Microeconomics III: Problem Set 11[a]

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[a] Slides created for exercise class 3 and 4, with reservation for possible errors.

Outline

PS11, Ex. 1 (A): Effect of the GED education as a signal

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Does signaling work? Read the article by Tyler, Murnane and Willett and think about their results. What is their hypothesis for why they do not find an effect for minority groups? Come up with an example of an education program that has mostly signaling value in your country.

(This is a reflection question, no answer will be provided).

PS11, Ex. 2 (A): Asymmetric information (PBE)

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Exercise 4.11 in Gibbons (p. 250). Difficult. A buyer and a seller have valuations v_b and v_s. It is common knowledge that there are gains from trade (i.e., that $v_b > v_s$), but the size of the gains is private information, as follows: the seller's valuation is uniformly distributed on [0,1]; the buyer's valuation $v_b = kv_s$, where $k > 1$ is common knowledge; the seller knows v_s (and hence v_b) but the buyer does not know v_b (and hence v_s). Suppose the buyer makes a single offer, p, which the seller either accepts or rejects. What is the perfect Bayesian equilibrium when $k < 2$? When $k > 2$? (See Samuelson 1984.)

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Step 1: **Consider the uniform distribution $x \sim U(a, b)$. Use the cumulative distribution function (CDF) to write up the probability that a random draw of x is lower than a constant c. Use the mean to write up the expected value of a random draw of x where x is lower than a constant $c \in [a, b]$.**

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CDF: $F(x) = \frac{x-a}{b-a} \Rightarrow \mathbb{P}(x < c) = \frac{c-a}{b-a}$ (†)

Mean: $\mu = \frac{a+b}{2} \Rightarrow \mathbb{E}(x < c) = \frac{a+c}{2}$ (‡)

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$$\max_p \mathbb{P}[v_s < p]\mathbb{E}[v_b - p | v_s < p]$$

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$$= \max_p \frac{p-0}{1-0}\mathbb{E}[kv_s - p | v_s < p] \qquad \text{using } (\dagger)$$

$$= \max_p p\left(k\mathbb{E}[v_s < p] - p\right)$$

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Step 4: Take the first-order condition:

$$\frac{\delta u_b(p,k)}{\delta p} = 0$$

$$2p\left(\frac{k}{2} - 1\right) = 0$$

$$2p\frac{k}{2} = 2p$$

$$p\frac{k}{2} = p$$

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Step 5: Maximize buyer's utility for $k < 2$.

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Step 7: **Looking at the seller's strategy, will trade occur when $k > 2$? What about $k \in (1,2)$? Have we seen something similar before?**

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Step 5: Maximize buyer's utility for $k < 2$.

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Step 7: $\boldsymbol{k > 2}$: As $v_s \in [0,1] \leq 1 = p^{**}$, seller will always accept this price. **What about $\boldsymbol{k \in (1,2)}$? Have we seen something similar before?**

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Step 7: $\boldsymbol{k > 2}$: As $v_s \in [0,1] \leq 1 = p^{**}$, seller will always accept this price. $\boldsymbol{k \in (1,2)}$: Seller will not accept if $v_s > 0$, though trade would benefit both under perfect information. Similar to Akerlof's *'Lemons'*.

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Signaling games in general

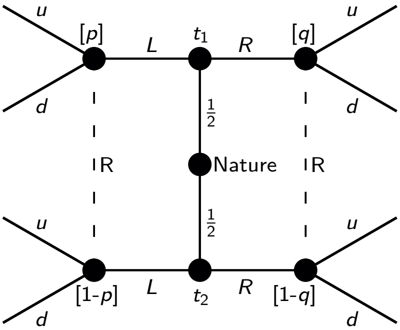
PS11: Signaling games in general

Players:

- 2 players: Sender (S) and receiver (R). E.g. firm and consumer, or employer and employee (Spence).

Timing:

1. Nature chooses the sender's type from $T = \{t_1, ...\}$.
2. S: The sender realizes her type and sends a signal from $M = \{m_1, ...\}$, typically either L (left) or R (right).
3. R: The receiver observes m (but not the type t!) and forms his beliefs:
   $\mu(t_1|L) = p$ and $\mu(t_1|R) = q$
   Consequently, for S having two possible types:
   $\mu(t_2|L) = 1 - p$ and $\mu(t_2|R) = 1 - q$
4. R: The receiver chooses an action from $A = \{a_1, ...\}$, e.g. *up* or *down*.
5. Payoffs are realized.



PS11: Signaling games in general

Players:

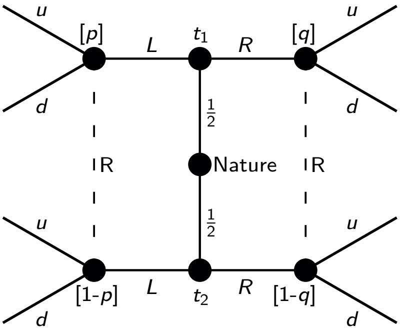
- 2 players: Sender (S) and receiver (R). E.g. firm and consumer, or employer and employee (Spence).

Timing:

1. Nature chooses the sender's type from $T = \{t_1, ...\}$.
2. S: The sender realizes her type and sends a signal from $M = \{m_1, ...\}$, typically either L (left) or R (right).
3. R: The receiver observes m (but not the type t!) and forms his beliefs:
   $p = \mu(t_1|L)$ and $q = \mu(t_1|R)$
   Consequently, for S having two possible types:
   $1 - p = \mu(t_2|L)$ and $1 - q = \mu(t_2|R)$
4. R: The receiver chooses an action from $A = \{a_1, ...\}$, e.g. *up* or *down*.
5. Payoffs are realized.

Four possible equilibria for two types:

- Pooling on L or pooling on R.
- Separating: t_1 plays L and t_2 plays R or the other way around.



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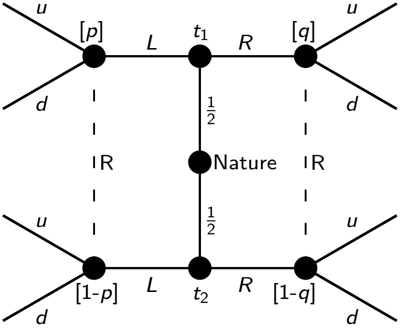


Cookbook: For each possible equilibrium go over signaling requirements 3 and 2:

SR3: R: Find the beliefs p, q given S's eq. strategy. (Only consider beliefs that are consistent with S's eq. strategy.)

SR2R: R: Given beliefs, find $a(m_j|\mu(t_1|m_j))$.

SR2S: S: Does t_1 or t_2 want to deviate?

PBE: No deviation $\rightarrow$ PBE. Pooling on L: Find off-eq. $a(R|q)$ $\rightarrow$ possibly two different PBE for different q.

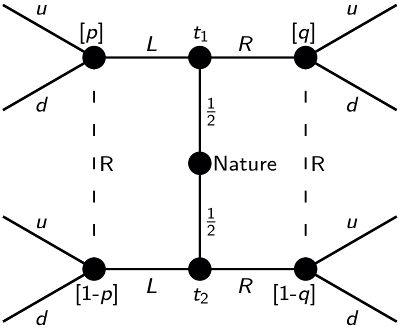
PS11, Ex. 3: Signaling game (pooling and separating PBE)

PS11, Ex. 3: Signaling game (pooling and separating PBE)

Consider the signaling game in Figure 1.

(a) Suppose there is a pooling PBE where the Sender sends message L regardless of his type. What are the beliefs in this equilibrium?

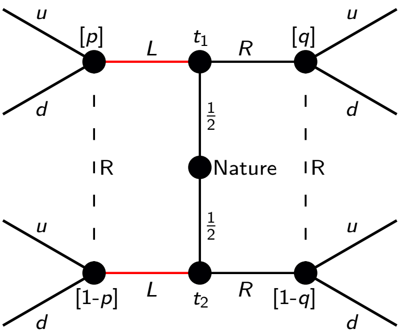
(b) Consider a possible separating PBE where t_1 sends message R, t_2 sends message L, and where the receiver chooses u if and only if he receives message L. Can you write down payoffs for this game such that nobody has an incentive to deviate?



PS11, Ex. 3.a: Signaling game (pooling and separating PBE)

(a) Suppose there is a pooling PBE where the Sender sends message L regardless of his type. What are the beliefs in this equilibrium?

SR3: **R: Find the beliefs of R given S's equilibrium strategy. (In equilibrium, we only consider beliefs of R that are consistent with S's equilibrium strategy.)**



PS11, Ex. 3.a: Signaling game (pooling and separating PBE)

(a) Suppose there is a pooling PBE where the Sender sends message L regardless of his type. What are the beliefs in this equilibrium?

SR3: R: Find the beliefs of R given S's equilibrium strategy. (In equilibrium, we only consider beliefs of R that are consistent with S's eq. strategy.):

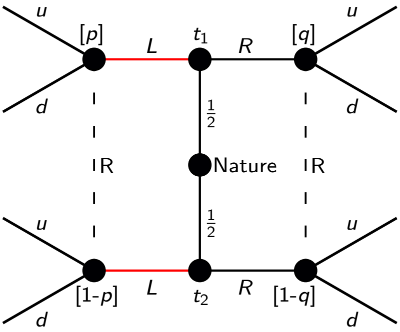
$$\mu(t_1|L) = \mu(t_2|L) = \frac{1}{2}$$

$$\Rightarrow p = 1 - p = \frac{1}{2}$$

$$q \in [0; 1]$$

I.e. in a pooling perfect Bayesian equilibrium where S always sends the message L, the receiver R believes that S can be type t_1 or t_2 with equal probability as the signal does not reveal anything.

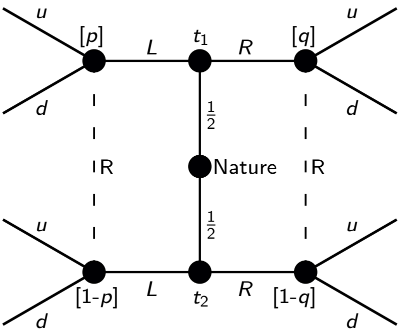
As the message R is not a part of S's equilibrium strategy, the receiver R has no beliefs about q other than $q \in [0, 1]$ in the case where S would unexpectedly send the message R instead.



PS11, Ex. 3.b: Signaling game (pooling and separating PBE)

(b) Consider a possible separating PBE where t_1 sends message R, t_2 sends message L, and where the receiver chooses u if and only if he receives message L. Can you write down payoffs for this game such that nobody has an incentive to deviate?

SR3:



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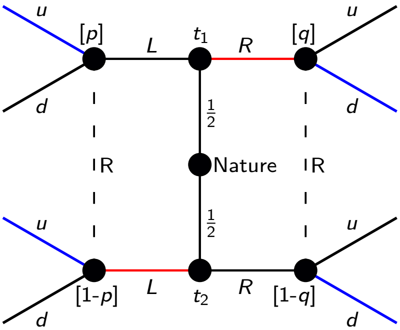

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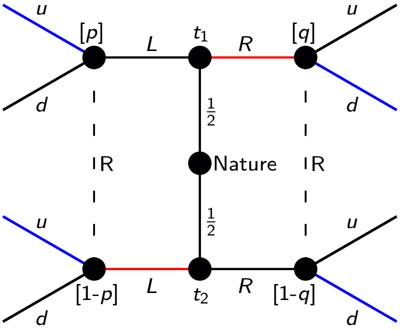
SR2R:

SR2S:

PBE:



SR3: In the separating PBE, R has beliefs:

$$\mu(t_1|L) = p^* = 0$$

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(b) Consider a possible separating PBE where t_1 sends message R, t_2 sends message L, and where the receiver chooses u if and only if he receives message L. Can you write down payoffs for this game such that nobody has an incentive to deviate?

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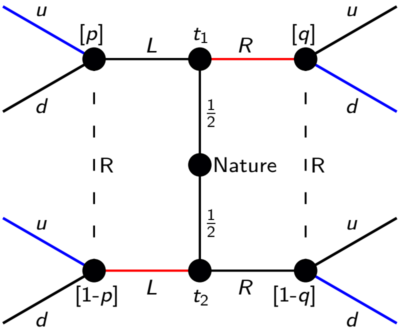
SR2R: R: Find R's optimal strategy given beliefs about S's strategy.

SR2S: S: Check whether S wants to deviate.

PBE: **Write up the conditions such that SR2R and SR2S hold (no incentive to deviate) for the following PBE:**

$$\{(\underbrace{R}_{m(t_1)}, \underbrace{L}_{m(t_2)}), (\underbrace{u}_{a(L)}, \underbrace{d}_{a(R)}), \underbrace{p=0}_{\mu(t_1|L)}, \underbrace{q=1}_{\mu(t_1|R)}\}$$



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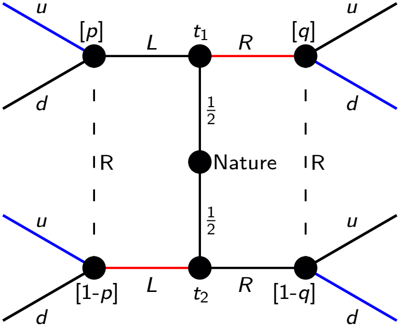

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PS11, Ex. 3.b: Signaling game (pooling and separating PBE)

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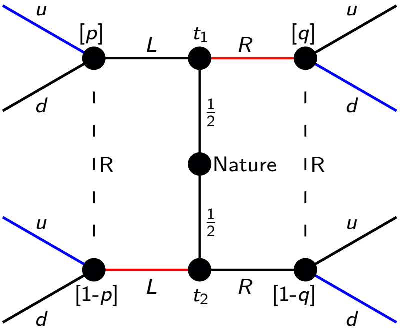

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→ **Construct payoffs that live up to these conditions.**

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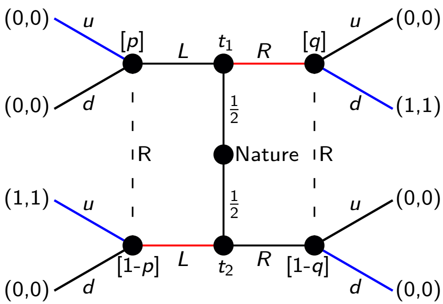

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i: *Simplest possible example.*

PS11, Ex. 3.b: Signaling game (pooling and separating PBE)

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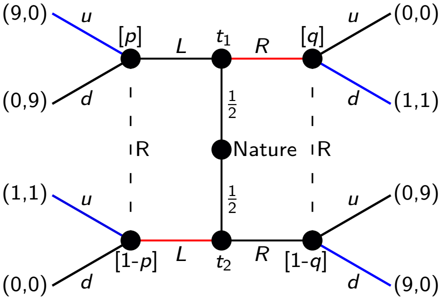
→ Construct payoffs that live up to these conditions.

i: Simplest possible example.

ii: **Does the PBE still hold for this example?**



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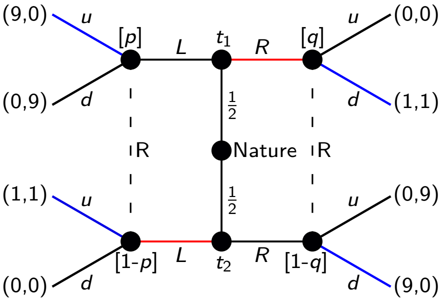

$$\{(\underbrace{R}_{m(t_1)}, \underbrace{L}_{m(t_2)}), (\underbrace{u}_{a(L)}, \underbrace{d}_{a(R)}), \underbrace{p=0}_{\mu(t_1|L)}, \underbrace{q=1}_{\mu(t_1|R)}\}$$

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→ Construct payoffs that live up to these conditions.

i: Simplest possible example.

ii: *Yes, all conditions still hold.*

PS11, Ex. 3.b: Signaling game (pooling and separating PBE)

(b) Consider a possible separating PBE where t_1 sends message R, t_2 sends message L, and where the receiver chooses u if and only if he receives message L. Can you write down payoffs for this game such that nobody has an incentive to deviate?

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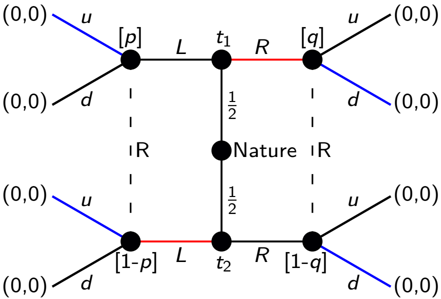
→ Construct payoffs that live up to these conditions.

i: Simplest possible example.

ii: Yes, all conditions still hold.

iii: **What about zero payoffs all over?**



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PS11, Ex. 3.b: Signaling game (pooling and separating PBE)

(b) Consider a possible separating PBE where t_1 sends message R, t_2 sends message L, and where the receiver chooses u if and only if he receives message L. Can you write down payoffs for this game such that nobody has an incentive to deviate?

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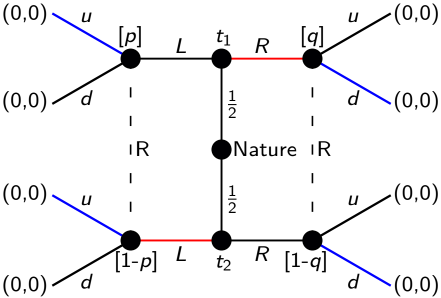
→ Construct payoffs that live up to these conditions.

i: Simplest possible example.

ii: Yes, all conditions still hold.

iii: *All conditions hold with equality.*



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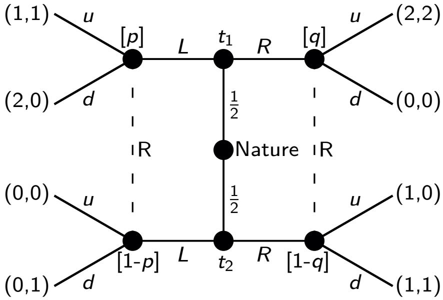
$u_S(L, u|t_2) \geq u_S(R, u|t_2)$

PS11, Ex. 4: Signaling games (pooling and separating PBE)

PS11, Ex. 4.a: Signaling games (pooling and separating PBE)

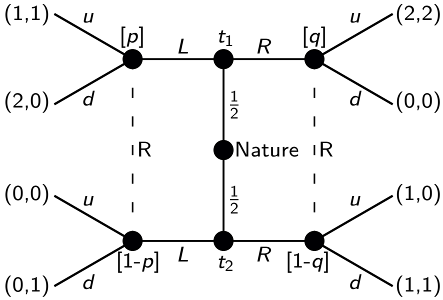
Exercise 4.4.a in Gibbons (p. 248). Describe all the pure-strategy pooling and separating perfect Bayesian equilibria in the following signaling game.



PS11, Ex. 4.a: Signaling games (pooling and separating PBE)

Exercise 4.4.a in Gibbons (p. 248). Describe all the pure-strategy pooling and separating perfect Bayesian equilibria in the following signaling game.

Step 1: **Write up S's possible strategies.**



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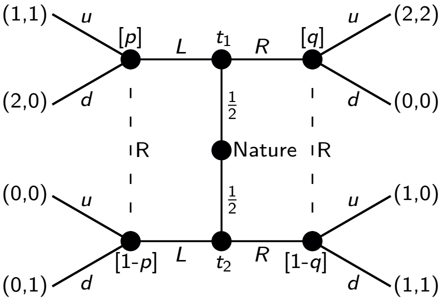
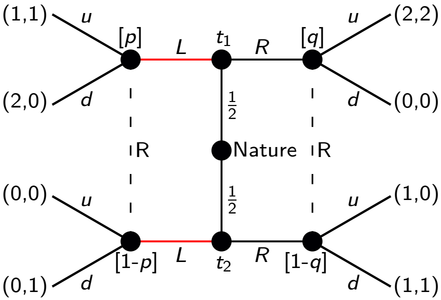


1. $S_S = \{(L, L); (R, R); (L, R); (R, L)\}$

Exercise 4.4.a in Gibbons (p. 248). Describe all the pure-strategy pooling and separating perfect Bayesian equilibria in the following signaling game.

Step 1: Write up S's possible strategies.

Step 2: **For the pooling strategy (*L*,*L*), go over SR3, SR2R, and SR2S.**



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PS11, Ex. 4.a: Signaling games (pooling and separating PBE)

Exercise 4.4.a in Gibbons (p. 248). Describe all the pure-strategy pooling and separating perfect Bayesian equilibria in the following signaling game.

Step 1: Write up S's possible strategies.

Step 2: For the pooling strategy (L,L), go over SR3, SR2R, and SR2S:

SR3: R: Beliefs given S's eq. strategy:

$$\mu(t_1|L) = p = \frac{1}{2} \text{ and } \mu(t_1|R) = q \in [0,1]$$

SR2R: R: Indifferent between u and d:

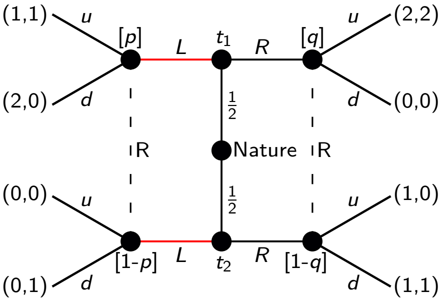
$$\mathbb{E}[u_R(L, u|p)] = \mathbb{E}[u_R(L, d|p)]$$

$$1p + 0[1-p] = 0p + 1[1-p]$$

$$\frac{1}{2} = \frac{1}{2}$$

SR2S: S: t_2 wants to deviate as $L|t_2$ is strictly dominated by $R|t_2$.

PBE: Not a PBE as t_2 would deviate.



1. $S_S = \{(L, L); (R, R); (L, R); (R, L)\}$
2. No PBE that includes (L, L).

PS11, Ex. 4.a: Signaling games (pooling and separating PBE)

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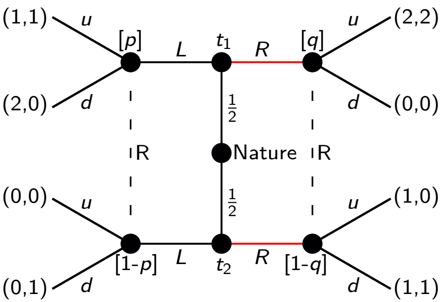

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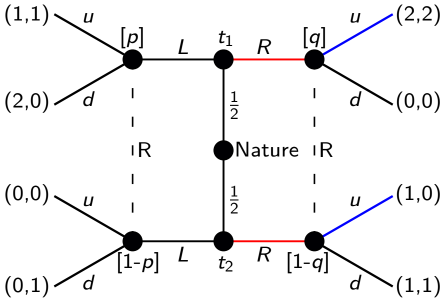

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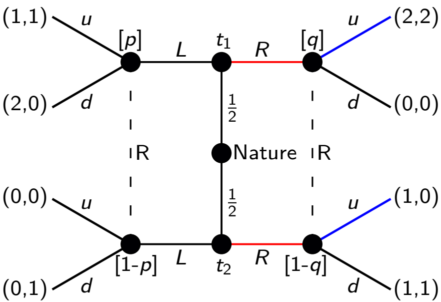

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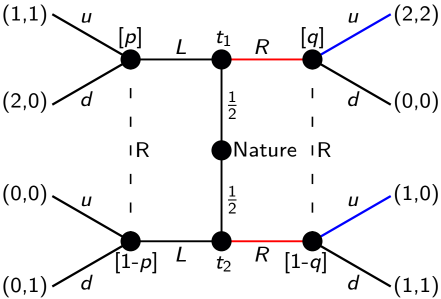

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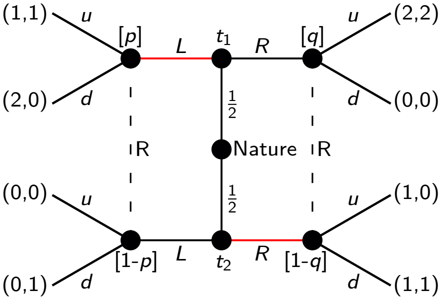

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SR3: R: Beliefs given S's eq. strategy:

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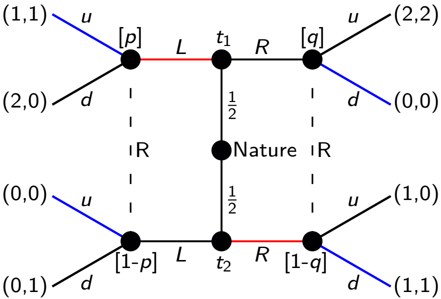
SR2S: t_1 will not deviate as

$$u_S(L, u|t_1) = 1 > 0 = u_S(R, d|t_1)$$

t_2 will not deviate as

$$u_S(R, d|t_2) = 1 > 0 = u_S(L, u|t_2)$$

PBE: No deviation, thus, it's a PBE.



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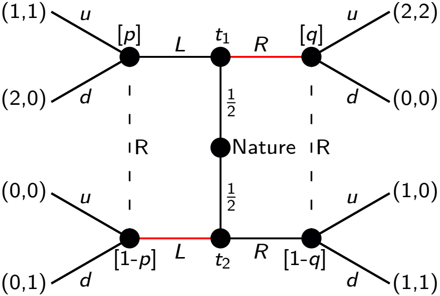

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Step 5: For the separating strategy (R,L), go over SR3, SR2R, and SR2S:

SR3: R: Beliefs given S's eq. strategy:

$$\mu(t_1|L) = p = 0 \text{ and } \mu(t_1|R) = q = 1$$

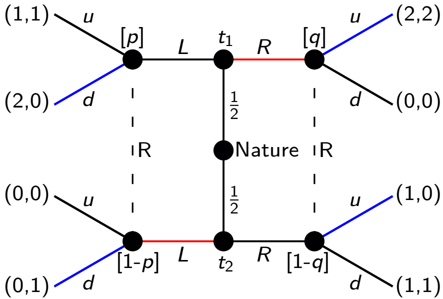
SR2R: R: Best response is to play $d|L, u|R$.

SR2S: t_2 wants to deviate as

$$u_S(L,d|t_2) = 0 < 1 = u_S(R,u|t_2)$$

PBE: No PBE as t_2 will want to deviate.

Step 6: **Write up the full set of PBE.**



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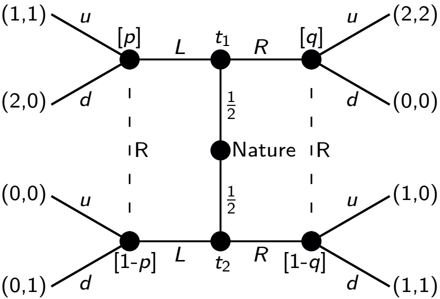

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SR2S: t_2 wants to deviate as

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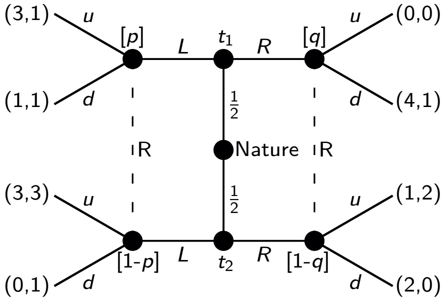

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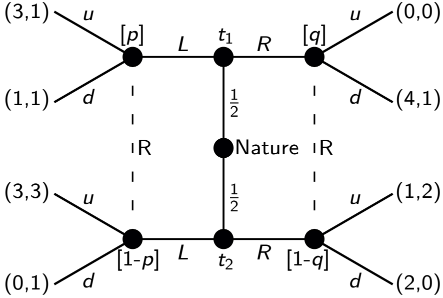

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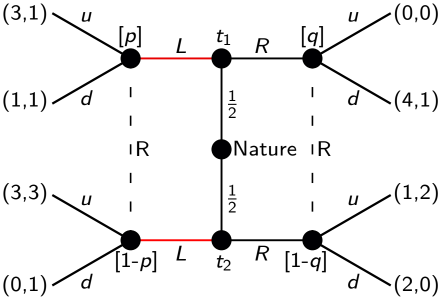

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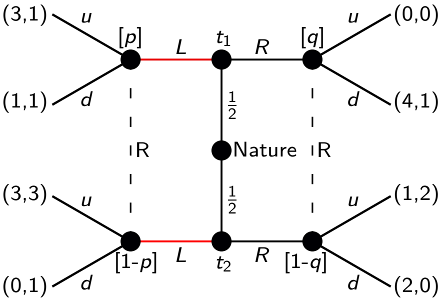

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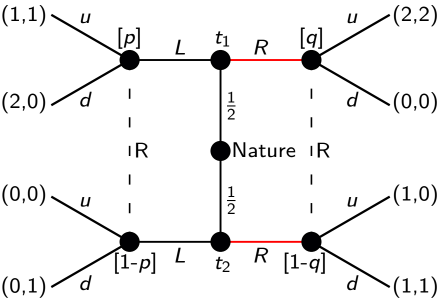

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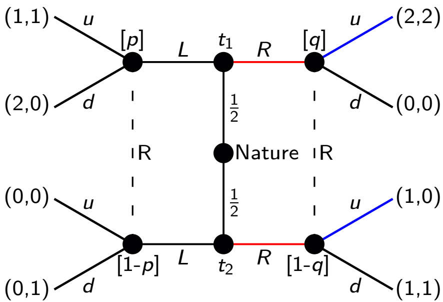

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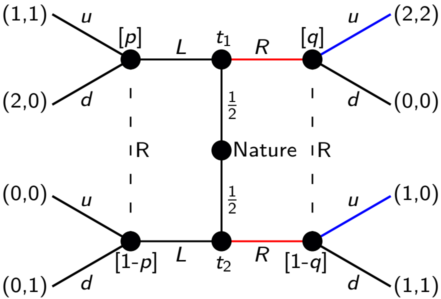

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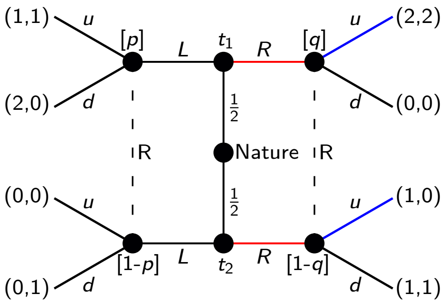


1. $S_S = \{(L,L); (R,R); (L,R); (R,L)\}$
2. No PBE that includes (L,L).
3. $\left\{ \begin{array}{l} (R,R),(u,u), p \geq \frac{1}{2}, q = \frac{1}{2} \\ (R,R),(d,u), p \leq \frac{1}{2}, q = \frac{1}{2} \end{array} \right\}$

PS11, Ex. 4.b: Signaling games (pooling and separating PBE)

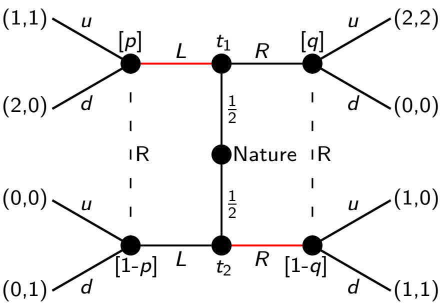
Exercise 4.4.b in Gibbons (p. 248). Describe all the pure-strategy pooling and separating perfect Bayesian equilibria in the following signaling game.

Step 1: Consider S's possible strategies:
$S_S = \{(L, L); (R, R); (L, R); (R, L)\}$

Step 2: For the pooling strategy (L,L), go over SR3, SR2R, and SR2S.

Step 3: For the pooling strategy (R,R), go over SR3, SR2R, and SR2S.

Step 4: **For the separating strategy (L,R), go over SR3, SR2R, and SR2S.**



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Step 4: For the separating strategy (L,R), go over SR3, SR2R, and SR2S:

SR3: R: Beliefs given S's eq. strategy:

$$\mu(t_1|L) = p = 1 \text{ and } \mu(t_1|R) = q = 0$$

SR2R: R: Best response is to play $u|L, d|R$.

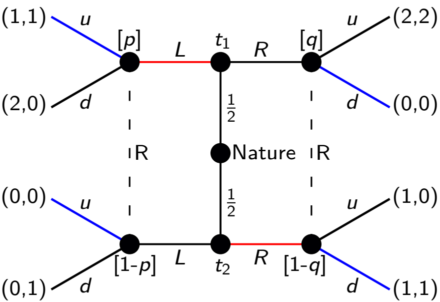
SR2S: t_1 will not deviate as

$$u_S(L, u|t_1) = 1 > 0 = u_S(R, d|t_1)$$

t_2 will not deviate as

$$u_S(R, d|t_2) = 1 > 0 = u_S(L, u|t_2)$$

PBE: No deviation, thus, it's a PBE.



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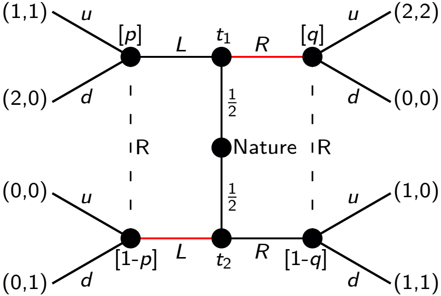
Step 5: **For the separating strategy (R,L), go over SR3, SR2R, and SR2S.**



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PS11, Ex. 4.b: Signaling games (pooling and separating PBE)

Exercise 4.4.b in Gibbons (p. 248). Describe all the pure-strategy pooling and separating perfect Bayesian equilibria in the following signaling game.

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Step 5: For the separating strategy (R,L), go over SR3, SR2R, and SR2S:

SR3: R: Beliefs given S's eq. strategy:

$$\mu(t_1|L) = p = 0 \text{ and } \mu(t_1|R) = q = 1$$

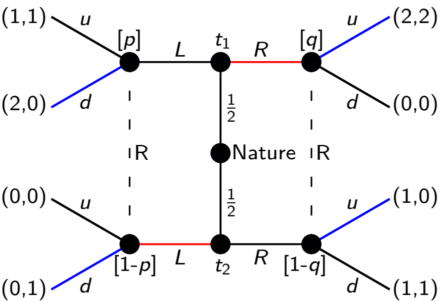
SR2R: R: Best response is to play $d|L, u|R$.

SR2S: t_2 wants to deviate as

$$u_S(L, d|t_2) = 0 < 1 = u_S(R, u|t_2)$$

PBE: No PBE as t_2 will want to deviate.

Step 6: **Write up the full set of PBE.**



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4. $\left\{ (L, R), (u, d), p = 1, q = 0 \right\}$
5. No PBE that includes (R, L).

PS11, Ex. 4.b: Signaling games (pooling and separating PBE)

Exercise 4.4.b in Gibbons (p. 248). Describe all the pure-strategy pooling and separating perfect Bayesian equilibria in the following signaling game.

Step 1: Consider S's possible strategies:
$S_S = \{(L, L); (R, R); (L, R); (R, L)\}$

Step 2: For the pooling strategy (L,L), go over SR3, SR2R, and SR2S.

Step 3: For the pooling strategy (R,R), go over SR3, SR2R, and SR2S.

Step 4: For the separating strategy (L,R), go over SR3, SR2R, and SR2S.

Step 5: For the separating strategy (R,L), go over SR3, SR2R, and SR2S:

SR3: R: Beliefs given S's eq. strategy:

$$\mu(t_1|L) = p = 0 \text{ and } \mu(t_1|R) = q = 1$$

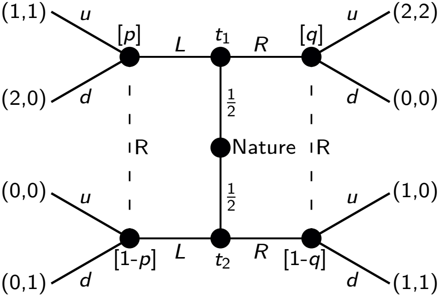
SR2R: R: Best response is to play $d|L, u|R$.

SR2S: t_2 wants to deviate as

$$u_S(L, d|t_2) = 0 < 1 = u_S(R, u|t_2)$$

PBE: No PBE as t_2 will want to deviate.

Step 6: Write up the full set of PBE:



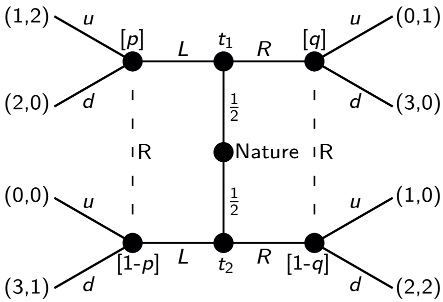
1. $S_S = \{(L, L); (R, R); (L, R); (R, L)\}$
2. No PBE that includes (L, L).
3. $\left\{ \begin{array}{c} (R, R), (u, u), p \geq \frac{1}{2}, q = \frac{1}{2} \\ (R, R), (d, u), p \leq \frac{1}{2}, q = \frac{1}{2} \end{array} \right\}$
4. $\left\{ (L, R), (u, d), p = 1, q = 0 \right\}$
5. No PBE that includes (R, L).

$$PBE = \left\{ \begin{array}{c} (R, R), (u, u), p \geq \frac{1}{2}, q = \frac{1}{2} \\ (R, R), (d, u), p \leq \frac{1}{2}, q = \frac{1}{2} \\ (L, R), (u, d), p = 1, q = 0 \end{array} \right\}$$

PS11, Ex. 5: Signaling games (pooling PBE)

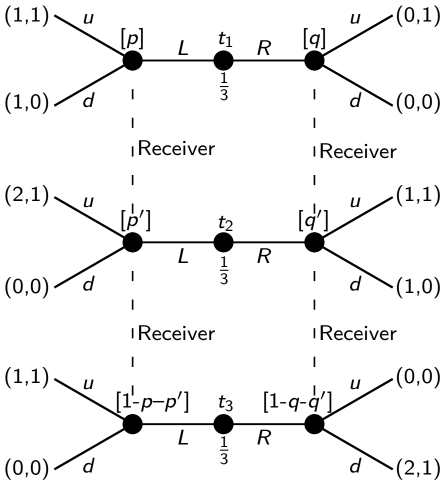
PS11, Ex. 5.a: Signaling games (pooling PBE)

Exercise 4.3.a in Gibbons (p. 246). Specify a pooling perfect Bayesian equilibria in which both Sender types play R in the following signaling game.



PS11, Ex. 5.b: Signaling games (pooling PBE)

Exercise 4.3.b in Gibbons (p. 246). The following three-type signaling game begins with a move by nature, not shown in the tree, that yields one of the three types with equal probability Specify a pooling perfect Bayesian equilibria in which all three Sender types play L.



PS11, Ex. 6: Spence's education signaling model (PBE)

PS11, Ex. 6: Spence's education signaling model (PBE)

Consider the following version of Spence's education signaling model, where a firm is hiring a worker. Workers are characterized by their type θ, which measures their ability. There are two worker types: $\theta \in \{\theta_L, \theta_H\}$. Nature chooses the worker's type, with $p_H = \mathbb{P}[\theta = \theta_H]$ and $p_H = \mathbb{P}[\theta = \theta_H] = 1 - p_H$.

The worker observes his own type, but the firm does not. The worker can choose his level of education: $e \in \mathbb{R}^+$. The cost to him of acquiring this education is $c_\theta(e) = e/\theta$. Education is observed by the firm, who then forms beliefs about the workers type: $\mu(\theta|e)$. We assume that the marginal productivity of a worker is equal to his ability and that the company is in competition such it pays the marginal productivity: $w(e) = \mathbb{E}[\theta|e]$. Thus, the payoff to a worker conditional on his type and education is $u_\theta(e) = w(e)c_\theta(e)$. Suppose for this exercise that $\theta_H = 3$ and $\theta_L = 1$.

(a) Find a separating pure strategy Perfect Bayesian Equilibrium.

(b) Find a pooling pure strategy Perfect Bayesian Equilibrium.