Repeated games:
Overlapping generations

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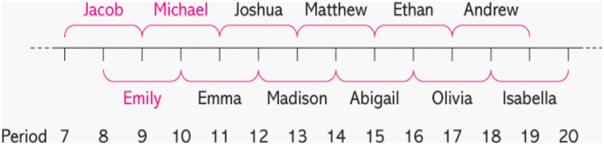
Chapter 15

1. Chapter 15 (Harrington) - Cooperation in infinitely lived institutions.
2. So far individuals interacting in an infinitely repeated game knew there were some chances they were going to meet each other again.
   1. i.e., cooperation was sustained by the "shadow of the future" hanging over future encounters.
3. But in some cases individuals know for sure they won't see each other again.
   1. Why do people cooperate then?
4. In this chapter we will examine cooperation in institutions where
   1. individuals are finitely lived, but
   2. the institution lasts forever.

1. An infinitely lived institution can be understood as an overlapping generations model in macroeconomics.
    1. That is, at any stage some people are young, some are middle-aged, some are old.
    2. Importantly, when the old die in the following period, the population is replenished by newborns.



    3. Hence, the institution lives forever.
2. How can we sustain cooperation in these settings?

1. **Another potentially problematic setting:**
   1. People interact only one period: Businessmen A and B meet only once.
   2. If I am businessman A, how I am going to discipline B (playing a punishment strategy, as in the GTS) if I never meet businessman B again?
   3. Although one person cannot discipline another, society at large might be able to perform that function.
   4. For example, if information about past encounters is observed by other people who will interact with businessman B in the future, they can punish him for acting improperly towards A.
2. We will describe how to sustain cooperation in these settings.

Overlapping generations and tribal defense

1. Consider a nation, a village, or tribe with $N \geq 2$ members.
2. Each member decides:
   1. whether to exert effort defending the group (public project), at a private cost of 10, or
   2. shirk.
3. Every member obtains a benefit of 6 units for every individual who exerts effort.
4. Hence, if m members exert effort, my utility is

$$u_i(s_i, m) = \begin{cases} 6(m + \overbrace{1}^{\text{Me!}}) \overbrace{-10}^{\text{Cost}} & \text{if } s_i = \text{exert effort} \\ 6m & \text{if } s_i = \text{no effort} \end{cases}$$

Overlapping generations and tribal defense

1. Given utility

$$u_i(s_i, m) = \begin{cases} 6(m+1) - 10 & \text{if } s_i = \text{exert effort} \\ 6m & \text{if } \quad s_i = \text{no effort} \end{cases}$$

   it is immediate to show that exering effort is a strictly dominated strategy.

2. In particular,

$$6(m+1) - 10 < 6m \iff 6m - 4 < 6m \iff -4 < 0$$

   which holds for any value of m.

3. That is, I have incentives to free-ride (shirk) regardless of the number of individuals who end up exerting effort.
4. Hence, the psNE of the unrepeated game has $s_i =$no effort for every player $i \in N$.

Overlapping generations and tribal defense

1. For simplicity, let's solve this game as we know so far: when players **interact infinitely often** (they never die).
2. In this case, we can design the following modified GTS:.
    1. At $t = 1$, exert effort (cooperate)
    2. At $t > 1$, exert effort if all players exerted effort in all previous periods...
        1. but temporarily revert to no effort for one period if any player deviates from exerting effort in previous periods.
        2. Then, after one period of reversion (punishment), go back to the cooperative outcome, i.e., exert effort.

Overlapping generations and tribal defense

1. After a history of cooperation, my payoff if I keep cooperating is:

$$(6N-10)+\delta(6N-10)+\delta^2(6N-10)+\ldots$$

2. While my payoff from deviating to no effort is:

$$\underbrace{6(N-1)}_{\substack{\text{you are not coop}\\ \text{while all other } (N-1)\\ \text{members cooperate}}} \quad + \quad \underbrace{\delta 0}_{\text{punishment in psNE}} \quad + \underbrace{\delta^2(6N-10)}_{\text{go back to coop}} + \ldots$$

Overlapping generations and tribal defense

1. Comparing these payoffs, cooperation can be sustained as the SPNE of the infinitely repeated game if:

$$\begin{aligned} & (6N-10)+\delta(6N-10)+\cancel{\delta^2(6N-10)+\ldots} \\ \geq \quad & 6(N-1)+\delta 0+\cancel{\delta^2(6N-10)+\ldots} \end{aligned}$$

   Rearranging,

$$6N-10+\delta(6N-10)\geq 6N-6$$

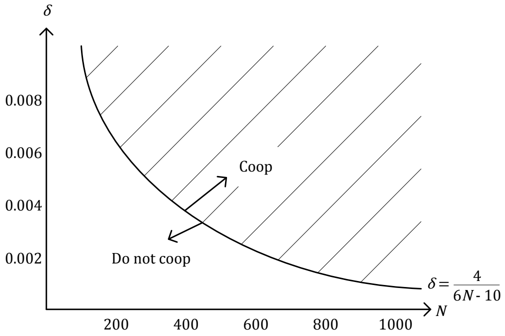
   Hence,

$$\delta \geq \frac{4}{6N-10}$$

2. Figure of this cutoff for δ (next slide)

Overlapping generations and tribal defense

- Minimal discount factor supporting cooperation in the Overlapping Generation-Tribal defense game, as a function of the population size, N



- Cooperation is easier to sustain the larger the population is.

Overlapping generations and tribal defense

1. But, what if players **do not interact infinitely often**?
2. You live during T periods only, and there are N members in total.
3. At any period T, there are $\frac{N}{T}$ members currently alive in this generation T.
    1. *Example*: $N = 100$ and $T = 4$ years, then $\frac{N}{T} = \frac{100}{4} = 25$ members are children, 25 are teenagers, 25 are adults, and 25 are seniors.

Overlapping generations and tribal defense

1. Then, at any period,

$$N - \frac{N}{T} \text{ people are younger than age T}$$

$$= \frac{NT - N}{T} = \left(\frac{T-1}{T}\right) N$$

   1. In the previous example where $N = 100$ and $T = 4$ years, $\left(\frac{T-1}{T}\right) N = \left(\frac{3-1}{4}\right) 100 = 75$ individuals are younger than the maximum age any member in the population reaches.
   2. In particular, 25 members are children, 25 are teenagers, and 25 are adults.

Overlapping generations and tribal defense

1. Let us now analyze how to support cooperation in this setting.
2. Consider the following strategy
    1. At the *last* period of your life (period T), you don't exert any effort (e.g., retirement for seniors).
        1. How would I be disciplined otherwise? When we meet them in the afterlife?
    2. During all previous $T-1$ periods, you exert effort, but if someone deviates from this strategy:
        1. you revert to the psNE of the stage game during one period (temporary punishment), and
        2. move to the cooperative outcome (exerting effort) afterwards.

Overlapping generations and tribal defense

1. In order to show that such strategy can be sustained as SPNE of the game, we must show that it is optimal for:
   1. the individual who is in the last period (T) of his life (of course!).
   2. the individual who is in the penultimate period ($T - 1$) of his life.
   3. the individual who is in period $T - 2$ of his life.
   4. the individual who is in period $T - 3$ of his life, etc.

Overlapping generations and tribal defense

- Payoff in penultimate period of life, i.e., $T-1$:
- Payoff from cooperating:

$$\underbrace{\left[6\underbrace{\left(\frac{T-1}{T}\right)N}_{m}-10\right]}_{\text{effort}}+\delta\underbrace{\left[6\underbrace{\left(\frac{T-1}{T}\right)N}_{m}\right]}_{\substack{\text{no effort, he is a senior}\\ \text{but } m \text{ is unaffected,}\\ \text{thanks to the newborns!}}}$$

- Payoff from deviating:

$$6\left[\underbrace{\left(\frac{T-1}{T}\right)N-1}_{m\text{, without you}}\right]+\underbrace{\delta\cdot 0}_{\substack{\text{punished during}\\ \text{retirement!}}}$$

Overlapping generations and tribal defense

- Comparing,

$$\cancel{6\left(\frac{T-1}{T}\right)N} - 10 + \delta\left[6\left(\frac{T-1}{T}\right)N\right] \geq \cancel{6\left(\frac{T-1}{T}\right)N} - 6$$

$$\delta \geq \frac{4}{6\left(\frac{T-1}{T}\right)N} = \frac{2}{3\left(\frac{T-1}{T}\right)N} \qquad \text{(Condition 1)}$$

Overlapping generations and tribal defense

- Player who is still two periods from retirement, i.e., $T-2$ (Teenager):
- Payoff from cooperation:

$$\underbrace{\left[6\left(\frac{T-1}{T}\right)N-10\right]}_{\text{effort as a teenager}}+\delta\underbrace{\left[6\left(\frac{T-1}{T}\right)N-10\right]}_{\text{effort as an adult}}+\delta^2\underbrace{\left[6\left(\frac{T-1}{T}\right)N\right]}_{\text{no effort as a senior}}$$

- Payoff from deviating to no effort:

$$\underbrace{6\left[\left(\frac{T-1}{T}\right)N-1\right]}_{\text{I shirk as a teenager...}}+\underbrace{\delta\cdot 0}_{\text{punished as an adult...}}+\delta^2\underbrace{\left[6\left(\frac{T-1}{T}\right)N\right]}_{\text{but enjoy life as a senior!}}$$

Overlapping generations and tribal defense

- Let's compare the payoffs.
  - First, note that last period payoffs were the same. Hence, we don't even write them in our payoff comparison.

$$\cancel{6\left(\frac{T-1}{T}\right)} N - 10 + \delta\left[6\left(\frac{T-1}{T}\right) N - 10\right] \geq \cancel{6\left(\frac{T-1}{T}\right)} N - 6$$

$$\begin{aligned} \Longrightarrow \quad & \delta\left[6\left(\frac{T-1}{T}\right) N - 10\right] \geq 10 - 6 \\ \Longrightarrow \quad & \delta \geq \frac{4}{6\left(\frac{T-1}{T}\right) N - 10} \\ = \quad & \frac{2}{3\left(\frac{T-1}{T}\right) N - 5} \qquad \text{(Condition 3)} \end{aligned}$$

Overlapping generations and tribal defense

- Similarly for individuals in previous periods, e.g., $T-3$:
- Payoff from cooperation:

$$\underbrace{\left[6\left(\frac{T-1}{T}\right)N-10\right]}_{\text{effort as a child}}+\delta\underbrace{\left[6\left(\frac{T-1}{T}\right)N-10\right]}_{\text{effort as a teenager}}$$

$$+\delta^2\underbrace{\left[6\left(\frac{T-1}{T}\right)N-10\right]}_{\text{effort as an adult}}+\delta^3\underbrace{\left[6\left(\frac{T-1}{T}\right)N\right]}_{\text{no effort as a senior}}$$

Overlapping generations and tribal defense

- Payoff from deviating to no effort:

$$\underbrace{6\left[\left(\frac{T-1}{T}\right)N-1\right]}_{\text{I shirk as a child}}+\underbrace{\delta\cdot 0}_{\substack{\text{punished as}\\ \text{a teenager}}}$$

$$+\delta^2\underbrace{\left[6\left(\frac{T-1}{T}\right)N-10\right]}_{\text{effort as an adult}}+\delta^3\underbrace{\left[6\left(\frac{T-1}{T}\right)N\right]}_{\text{no effort as a senior}}$$

Overlapping generations and tribal defense

- Comparing
  - Note that the last two period payoffs were the same. Hence, we don't need to write it down in our payoff comparison.

$$\cancel{6\left(\frac{T-1}{T}\right)}N-10+\delta\left[6\left(\frac{T-1}{T}\right)N-10\right]\geq\cancel{6\left(\frac{T-1}{T}\right)}N-6$$

$$\begin{aligned}\implies \quad & \delta\left[6\left(\frac{T-1}{T}\right)N-10\right]\geq 10-6 \\ \implies \quad & \delta\geq\frac{4}{6\left(\frac{T-1}{T}\right)N-10}=\frac{2}{3\left(\frac{T-1}{T}\right)N-5}\end{aligned}$$

- (Coincides with our above Coindition 2)

Overlapping generations and tribal defense

1. In sum, this strategy profile is a SPNE if both conditions

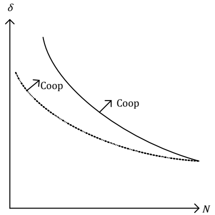
$$\underbrace{\delta \geq \frac{2}{3\left(\frac{T-1}{T}\right)N-5}}_{\text{Condition 2}} \quad \text{and} \quad \underbrace{\delta \geq \frac{2}{3\left(\frac{T-1}{T}\right)N}}_{\text{Condition 1}} \quad \text{hold}$$

2. But note that one condition is more restrictive than another one since...

$$\delta \geq \frac{2}{3\left(\frac{T-1}{T}\right)N-5} > \frac{2}{3\left(\frac{T-1}{T}\right)N}$$

Overlapping generations and tribal defense

- Plotting both cutoffs for different values of N, we obtain:



- **Solid Line:** Cutoff for the player in her $T-2$ period of life

$$\delta \geq \frac{2}{3\left(\frac{T-1}{T}\right)N-5} \qquad \text{(Teenager)}$$

- **Dashed Line:** Cutoff for the player in her $T-1$ period of life

$$\delta \geq \frac{2}{3\left(\frac{T-1}{T}\right)N} \qquad \text{(Adult)}$$

Overlapping generations and tribal defense

1. **Intuition**:
   1. the temptation to cheat is weaker for someone in her penultimate period of life, because...
   2. cheating today would result in her foregoing the "retirement benefit" of $6\left(\frac{T-1}{T}\right)N$ in the following period (her retirement years).
2. In other words, the real challenge is inducing people to sacrifice when they are further away from receiving their retirement benefit.
   1. In our model, this implied that the condition to induce an individual to cooperate in period $T-2$, i.e., $\delta \geq \frac{2}{3\left(\frac{T-1}{T}\right)N-5}$,
   2. was more demanding than the similar condition for an individual in period $T-1$, i.e., $\delta \geq \frac{2}{3\left(\frac{T-1}{T}\right)N}$.

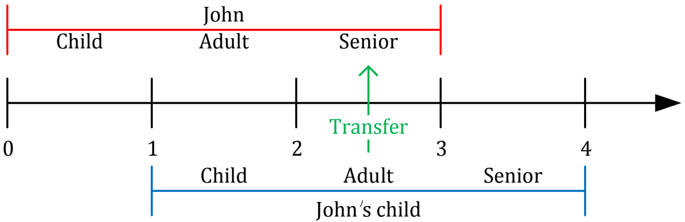
Overlapping generations and tribal defense

1. Cooperation can then be supported as a SPNE of the infinitely repeated game:
    1. even if agents do not live forever,
    2. but the institution is infinitely lived, so that younger individuals entering the population can punish players who previously defected.
2. *Check your understanding* exercise 15.1:
    1. Same exercise as tribal defense, but...
    2. suppose that punishment lasts as long as the lifetime of the person who shirks.
    3. That is, if a person shirks in period t of her life (when she was supposed to work), then everyone shirks for the rest $T - t$ periods.
    4. Find the conditions on δ that sustain cooperation.

Taking care of elderly parents

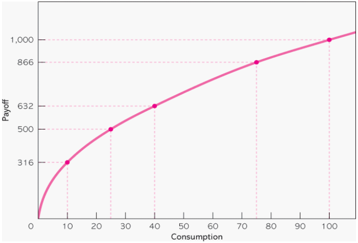
1. Let us now consider a variation in the above OLG model.
2. People live for 3 stages: youth, adult and senior.
3. People only generate income as adults, for an amount of \$100.
    1. and they have a child.
4. They cannot generate any income as seniors, and therefore they rely on the generosity (transfers) of adults.
    1. For simplicity, we assume that grandchildren cannot make intergenerational transfers to their grandparents!
5. How can cooperation be sustained in the SPNE of the game?

Taking care of elderly parents



Taking care of elderly parents

1. Before we proceed with a particular strategy, we also consider that utility is concave in money...



suggesting that additional amounts of money provide smaller increments in utility, e.g., $u(x) = 100 \cdot \sqrt{x}$

Taking care of elderly parents

1. Consider the following strategy:
   1. Transfer \$25 to your elderly parent if she helped her parents before, but...
   2. Transfer \$0 to your elderly parent if she didn't help her parents before.
2. The essense of this intergenerational norm is that:
   1. a person has an obligation to take care of a parent, **unless** that parent was negligent with respect to his or her parent, in which case neglect is the punishment.

Taking care of elderly parents

1. If I cooperate (sticking to this intergenerational norm) my payoffs are

$$866 + \delta 500$$

   1. where 866 is my utility after transfering \$25 to my elderly parents, i.e., utility from \$100-\$25=\$75 ($100 \cdot \sqrt{75} = 866$),
   2. and 500 is the utility from the \$25 that my children will give me tomorrow (when I become an elderly, $100 \cdot \sqrt{25} = 500$).

2. If, in contrast, I deviate (making no transfers to my elderly parents today), my payoffs are

$$1,000 + \delta 0$$

   1. where $1,000$ is the utility from keeping all my income (\$100) without making any transfer ($100 \cdot \sqrt{100} = 1000$), and
   2. and 0 represents that I won't be receiving any transfer from my children (since my kids observe I was negligent with their grandpa).

Taking care of elderly parents

1. Comparing these payoffs, cooperation can be sustained in the SPNE if

$$866 + \delta 500 \geq 1,000 + \delta 0$$

and solving for δ, we obtain

$$\delta \geq \frac{134}{500} = 0.268$$

Taking care of elderly parents

Conclusions:

1. When there is no inheritance to act as a lure, the elderly parent cannot punish the adult for failing to take care of him.
2. In this context, the disciplining device lies not with the elderly parent, but with her grandchild!
3. Elderly parents are taken care of "even by the selfish child," since otherwise they will be punished by their own children later on.

Cooperation in large populations

1. Let us now move to the second question in this chapter:
   1. How to support cooperation when players interact only once?
   2. *Example*: eBay
2. Buyers and sellers have incentives to be fraudulent since they will rarely meet again.
3. How to promote cooperation in this setting?
   1. Feedback system.

eBay

1. Let's start with a description of the game.
2. Consider a seller who can sell three types of goods

True Quality	Seller's Cost	Buyer's Value
Excellent	13	30
Very good	8	15
Shoddy	2	0

   at only three possible prices: \$5, \$10 and \$20.
3. Before clicking on "Buy It Now" the buyer observes the price and the seller's feedback score.
4. If the buyer chooses not to buy, his payoff is zero.

eBay

1. If the buyer buys the product, payoffs are

True Quality	Price	Seller's Cost	Seller's Payoff	Buyer's Value	Buyer's Payoff
Excellent	20	13	7	30	10
Excellent	10	13	−3	30	20
Excellent	5	13	−8	30	25
Very good	20	8	12	15	−5
Very good	10	8	2	15	5
Very good	5	8	−3	15	10
Shoddy	20	2	18	0	−20
Shoddy	10	2	8	0	−10
Shoddy	5	2	3	0	−5

2. **Example:** a good of excellent quality sold at a price of $20, provides a net payoff of 20-13=7 to the seller, and a net payoff of 30-20=10 to the buyer.

eBay

1. There are an infinite number of periods, but a particular buyer and seller meet only once.
2. Consider the following strategy:
3. **Seller:**
    1. If I don't have negative comments, then choose *Excellent* quality and charge a price of $20.
    2. If I have one negative comment, then choose *Very good* quality and charge a price of $10.
    3. If I have two or more negative comments, then choose *Shoddy* quality and charge a price of $5.

eBay

1. **Buyer's buying strategy:**
   1. If the seller doesn't have negative comments, then Buy.
   2. If the seller has one negative comment, then Buy only if the price is 10 or lower.
   3. If the seller has two or more negative comments, then Don't buy.
2. **Buyer's feedback strategy (in case she buys):**
   1. Provide positive feedback if:
      1. the quality of the product was Excellent, or
      2. the quality of the product was Very good and its price was 10 or lower.
   2. Provide negative feedback if:
      1. the quality of the product was Very good but the price was $20, or
      2. the quality of the product was Shoddy.

eBay

1. Given the above strategy, the buyer expects:
    1. Excellent quality from a seller with **no** negative comments,
    2. Very good quality from a seller with **only one** negative comment, and
    3. Shoddy quality from a seller with **two or more** negative comments.
2. Let's start checking that this strategy is optimal for the buyer, then we will move to the seller.

eBay

1. **Checking the Buyer's buying strategy:**
   1. If the seller has no negative feedback, then the buyer expects the good to be of Excellent quality, and
   2. therefore buys regardless of price (see table).

True Quality	Price	Seller's Cost	Seller's Payoff	Buyer's Value	Buyer's Payoff
Excellent	20	13	7	30	10
Excellent	10	13	−3	30	20
Excellent	5	13	−8	30	25
Very good	20	8	12	15	−5
Very good	10	8	2	15	5
Very good	5	8	−3	15	10
Shoddy	20	2	18	0	−20
Shoddy	10	2	8	0	−10
Shoddy	5	2	3	0	−5

eBay

1. **Checking the Buyer's buying strategy:**
   1. If the seller has only one negative comment, then the buyer expects the good to be of Very good quality, and
   2. he should buy only if the price is $10 or lower (see table).

True Quality	Price	Seller's Cost	Seller's Payoff	Buyer's Value	Buyer's Payoff
Excellent	20	13	7	30	10
Excellent	10	13	−3	30	20
Excellent	5	13	−8	30	25
Very good	20	8	12	15	−5
Very good	10	8	2	15	5
Very good	5	8	−3	15	10
Shoddy	20	2	18	0	−20
Shoddy	10	2	8	0	−10
Shoddy	5	2	3	0	−5

1. **Checking the Buyer's buying strategy:**
   1. If the seller has two or more negative comments, the buyer expects the good to be of Shoddy quality (zero value), and
   2. he does not buy, regardless of the price (see table).

True Quality	Price	Seller's Cost	Seller's Payoff	Buyer's Value	Buyer's Payoff
Excellent	20	13	7	30	10
Excellent	10	13	−3	30	20
Excellent	5	13	−8	30	25
Very good	20	8	12	15	−5
Very good	10	8	2	15	5
Very good	5	8	−3	15	10
Shoddy	20	2	18	0	−20
Shoddy	10	2	8	0	−10
Shoddy	5	2	3	0	−5

1. **Checking the Buyer's feedback strategy:**
    1. Since providing feedback is assumed to be costless...
    2. it is optimal for the buyer to provide truthful feedback.
    3. (We will comment on this later on).

eBay

1. **Checking the Seller's strategy:**
   1. When the seller has **two or more negative comments**, he can anticipate that the buyer:
      1. will infer that the good is of Shoddy quality, and hence won't buy, redardless of the quality the seller reports and regardless of his pricing strategy.
      2. Then offering Shoddy quality (as prescribed) is as good as offering any other type, since the seller won't be able to sell any unit.

eBay

1. **Checking the Seller's strategy:**
   1. When the seller has **one negative comment**, the buyer anticipates him to offer Very good quality.
      1. If he offers this quality at an equilibrium price of \$10, his profit is \$2 (see table), entailing a positive comment from this buyer.
      2. In this case, he can anticipate earning a profit stream of 2, i.e., $\frac{2}{1-\delta}$.
      3. By instead charging a price of \$5, he still makes the sale but obtaining lower profits.
      4. By instead charging a price of \$20, he doesn't make the sale and gets zero profit. (Neither option is interesting)

1. **Checking the Seller's strategy:**
   1. When the seller has one negative comment (continues):

True Quality	Price	Seller's Cost	Seller's Payoff	Buyer's Value	Buyer's Payoff
Excellent	20	13	7	30	10
Excellent	10	13	−3	30	20
Excellent	5	13	−8	30	25
Very good	20	8	12	15	−5
Very good	10	8	2	15	5
Very good	5	8	−3	15	10
Shoddy	20	2	18	0	−20
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eBay

1. **Checking the Seller's strategy:**
   1. When the seller has one negative comment (continues):
      1. The only interesting deviation is to offering Shoddy quality at a price of $10.
      2. This raises his profit today to $8 (see table), but...
      3. at the expense of increasing the number of negative comments to two, yielding no sales thereafter.
      4. Hence, this seller is willing to act as prescribed if

$$\frac{2}{1-\delta} \geq 8 \Longleftrightarrow \delta \geq \frac{3}{4}$$

1. **Checking the Seller's strategy:**
   1. When the seller has one negative comment (continues):

True Quality	Price	Seller's Cost	Seller's Payoff	Buyer's Value	Buyer's Payoff
Excellent	20	13	7	30	10
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Shoddy	20	2	18	0	−20
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Shoddy	5	2	3	0	−5

eBay

1. **Checking the Seller's strategy:**
   1. Let us now examine the seller with **no negative comments**:
      1. Equilibrium prescribes him offering Excellent quality at a price of \$20, yielding a profit of 7 today.
      2. Good reputation is maintained, yielding a stream of \$7 profits thereafter, i.e., $\frac{7}{1-\delta}$.
      3. The best deviation is to a Shoddy quality, with profits of 18 (since both Shoddy and Very good trigger a negative comment from the current customer).
      4. Such negative comment makes the seller move to a situation similar to that analyzed above (with one negative comment) with payoffs $\frac{2}{1-\delta}$.
      5. Hence, he behaves as prescribed if

$$\frac{7}{1-\delta} \geq 18 + \delta \frac{2}{1-\delta} \iff \delta \geq \frac{11}{16}$$

eBay

1. **Checking the Seller's strategy:**
   1. When the seller has one negative comment (continues):

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Excellent	20	13	7	30	10
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eBay

1. Hence, this strategy profile is an equilibrium if both $\delta \geq \frac{3}{4} = 0.75$ and $\delta \geq \frac{11}{16} \simeq 0.68$ hold.
2. But since $\delta \geq \frac{3}{4} = 0.75$ is more restrictive than $\delta \geq \frac{11}{16} \simeq 0.68$ ...
    1. we can simply say that this strategy profile can be sustained in the SPNE of the game if $\delta \geq \frac{3}{4}$.
3. **Intuition:**
    1. The feedback score allows the population of buyers to have a "collective memory" so that any of them can learn how a seller behaved in past transactions.
    2. The punishment to the seller for misbehaving is therefore provided by future buyers.
    3. It is the prospect of those future sales that deters a seller from cheating buyers.