

# 経済学科の学生はクールノー均衡を選ぶか？

— コロラド大学ボルダー校での予備実験結果 —

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## 1 はじめに

寡占経済学においてよく用いられるクールノー・モデルの説明力を確認するために実験経済的アプローチを行うための予備実験を行った。1999年1月19日(火)<sup>1</sup>コロラド大学ボルダー校のシャオ (Frank Hsiao) 教授の協力により、同校経済学部専門科目 ECON4838<sup>2</sup>の時間に実行し、以下のデータを手に入れた<sup>3</sup>。

科目履修生は7人おり、3,4年生<sup>4</sup>の男子学生である。

なお、利用した教室には、Windows95搭載のDOS/Vコンピュータが20台あり、ひとりで1台利用可能な状態である。

## 2 手続きと結果

### Step 1:

当日の受講生7人に寡占経済学でよく用いられる、クールノー・モデルの利得表 Tables 1 & 2 および利潤曲面のグラフ2枚を印刷した資料<sup>5</sup>を配布し、利得表の内容について説明する。

それは、企業1の利潤を示す利得表と企業2の利潤を示す利得表である。それぞれの利潤は、2つの企業の生産量に依存している。これは、利潤曲面

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\*コロラド大学ボルダー校経済学部のシャオ教授には、常日頃お世話になっているが、ボルダー滞在中は、特に資料の作成、データの収集等に際し、多大の援助を得た。ここに記して感謝する。もちろん、ありうべき誤りは筆者の責任である。

なお、この論文をまとめるのに、平成10・11年度科学研究費基盤研究(C(2)) (課題番号10630001:鶴沢 秀(研究代表者)、若林信夫、船津秀樹、篠塚友一)「コンピュータ利用による経済学学習プログラムと実験経済学」の研究助成を受けている。記して感謝したい。

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URL: <http://www.res.otaru-uc.ac.jp/~uzawa/cal-ee.html>

<sup>1</sup>アメリカ現地時間

<sup>2</sup>この科目は、Microcomputer Applications in Economics (Tu & Th 9:30-10:45) である。

<sup>3</sup>紙幅の関係で、日本でのデータとの比較は別の機会に行う。

<sup>4</sup>シャオ教授からの情報による。アンケートによれば、subject # 3 のみが4年生と答えている。他の6人は未記入であった。

<sup>5</sup>付録に、MS Excel97 で作成した、利得表 Tables 1 & 2 および利潤曲面のグラフ (Cournot3Graph1line.xls) を ps ファイルに変換し、さらに、Adobe Acrobat Distiller を用いて、pdf ファイルにした cournot3graph1line.pdf を掲載した。

のグラフをみれば明らかになる。

最初の質問 は以下の内容である。

Please look at payoffs in Tables 1 and 2 you have already given.  
If you were the CEO of firm 1, and I were the CEO of firm 2, what amount of product do you want to produce?  
Please write the reason why do you want to produce it.

この質問に対して、受講者 7 人全員が 12 単位の生産量を選んだ。その理由とともに結果を以下にまとめておこう。

Subject	[1]Output	[1]Reason
# 1	12	Because that's the maximize output profit, if firm 2 doesn't.
# 2	12	The potential for max profits is 144.
# 3	12	The possible risk is equal to the possible returns.
# 4	12	because at that output, there is the highest possible profit of 144.
# 5	12	If firm 1 produces 12 units and firm 2 produces 0 units, I will maximize profits at 144. If firm 2 produces up to 12 units, firm 1 will at least break even.
# 6	12	It has the most potential for profit without much potential for loss.
# 7	12	I would choose 12 units of output because it yields the highest profit margin.

### Step 2:

私の WWW ページを指示し、<sup>6</sup> ファイル “Looking at the Cournot Equilibrium by using *MATHEMATICA*” (ファイル名 9901cournot.ppt) を download させる。全員、トラブルもなく download に成功する。これは、全員のコンピュータ・リテラシーを見るねらいもあった。学生は、このファイルに

<sup>6</sup>実施時の 1999 年 1 月時点では、<http://www.res.otaru-uc.ac.jp/~uzawa/cal-ee.html> であったが、2000 年 2 月現在では、<http://www.res.otaru-uc.ac.jp/~uzawa/cal-economics/cal-ee.html> に変更されている。

記載されているスライド 56 枚<sup>7</sup> を自分の目の前のコンピュータ画面でも、あるいは、OHP で拡大表示された画像でも見ることができる。

内容はクールノー・モデルにおける Cournot-Nash 均衡をグラフィックスを用いて詳しく説明したものである。なお、時間の制約を考慮して、クールノー均衡を *MATHEMATICA* のグラフィックスで説明するスライド 1-31 の部分のみを紹介した<sup>8</sup>。

### Step 3:

授業の最後に、再び、Tables 1 & 2 をよく見てもらい、以下のような Step 1 の質問と同じ質問をした。

**After you have my lecture, you are invited to answer some questionnaire. Please look again at payoffs in Tables 1 and 2. If you were the CEO of firm 1, and I were the CEO of firm 2, what amount of product do you want to produce? Please write the reason why do you want to produce it. If your decision would differ the previous one at the beginning of my lecture, please write down the reason, again.**

その結果、無回答者<sup>9</sup> の subject #1 を除いた 6 人は、8 単位の生産量を選ぶと答えた。実は、8 単位の生産量は、Step 2 で説明した Cournot-Nash 均衡になっている<sup>10</sup>。

その理由とともに結果を以下にまとめた。

<sup>7</sup>このスライドは、その内容を *MATHEMATICA* でまず作成し、html フォーマットで保存してできる説明と画像を MS PowerPoint97 を利用して作成したものである。参考のために、付録に、このスライドの内容を縮約した 2000cournot-slides2.doc[3,416KB] から作成した 2000cournot-slides2.pdf[262KB] を収録した。

<sup>8</sup>後半部分は、別の方法で、クールノー均衡の特徴を明らかにしている部分である。

<sup>9</sup>この学生は私的により申し出のないまま途中退席した。

<sup>10</sup>鶴沢 [6] を参照せよ。

Subject	[2]Output	[2]Reason
# 1	No answer	No answer
# 2	8	This is when both firms are max.
# 3	8	At the point, profit is maximized.
# 4	8	because 8 units is the Cournot Equilibrium. That is a move by either firm would be harmful.
# 5	8	I would expect firm 2 to produce 8 units maximizing profits with 64. Firm 2 will also have profits of 64.
# 6	8	After game theory, there could be no way for either party to gain any if they were to produce more or less of either good.
# 7	8	Following the table given both companies can expect to maximize their profits at 8 units a Cournot's equilibrium.

### 3 まとめ

コロラド大学ボルダー校の学生はクールノー・モデルを学ぶ前と後では生産量を同じように変えている。すなわち、Step 1 では、相手企業がゼロの生産量を選んだときに最適な生産量 12 単位を選んでいる。これに対して、講義を受けた後では、クールノー均衡の生産量 8 単位を選んでいる。

他方、私が試みた、日本の学生の場合は全員が同じ生産量を選ばない。この比較は別の機会に述べる。

## 参考文献

- [1] Bergstrom, Theodore C. and John H. Miller, *Experiments with Economic Principles*, The McGraw-Hill Companies, Inc., New York, 1997.
- [2] Davis, Douglas and Charles Holt, *Experimental Economics*, Princeton University Press, Princeton, N.J., 1993.
- [3] Kagel, John and Alvin Roth (eds.), *Handbook of Experimental Economics*, Princeton University Press, Princeton, N.J., 1995.
- [4] Wolfram, Stephen, The **MATHEMATICA** Book, 3rd ed., Wolfram Media/Cambridge University Press, 1996
- [5] Wolfram, Stephen, The **MATHEMATICA** Book, 4th ed., Wolfram Media/Cambridge University Press, 1999
- [6] 鶴沢 秀「数式処理システム Mathematica の応用とインターネットを利用した経済学学習について」『商学討究』（小樽商科大学）第 48 卷第 2・3 合併号（1998 年 1 月），pp.49-74.

付録 1

Profit for firm 1

		Firm 1's output																								
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Firm 2's output	24	0	-1	-4	-9	-16	-25	-36	-49	-64	-81	-100	-121	-144	-169	-196	-225	-256	-289	-324	-361	-400	-441	-484	-529	-576
	23	0	0	-2	-6	-12	-20	-30	-42	-56	-72	-90	-110	-132	-156	-182	-210	-240	-272	-306	-342	-380	-420	-462	-506	-552
	22	0	1	0	-3	-8	-15	-24	-35	-48	-63	-80	-99	-120	-143	-168	-195	-224	-255	-288	-323	-360	-399	-440	-483	-528
	21	0	2	2	0	-4	-10	-18	-28	-40	-54	-70	-88	-108	-130	-154	-180	-208	-238	-270	-304	-340	-378	-418	-460	-504
	20	0	3	4	3	0	-5	-12	-21	-32	-45	-60	-77	-96	-117	-140	-165	-192	-221	-252	-285	-320	-357	-396	-437	-480
	19	0	4	6	6	4	0	-6	-14	-24	-36	-50	-66	-84	-104	-126	-150	-176	-204	-234	-266	-300	-336	-374	-414	-456
	18	0	5	8	9	8	5	0	-7	-16	-27	-40	-55	-72	-91	-112	-135	-160	-187	-216	-247	-280	-315	-352	-391	-432
	17	0	6	10	12	12	10	6	0	-8	-18	-30	-44	-60	-78	-98	-120	-144	-170	-198	-228	-260	-294	-330	-368	-408
	16	0	7	12	15	16	15	12	7	0	-9	-20	-33	-48	-65	-84	-105	-128	-153	-180	-209	-240	-273	-308	-345	-384
	15	0	8	14	18	20	20	18	14	8	0	-10	-22	-36	-52	-70	-90	-112	-136	-162	-190	-220	-252	-286	-322	-360
	14	0	9	16	21	24	25	24	21	16	9	0	-11	-24	-39	-56	-75	-96	-119	-144	-171	-200	-231	-264	-299	-336
	13	0	10	18	24	28	30	30	28	24	18	10	0	-12	-26	-42	-60	-80	-102	-126	-152	-180	-210	-242	-276	-312
	12	0	11	20	27	32	35	36	35	32	27	20	11	0	-13	-28	-45	-64	-85	-108	-133	-160	-189	-220	-253	-288
	11	0	12	22	30	36	40	42	42	40	36	30	22	12	0	-14	-30	-48	-68	-90	-114	-140	-168	-198	-230	-264
	10	0	13	24	33	40	45	48	49	48	45	40	33	24	13	0	-15	-32	-51	-72	-95	-120	-147	-176	-207	-240
	9	0	14	26	36	44	50	54	56	56	54	50	44	36	26	14	0	-16	-34	-54	-76	-100	-126	-154	-184	-216
	8	0	15	28	39	48	55	60	63	64	63	60	55	48	39	28	15	0	-17	-36	-57	-80	-105	-132	-161	-192
	7	0	16	30	42	52	60	66	70	72	72	70	66	60	52	42	30	16	0	-18	-38	-60	-84	-110	-138	-168
	6	0	17	32	45	56	65	72	77	80	81	80	77	72	65	56	45	32	17	0	-19	-40	-63	-88	-115	-144
	5	0	18	34	48	60	70	78	84	88	90	90	88	84	78	70	60	48	34	18	0	-20	-42	-66	-92	-120
	4	0	19	36	51	64	75	84	91	96	99	100	99	96	91	84	75	64	51	36	19	0	-21	-44	-69	-96
	3	0	20	38	54	68	80	90	98	104	108	110	110	108	104	98	90	80	68	54	38	20	0	-22	-46	-72
	2	0	21	40	57	72	85	96	105	112	117	120	121	120	117	112	105	96	85	72	57	40	21	0	-23	-48
	1	0	22	42	60	76	90	102	112	120	126	130	132	132	130	126	120	112	102	90	76	60	42	22	0	-24
0	0	23	44	63	80	95	108	119	128	135	140	143	144	143	140	135	128	119	108	95	80	63	44	23	0	

How to show the above payoffs-matrix table for firm 1's profit?

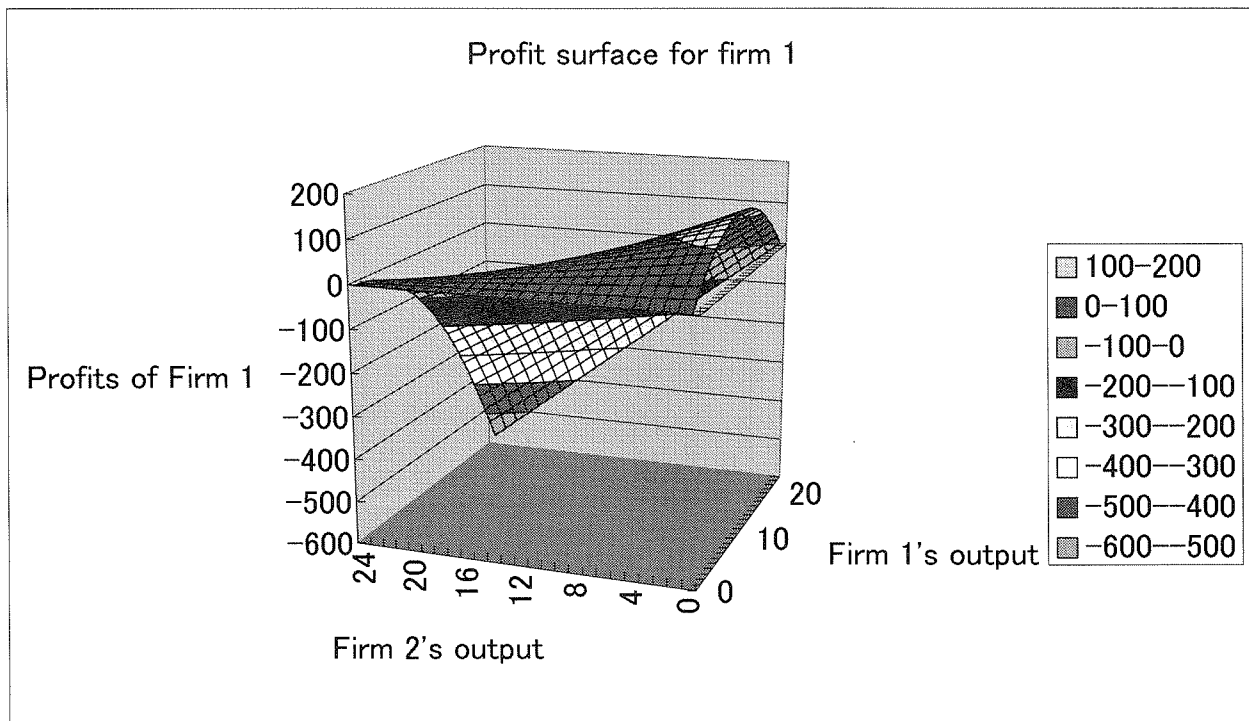
If your firm (firm 1) produces, say, 3 units of output and firm 2 produces, say, 10 units of output, then your firm (firm 1) gets 33 units of profit.

Profit for firm 2

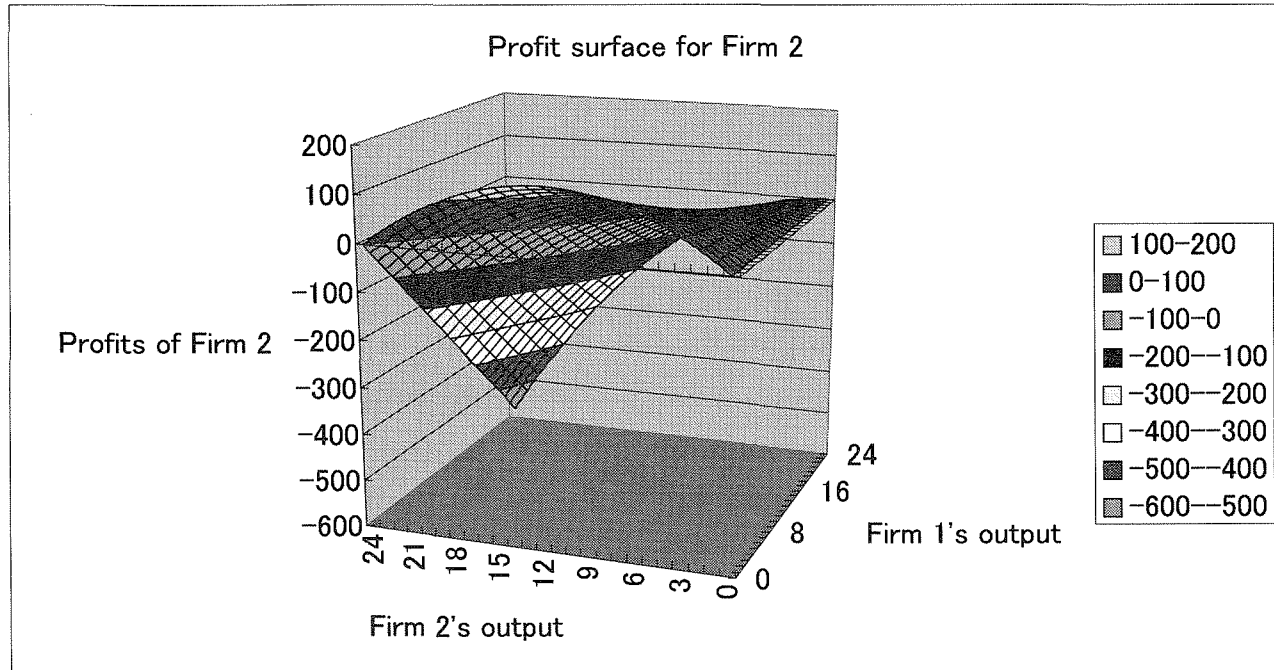
		Firm 1's output																								
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Firm 2's output	24	0	-24	-48	-72	-96	-120	-144	-168	-192	-216	-240	-264	-288	-312	-336	-360	-384	-408	-432	-456	-480	-504	-528	-552	-576
	23	23	0	-23	-46	-69	-92	-115	-138	-161	-184	-207	-230	-253	-276	-299	-322	-345	-368	-391	-414	-437	-460	-483	-506	-529
	22	44	22	0	-22	-44	-66	-88	-110	-132	-154	-176	-198	-220	-242	-264	-286	-308	-330	-352	-374	-396	-418	-440	-462	-484
	21	63	42	21	0	-21	-42	-63	-84	-105	-126	-147	-168	-189	-210	-231	-252	-273	-294	-315	-336	-357	-378	-399	-420	-441
	20	80	60	40	20	0	-20	-40	-60	-80	-100	-120	-140	-160	-180	-200	-220	-240	-260	-280	-300	-320	-340	-360	-380	-400
	19	95	76	57	38	19	0	-19	-38	-57	-76	-95	-114	-133	-152	-171	-190	-209	-228	-247	-266	-285	-304	-323	-342	-361
	18	108	90	72	54	36	18	0	-18	-36	-54	-72	-90	-108	-126	-144	-162	-180	-198	-216	-234	-252	-270	-288	-306	-324
	17	119	102	85	68	51	34	17	0	-17	-34	-51	-68	-85	-102	-119	-136	-153	-170	-187	-204	-221	-238	-255	-272	-289
	16	128	112	96	80	64	48	32	16	0	-16	-32	-48	-64	-80	-96	-112	-128	-144	-160	-176	-192	-208	-224	-240	-256
	15	135	120	105	90	75	60	45	30	15	0	-15	-30	-45	-60	-75	-90	-105	-120	-135	-150	-165	-180	-195	-210	-225
	14	140	126	112	98	84	70	56	42	28	14	0	-14	-28	-42	-56	-70	-84	-98	-112	-126	-140	-154	-168	-182	-196
	13	143	130	117	104	91	78	65	52	39	26	13	0	-13	-26	-39	-52	-65	-78	-91	-104	-117	-130	-143	-156	-169
	12	144	132	120	108	96	84	72	60	48	36	24	12	0	-12	-24	-36	-48	-60	-72	-84	-96	-108	-120	-132	-144
	11	143	132	121	110	99	88	77	66	55	44	33	22	11	0	-11	-22	-33	-44	-55	-66	-77	-88	-99	-110	-121
	10	140	130	120	110	100	90	80	70	60	50	40	30	20	10	0	-10	-20	-30	-40	-50	-60	-70	-80	-90	-100
	9	135	126	117	108	99	90	81	72	63	54	45	36	27	18	9	0	-9	-18	-27	-36	-45	-54	-63	-72	-81
	8	128	120	112	104	96	88	80	72	64	56	48	40	32	24	16	8	0	-8	-16	-24	-32	-40	-48	-56	-64
	7	119	112	105	98	91	84	77	70	63	56	49	42	35	28	21	14	7	0	-7	-14	-21	-28	-35	-42	-49
	6	108	102	96	90	84	78	72	66	60	54	48	42	36	30	24	18	12	6	0	-6	-12	-18	-24	-30	-36
	5	95	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25
	4	80	76	72	68	64	60	56	52	48	44	40	36	32	28	24	20	16	12	8	4	0	-4	-8	-12	-16
	3	63	60	57	54	51	48	45	42	39	36	33	30	27	24	21	18	15	12	9	6	3	0	-3	-6	-9
	2	44	42	40	38	36	34	32	30	28	26	24	22	20	18	16	14	12	10	8	6	4	2	0	-2	-4
	1	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	-1
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

How to show the above payoffs-matrix table for firm 2's profit?

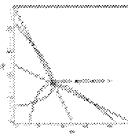
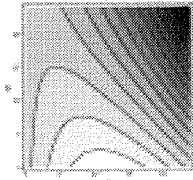
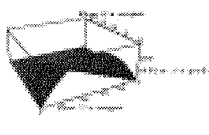

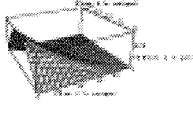
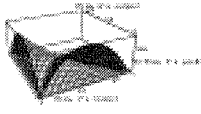
If your firm (firm 1) produces, say, 3 units of output and firm 2 produces, say, 10 units of output, then firm 2 gets 110 units of profit.

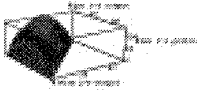

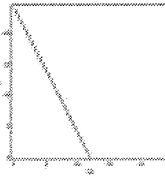




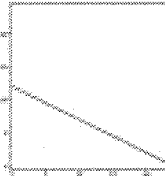









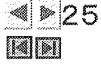








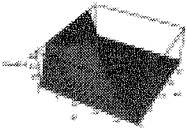






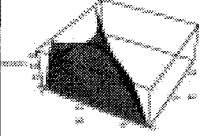
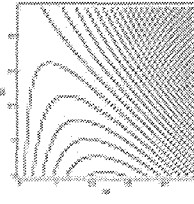
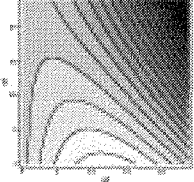
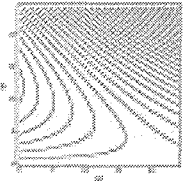
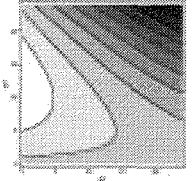


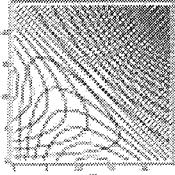
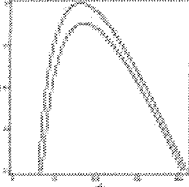
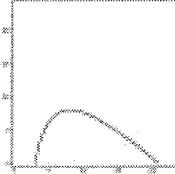
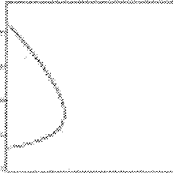
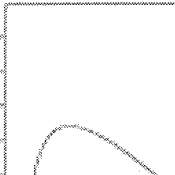
# 付録 2

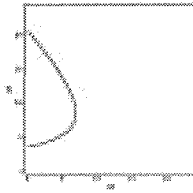
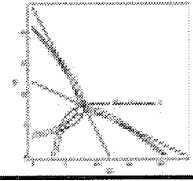
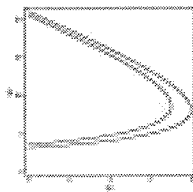
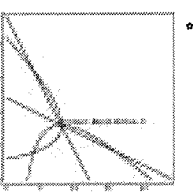
スライド 1	<p>Looking at the Cournot Equilibrium by using the fully integrated technical computing system MATHEMATICA</p> <p>Two reaction curves cross each other at one point, the Cournot Equilibrium. There is a lens-shaped area surrounded by two iso-profit curves through the Cournot Equilibrium. In this region, pairs of two firms' profits are larger than the pair of profits in Cournot Equilibrium.</p> 	スライド 6	<p>We get the firm 1's iso-profit curves.</p>  <ul style="list-style-type: none"> <li>The figure shows the firm 1's iso-profit curves.</li> <li>Please note that the more lighter color, the more profit of firm 1.</li> </ul>
スライド 2	<p>Cournot Duopoly Model</p> <p>Two firms produce the homogeneous good in the market. We call them firm 1 and firm 2, respectively. Let the cost function of firm 1 to be <math>c_1=q_1</math> and the cost function of firm 2 to be <math>c_2=q_2</math>, where we denote <math>q_1</math> and <math>q_2</math> as firm 1's output and firm 2's one, respectively. The demand curve for this good is <math>p=25-(q_1+q_2)</math>. The profit for firm 1(<math>\pi_1</math>) is <math>\pi_1=pq_1-c_1</math> and the profit for firm 2(<math>\pi_2</math>) is <math>\pi_2=pq_2-c_2</math>, by definition. Then we have the following:</p> <pre> pi1[1] = 25 q1 - q1^2 - q2^2 pi2[1] = 25 q2 - q1 q2 - q2^2 </pre>	スライド 7	<p>We can neglect firm 1's negative profits (in fact, we set them zero) because we are interested in the maximum profit for two firms. How to do for that?</p> <ul style="list-style-type: none"> <li>We may input the following manner in MATHEMATICA to get the desired results:</li> </ul> <pre> Plot[Table[Table[Plot[Evaluate[pi1[q1, q2]], {q1, 0, 25}], {q2, 0, 25}], {q1, 0, 25}], {q2, 0, 25}]; Plot[Table[Table[Plot[Evaluate[pi2[q1, q2]], {q1, 0, 25}], {q2, 0, 25}], {q1, 0, 25}], {q2, 0, 25}]; </pre>
スライド 3	<p>How to get the graph of Firm 1's profits?</p> <ul style="list-style-type: none"> <li>Please check the fact that firm 1's profit depends both firm 1's output and firm 2's one.</li> <li>If you see the graph of firm 1's profits, then you may input the following expression in Mathematica.</li> </ul> <pre> Profit1 = Profit[pi1[q1, q2], {q1, 0, 25}, {q2, 0, 25}]; Show[Plot[Profit1, {q1, 0, 25}], {q2, 0, 25}]; </pre>	スライド 8	<p>We get the modified graph of profits for firm 1.</p>  <ul style="list-style-type: none"> <li>We set zero for the negative profit for firm 1.</li> <li>The figure shows the modified graph of profits for firm 1.</li> </ul>
スライド 4	<p>We get the graph of firm 1's profits.</p>  <ul style="list-style-type: none"> <li>The figure shows the firm 1's profits in terms of firm 1's output and firm 2's one.</li> </ul>	スライド 9	<p>We also get the modified graph of profits for firm 2</p>  <ul style="list-style-type: none"> <li>We set zero for negative profit for firm 2.</li> <li>The figure shows the modified profits for firm 2.</li> </ul>
スライド 5	<p>We want to look at firm 1's profits from another point of view. How to do?</p> <ul style="list-style-type: none"> <li>We want to see the graph of firm 1's profits from another point of view, namely, the sliced graph at each profit levels. We call the locus of the sliced graph the "iso-profit curve".</li> <li>To get them, we may input the following manner in MATHEMATICA:</li> </ul> <pre> ContourPlot[Show[Profit1, {q1, 0, 25}], {q1, 0, 25}, Contours -&gt; 10]; </pre>	スライド 10	<p>Two modified graph of profits for both firms are set in together.</p>  <ul style="list-style-type: none"> <li>Two modified graphs of profits for both firms are set in together. This enable us to see the properties of both profit surfaces.</li> </ul>

スライド 11	<p>We want to see the set-in-together graph of two firm's profits from another view angle.</p>  <ul style="list-style-type: none"> <li>We can see the set-in-together graph in previous page from another view angle. The figure shows the graph of two firm's profits.</li> </ul> 	スライド 16	<p>Here is the graph of firm 1's reaction function (reaction curve).</p>  <ul style="list-style-type: none"> <li>The figure shows the graph of firm 1's reaction function (reaction curve). In this case, it is the straight line segment.</li> </ul> 
スライド 12	<p>We want to derive the reaction functions of two firms. How to do?</p> <ul style="list-style-type: none"> <li>Under given firm 2's output, firm 1 can find the output that maximizes her (or his) profit. We call this relationship as the firm 1's reaction function. We can get the firm 2's reaction function by same procedure.</li> <li>It is suffice to input the following to get the reaction function in MATHEMATICA:</li> </ul> <pre>FOC = {D[pai1, q1] == 0, D[pai2, q2] == 0} {24 - 2 q1 - q2 == 0, 24 - q1 - 2 q2 == 0}</pre> 	スライド 17	<p>How to display the firm 2's reaction function (reaction curve)?</p> <ul style="list-style-type: none"> <li>To display the graph of firm 2's reaction function (reaction curve), you may follow the same procedure in pages 14 and 15.</li> <li>You can see the graph of firm 2's reaction function (reaction curve).</li> </ul> <pre>GrReaction2=ContourPlot[ReactionFunction2, {q1,0,24},{q2,0,24}, Contours-&gt;{0}, ContourShading-&gt;False, FrameLabel-&gt;{q1,q2}]</pre> 
スライド 13	<p>How to get the firm 1's reaction function?</p> <ul style="list-style-type: none"> <li>In get the firm 1's reaction function, we solve the First Order Condition for profit maximization (FOC[[1]]) with respect to q1, then we get it:</li> <li><math>q1 = r1(q2) = (24 - q2) / 2</math></li> </ul> <pre>Reaction1 = Solve[FOC[[1]], q1][[1]]</pre> $\left\{ q1 \rightarrow \frac{24 - q2}{2} \right\}$ 	スライド 18	<p>Here is the graph of firm 2's reaction function (reaction curve).</p>  <ul style="list-style-type: none"> <li>The figure shows the graph of firm 2's reaction function (reaction curve). In this case, it is the straight line segment.</li> </ul> 
スライド 14	<p>How to get the firm 2's reaction function?</p> <ul style="list-style-type: none"> <li>To get the firm 2's reaction function, we solve the First Order Condition for profit maximization (FOC[[2]]) with respect to q2, then we get it:</li> <li><math>q2 = r2(q1) = (24 - q1) / 2</math></li> </ul> <pre>Reaction2 = Solve[FOC[[2]], q2][[1]]</pre> $\left\{ q2 \rightarrow \frac{24 - q1}{2} \right\}$ 	スライド 19	<p>How to show two reaction curves together and to write "Cournot Equilibrium C" at the cross point of two reaction curves?</p> <ul style="list-style-type: none"> <li>The cross point of two reaction curves is the Cournot Equilibrium. We want to do so by using graphical setting.</li> <li>In MATHEMATICA, you can only input the following manner:</li> </ul> <pre>TextCournot=Graphics[Text["Cournot Equilibrium C", {8+6,8+0.5}]] CournotNashEquilibrium=Show[GrReaction1,GrReaction2, TextCournot]</pre> 
スライド 15	<p>How to display the graph of firm 1's reaction function (reaction curve)?</p> <ul style="list-style-type: none"> <li>To display the graph of firm 1's reaction function (reaction curve), you may input the following manner in MATHEMATICA.</li> <li>You can see the firm 1's reaction curve in the next page.</li> </ul> <pre>GrReaction1=ContourPlot[ReactionFunction1, {q1,0,24},{q2,0,24}, Contours-&gt;{0}, ContourShading-&gt;False, FrameLabel-&gt;{q1,q2}]</pre> 	スライド 20	<p>Here is the graph of two reaction curves and message of "Cournot Equilibrium C" at the cross point.</p>  <ul style="list-style-type: none"> <li>The cross point of two reaction curves is the Cournot Equilibrium.</li> </ul> 

スライド 21	<p>How to Look at the Cournot Equilibrium from another point of view?</p> <ul style="list-style-type: none"> <li>The cross point of two reaction curves is the Cournot Equilibrium. The Cournot output for two firms is 8 and the Cournot profit for two firms is 64 (See pages 1 and 11).</li> <li>Now we want to show the modified graph of firm 1's profits sliced at profit level(64).</li> </ul> <pre>Profit1at64=Plot3D[pa1,{q1,0,24},{q2,0,24},   AxesLabel-&gt;{q1,q2,Profit},PlotRange-&gt;{0,64},   PlotPoints-&gt;48]</pre> 	スライド 26	<p>How to show the graph of firm 1's modified profits sliced at profit level(72)?</p> <ul style="list-style-type: none"> <li>To get the graph of firm 1's modified profits sliced at profit level(72), you may input the following manner in MATHEMATICA:</li> </ul> <pre>Profit1at72=Plot3D[pa1,{q1,0,24},{q2,0,24},   AxesLabel-&gt;{q1,q2,Profit},   PlotRange-&gt;{0,72},PlotPoints-&gt;48]</pre> 
スライド 22	<p>Here is the modified graph of firm 1's profits sliced at profit level(64).</p>  <ul style="list-style-type: none"> <li>The figure shows the modified graph of firm 1's profits sliced at profit level(64).</li> </ul> 	スライド 27	<p>Here is the the graph of firm 1's modified profits sliced at profit level(72).</p>  <ul style="list-style-type: none"> <li>The figure shows the graph of firm 1's modified profits sliced at profit level(72).</li> </ul> 
スライド 23	<p>How to get the graph of firm 2's profits sliced at the profit level(64)?</p> <ul style="list-style-type: none"> <li>In order to get the graph of firm 2's profits sliced at the profit level(64), you may input the following manner in MATHEMATICA:</li> </ul> <pre>Profit2at64=Plot3D[pa2,{q1,0,24},{q2,0,24},   AxesLabel-&gt;{q1,q2,Profit},   PlotRange-&gt;{0,64},PlotPoints-&gt;48]</pre> 	スライド 28	<p>How to show the graph of firm 2's modified profits sliced at profit level(72)?</p> <ul style="list-style-type: none"> <li>To get the graph of firm 2's modified profits sliced at profit level(72), you may input the following manner in MATHEMATICA:</li> </ul> <pre>Profit2at72=Plot3D[pa2,{q1,0,24},{q2,0,24},   AxesLabel-&gt;{q1,q2,Profit},   PlotRange-&gt;{0,72},PlotPoints-&gt;48]</pre> 
スライド 24	<p>Here is the graph of firm 2's profits sliced at the profit level(64).</p>  <ul style="list-style-type: none"> <li>The figure shows the graph of firm 2's profits sliced at profit level(64).</li> </ul> 	スライド 29	<p>Here is the graph of firm 2's modified profits sliced at profit level(72).</p>  <ul style="list-style-type: none"> <li>The figure shows the graph of firm 2's modified profits sliced at profit level(72).</li> </ul> 
スライド 25	<p>Here is the set-in-together graph of two modified profits sliced at profit level(64).</p>  <ul style="list-style-type: none"> <li>The figure shows the graph of two firms' modified profits sliced at profit level(64) set in together.</li> <li>Please note that there is a lens shaped region sliced at profit level(64). In this region, two firms have larger pair of profits than the pair of Cournot profits(64,64).</li> </ul> 	スライド 30	<p>How to show the set-in-together graph of two firms' modified profits sliced at profit level(72)?</p> <ul style="list-style-type: none"> <li>To show the set-in-together graph of two firms' modified profits sliced at profit level(72), you may input the following manner in MATHEMATICA:</li> </ul> <pre>ContourPlot3D[pa1+pa2,{q1,0,24},{q2,0,24},   AxesLabel-&gt;{q1,q2,Profit},   PlotRange-&gt;{0,72},PlotPoints-&gt;48]</pre> 

スライド 31	<p>Here is the set-in-together graph of two firms' modified profits sliced at profit level(72).</p>  <ul style="list-style-type: none"> <li>The figure shows the set-in-together graph of two firms' modified profits sliced at profit level(72).</li> <li>Please note that two iso-profit curves of 72 touched at tangentially each other at (6,6).</li> </ul>	スライド 36	<p>We want to show the iso-profit curves for firm 1 without grading colors.</p> <p>How to do?</p> <ul style="list-style-type: none"> <li>You may utilize the graph of iso-profit curves for firm 1 with grading colors. In MATHEMATICA, you can input the following:</li> </ul> <pre>Show[ContourPlot[Contour=ContourPlot[pa1,{q1,0,24},{q2,0,24}, Contours-&gt;20,PlotPoints-&gt;100,FrameLabel-&gt;{q1,q2}]]</pre>
スライド 32	<p>Now we want to show the firm 1's iso-profit curves. How to do ?</p> <ul style="list-style-type: none"> <li>The iso-profit curve of firm 1 at any profit level shows the set of pairs of two firms' output which provide the same profit level for firm 1.</li> <li>You may input as follows in MATHEMATICA:</li> </ul> <pre>Cournot1Contour=ContourPlot[pa1,{q1,0,24},{q2,0,24}, Contours-&gt;20,PlotPoints-&gt;100,FrameLabel-&gt;{q1,q2}]]</pre>	スライド 37	<p>Here is the the iso-profit curves for firm 1 without grading colors at 30 different profit levels.</p>  <ul style="list-style-type: none"> <li>The figure shows the iso-profit curves for firm 1 with grading colors at 30 different profit levels.</li> </ul>
スライド 33	<p>Here is the firm 1's iso-profit curves at different profit levels.</p>  <ul style="list-style-type: none"> <li>The iso-profit curve of firm 1 at any profit level shows the set of pairs of two firms' output which provide the same profit level for firm 1.</li> <li>Please check that the lower position the iso-profit curve, the larger profit for firm 1.</li> </ul>	スライド 38	<p>We want to show the iso-profit curves for firm 2 without grading colors.</p> <p>How to do?</p> <ul style="list-style-type: none"> <li>You may utilize the graph of iso-profit curves for firm 2 with grading colors. In MATHEMATICA, you can input the following:</li> </ul> <pre>Show[ContourPlot[Contour=ContourPlot[pa2,{q1,0,24},{q2,0,24}, Contours-&gt;20,PlotPoints-&gt;100,FrameLabel-&gt;{q1,q2}]]</pre>
スライド 34	<p>How to show the firm 2's iso-profit curves at different profit levels.</p> <ul style="list-style-type: none"> <li>The iso-profit curve of firm 2 at any profit level shows the set of pairs of two firms' output which provide the same profit level for firm 2.</li> <li>You may inpt the following manner in MATHEMATICA:</li> </ul> <pre>Cournot2Contour=ContourPlot[pa2,{q1,0,24},{q2,0,24}, Contours-&gt;20,PlotPoints-&gt;100,FrameLabel-&gt;{q1,q2}]]</pre>	スライド 39	<p>Here is the iso-profit curves for firm 2 without grading colors at 30 different profit levels.</p>  <ul style="list-style-type: none"> <li>The figure shows the the graph of iso-profit curves for firm 2 without grading colors at 30 different profit levels.</li> </ul>
スライド 35	<p>Here is the firm 2's iso-profit curves at different profit levels.</p>  <ul style="list-style-type: none"> <li>The iso-profit curve of firm 2 at any profit level shows the set of pairs of two firms' output which provide the same profit level for firm 2.</li> <li>Please check that the more at left position the iso-profit curve, the larger the profit for firm 2.</li> </ul>	スライド 40	<p>We want to see the graph of two iso-profit curves set in together.</p> <p>How to do?</p> <ul style="list-style-type: none"> <li>In MATHEMATICA, you may input the following manner:</li> </ul> <pre>Show[Gr1Cournot , Gr2Cournot ]</pre>

スライド 41	<p>Here is the set-in-together graph of two iso-profit curves.</p>  <ul style="list-style-type: none"> <li>The figure shows the set-in-together graph of two iso-profit curves.</li> </ul>	スライド 46	<p>We will show you the set-in-together two iso-profit curves for firm 1 at profit levels 64 and 72. How to do so?</p> <ul style="list-style-type: none"> <li>In MATHEMATICA, you may input the following manner:</li> </ul> <pre>ISO1Profit64=Show[ISO1Profit64, ISO1Profit72]</pre>
スライド 42	<p>We want to get the iso-profit curve for firm 1 through the Cournot Equilibrium. How to do?</p> <ul style="list-style-type: none"> <li>In MATHEMATICA, you can get the desired result if you may input the following manner:</li> </ul> <pre>ContourPlot[pai1,{q1,0,24},{q2,0,24},Contours-&gt;{64},ContourShading-&gt;False,PlotPoints-&gt;100,FrameLabel-&gt;{q1,q2}]</pre>	スライド 47	<p>Here is the set-in-together graph of two iso-profit curves for firm 1 at profit levels 64 and 72.</p>  <ul style="list-style-type: none"> <li>The figure shows the iso-profit curves for firm 1 at profit levels 64 and 72.</li> <li>The lower the iso-profit curve, the larger the profit level for firm 1.</li> </ul>
スライド 43	<p>Here is the iso-profit curve for firm 1 through the Cournot Equilibrium. The profit level is 64.</p>  <ul style="list-style-type: none"> <li>The figure shows the iso-profit curve for firm 1 through the Cournot Equilibrium.</li> </ul>	スライド 48	<p>We want to see the iso-profit curve for firm 2 through the Cournot Equilibrium. How to do?</p> <ul style="list-style-type: none"> <li>In MATHEMATICA, you may input the following manner to get the result.</li> </ul> <pre>ISO2Profit64=ContourPlot[pai2,{q1,0,24},{q2,0,24},Contours-&gt;{64},ContourShading-&gt;False,PlotPoints-&gt;100,FrameLabel-&gt;{q1,q2}]</pre>
スライド 44	<p>We want to see the iso-profit curve for firm 1 at profit level 72. How to do?</p> <ul style="list-style-type: none"> <li>In MATHEMATICA, you may input the following manner to get the result.</li> </ul> <pre>ISO1Profit72=ContourPlot[pai1,{q1,0,24},{q2,0,24},Contours-&gt;{72},ContourShading-&gt;False,PlotPoints-&gt;100,FrameLabel-&gt;{q1,q2}]</pre>	スライド 49	<p>Here is the graph of iso-profit curve for firm 2 through the Cournot Equilibrium. The profit level is 64.</p>  <ul style="list-style-type: none"> <li>The figure shows the iso-profit curve for firm 2 at profit level 64.</li> <li>It goes through the Cournot Equilibrium.</li> </ul>
スライド 45	<p>Here is the iso-profit curve for firm 1 at profit level 72.</p>  <ul style="list-style-type: none"> <li>The figure shows the iso-profit curve for firm 1 at profit level 72.</li> </ul>	スライド 50	<p>How to get the graph of iso-profit curve for firm 2 at profit level 72?</p> <ul style="list-style-type: none"> <li>In MATHEMATICA, you may input the following manner:</li> </ul> <pre>ISO2Profit72=ContourPlot[pai2,{q1,0,24},{q2,0,24},Contours-&gt;{72},ContourShading-&gt;False,PlotPoints-&gt;100,FrameLabel-&gt;{q1,q2}]</pre>

スライド 51	<p>Here is the graph of iso-profit curve for firm 2 at profit level 72.</p>  <ul style="list-style-type: none"> <li>The figure shows the iso-profit curve for firm 2 at profit level 72.</li> </ul>	スライド 56	<p>We want to see the pair of profits that dominates the pair of Cournot Equilibrium profits. How to do?</p> <ul style="list-style-type: none"> <li>In MATHEMATICA, you may input the following manner:</li> </ul> <pre>GrDominated=Show[CournotNashEquilibrium,ISO1Profit64,ISO2Profit64,ISO1Profit72,ISO2Profit72]</pre>
スライド 52	<p>We will show you the set-in-together two iso-profit curves for firm 2 at profit levels 64 and 72. How to do?</p> <ul style="list-style-type: none"> <li>In MATHEMATICA, you may input the following manner:</li> </ul> <pre>ISO1Profit64, ISO2Profit64, ISO1Profit72, ISO2Profit72</pre>	スライド 57	<p>Here is the graph of the pair of profits that dominates the pair of Cournot Equilibrium profits.</p> <p><b>The Cournot Equilibrium is not Pareto Efficient.</b></p>  <ul style="list-style-type: none"> <li>There is lens shaped region in which the pair of profits dominates the pair of Cournot Equilibrium profits.</li> <li>Two iso-profit curves at profit level 72 contact tangentially at (6,6) each other.</li> </ul>
スライド 53	<p>Here is the set-in-together graph of two iso-profit curve for firm 2 at profit levels 64 and 72.</p>  <ul style="list-style-type: none"> <li>The figure shows the iso-profit curves for firm 2 at profit levels 64 and 72.</li> <li>The more left position the iso-profit curve, the larger the profit level for firm 2.</li> </ul>	スライド 58	<p>How about this program? Did you enjoy it?</p> <p>End</p> <p>Masam Uzawa (Otari University of Commerce)</p> <p>E-mail: uzawa@res.otari-uc.ac.jp</p>
スライド 54	<p>We want to see the Cournot Equilibrium cum two reaction curves and two iso-profit curves through the Cournot Equilibrium. How to do?</p> <ul style="list-style-type: none"> <li>In MATHEMATICA, you may input the following manner:</li> </ul> <pre>Show[CournotEquilibrium,Reaction1,Reaction2,ISO1Profit64,ISO2Profit64]</pre>		
スライド 55	<p>Here is the graph of the Cournot Equilibrium cum two reaction curves and two iso-profit curves through the Cournot Equilibrium.</p>  <ul style="list-style-type: none"> <li>The figure shows the Cournot Equilibrium cum two reaction curves (in this case, two straight line segments) and two iso-profit curves through the Cournot Equilibrium.</li> </ul>		