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The information content of trading volume
NEW YORK STOCK EXCHANGE
LIVERMORE

Outline

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- Prices are generally regarded as a key source of information and in response to the overall trading demand, these prices are adjusted to reflect the information conveyed through the demand.
- Often, however, it is not clear how much information is actually conveyed; it is usually not known how many traders are informed and we also do not know how precise the information they hold is.
- We will look at an additional source of information to address this problem: trading volume.

Outline

- We will first outline the potential for trading volume as an additional source of information.
- After that we will explore how we can use trading volume extract information on the number of informed traders and then the precision of the information they hold.
- Finally we will combine uncertainty about the number of informed traders and the precision of their information and explore how trading volume can be used to obtain information on both uncertainties simultaneously.

- We will first outline the idea behind using trading volume as another source of information, in addition to the price.

Uncertainties when trading

- Traders face uncertainty about the value of the asset they are trading and the amount of noise trading
- Some investors will have obtained information about the value of the asset
- Informed and uninformed traders often do not know how many investors are informed
- Uninformed investors may also now know how precise the information is

Uncertainties when trading

→ When trading in financial markets, there is not only uncertainty about the value of the asset that is traded, but other uncertainties exist.

- Uncertainty about the value of the asset that is traded often dominates the concerns of traders,
- But there is also uncertainty about the amount of noise trading, that is the trading that is not originating from profit-maximizing traders, but by traders who trade for exogenous reasons, such as requiring liquidity or holding excess liquidity.

- It is reasonable to assume that in many instances some investors will have better information about the future value of the asset than other investors, these investors we all 'informed' and those without this better information are 'uninformed'.
- In general neither, informed or uninformed traders, will know how many are informed. Knowing how many traders are informed would affect the demand of informed traders as with more informed traders they face additional competition to make profits; these different trading strategies will also affect market qualities such as efficiency and liquidity.
- While informed traders might have knowledge about the precision of the information they hold and might reasonably infer the quality of information of other informed traders, uninformed traders might have no knowledge about the quality of information that informed traders have access. Of course, having this knowledge will affect the price determination and hence the efficiency and liquidity of the market.

→ We will develop a model to address these uncertainties and how to make inferences about these aspects using trading volume.

Trading volume as a source of information

- It is common to use the price of an asset as an indication of the information some traders will have received
- Traders have another variable they can observe for free, trading volume
- The importance of trading volume is often neglected, but can provide important insights into the amount of information available in the market

Trading volume as a source of information

→ Trading volume as a source of information is mostly neglected.

- The most common way extract information from market observations is to use the price and its change; this price change is then seen as an imperfect indication about the information some traders will have received.
- Prices are essentially free to observe as they are widely publicised; another variable is also widely publicised and that is the trading volume. Trading volume is the total amount of assets bought and sold in a given time period; the time period is often a trading day, but might be as low as a minute.
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  - In most theories of financial markets, trading volume is not considered as a source of information. Similarly, most trading rules, in those used by particular technical traders or chartists, make rarely use of trading volume and rely on prices in most cases.
  - We will argue below that we can use trading volume as an indicator for the amount of information that is available in the market. This could be a large number of informed investors holding information of low precision, or a small number of informed traders holding very precise information.

→ We can now look a bit closer at the relationship between the information (signal) and the trading volume.

Signal and trading volume

- The further the information that has been received moves the value of the asset from its current price, the larger the opportunities for profits by informed traders

$\Rightarrow$ Traders will trade more to exploit their informational advantage as moving the price towards the new value will only affect their profits minimally

$\Rightarrow$ Trading volume increases the more the value changes

- Given the large amount of trading, prices will also move considerably

$\Rightarrow$ Trading volume does not add much information over observing the price about the signal

Signal and trading volume

→ We will now argue first that observing trading volume might not add that much information.

- If the true value of the asset is far away from the current price, the potential for profits are high; even if large orders will move the price considerably, informed traders will still make profits.
- [⇒] The consequence is that traders will submit larger orders to generate larger profits; any move of the price towards the true value will only be small relative to the difference of the price and value.
- [⇒] With informed traders submitting larger orders, the trading volume will increase as the signal becomes more extreme, that is moves the fundamental value (true value) further away from the current price.
- As the orders submitted are large, the price adjustment will be large.
- [⇒] We observe a positive correlation between the size of the signal and trading volume. This suggests that trading volume and the signal are providing similar information; they can be seen as a substitutes. Based on this analysis, it would seem that trading volume does not convey much additional information above the price change.

→ The line of argument followed here would suggest that trading volume can safely be ignored. We will however see now that there are subtle differences between trading volume and the prize that can be used to extract additional information.

- We will now argue that trading volume can provide additional information on the number of informed traders (or their fraction if we keep the total number of traders constant) in the market.

Increasing fraction of informed traders

- If only few traders are informed, there will not be much informed trading, but this will increase as more traders are informed

$\Rightarrow$ Trading volume will be increasing in the number of informed traders

- As the number of informed traders increases, they will compete with each other and as not to reveal too much information, reduce their trading

$\Rightarrow$ Trading volume will be decreasing in the number of informed traders

$\Rightarrow$ Trading volume initially increases and then decreases as the number of informed traders increases

Increasing fraction of informed traders

→ We will make our arguments on the effect informed traders have on trading volume more succinct to see that there is an impact on that allows us to determine the number of informed traders.

- Assume we only have very few informed traders, in this case virtually all trades are conducted by noise traders and the trading volume will be low as informed traders contribute very little.
- If we now increase the number of informed traders, they will continue to trade and their trading volume is increasing.

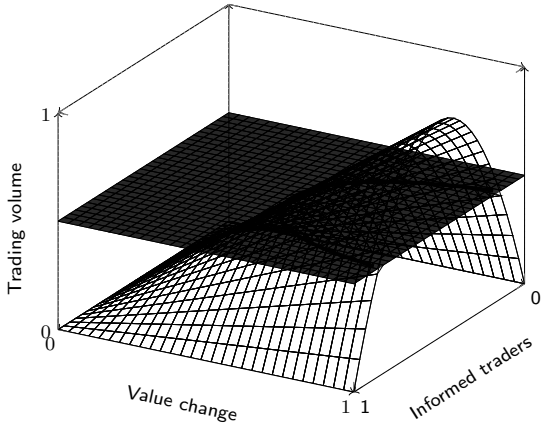
- [⇒] We thus see that the trading volume will be increasing in the fraction of informed traders.

- Consider now the trading volume having increased substantially. Once the informed traders are sufficiently common in the market, they will start to have a significant impact on the price due to trading nor being dominated by noise traders any more. Thus they will start to compete with each other for the profits that can be obtained.
- Taking into account that they will affect prices if submitting large orders and aware that their trading will reveal information, they will reduce the size of their orders, thus reducing trading by informed traders.

- [⇒] We thus see that once there are sufficient informed traders, they will reduce trading and thus the overall trading demand is decreasing as the fraction of informed traders increases. With the demand by informed traders reducing, the overall trading volume will reduce.
- [⇒] We thus have that trading volume in increasing in the number of informed traders for small fraction of informed traders, but decreasing if the fraction of informed traders is higher.

→ We can now use this argument to extract information from trading volume to determine the fraction of informed traders in the market.

Fraction of informed investors and trading volume



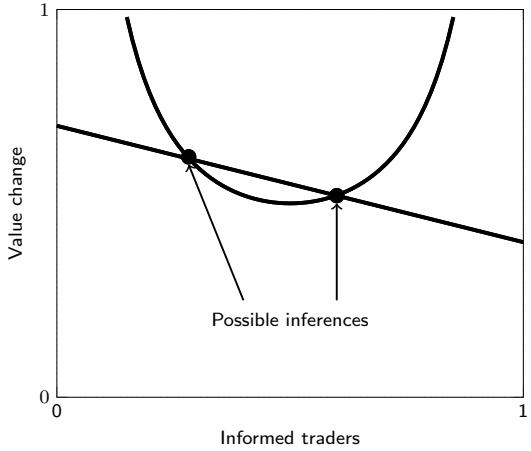
Fraction of informed investors and trading volume

→ We will now graphically illustrate the results we have discussed so far.

- We consider the two uncertainties we have for uninformed traders: the change in the value of the asset and the fraction of informed traders. We will see how these two unknowns affect the trading volume.
- From the above said, we firstly have that the trading volume is increasing as the true value changes more from the current price. Secondly, we had argued that for small fractions of informed traders the trading volume is increasing as we increase the informed traders, and for larger fractions of informed traders this was decreasing.
- Assume now that we observe a certain trading volume as indicated here in red. This trading volume will then correspond to a number of combinations in the number of informed traders and the change in the value (the information itself).
- The red line indicates those points at which the trading volume is consistent with the number of informed traders and the change in the value (the information itself). These are possible inferences about these two variables.

→ We can now use this information extracted from the trading volume and combine it with the information extracted from the price.

Inferring the fraction of informed investors



Inferring the fraction of informed investors

→ We will now look at combining information from observing the price and the trading volume.

- We will take the trading volume as given now as we have observed this and will focus on possible combination of the change in the asset value (the information itself) and the fraction of informed traders (how many hold this information).
- We know from the previous graph the possible combinations of the value change and fraction of informed traders for a given trading volume. The red line gives all possible combinations of value change and fraction of informed traders that are consistent with the observed trading volume.
- We now add to this information from observing the price. We have observed a certain price change and now have to relate this to the change in the value of the asset. We know that the more informed traders there are, the more the price adjusts as the market becomes more efficient; this is for a given change in the value of the asset. We now need to reverse the logic of this argument as the change in the value is not known. If we observe a given price change, this means that as the price adjustment is lower with less informed investors, the price change must be higher if there are less informed investors. We will therefore observe a negative relationship between the value change and the fraction of informed traders as indicated here. The blue line gives all possible combinations of value change and fraction of informed traders that are consistent with the observed price change.
- This will give us in general two possible combinations that are consistent with the trading volume (red line) and the price change (blue line).

→ While we are not able to determine a single possible value for the information itself (value change) and how widely this information is known (fraction of informed traders), this has been reduced two just two possible solutions.

Combining price and volume information

- A given trading volume can be used to determine the possible fraction of informed traders consistent with the change in the value of the asset
- Using the price, similar inferences can be made
- Combining this information, inferences about the fraction of informed traders can be made
- There might be two possible inferences consistent with the observations
- Often one of these possibilities can be ruled out, such as the majority of traders to be informed

Combining price and volume information

→ We have graphically analysed how trading volume can provide additional information, we can now summarise these results.

- We can use the trading volume to narrow down significantly the possible combinations of the information itself (value change) and the spread of this information (informed traders).
- We can then use the price change to make the same inferences.
- If we combine these two sources of information, the trading volume and the price, we can determine information (value change) and its spread (informed traders) simultaneously.
- There will usually be two possible solutions, one will have a large signal (value change) known to few traders and the other a low signal (value change) known by many traders.
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  - Depending on the parameter constellation, it will often be the case that we can exclude one of the two possible solutions.
  - It seems in most cases unlikely that a large number of traders are informed, or even that a majority of traders will be informed.

→ If we are able to exclude one of the possible solutions, we can determine the information (value change) and how widely it is known (informed traders).

- We have established how trading volume can be used to determine the traction of informed traders in a market. Another uncertainty often is that those not having access to information, do not know how reliable the information others have, is.
- Often it may be known that some traders have information, but is not known how good this information is. We will now explore how trading volume can be used to extract information about this uncertainty.

Increasing precision of information

- If information precision is low, informed traders will only be trading cautiously, there will not be much informed trading, but this will increase as information precision increases

$\Rightarrow$ Trading volume will be increasing in the information precision

- If information is imprecise, informed traders will disagree on the value and will trade with each other, but this reduce as traders agree more and more with information precision increasing

$\Rightarrow$ Trading volume will be decreasing in the information precision

$\Rightarrow$ Trading volume initially increases and then decreases as the information precision increases

Increasing precision of information

→ As above, we will first look at the impact that more precise information has on trading volume. We have to change the modelling assumption slightly; thus far we have implicitly assumed that informed traders had perfect information about the future value if the asset. We lift this assumption now and assume that information is not perfect, but also that now all informed traders obtain the same information. However, all traders receive information of the same precision, only the signal (information) they receive might differ randomly.

- If the information is not very precise, informed traders will face substantial risk that the true value is different from the information they have received. As traders are risk-averse, they would not have a large trading demand and thus trade cautiously.
- Hence the amount of informed trading will be low.
- As information becomes more precise, the confidence of informed traders increases and their trading would increase.

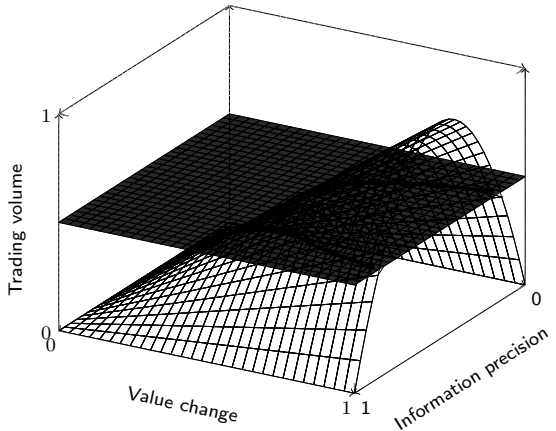
- [⇒] We thus see that trading volume should increase as information becomes more precise.

- There is another effect though, and that is about informed traders trading with each other. Assume information is imprecise, then the information traders receive will differ widely as each gets a different signal which is widely spread.
- This will allow informed traders to trade with each other. A trader with a low signal might be willing to sell to a trader with a high signal. Thus it opens up additional trading opportunities.
- As information becomes more and more precise, the signals of informed traders become more and more similar, reducing the scope for profitable trades.

- [⇒] We thus see that trading volume should decrease as information becomes more precise.
- [⇒] We therefore have two effects that need to be combined. It can be shown that initially the effect increasing trading volume will dominate as an increase in information precision does not affect the opportunities to trade with other informed traders much if the signals are sufficiently varied, but the confidence in information will increase and lead to a higher trading volume. For more precise information, the relationship reverses, however. Once information is very precise, a further increase has very little effect on the trading demand, but the few remaining trading opportunities between informed traders are further curtailed; thus the trading volume will reduce.

→ We can now use this argument to extract information from trading volume to determine the information precision of informed traders.

Information precision and trading volume



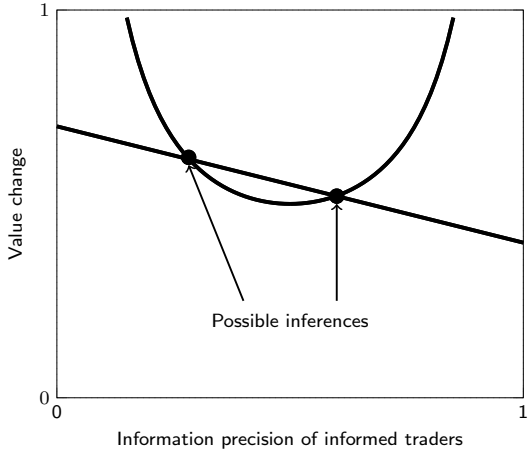
Information precision and trading volume

→ We will now graphically illustrate the results we have discussed so far.

- We consider the two uncertainties we have for uninformed traders: the change in the value of the asset and the information precision informed traders. We will see how these two unknowns affect the trading volume.
- From the above said, we firstly have that the trading volume is increasing as the true value changes more from the current price. Secondly, we had argued that for imprecise the trading volume is increasing as we increase the information precision, and for more precise information this was decreasing.
- Assume now that we observe a certain trading volume as indicated here in red. This trading volume will then correspond to a number of combinations in the information precision and the change in the value (the information itself).
- The red line indicates those points at which the trading volume is consistent with the information precision and the change in the value (the information itself). These are possible inferences about these two variables.

→ We can now use this information extracted from the trading volume and combine it with the information extracted from the price.

Inferring the information precision of informed traders



Inferring the information precision of informed traders

→ We will now look at combining information from observing the price and the trading volume.

- We will take the trading volume as given now as we have observed this and will focus on possible combination of the change in the asset value (the information itself) and the information precision.
- We know from the previous graph the possible combinations of the value change and information precision for a given trading volume. The red line gives all possible combinations of value change and information precision that are consistent with the observed trading volume.
- We now add to this information from observing the price. We have observed a certain price change and now have to relate this to the change in the value of the asset. We know that with more precise information the adverse selection is higher and the price adjusts more as the market becomes more efficient; this is for a given change in the value of the asset. We now need to reverse the logic of this argument as the change in the value is not known. If we observe a given price change, this means that as the price adjustment is lower with less precise information, the price change must be higher the less precise information. We will therefore observe a negative relationship between the value change and the information as indicated here. The blue line gives all possible combinations of value change and information that are consistent with the observed price change.
- This will give us in general two possible combinations that are consistent with the trading volume (red line) and the price change (blue line).

→ While we are not able to determine a single possible value for the information itself (value change) and how precise the information is, this has been reduced two just two possible solutions.

Combining price and volume information

- A given trading volume can be used to determine the information precision consistent with the change in the value of the asset
- Using the price, this value change can be inferred
- Combining this information, inferences about the information precision can be made
- There might be two possible inferences consistent with the observations
- Often one of these possibilities can be ruled out, such as information being very precise or very imprecise

Combining price and volume information

→ We have graphically analysed how trading volume can provide additional information, we can now summarise these results.

- We can use the trading volume to narrow down significantly the possible combinations of the information itself (value change) and its precision.
- We can then use the price change to make the same inferences.
- If we combine these two sources of information, the trading volume and the price, we can determine information (value change) and its precision simultaneously.
- There will usually be two possible solutions, one will have a large, but imprecise signal (value change) and the other a low, but precise signal (value change).
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  - Depending on the parameter constellation, it will often be the case that we can exclude one of the two possible solutions.
  - It may be that in some cases unlikely that information will be very precise,
  - while in other situations it might be that information will either be very precise or no information at all is present.

→ If we are able to exclude one of the possible solutions, we can determine the information (value change) and its precision.

Persistence of price changes

- We can interpret the fraction of informed traders and the information precision as the amount of information available in the market
- If trading volume is high, this indicates a large amount of information in the market
- With a large amount of information, any observed price change is likely to be caused by information rather than noise trading

$\Rightarrow$ Price changes accompanied by high trading volume are persistent

- With a small amount of information, any observed price change is likely to be caused by noise trading rather than information

$\Rightarrow$ Price changes accompanied by low trading volume are often reversed

Persistence of price changes

→ With the results on the fraction of informed traders and information precision very similar, we can now offer a joint interpretation of these results and assess some implications.

- If many traders are informed, then this implies that a lot of information is available in the market due to the number of informed traders. If information is precise, then there is also a large amount of information available in the market. Thus we can interpret the fraction of informed traders as well as the information precision as the amount of information that is available in the market.
- Trading volume is higher the more the information is available, as long as the information content is not too high. We exclude the possibility that the information content is so high that we have a negative relationship between information content and trading volume; such a high information content is in most cases not realistic.
- In this case we know that with a large trading volume any price change is likely caused by informed trading, either by many informed investors or by very precisely informed investors. Their trading will most likely have caused the price move rather than a random realisation of trading activity by noise traders.
- [⇒] As the price change is probably induced by a lot of information, it is likely to be correct and the price will not fall back in the future.
- If trading volume is low, information is either held by few investors or the information precision is low, causing price changes to be the result of random noise trading as the small trading amount of informed traders has hardly any impact.
- [⇒] As the price change is not based on information, but due to the random fluctuation of noise traders, the price change is likely to be reversed.

→ We often see in real markets that persistent price changes are accompanied by high trading volume and price changes on the basis of low trading volume are often proven to be reversed after a short period of time. Many market commentators use trading volume to justify their assessment of the likely future of stocks, whether they will remain at the price level they have reached or will revert to their previous price level. We have here seen that this assessment is justified due to the high or low information available in the market. In a market with low information, the information will often be wrong as it is either imprecise or not picked up by many traders, the reason might be that the information was not reliable.

- We have investigated the fraction of informed traders and the information precision separately. We will now investigate the case where both uncertainties are present.

Uncertainty about informed traders and information precision

- So far it was assumed that traders were not aware of either the fraction of informed traders in the market or the precision of information they have
- In a more realistic scenario, neither would be known with certainty
- We can combine both effects on the trading volume and then seek to use the observed trading volume to determine both variables simultaneously

Uncertainty about informed traders and information precision

→ We can now combine our two models such that we assume we do neither know the information precision nor the fraction of informed traders in the market.

- We have in both instances assume that it was only the fraction of informed traders was unknown, but their information was known (implicitly we assumed it to be perfect), or the information precision was not known, but the number of informed traders was known.
- We will now look at the implications of both being unknown, which is the most realistic scenario in actual markets.
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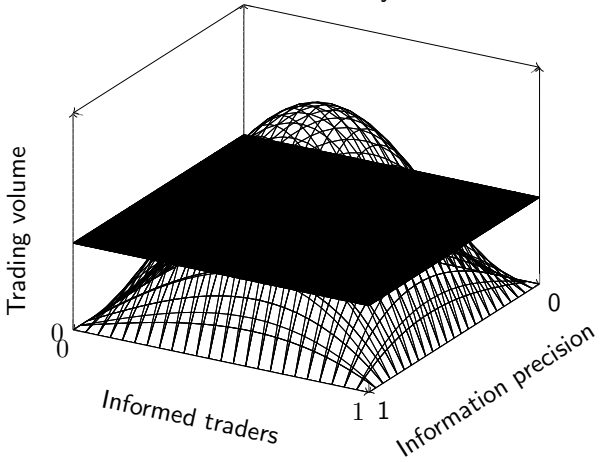
  - We can combine the effects of both models and they will not change the arguments made in each case. The information precision and the fraction of informed traders are independent of each other.
  - We will then again use the trading volume to determine which combination of the fraction of informed traders and information precision are feasible.

→ Again, we will seek a graphical analysis of this combined effect on trading volume.

Information precision and number of informed investors

Few informed investors and many informed investors

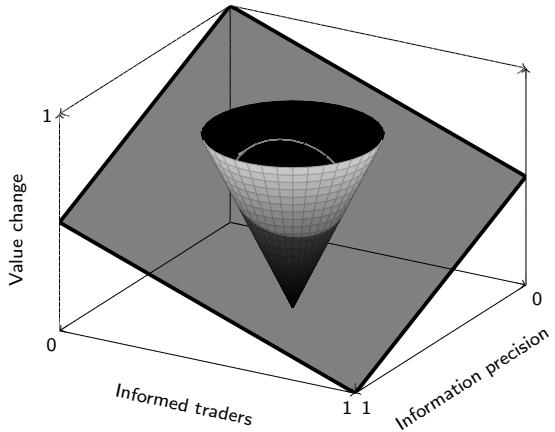


Information precision and number of informed investors

- We will, for a given change in the value of the asset, look at the impact different fractions of informed traders and different information precision have on the trading volume.
- As information precision and the fraction of informed traders are independent we can simply combine them as shown here. If information is either very precise or very imprecise, we will observe no trading, regardless of the fraction of informed traders as all traders will behave similarly. In the same way, in there are nearly no informed traders, there will not be much trading observed, regardless of the information precision, and if most traders are informed, their competition will be such that they trade very little, regardless of the information precision. The highest trading volume would be observed for a moderate fraction of informed traders and a moderate precision of information.
- For a specific trading volume observed, we see that a circular ring of possible solutions exists.
- If we increase the change of the value, we know that the trading volume will increase as shown here.
- For the same trading volume, the circular ring becomes bigger.

→ We can now use this relationship and see which combinations of informed traders and information being consistent with the trading volume observed, are also consistent with the price change that has been observed.

Combining trading volume and price information

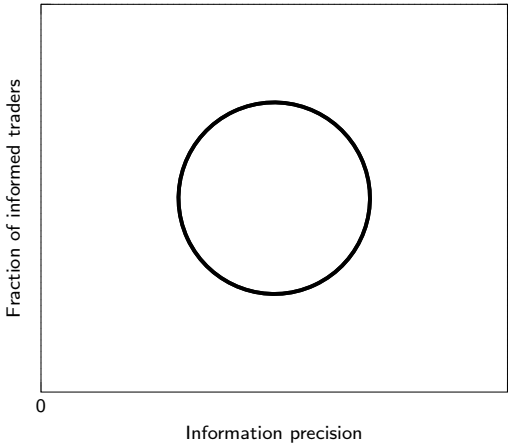


Combining trading volume and price information

- We know that the circular structure that is consistent with the observed trading volume has in increasing diameter the larger the value of the asset is. This will give us a cone-shaped area of possible combinations for the number of informed traders, the information precision, and the change in the asset value.
- We know that the value change, for a given observation of the price change is increasing in both the number of informed traders and information precision. Thus the plane generated by the blue line shows all possible combinations consistent with the price change observed.
- We now consider the points where the cone and the plane intersect as the points which are consistent with the observed price change and the trading volume. These points will be on the edge of the cone and form an ellipse.

→ We now analyse this result on the possible combinations of informed traders and information precision consistent with the observed price change and trading volume.

Inferring the information precision and number of informed traders



Inferring the information precision and number of informed traders

→ We will now look at the combination of the information from observing the price and the trading volume.

- We will look at the possible combinations of the fraction of informed traders and information precision.
- We see from the previous figure that the result will be an circular figure similar to the one depicted here. To obtain this figure we chose a trading volume and price and projected the resulting combination onto the plane.

→ We see that even if we were to know the change in the asset value, we have a range of possible combinations that are consistent with the trading volume observed.

Combinations of information precision and informed traders

- We can not determine a single combination of informed traders and information precision for a given trading volume and price change
- Instead we observe a trade-off between the fraction of informed traders and information precision
- Even if excluding a high fraction of informed traders and very high or low information precision, no single combination can be inferred
- We can determine the amount of information available in the market, but are unable to distinguish its sources: fraction of informed traders or information precision

Combinations of information precision and informed traders

→ We can now summarise and analyse these results.

- We have seen that an entire range of possible combinations of information precision and fraction of informed traders are consistent with an observation of a specific trading volume. We had assumed that the change of value was known when deriving this result, but this will not be the case in reality and for each possible value change we would obtain such a circular figure. Using the price as an additional source of information, will allow us to reduce the number of possible solutions, but they will remain large.
- We observe a trade-off between information precision and the fraction of informed traders, but this trade-off is not monotonous.
- We might be able to exclude that the fraction of informed traders is very high, leaving us with only the lower half of the circular shape. Even if we are then to exclude either very high or very low information precision, the solution would not be unique.
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  - The problem is that we can only determine the amount of information in the market,
  - where this information originates from cannot be established.
  - It could be a combination of the fraction of informed traders
  - and the information precision.

→ We have thus established that without additional information we cannot distinguish the source of the information content that is available in the market, thus which combination of information precision and fraction of informed traders, we are at best able to distinguish different amounts of information content.

- We can now summarize the key results from these models.

Uncertainties and observations

- We have four sources of uncertainty: noise trading, value of the asset, fraction of informed traders, and information precision
- We have only two variables that are observed: price and trading volume
- Even with taking expectations about all variables, this only reduces one more uncertainty, leaving three uncertainties for two variables
- If we knew either uncertainty, we had two uncertainties for two variables, which can be solved

Uncertainties and observations

→ Trading volume can increase our knowledge and understanding of market developments.

▶
- In our model we had four sources of uncertainty that an outside observer or uninformed trader would have no knowledge about.
- No one does know how much of the trading demand is due to noise traders.
- The value of the asset is only known to informed investors (and to them even not perfectly), but not other market participants.
- The fraction of informed traders is probably not known to any one, but we assumed implicitly that informed traders know how many there are and they would make decisions accpordingly.
- The precision of information is known to informed investors only.

▶
- In order to distinguish these four unknown variables, we only ha two sources of information.
- The price, which is freely available or at very low costs to anyone
- and the trading volume, which is available likewise.

▶
- We can take expectations to eliminate one uncertainty, for example we can ignore noise traders as their expected trading volume is zero.
- We would nevertheless be left with three uncertainties for which we have two sources of information.

▶
- In the initial model, we assumed that we know either the information precision or the fraction of informed traders, reducing the uncertainties to two.
- This allows us to solve two equations with two unknowns, although as functions are non-linear, multiple solutions can exist. In the general model considered last, the number of possible solutions will be infinite.

→ We have thus seen that trading volume provides additional information, but it is not enough to determine all possible uncertainties that uninformed traders are exposed to.

Using trading volume to assess market confidence in information

- The price of an asset can be used to assess the contents of information
- The trading volume can be used to assess the confidence of the market in this information
- Price changes accompanied by high trading volume are often seen as driven by information
- Price changes accompanied by low trading volume are often seen as driven by random events

Using trading volume to assess market confidence in information

→ Despite the limitations of trading volume in providing additional information, it is nevertheless an important addition to assess market conditions.

- We can use the price to determine the information itself, that is by how much the value of the asset is supposed to change from the current price, given the information informed traders hold.
- We can then use trading volume to assess the amount of information on which this assessment of informed traders is based, thus how confident the market is in the information actually being correct.
- In markets, price changes that are observed with a high trading volume are interpreted as being based on as yet unknown (to the wider public) information.
- In markets, price changes that are observed with a low trading volume are interpreted as not being based on as yet unknown (to the wider public) information.

→ Observing trading volume adds information to the price change and market observers can gain additional insights into market conditions by not only observing prices, but including trading volume into their analysis.

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