informed banks
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Summary
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Investor decisions

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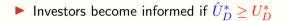
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Becoming informed

Becoming informed

$\rightarrow$ Investors need to decide whether to purchase information and thus become informed
▶ Investors will purchase information if the utility of doing so is higher.
▶ Inserting for all expressions, we can easily solve this condition for the signal to be sufficiently different from the risk-free rate.
▶ Only if the signal is sufficiently low, information sufficiently negative, can information be sold. This will exclude the possible high values for the signal
▶ *Formula*
▶ Information needs to be sufficiently negative to be of value to the buyer. This constraint is more strict than the constraint on the investment bank to identifies as being informed, $s < r$. Investors will only buy information if the its contents is sufficiently different from their current level of information, μ. Smaller deviations from their current information do not increase the utility of investors sufficiently to compensate them for the costs.
$\rightarrow$ Investors only buy information if it is sufficiently negative. As they cannot know the contents of the information prior to purchasing it, and the price is independent on the signal itself, investors have to reply on investment banks selling them only information that is valuable to them. Investment bank might do that in order to retain investors as clients by ensuring they are only offered information that is valuable to them.

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Informed banks
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Becoming informed

▶ Investors become informed if $\hat{U}_D^* \geq U_D^*$

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Summary
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Becoming informed

▶ Investors become informed if $\hat{U}_D^* \geq U_D^*$

▶ This becomes $(s - r)^2 \geq \frac{\sigma_\varepsilon^2}{\sigma_R^2} \left((\mu - r)^2 + \frac{2z\sigma_R^2 P^*}{N} \right)$

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Summary
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Becoming informed

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- This becomes $(s - r)^2 \geq \frac{\sigma_\varepsilon^2}{\sigma_R^2}\left((\mu - r)^2 + \frac{2z\sigma_R^2 P^*}{N}\right)$
- We need $s < r$ to have information being offered, this means
- $s \leq r - \frac{\sigma_\varepsilon}{\sigma_R}\sqrt{(\mu - r)^2 + \frac{2z\sigma_R^2 P^*}{N}} < r$

Becoming informed

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Becoming informed

- Investors become informed if $\hat{U}_D^* \geq U_D^*$
- This becomes $(s - r)^2 \geq \frac{\sigma_\varepsilon^2}{\sigma_R^2} \left((\mu - r)^2 + \frac{2z\sigma_R^2 P^*}{N} \right)$
- We need $s < r$ to have information being offered, this means
- $s \leq r - \frac{\sigma_\varepsilon}{\sigma_R} \sqrt{(\mu - r)^2 + \frac{2z\sigma_R^2 P^*}{N}} < r$
- Information is only bought if it is sufficiently negative

$\rightarrow$ Investors need to decide whether to purchase information and thus become informed
▶ Investors will purchase information if the utility of doing so is higher.
▶ Inserting for all expressions, we can easily solve this condition for the signal to be sufficiently different from the risk-free rate.
▶ Only if the signal is sufficiently low, information sufficiently negative, can information be sold. This will exclude the possible high values for the signal
▶ Formula
▶ Information needs to be sufficiently negative to be of value to the buyer. This constraint is more strict than the constraint on the investment bank to be identifies as being informed, $s < r$. Investors will only buy information if the its contents is sufficiently different from their current level of information, μ. Smaller deviations from their current information do not increase the utility of investors sufficiently to compensate them for the costs.
$\rightarrow$ Investors only buy information if it is sufficiently negative. As they cannot know the contents of the information prior to purchasing it, and the price is independent on the signal itself, investors have to reply on investment banks selling them only information that is valuable to them. Investment bank might do that in order to retain investors as clients by ensuring they are only offered information that is valuable to them.

Becoming informed

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Becoming informed

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▶ Only if the signal is sufficiently low, information sufficiently negative, can information be sold. This will exclude the possible high values for the signal

▶ *Formula*

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Problem and assumptions
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Uninformed banks
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Informed banks
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Purchase of information
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Summary
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Information content needed

→ Not all information is valuable to investors and not all information can be sold credibly. It will only be certain types of information that can be trusted to be true and valuable to investors.

▶ We had established a maximum price for information to ensure that uninformed investment banks have no incentive to sell negative information.

▶ If an investment bank were to charge a lower price than this maximum, it might be able to sell more information as the signal does not need to be less negative, giving it a chance to sell more information. Thus the maximum price P^* will only be charged for very negative information and a lower price for less negative information. We have therefore a relationship between the price charged and the information content; the more extreme the information; the higher the price.

▶ However, the information always needs to be sufficiently negative, even if the price charged approaches zero, will this only be purchased by investors if the information is sufficiently negative.

▶ We only observe the sale and purchase of information which is sufficiently negative. It needs to be negative in order to ensure that investors can distinguish informed from uninformed investment banks and sufficiently negative in order to justify the costs of purchasing the information.

→ Positive information is not sold. While there is a demand for positive information, provided it is sufficiently positive, banks cannot reliably communicate that they actually hold the information they are selling, making the market unviable.

Problem and assumptions
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Uninformed banks
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Informed banks
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Purchase of information
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Summary
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Information content needed

▶ The maximum price possible is P^* to prevent uninformed investment banks selling information

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Information content needed

▶ The maximum price possible is P^* to prevent uninformed investment banks selling information

▶ The lower the price the less negative the signal needs to be to be profitable

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Problem and assumptions
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Uninformed banks
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Purchase of information
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Summary
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Information content needed

- The maximum price possible is P^* to prevent uninformed investment banks selling information
- The lower the price the less negative the signal needs to be to be profitable
- Even at $P = 0$ the information needs to be sufficiently negative

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- We can now summarize the key model results and look at some implications this model has.

Problem and assumptions
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Uninformed banks
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Informed banks
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Purchase of information
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Summary
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Only negative information is sold

Only negative information is sold

→ A key result was that only negative information is sold and bought, positive information could not be sold as it was not verifiable that the investment bank held this information.
- Negative information can be sold as the investments into risky assets by the investment bank can be used to verify that they hold this information. They short position suggests that they have obtained negative information and as they put their own money on this information, information is seen as existing.
- In contrast, positive information, or nor sufficiently negative information, could be sold by uninformed investment banks. They can adjust their investments into the risky asset accordingly and still make a profit from selling this non-existent information.

▶ It is central that investors purchasing information can verify the existence of information by observing the investment banks' own investments. This investment will be based on the information, if any, of the investment bank and can therefore be seen as a proxy variable for the existence of the information itself.

▶ In principle, uninformed investment banks could adjust their investments so much that it represents negative information. However, the costs of deviating from their optimal investment are too high to be justified by the price they can obtain for their information. It was limiting the price informed investment banks charge for information that prevents uninformed investment banks from copying the investments of informed investment banks.

▶ Of course for information to be valuable to investors it needs to provide benefits that exceed the costs of obtaining this information. This is only achieved if the information is sufficiently different from the current information investors have; the information must be sufficiently negative.

→ We should observe that mainly negative information is sold in the market as it can be verified more easily when purchasing that the information is genuine. The sale of positive information is more difficult to achieve and would have to rely on a different mechanism to verify its existence.

Problem and assumptions
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Uninformed banks
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Informed banks
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Purchase of information
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Summary
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Only negative information is sold

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Problem and assumptions
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Uninformed banks
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Informed banks
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Purchase of information
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Summary
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Only negative information is sold

▶ Only negative information can be sold, as positive information can be copied by uninformed investment banks

Only negative information is sold

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Problem and assumptions
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Uninformed banks
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Informed banks
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Purchase of information
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Summary
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Only negative information is sold

▶ Only negative information can be sold, as positive information can be copied by uninformed investment banks

▶ To verify the existence of information, purchasers can observe the investments of investment banks

Only negative information is sold

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Uninformed banks
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Informed banks
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Purchase of information
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Summary
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Only negative information is sold

▶ Only negative information can be sold, as positive information can be copied by uninformed investment banks

▶ To verify the existence of information, purchasers can observe the investments of investment banks

▶ Selling negative information without having it, requires a too large adjustment of the investments, given the price they are charging

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Problem and assumptions
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Summary
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Market implications

Market implications

$\rightarrow$ These result have some implications for the type of information that is available in the market and also how the market reacts to such information.

▶ We have seen that negative information can be verified by the investment bank's action, it is therefore valuable to investors as they know they will obtain true information.

▶ Positive information could be sold by informed or uninformed investment banks, thus there is some degree of uncertainty whether the information is true or not. This makes the information much less valuable, and investors would be willing to pay less for it, but it will also increase the uncertainty about the expected returns. This increased risk will make investors more cautious about using the information and they will invest less into the risky asset compared to an equivalent negative information.

▶ An implication of this result is that investors should react stronger to negative information than positive information, given that negative information is more reliable. If they react more strongly in terms of their investment decisions, they will affect market price more for negative than positive information. Consequently, security prices should react more strongly to negative than to positive information.

$\rightarrow$ Investment banks are willing to sell information and investors are willing to purchase such negative information. However, the need to verify that an investment bank holds the information its ells, makes the sale of negative information much more common and reliable; this will have an impact on securities markets. It is therefore that investment banks have an impact on market prices through their sale of information and this impact is biased towards price reductions due to negative news being more dominant and more reliable.

Problem and assumptions
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Uninformed banks
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▶ Negative information is valuable as it will be based on actual information

▶ Positive information can be from informed or uninformed investment banks and much less valuable

▶ Investors should react stronger to negative information than positive information

Market implications

→ These result have some implications for the type of information that is available in the market and also how the market reacts to such information.

▶ We have seen that negative information can be verified by the investment bank's action, it is therefore valuable to investors as they know they will obtain true information.

▶ Positive information could be sold by informed or uninformed investment banks, thus there is some degree of uncertainty whether the information is true or not. This makes the information much less valuable, and investors would be willing to pay less for it, but it will also increase the uncertainty about the expected returns. This increased risk will make investors more cautious about using the information and they will invest less into the risky asset compared to an equivalent negative information.

▶ An implication of this result is that investors should react stronger to negative information than positive information, given that negative information is more reliable. If they react more strongly in terms of their investment decisions, they will affect market price more for negative than positive information. Consequently, security prices should react more strongly to negative than to positive information.

→ Investment banks are willing to sell information and investors are willing to purchase such negative information. However, the need to verify that an investment bank holds the information its ells, makes the sale of negative information much more common and reliable; this will have an impact on securities markets. It is therefore that investment banks have an impact on market prices through their sale of information and this impact is biased towards price reductions due to negative news being more dominant and more reliable.

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