08375
Economics of Uncertainty and Information

Topic 3.2: Information: Signalling and Screening

Plan:

- Topic 1: Introduction and Recap
- Topic 2: Uncertainty
- Topic 3: Information
- Topic 4: Current Research Areas

Plan:

- Topic 3: Information
  - 3.1 Adverse Selection
    - Lemons
    - Other applications
    - Experimental evidence
  - 3.2 Signalling and Screening
    - Signalling in the job market
    - Screening in the job market
    - Other applications
    - Experimental evidence
  - 3.3 Moral Hazard
    - Moral hazard in the insurance market
    - Other applications
    - Experimental evidence

Topic Outline

- By the end of this sub-topic, you should be able to analyse the following:
  - Describing the concept of a costly signal
  - Demonstrating the different possible equilibria under signalling, including pooling and separating
  - Demonstrating the impossibility of pooling screening equilibria
  - Showing how if a separating pooling equilibrium exists then it will be unique
  - Discussing real world applications
  - Explaining the experimental evidence about signalling
  - Discussing the endogeneity issue in relevant empirical approaches

What's it all about?

- In the last lecture, we saw how imperfect information can lead to adverse selection:
  - the *possibility* of accidentally buying (or hiring) a bad item (or worker) drives down the overall *price* (or wage) that the uninformed party is willing to pay.
  - the high quality sellers (or workers) leave the market, further reducing the expected quality and price.
  - Under certain circumstances the market unravelled completely, giving complete market breakdown.
- We saw how this was inefficient compared to full information, and resulted in lower welfare (gains from trade not exploited; under- or over-employment)

What's it all about?

- Here, we look at two mechanisms that can at least partially overcome the imperfect information problem: signalling and screening
- We had assumed that it was not possible to send credible signals about quality
  - Cheap talk
- Now, investigate how signals can combat problems of asymmetric information
- We will distinguish between two cases: signalling and screening
  - In signalling, the informed party chooses their signal, then the uninformed party observes the signal and makes a decision on that basis
  - In screening, the uninformed party offers a menu of contracts, then the informed party selects which contract to opt into
  - The order of moves is the distinguishing feature between these cases

What's it all about?

- To motivate our analysis, consider your own decisions about your career.
- You could have gone straight from school or college into a job. Instead, you came to UoB and chose to study a challenging degree program.
- We hope this is (at least partly) because you were excited to live here, interested in learning about economics, and keen to learn and develop your skills.
- But perhaps it was also because getting an economics degree here is great in the job market?

What's it all about?

- Why do you think your degree gives you a big advantage over others in the labour market?
  - Is it the subject-specific skills and knowledge you acquire?
  - Is it the transferable skills and abilities you develop during your degree?
  - Or is it because **only people with excellent natural aptitude are successful in getting into, and succeeding on, this degree program?**

- In this lecture, we will assume the first two points **do not apply**.
- We will focus on the third point:
  - **By succeeding in your degree, you demonstrate that you are exceptionally high quality in the areas valued by employers**

What's it all about?

- Why wouldn't everybody who wants a good job do this degree?
  - Differences in tastes?
  - Differences in geography?
  - **Differences in ability?**
- Many people would find it very difficult to get into, and to complete, this degree course. For those people, the (effort) **costs** of doing so would be too great compared to the benefits in the labour market.
- By doing the degree, you signal that, for you, the effort costs are not too great. Completing the degree is a **credible signal** of your underlying ability.
- This insight about the (effort) **cost** of the signal will be crucial in our analysis.

What's it all about?

- Signalling works as follows (using an education-hiring example)

1. Applicants decide how much education to invest in, pay the appropriate signal cost, and achieve that level of education
2. Employers cannot observe each applicant's productivity, but they can observe their signal. They form a probabilistic belief about the relationship between observed (public) signal and unobserved (private) productivity. They offer wages on that basis
3. After hiring, employers learn their employees' actual productivity

- Signalling is a possible pre-contractual solution to asymmetric information

What's it all about?

- Signalling equilibrium arises when:

1. Applicants have no incentive to change their signalling decision. Their signal reflects the optimal tradeoff between signalling costs and wage offers for the possible education levels
2. Employers (i) make competitive wage offers (make normal profits) and (ii) have confirmed beliefs, so their belief about the signal-productivity relationship is correct
   - if they believe an applicant is high productivity on the basis of the signal, then they actually are high productivity.
   - if not, the firm would want to change their wage offer, so it is not an equilibrium

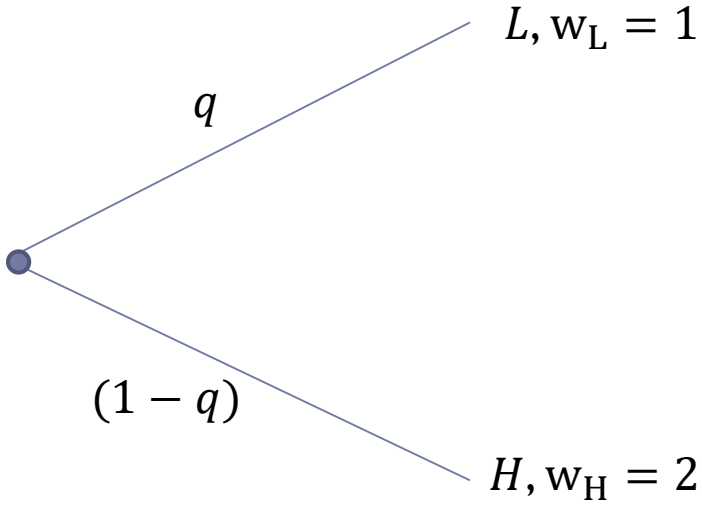
- Therefore a signalling equilibrium is a Nash equilibrium with best responding

A baseline model of productivity and wages

- Simple case with perfect and imperfect information
- Assume everyone is risk neutral (employers and applicants)
- Assume two types of applicant:
  - Type L: low productivity ($MP = 1$) proportion in population = q
  - Type H: high productivity ($MP = 2$) proportion in population = $(1 - q)$
- It is just worth it pay type L workers wage = 1 and type H workers wage = 2
  - i.e. normal profits at these wages
- Productivity is assumed FIXED and NOT affected by education level
  - See Kreps (1990) for a relaxation of this assumption
- Assume outside option is not productive (stay home and don't do anything) so as to avoid adverse selection (lemons) issues

A formal model of signalling

- With perfect information employers can observe productivity:
  - Type L workers get wage = MP = 1
  - Type H workers get wage = MP = 2

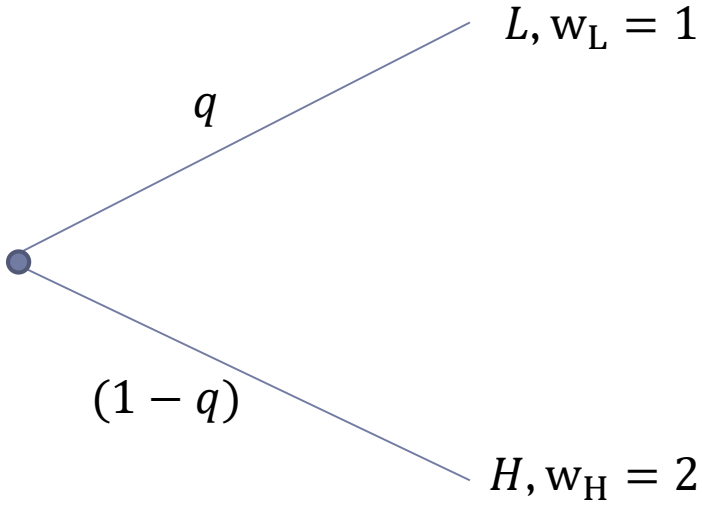


A formal model of signalling

- With imperfect information employers cannot observe productivity.

<u>Case 1: no signalling</u>

- wage = expected productivity: $qMP_L + (1-q)MP_H = q - (1-q)2 = 2 - q$



- Proportionally more L applicants results in a lower wage
- Proportionally more H applicants results in a higher wage
- Normal expected profits because the firm makes a loss paying $(2-q)$ to L workers and makes a profit paying $(2-q)$ to H workers, which cancel out overall

A formal model of signalling

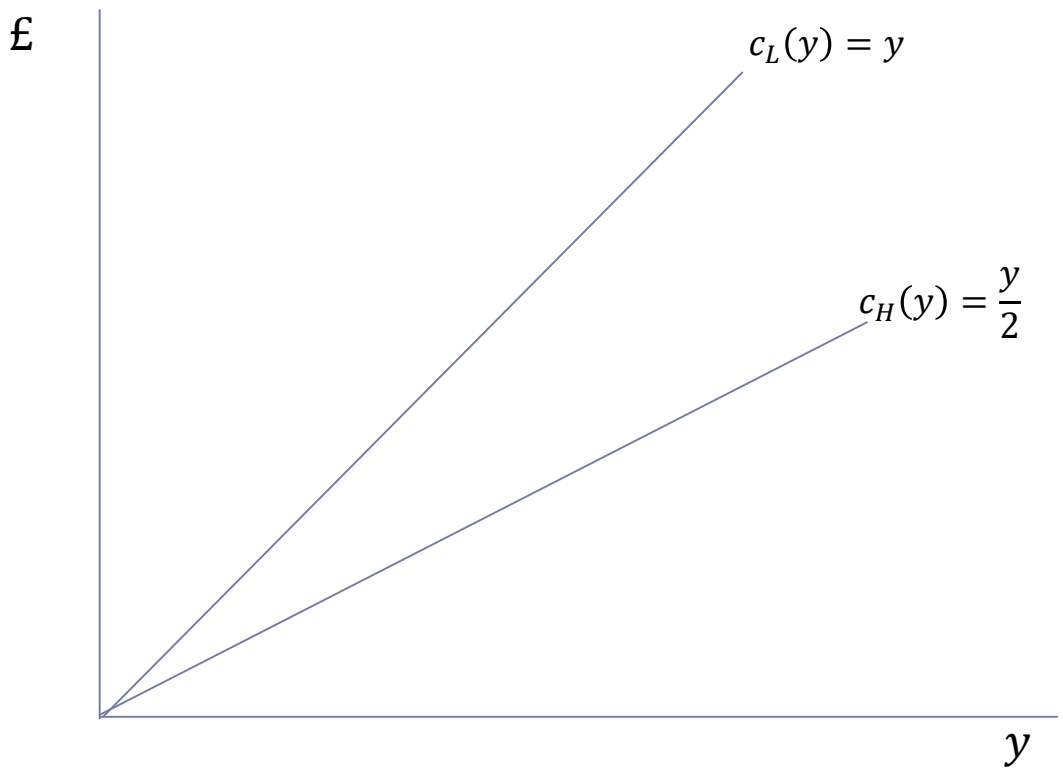
- With imperfect information employers cannot observe productivity.

<u>Case 2: signalling and separating equilibria</u>

- Workers can get educated. Let y be the attained level of education.
- The two types of worker differ in how costly it is to get educated
  - $c_L(y) = y$ implies low productivity workers pay costs of education that increase one-for-one with the level of education
  - $c_H(y) = \frac{y}{2}$ implies high productivity workers pay costs of education that are half as much as low productivity workers for any given education level.
- Costs can be psychological, social, financial or anything else. Here, assume £.
- The "single crossing property" is that the cost curves only cross once, here it is at the origin.

A formal model of signalling

- $c_L(y) = y$ and $c_H(y) = \frac{y}{2}$



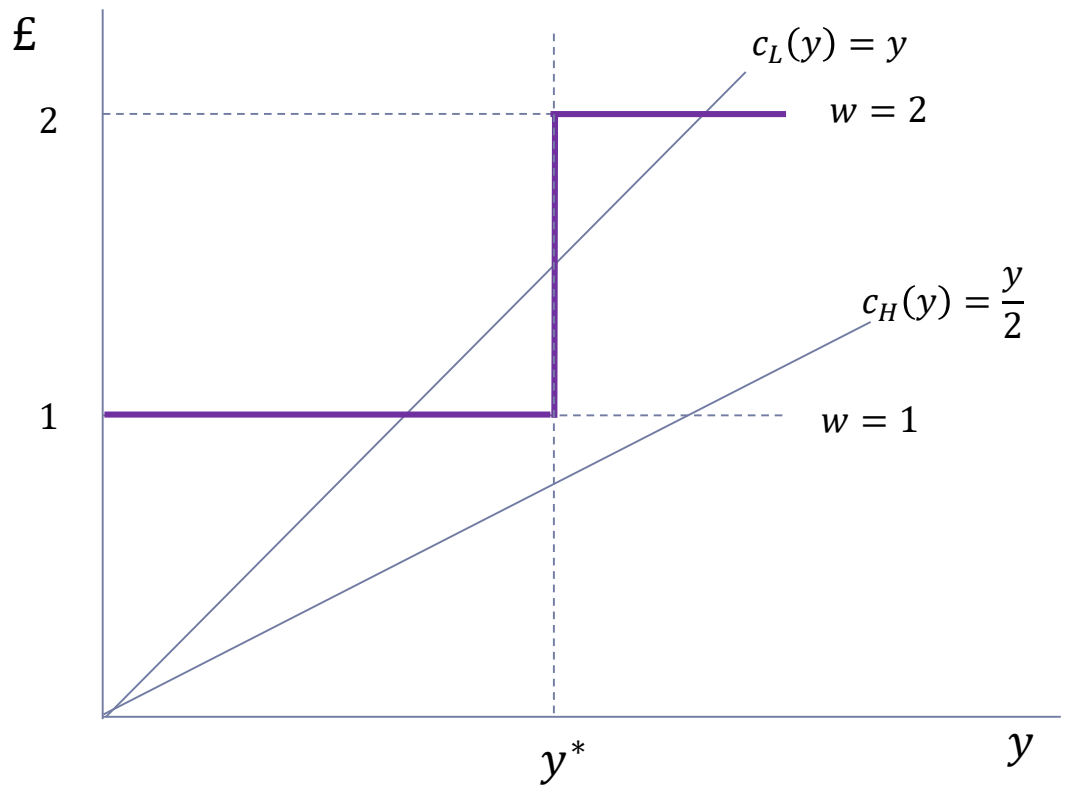
A formal model of signalling

- We are (as ever) seeking the point where marginal benefit of an additional unit of education is equal to the marginal cost
- So what is the benefit?

- Education acts as a signal, such that employers perceive a given education level to reveal underlying ability.
- Let the firms believe education level $y \geq y^*$ reveals high productivity, otherwise low productivity.
- Then, wages for $y \geq y^* = 2$ and wages for $y < y^* = 1$

A formal model of signalling

- $c_L(y) = y$ and $c_H(y) = \frac{y}{2}$

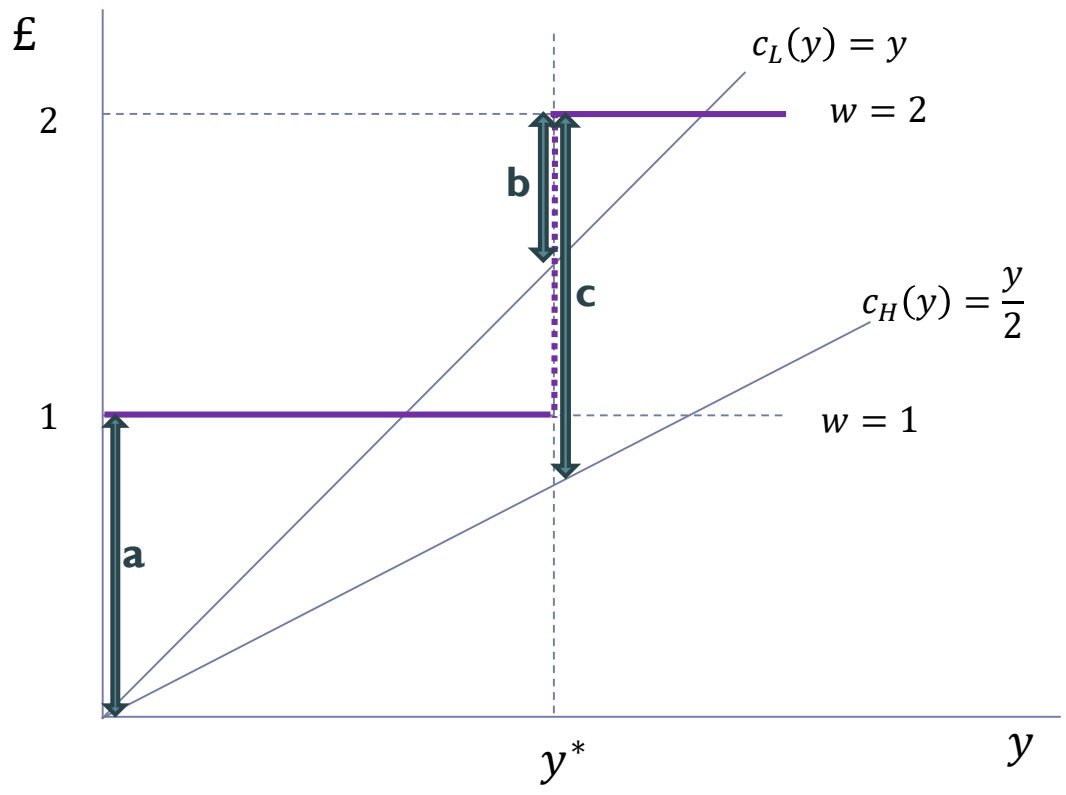


- Purple line gives the wage offer curve
- It will never be worth getting education level $y > y^*$
  - Incur extra cost at no benefit vs. y^*
- It will never be worth getting education level $0 < y < y^*$
  - Incur extra cost at no benefit vs. 0
- The only plausible levels are 0 or y^*

- Who will pick which option?

A formal model of signalling

- $c_L(y) = y$ and $c_H(y) = \frac{y}{2}$



- Type L:
  - If pick $y = 0$, gain $w = 1$ and $w - c(y) = a$
  - If pick $y = y^*$, gain $w = 2$ and $w - c(y) = b$
  - $a > b$ so pick $y = 0$ at cost = 0.
- Type H:
  - If pick $y = 0$, gain $w = 1$ and $w - c(y) = a$
  - If pick $y = y^*$, gain $w = 2$ and $w - c(y) = c$
  - $c > a$ so pick $y = y^*$ at cost = $\frac{y^*}{2}$.

A formal model of signalling

- Is this an equilibrium?

- High productivity applicants get the high education level
- Low productivity applications do not get the high education level
- Employers correctly believe that education at y^* signals high productivity applicants and that $y < y^*$ signals low productivity applicants
- Wages are set such that the wage paid equates to the productivity for each applicant
- Neither the firm nor the applicants have an incentive to change their behaviour

- So it **is an equilibrium**
- Moreover, it is a **separating** equilibrium because the types are separated.

A formal model of signalling

- Under what conditions will we find a separating equilibrium like this?
  - To answer, we need to know what circumstances lead to L types choosing $y = 0$ and H types choosing $y = y^*$.
- We write down "self-selection constraints" for each type
  - L: set $y = 0$ if $w(y = 0) \geq w(y = y^*) - c_L(y = y^*)$ *(1)*
  - H: set $y = y^*$ if $w(y = y^*) - c_H(y^*) \geq w(y = 0)$ *(2)*

  - *(1)* implies $1 \geq 2 - y^*$ *i.e.* $y^* \geq 1$
  - *(2)* implies $2 - \frac{y^*}{2} \geq 1$ *i.e.* $2 \geq y^*$

- Together, these imply that a signalling equilibrium holds given employers' beliefs as long as $1 \leq y^* \leq 2$

A formal model of signalling

- Properties of the signalling equilibrium (1)
  - **Separating**: type L and type H applicants are separated out in the equilibrium. The signal is informative.
  - **Not unique**: there are multiple possible equilibria, one for each possible value of y between 1 and 2. In fact, infinitely many!
  - **Pareto-ranking of criteria**:
    - the closer is y^* to 2, the worse off are type H workers because they incur a higher education cost for no additional wage (paid 2 regardless of the exact level of y^*). **Overinvestment** in the signal
    - the closer is y^* to 1, the better off are type H workers because they incur a lower education cost for no loss of wage (paid 2 regardless of the exact level of y^*)
    - type L have the same costs and benefits at any $y^*|: 1 \leq y^* \leq 2$, since they have no costs of education and their wage is constant at 1
    - Hence, $y^* = 1$ is the Pareto-efficient separating equilibrium.

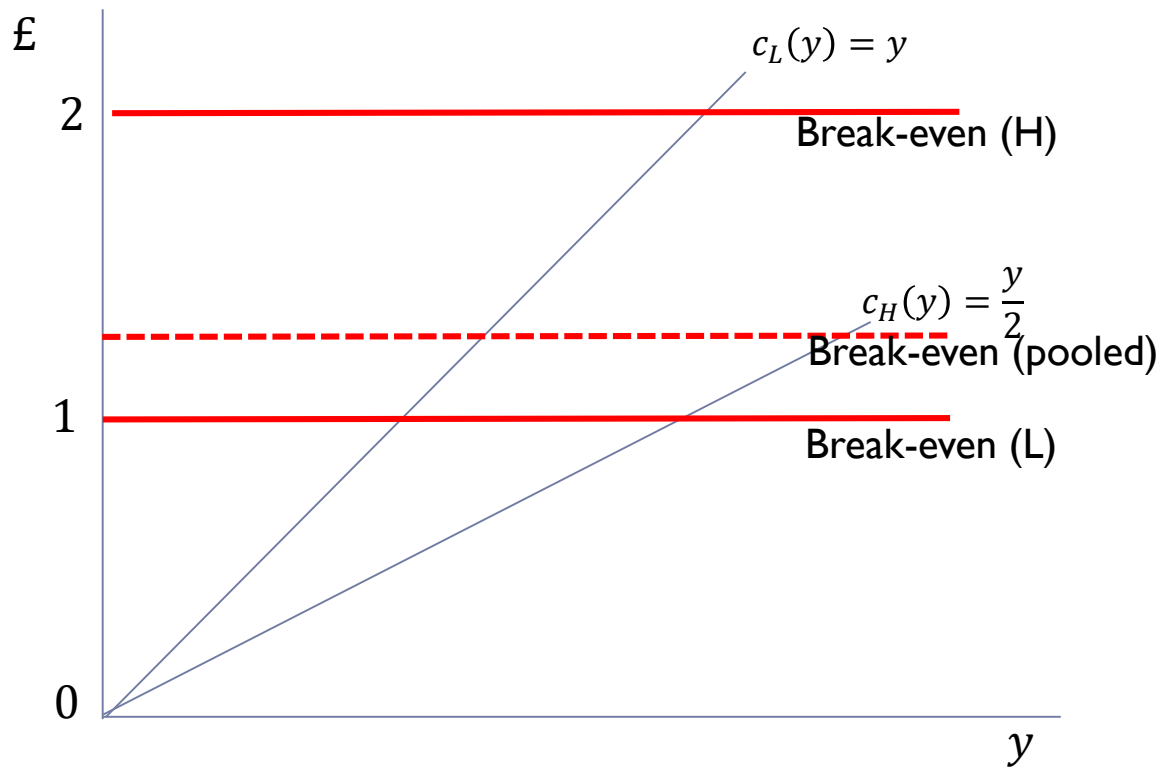
Introduction to Screening

- Now we flip the order of moves to think about *screening* mechanisms instead of *signalling*.
- Employers offer a menu of contracts. Each contract consists of a wage-education pair (w, y) specifying a wage offer for a given education level
- Job applicants select their preferred contract out of the menu, and then achieves the relevant education levels.

- We specify two conditions:
  - No contracts make expected losses (or they would be withdrawn by the firm)
  - No contract outside the market makes positive profits (or they would be offered)
- Therefore, in competitive markets, all contracts make normal profits in equilibrium.

A formal model of screening

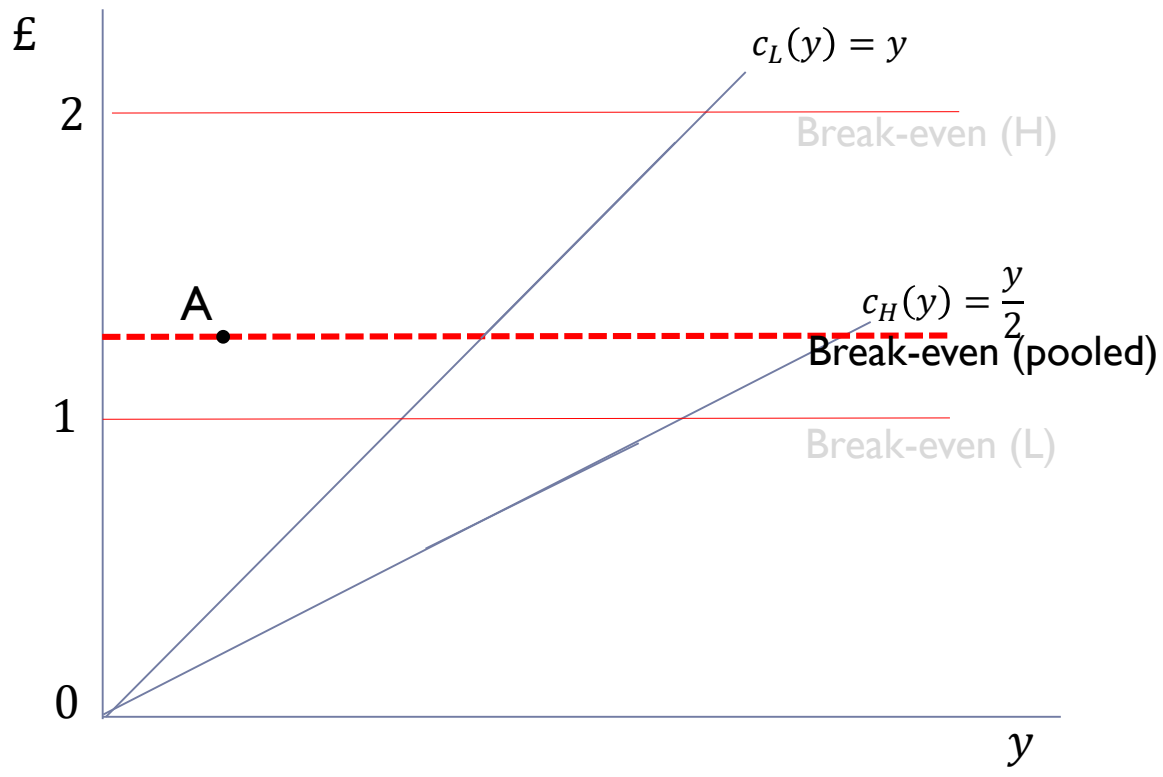
- $c_L(y) = y$ and $c_H(y) = \frac{y}{2}$ as before.



- Any contract is a point in $(y, £)$ space
- Break-even lines can be specified for each type.
- They include all the contracts that make normal profits for that type.
  - For type H: productivity = 2 so wage must = 2 to break even
    - Higher: make a loss
    - Lower: make positive profits
  - Similar process holds for L where productivity = 1
- Pooled line is the contracts with normal profits if ALL workers accept that contract. It lies between H and L cases, determined by the proportion.

A formal model of screening

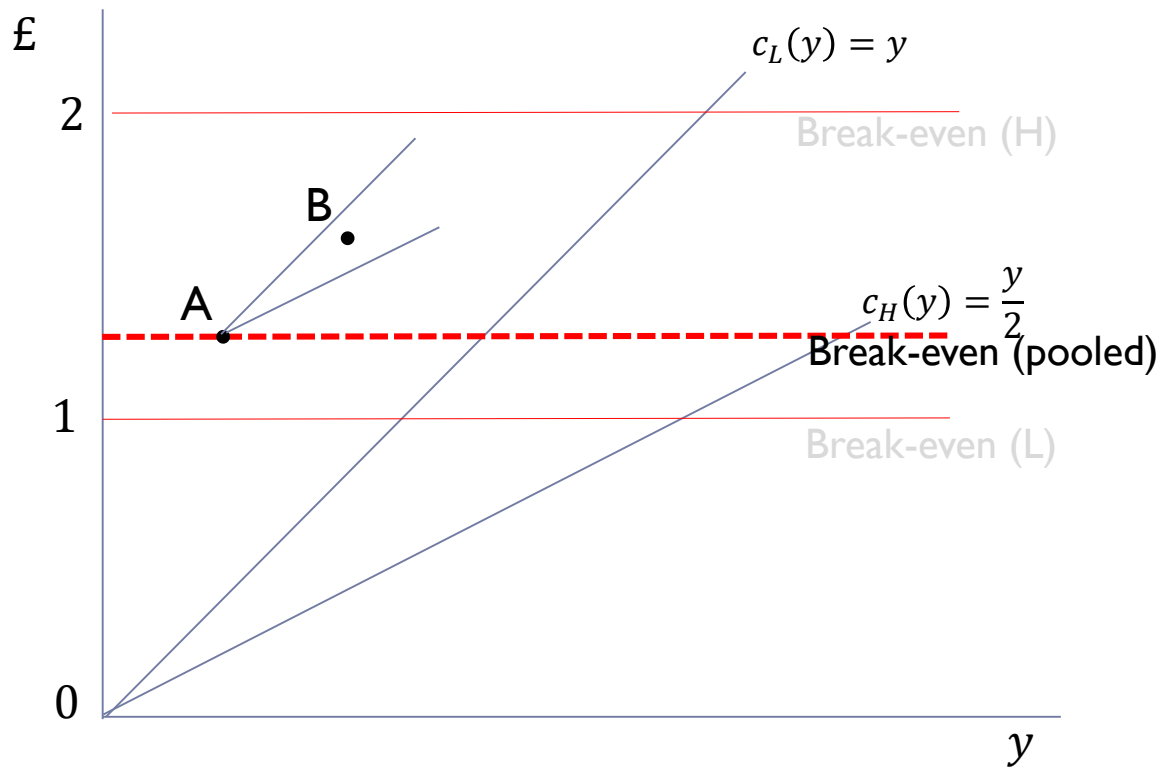
- $c_L(y) = y$ and $c_H(y) = \frac{y}{2}$ as before.



- Can any pooling contract be an equilibrium?
- The answer is "no".
- If it is an equilibrium, it must lie on the break-even (pooled) line (due to first equilibrium condition)
- But consider one such point, A. From here, how much would it cost to gain more education for each type?

A formal model of screening

- $c_L(y) = y$ and $c_H(y) = \frac{y}{2}$ as before.

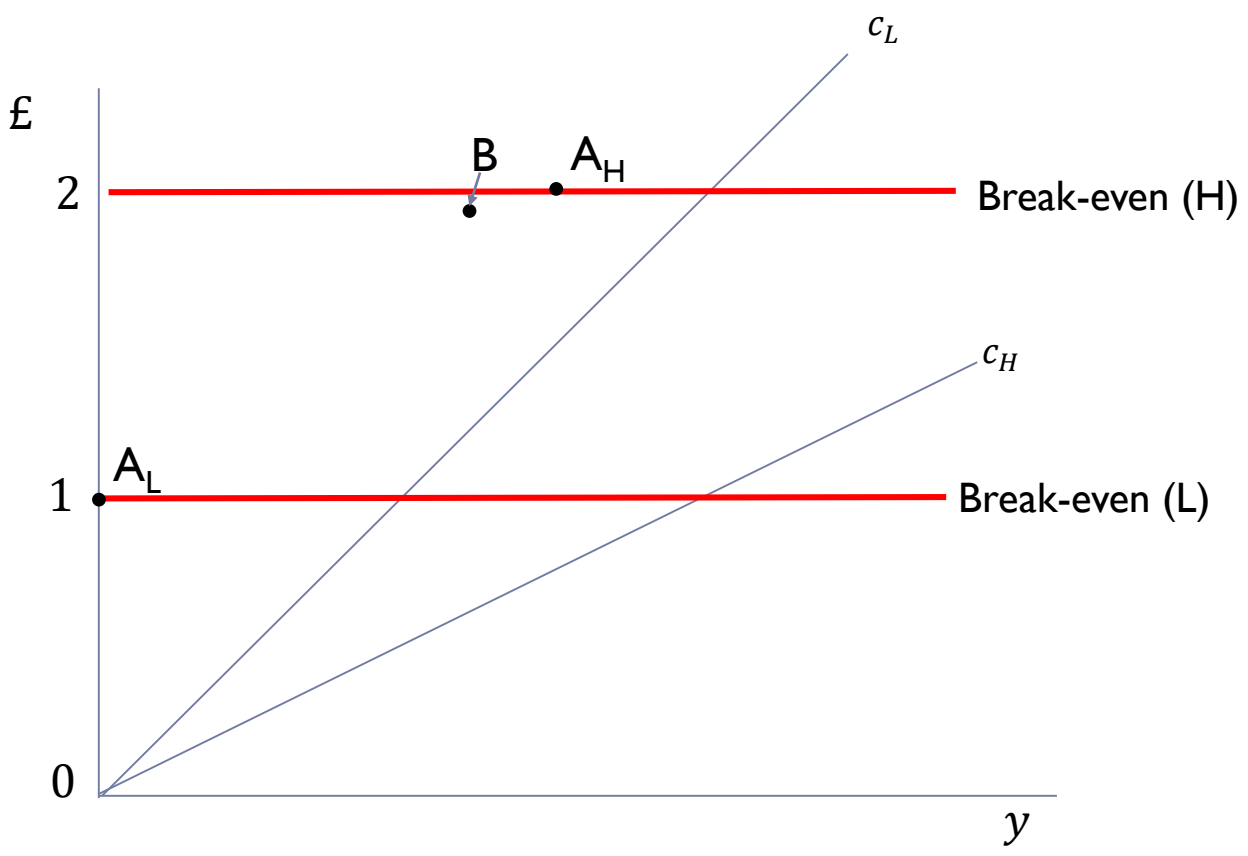


- Point B offers a higher wage than A and demands more education.
- For L types, cost of getting educated is not worth the wage
- But for H types, the wage increase is bigger than the cost of increased education
- Contract B would attract all the H types
- It **would make a profit**: high workers would take it, and it would involve paying them less than their worth (=2).
- So A cannot be an equilibrium, since an outside contract was profitable.
- For any point on the pooling line, we can find a contract like B. **So there is no pooling equilibrium in screening.**

A formal model of screening

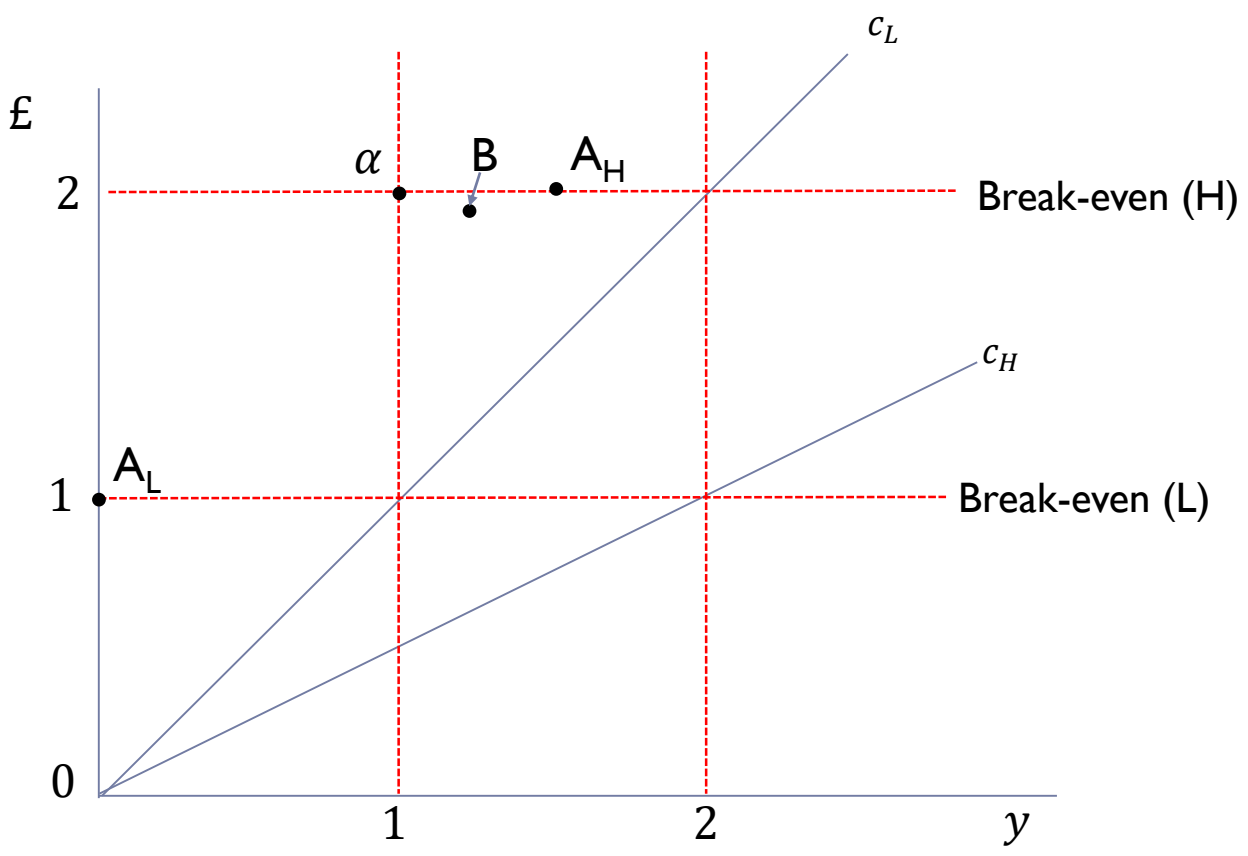
- We showed that there can exist no pooling equilibrium within screening.
- What about a separating equilibrium?
- It will turn out that **a separating equilibrium can exist in screening models.**
- Moreover, **if a separating equilibrium exists in a screening model, it will be unique**
- Compare this to signalling, where we have infinitely many separating equilibria

A formal model of screening



- Consider A_H and A_L.
- These are examples of contracts such that A_H is preferred by type H and A_L is preferred by type L
  - For L, the cost of education to get to A_H is not worth the higher wage it offers.
- They are on the break even lines. However, they cannot yield an equilibrium. Why not?
- Other contracts that could be offered would be preferred and profitable!
- For example, B offers almost as high a wage but for lower signalling costs.
- B would attract all H and still no L, so A_H cannot have been an equilibrium

A formal model of screening

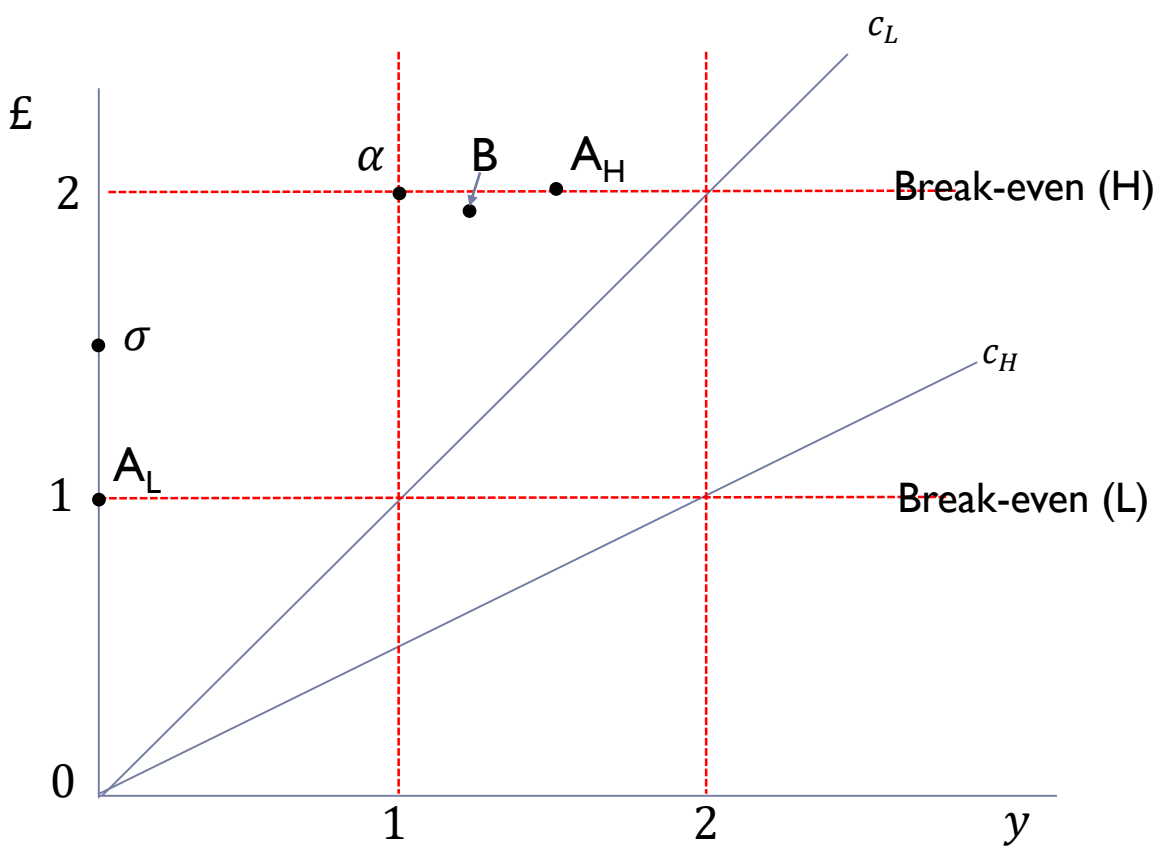


- In fact, any contract on the break-even (H) line that demands y>1 will suffer from the same problem: another contract with slightly lower wages and with lower signalling costs will be preferred.
- Now consider contract α where $y = 1$ and $w = 2$.
  - It is on the break-even line
  - Any contract with $y < 1$ and $w = 2$ would be preferred by type L workers, and so undercutting α by reducing y is not possible
    - Increasing education from 0 to 1 costs as much as the wage increase offered by α instead of A_L
- So, are contracts A_L and α a separating equilibrium?

A formal model of screening

- So, are contracts A_L and α a separating equilibrium?
  - Maybe.
- We showed they can't be undermined by another separating equilibrium
  - Both are at the minimum education level for their type (0 for low, 1 for high as this is the minimum that type L would not prefer)
- But what about a pooling contract?
- First, consider what the net return for each type is, at their respective contract:
  - Net return to H from α is $2 - 0.5 = 1.5$
  - Net return to L from A_L is 1
- Can we find a pooling contract which both types would prefer over their separating contracts?

A formal model of screening



- Net return for H = 1.5 and for L = 1
- σ also offers net return of 1.5, so it is preferred by L and just as good for H, compared to their current contracts
- But does it make profits?
- The answer to this depends on the proportion of types in the economy:

  <u>If at least 50% are high quality</u>
  - σ is profit-making (break-even line below 1.5)
  - Therefore A_L and α do not give an equilibrium.
  - But neither does σ (no pooling equilibrium can exist)
  - No equilibrium exists at all!

  <u>If less than 50% are high quality</u>
  - σ is loss making (break-even line above 1.5)
  - In this case, A_L and α do give an equilibrium.

Summarising screening

- In screening, the uninformed party moves first by offering a menu of contracts specifying education-wage bundles. The informed party chooses one, attains the signal level and gets the wage.
- There can be no pooling equilibrium because we can always find a better bundle that the high types will prefer over a pooling bundle
- There can exist a separating equilibrium. If so, it is unique. It exists as long as there are not so many high types that a pooling bundle seen as equally good by the high types is also profitable in expectation.
- Too many high types leads to no equilibrium at all in a screening model

Summarising screening

<u>Welfare</u>

- The separating equilibrium that is unique is also Pareto optimal since the signalling costs are as low as they can be to still be separating.

- However, the welfare is lower than under full information because the high ability workers have to invest in the signal, which does not lead to higher productivity.

Other applications

Biology

- Springbok "pronking" to show they are fit and strong enough to do this.
- Signals to predators that they should target a weaker alternative.
  - https://learningonscreen.ac.uk/ondemand/index.php/clip/165131

Other applications

<u>Poker</u>

- Poker is a complex signalling game (amongst other things)
- When your hand is bad, you may wish to signal that it is good by bluffing.
- Placing a high stake is a costly signal (if your bluff is called it will be very costly) so the higher the stake the more credible the signal
- Keeping a "poker face" means that the stake is the only signal you send

<u>Advertising</u>

- Sometimes advertising is not informative or persuasive.
- But if the firm is low quality, advertising has low returns (choose it once only)
- Advertising can thereby signal the quality of the business since the **returns** to advertising are bigger for high quality firms.

Other applications

<u>Entry deterrence</u>

- A potential entrant will only wish to enter if the incumbent monopoly is low efficiency.
- Incumbent firm knows whether it is efficient or inefficient, potential entrant does not know incumbent's efficiency.
- The potential entrant can calculate the profit maximising output for a high efficiency and a low efficiency firm
  - If the incumbent is high efficiency, it will produce the high efficiency output
  - If the incumbent is low efficiency, it might **mimic the high efficiency firm** by **foregoing profits** in order to produce output **as if it were high efficiency**
- If it works and deters the new entrant, this may boost future profits

Experimental evidence

- We will focus on the version by Miller and Plott (1986)
  - Miller, R. M., & Plott, C. R. (1985). Product quality signaling in experimental markets. *Econometrica: Journal of the Econometric Society*, 837-872.
  - Hereafter MP
- As with LMPP from last lecture, we have buyers and sellers trading Regulars and Supers in an experimental market.
- This time, sellers are told whether they are selling Regulars or Supers
  - In LMPP they could choose, here they cannot
- We introduce a costly signal of quality: "add-ons"
- These add-ons cost more to produce on Regulars than on Supers
  - Hence, the signal is more costly for low quality cars

Experimental evidence

- Buyers
  - As previously, buyers are told their redemption value if they buy a car.
  - The value depends on whether the car is regular or super
  - It also depends on the number of add-ons
    - This deviates from the Spence model where signals didn't increase inherent value
  - $Buyer\ payoff\ =\ Redemption\ value\ -\ price$
- Sellers
  - Sellers earn the agreed price from the market, minus the cost of add-ons
  - 15 cents per add-on for regulars; 2 cents for supers
  - $Seller\ payoff\ =\ price\ -\ cost$

Experimental evidence

- Trading
  - Double auction: buyers tendered buds to buy
    - Specify price WTP and how many add-ons they want for that price
    - E.g. I'd like to buy a unit with 50 add-ons for $6.00
  - Sellers responded with offers to sell
    - E.g. I'd sell you a unit with 40 add-ons for $6.00
  - Eventually an offer is accepted and the trade is made
  - Only after agreement do buyers learn the quality of their purchase
- A useful statistic: "excess value"
  - $x(q) = p(q) - RVR(q)$
  - Price paid given q add-ons, less redemption value for Regular with q add-ons
  - Indicates how confident buyers are in the unit being a Super

Experimental evidence

- Results
  - Separation occurred in all 8 experimental markets
    - The number of quality add-ons for Supers exceeded that for Regulars
  - Separation was due to signalling in 6 of these 8 markets
    - The excess value statistic rose with q in these 6 markets, indicating that buyers trusted that more add-ons signified that the unit was likely to be a Super
  - In three markets the equilibrium price difference between regulars and supers was as the theory predicted ($2 difference since this was the difference in redemption values)
    - In three more markets it was "approaching" this result but hadn't converged yet
- Conclusions
  - Some evidence for separating signalling equilibria in this experiment

Other empirical evidence

- It's very challenging to use real data to investigate signalling because of the endogeneity between the signal value and the increased productivity.
  - Education both raises the skills of the worker (human capital gains) AND signals their innate ability
  - Most of the empirical literature in this area aims to disentangle these effects
  - We will briefly introduce two such papers.

Other empirical evidence

Wolpin (1977)

- Innovation: signal value is not meaningful for self-employed people
- Approach: compare returns to degree education for the self-employed versus employees
- Results: human capital effects were present and large, but also found some additional return to employees indicating some signalling as well.

Riley (1979)

- Innovation: Unobservability of productivity (i.e. the asymmetric information) is likely to be stronger in some occupations than others
- Approach: Compare returns to degree education across occupations
- Results: evidence in support of signalling theory

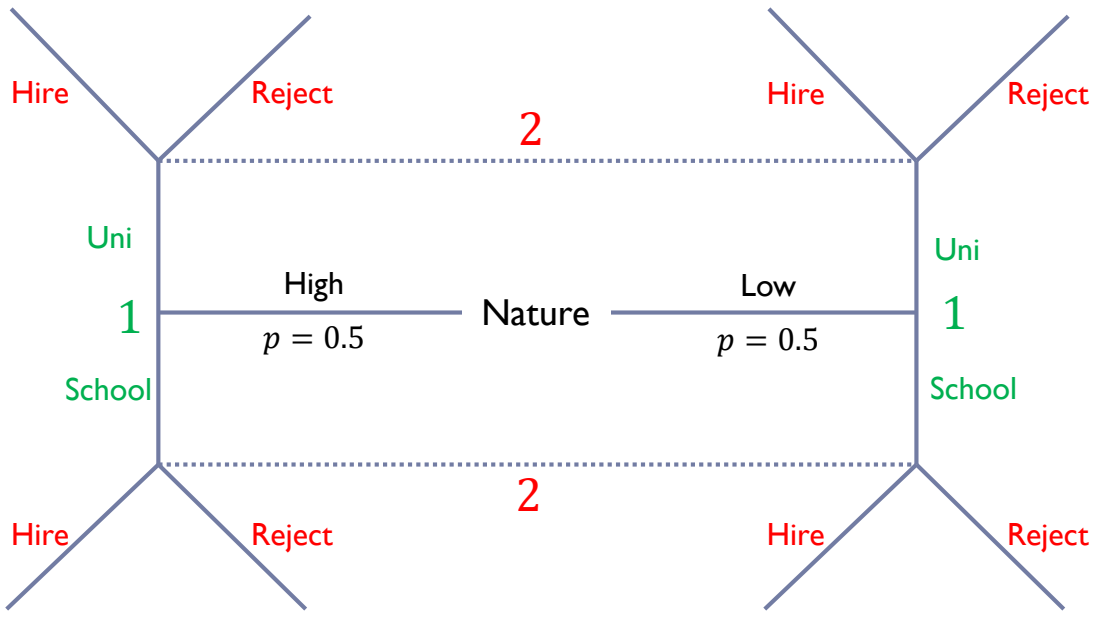
To sum up:

- Costly signals can combat asymmetric information problems by revealing the type (quality), since the signal acquisition is less costly for high quality than low quality types
- Signalling models can generate pooling equilibria and separating equilibria, though these separating equilibria are not unique
- We can identify Pareto-efficient separating equilibria
- An alternative approach is screening, where the uninformed party offers contracts
- In separating screening equilibria, types will self-select into contracts and if a separating screening equilibrium exists it will be unique.
- No pooling equilibria can exist in screening
- Welfare losses persist because the signal is costly and yet unproductive

References and readings:

- Miller, R. M., & Plott, C. R. (1985). Product quality signaling in experimental markets. *Econometrica: Journal of the Econometric Society*, 837-872.
- Riley, J. G. (1979). Testing the educational screening hypothesis. *Journal of Political Economy*, *87*(5, Part 2), S227-S252.
- Spence, M. (1978). Job market signaling. In *Uncertainty in economics* (pp. 281-306). Academic Press.
- Wolpin, K. (1975). *Education and screening* (No. w0102). National Bureau of Economic Research.

Signalling in game theory



<u>All strategies</u>

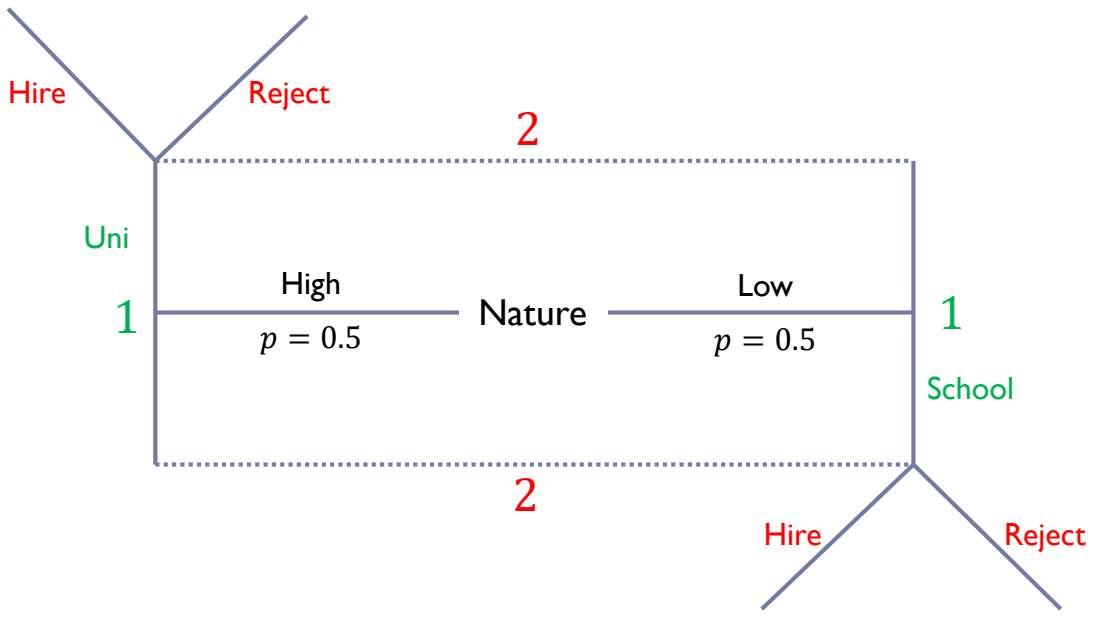
No payoffs as yet – just learning the structure of the game

Both types (high and low) of worker (1) can either choose university or choose to stop after school.

The firm (2) observes the signal without knowing which type they are (dotted line)

They then make a hiring decision based on the signal.

Signalling in game theory



<u>Separating strategies</u>

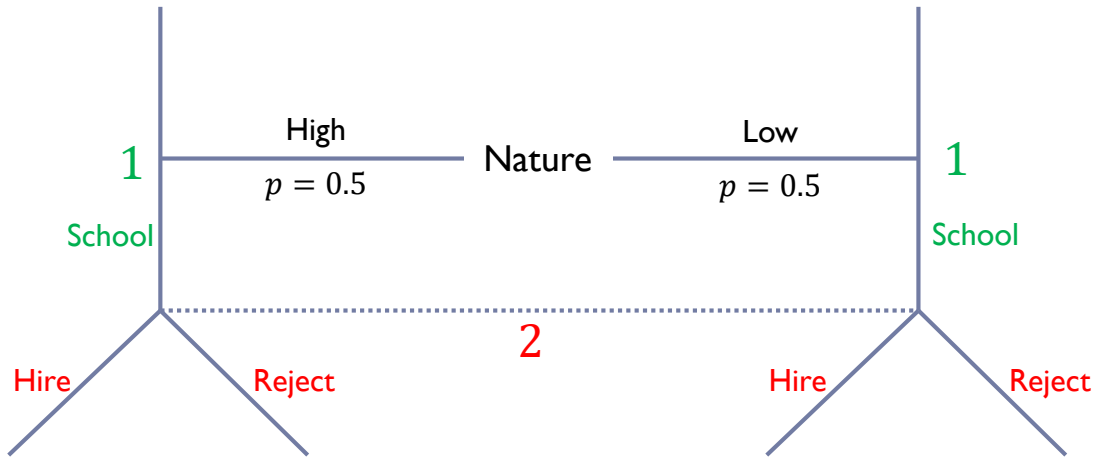
No payoffs as yet – just learning the structure of the game

Only high types of worker (1) choose university and only low types of worker (1) choose to stop after school.

The firm (2) observes the signal and this time can infer which type they are from the signal

They then make a hiring decision based on the signal.

Signalling in game theory



<u>Pooling strategies</u>

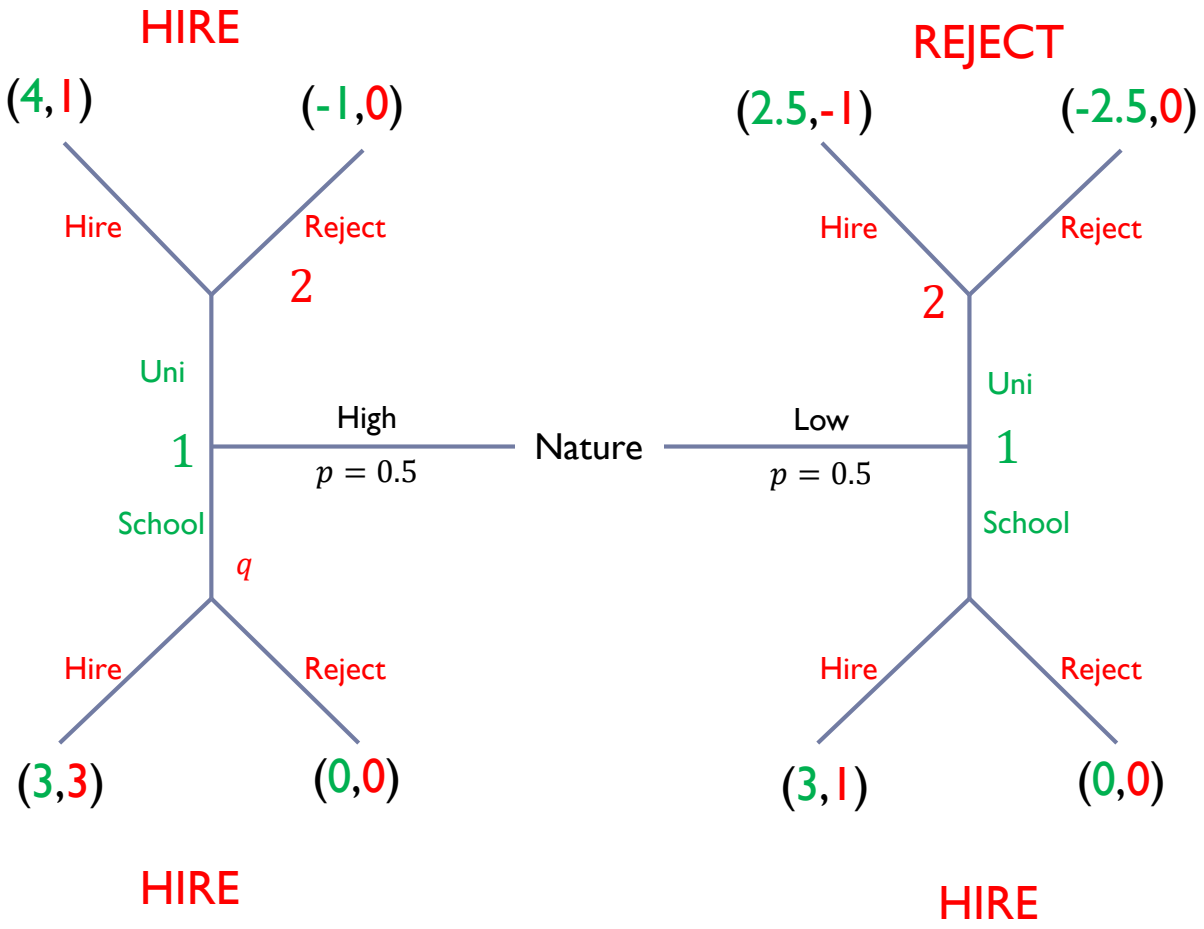
No payoffs as yet – just learning the structure of the game

Both types (high and low) of worker (1) choose to stop after school. (could have had them both choosing uni)

The firm (2) observes the signal without knowing which type they are (dotted line)

They then make a hiring decision based on the signal.

Signalling in game theory



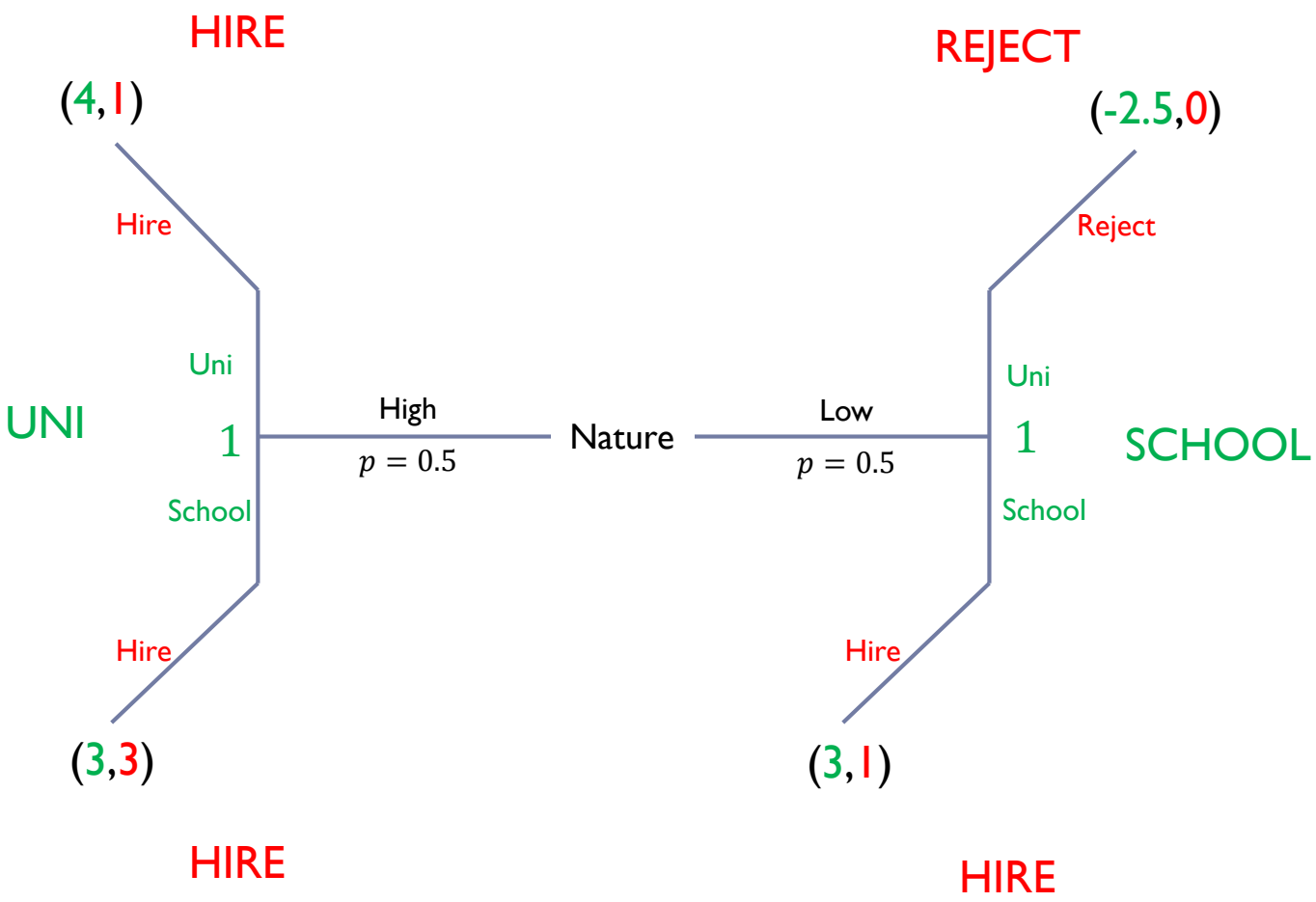
Wage for graduates = 5
Wage for school leavers = 3
Cost of HE for high types = 1
Cost of HE for low types = 2.5
MP of high type = 6
MP of low type = 4

Payoff(employee, employer)

Under full information,

- High quality graduates are hired into graduate jobs, low quality graduates are rejected from these.
- High and low quality school leavers are hired into school leaver jobs.
- So what do the types choose?

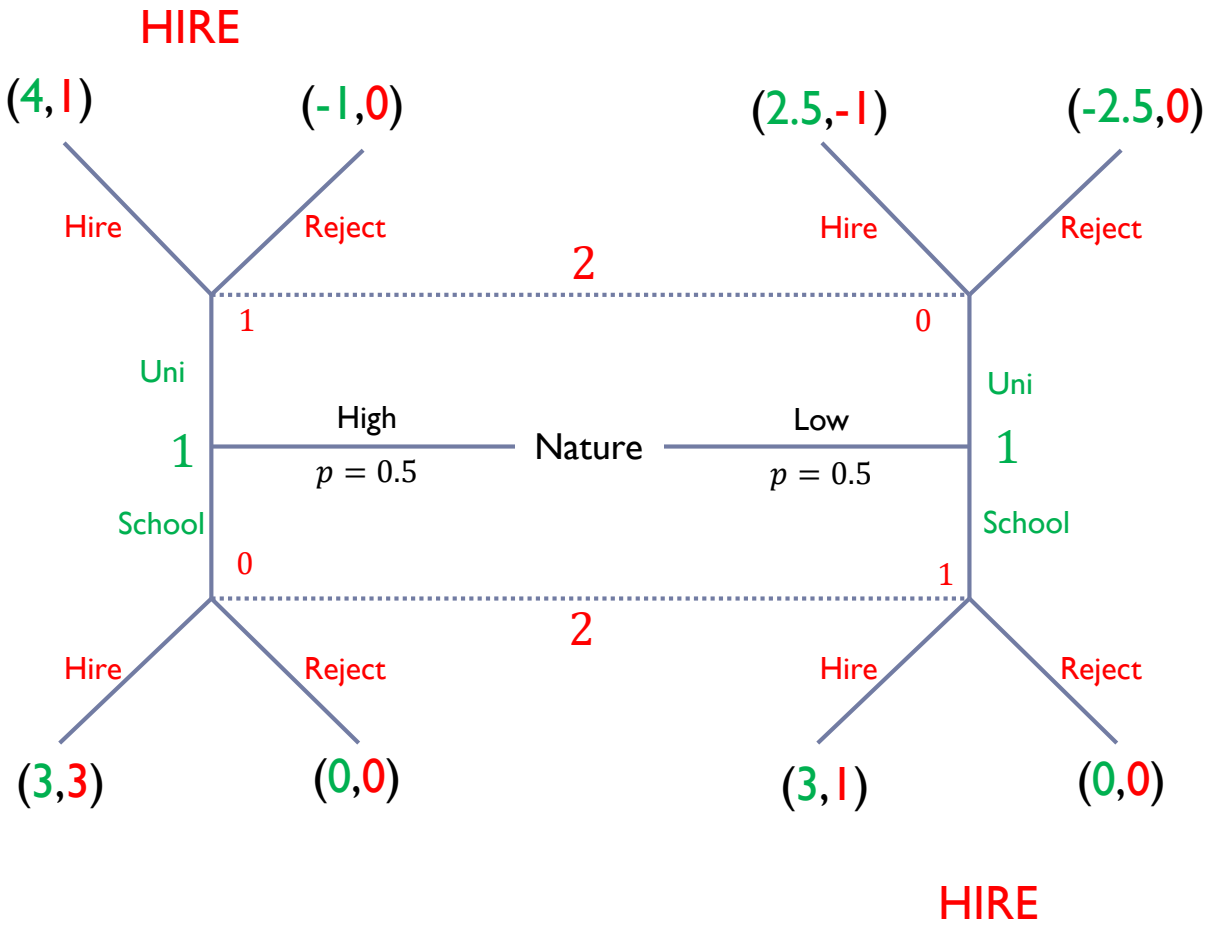
Signalling in game theory



Equilibrium with full information:

- High ability types go to university and get hired as graduates
- Low ability types stop after school and get hired

Signalling in game theory



Under imperfect information

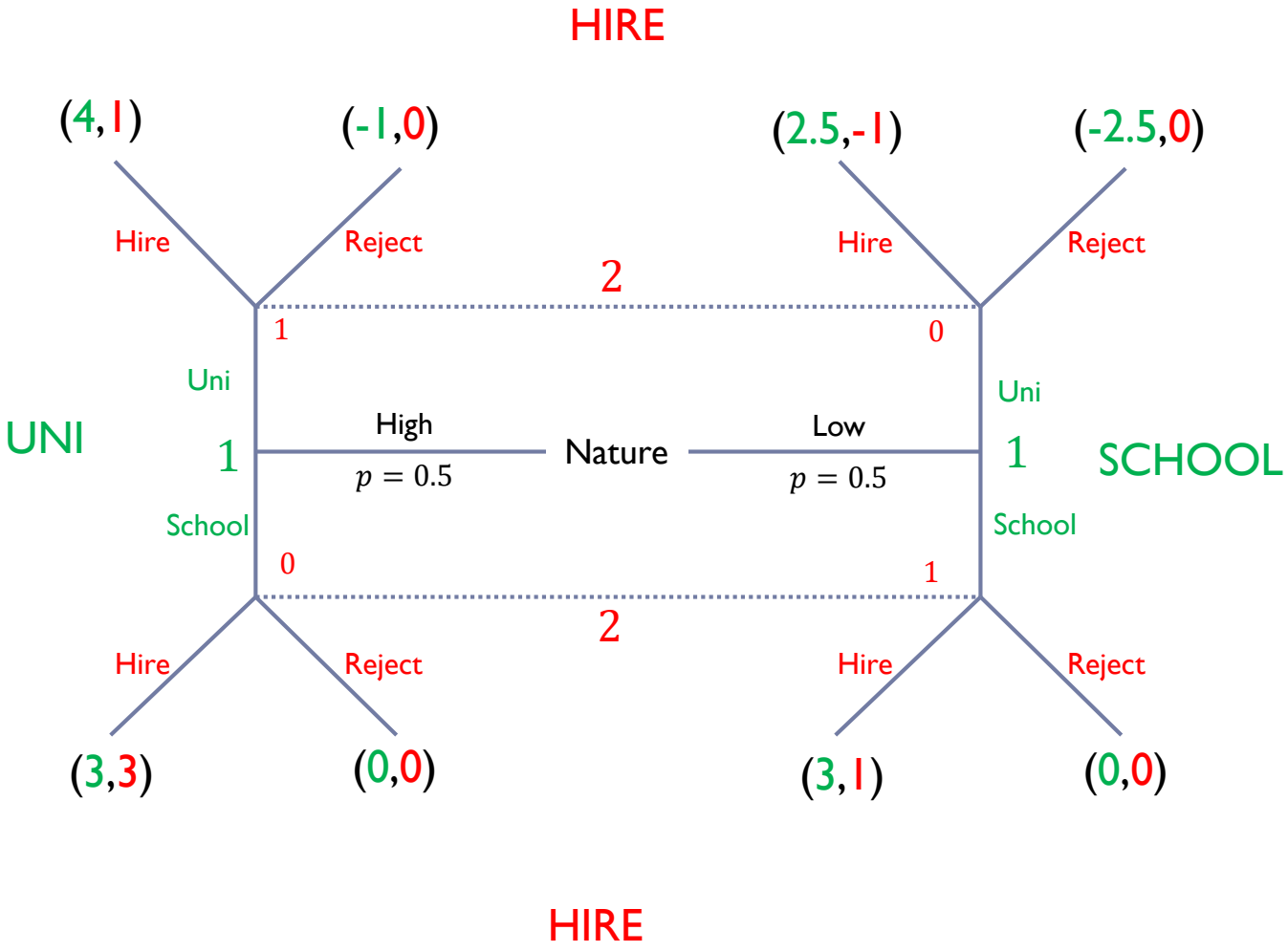
- Find a separating equilibrium where high ability types get university educated and low ability types do not.
- This means, set $p = 1$ and $q = 0$

- Is this an equilibrium?

- First, what will firms do?
  - If observe uni, given belief $p = 1$,
  - HIRE as 1>0
  - If observe school, given belief $q = 0$,
  - HIRE as 1>0

- Does either type wish to pick the other signal?

Signalling in game theory



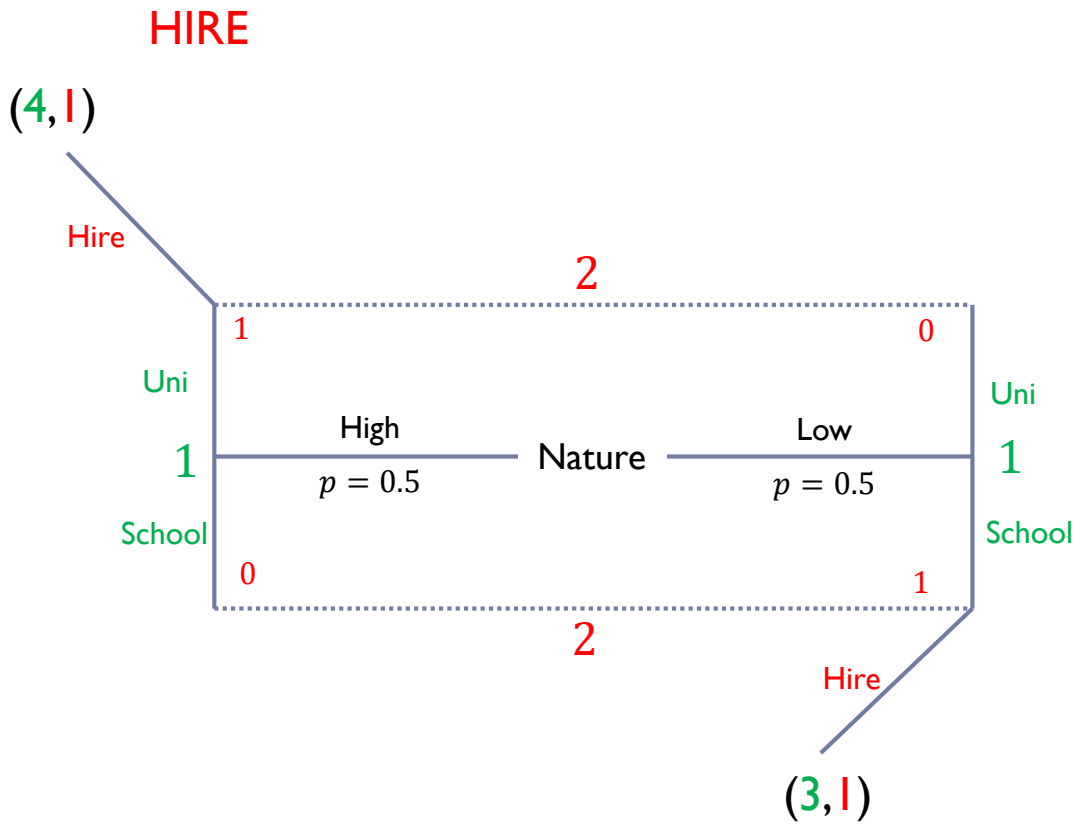
- Does either type wish to pick the other signal?

- High:
  - compare 4 with 3 (payoff if leave school).
  - 4>3 so no deviation

- Low:
  - compare 3 with 2.5 (payoff if go to uni).
  - 3>2.5 so no deviation

- So we found a separating equilibrium!

Signalling in game theory



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- So we found a separating equilibrium!