Cycle ENM

Économie Industrielle

D.M.

Instructions :
Ce devoir est à réaliser en trinôme. Il devra être remis
en version imprimée au début de la séance prévue le **17 Novembre 2021**

N.B. : la date de remise est IMPERATIVE !

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Problem I : Demand, understanding an empirical study

Part 1 – open questions

1. What is the difference (conceptually) between the short run price and income elasticities of the demand for gasoline and the long run price and income elasticities of the demand for gasoline?
2. Why are measured long-run elasticities larger than measured short-run elasticities?

Part 2 – understanding empirical studies

The following questions review your hability to read and understand a multivariate regression analysis[1]. It requires you to answer questions related to the attached article (document #I) : Hughes, J., C. Knittel, and D. Sperling. "Evidence of a Shift in the Short-Run Price Elasticity of Gasoline Demand." Center for the Study of Energy Markets, Working Paper 159 (2006).

In section 2, the authors estimate the following demand equation:

$$\ln G_{jt} = \beta_0 + \beta_1 \ln P_{jt} + \beta_2 \ln Y_{jt} + \varepsilon_j + \varepsilon_{jt}$$

where G_{jt} is per capita gasoline consumption in gallons in month j and year t, P_{jt} is thee real retail price of gasoline in month j and year t, Y_{jt} is real per capita disposable income in month j and year t, ε_j represents unobserved demand factors that vary at the month level and ε_{jt} is a mean zero error term.

1. What have the authors assumed about the price elasticity of demand when they wrote down the demand equation in this form? Remember the price elasticity of demand $E_p = \frac{P}{G}\frac{\partial G}{\partial P}$.
2. Go to table 1 in the appendix, now assuming the authors have obtained unbiased estimates of the parameters β_0, β_1 and β_2 what do they mean? (eg. the coefficient β_1 is -0.335 in the period 1975-1980, this represents...)
3. Interpret the values of the monthly unobserved demand factors (ε_j)? What are these relative to? What can you say about the yearly pattern of gasoline demand from these coefficients?
4. From the information presented in this table calculate the appropriate t-statistics for each of the β's to test if it is different from 0. You will need the standard errors for each coefficient which are

[1] Some of you may find the Working Paper "An introduction to regression analysis" by A. Sykes (1993) is a useful reference. It can be downloaded on http://www.law.uchicago.edu/Lawecon/WkngPprs_01-25/20.Sykes.Regression.pdf

presented in brackets below the respective coefficient value in the table. For instance the standard error for the coefficient β_1 in the period 1975-1980 is 0.024.

5. What do the *** next to some of the entries in the table indicate? How are they related to the t-statistics you calculated?
6. The table presents the adjusted R-squared statistic for the two regressions. What does this number mean? If we calculated the unadjusted R-squared values, can we say whether these are larger or smaller than the adjusted R-squared values of 0.84 and 0.94 in this table?

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Problem II : competition and exhaustible resources, a simplified coal example

The goal of this problem is to study whether classic competition outcomes holds when the good is an exhaustible resource such as coal.

Preliminary question:
Can you propose some arguments to support the idea that the global coal market can reasonably be considered as competitive? (Don't forget to quote your sources)

An oversimplified perspective:
Suppose that only two periods of time: 1 and 2 (two year for example) are considered. Denote p_1 and p_2: the prices for coal in each period. Assume that the marginal extraction cost can be kept constant and equal to c. In the following, it will be assumed that all the suppliers will use a common interest rate: r %.

These first questions relates to a firm-level perspective:

1. All firms within the industry are supposed symmetric. As a consequence, we are first studying the decision of an individual firm denoted i, that owns a total coal reserve $\overline{Coal_i}$ and must decide an optimal extraction policy $\left(q_1^i, q_2^i\right)$. Write the objective function of this competitive coal supplier (its total profit for both periods) and the associated resource constraint. Using a standard optimization technique, write the first order conditions that are satisfied at the optimum (Kuhn and Tucker optimal conditions). In the special case where $c=0$, can you give a simple arbitrage condition that links p_2 as a function of p_1?
2. Here we are looking at an alternative reasoning : can you find a simple arbitrage condition that links r, the optimal marginal revenue obtained in period 1 and the optimal marginal revenue obtained in period 2? Is this result consistent with your answer to question (1)?

As firms are supposed to be symmetric, let's turn now to an industry level perspective:
Suppose now that there is a fixed amount of coal (Q) available that can be produced and consumed in period 1 (q_1) and/or period 2 (q_2). The demand function for coal in each period is the same and is given by

$$q_1 = 200 - p_1$$

$$q_2 = 200 - p_2$$

$$Q = q_1 + q_2$$

where p_1 and p_2 are the prices for coal in each period. The marginal extraction cost is assumed to be 0. Assume also that the industry behave "competitively" (without knowing how the demand elasticity can affect marginal revenue).

3. Calculate the equilibrium price and quantity in each period assuming that Q = 169, the interest rate used by coal suppliers is set at r %, and coal suppliers are price takers (behaves competitively). Give a numerical value of the equilibrium price and quantity in each period assuming that r = 10%. What is your opinion regarding those prices (please compare them to the classic pure and perfect competition outcomes when the good is a non exhaustible resource)?

4. Give a numerical value of the equilibrium price and quantity in each period assuming that r = 20%. What can be said about the influence of the interest rate?
5. Calculate the equilibrium price and quantity in each period assuming that $Q \geq 400$, the interest rate used by coal suppliers is 10% per year, and coal suppliers are price takers (behaves competitively). Same question with. Can you infer a key point regarding the relationship between the reserves and the price of an exhaustible commodity?
6. How would an increase in the interest rate to 20% in question #5 affect your answer and why?
7. Calculate the equilibrium price and quantity in each period assuming that Q = 169, there is a <u>monopoly</u> coal supplier that owns the entire resource, and the monopoly uses a discount (interest) rate of 10% per year.

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Problem III : Monopsony - an application to LNG imports in Japon

Japan began importing LNG from Alaska in 1969. From 1969 to 1986, Japan was the sole buyer of LNG in East of the Ormuz Strait (In 1986, South Korea began to import LNG). The goal of this problem is to provide a stylised analysis of the Pacific LNG market during that period.

On the supply side, LNG was produced in different countries by various companies (see Table 1).

<u>Table 1: List of LNG liquefaction Plants that supplied Japan during the 1969-1986 period (Source : Morikawa T. (2007))</u>

	Project (Train)	Start Up	Capacity (MT/y)	Investors: Gas Field	Investors: Liquefaction Plant	Exemple of LNG Contracts: Buyer (Quantity) Duration
USA	Kenai (Train 1, 2)	1969	1.3	ConocoPhilips(70), Marathon(30)		Tokyo Electric(0.92)
Brunei	Brunei LNG (Train 1-5)	1972 - 1974	7.2	Brunei Government(50), Shell(50)	Brunei Government(50), Shell(25), Mitsubishi(25)	Tokyo Electric(4.03): 1973-2013 Tokyo Gas(1.24): 1973-2013 Osaka Gas(0.74): 1973-2013
				Total(37.5), Shell(35), Jasra(22.5), Pg Jaya(5)		
Indonesia	Bontang I (Train A, B)	1977	5.2	VICO, Total, INPEX, Chevron Offshore - Mahakam Total(50), INPEX(50) - Attaka Unit Chevron(50), INPEX(50)	Pertamina(55), VICO(20), JILCO(15), Total(10）	Japanese utilities
	Bontang II (Train C, D)	1983	5.2			
	Arun I (Train 1)	1978	1.5	ExxonMobil(100)	Pertamina(55),. ExxonMobil(30), JILCO(15）	Japanese utilities
	Arun II (Train 4, 5)	1984	3.0			
Malaysia	Malaysia LNG I (Satu) (Train 1-3)	1983	8.1	Shell(50), Carigali(50)	Petronas(90), Sarawak Government(5), Mitsubishi(5)	Tokyo Electric Tokyo Gas
Abu Dhabi	ADGAS Train 1, 2)	1977	3.1	ADNOC(100)	ADNOC(70), Mitsui(15), BP(10),Total(5)	Tokyo Electric

On the demand side, several Japanese companies were involved in LNG importing activities. Those importers were the three largest gas companies (Tokyo Gas, Osaka Gas, and Toho), and large electric companies such as Tokyo Electric Power Company (Tepco) or Kansai Electric Power. The following features could help to understand the relationships between the Japanese gas and electricity firms:

a) The first oil crisis made the Japanese government understand the importance of a secure energy supply and the need for oil-alternative energy. Because of the country's fragile energy supply structure, the Ministry of International Trade and Industry (MITI) gave a high priority to its energy policy. As a result, both regulation and government intervention really shaped the Japanese energy business, especially in the gas and power industries. In fact, the MITI used its administrative prerogatives to constrain Japanese utilities behaviour. As both a utility regulator (who had the power to fix end-users tariffs) and an international trade coordinator, the MITI acted almost as a central planning agency. As a result, the MITI played a critical role in the negotiations of all LNG import contracts signed by Japanese companies[2].

b) Competition was inexistent among the regulated gas companies (in fact, their networks were not interconnected in most of their supply areas).

c) Gas companies and electric producers shared commons interests in LNG business[3]: Tokyo Gas had a close relationship with the Tokyo Electric Power Company (Tepco) to share LNG facilities. A fairly similar story existed with Osaka Gas and Kansai Electric Power.

Why a monopsony model?

1. Preliminary question: in this problem, we propose to model the 1983-1985 Pacific LNG market as a Japanese monopsony. What are the main arguments to support such a conjecture? What are the underlying hypotheses? Can you discuss in particular the fact that gas and electric utilities were regulated whereas traditional monopsony model assumes a competitive output market?

A very simple monopsony model

For the rest of the problem, we assume that electric production was the only one end-use of those LNG imports (in fact about 75% of Japan's LNG purchases go to produce electric power). Suppose that the regulators set the price of electricity at P_e and that you can sell all you want at that price (we are assuming a large electricity market with an absolute cost advantage for the gas technologies compared to other energy sources such as coal).

Denote:

- L the quantity of LNG imported by Japan (in Mcf)
- $E(L)$ the production function for electricity that gives the quantity of electricity produced (in kWh) as a function of the quantity of LNG (in Mcf)
- $P_L(L)$ the inverse supply function of LNG landed in Japan (based on the aggregate marginal cost curve for the competitive producers of LNG)[4]

Assume also that Japanese cost function $C(L)$ exhibits a zero marginal cost (that's a strong hypothesis) and that Japanese thermal power plant do not exhibit capacity constraints[5].

2. What is the objective function of a Japan in the LNG market?

3. Write the first order conditions for Japan's optimization problem. (Please give an interpretation in terms of marginal revenue product and marginal factor cost)

4. Compute the optimal Japanese policy (quantity of LNG bought, price paid) with the following hypotheses:

   - P_e = 0.11 \$/kWh,
   - Thermal efficiency for the whole Japanese chain that convert LNG energy into electricity (re-gasification, on-land transport and power plant) : 35% ,
   - Energy content of gas: we assume here that 1 Mcf of gas contain 296.6 kWh.
   - An LNG inverse supply function of $P_L(L) = 0.2 + 0.01L$

5. Compare this situation with a case where the MITI no longer bargains for the utilities so that utilities lose their monopsony power and must compete for natural gas (assume a perfect competition).

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[2] Namikawa R. (2003) « Take-or-Pay under Japanese energy policy », Energy Policy, 31 (2003) 1327–1337.

[3] Lam P.L. (2000) « The growth of Japan's LNG industry: lessons for China and Hong Kong », Energy Policy, 28 p. 327-333

[4] This cost function includes gas production cost, liquefaction and shipping to Japan.

[5] That's also a strong hypothesis. It can also be removed but this is not the goal of this small exercise.

6. What is your opinion regarding this oversimplified model? What kind of arguments can be proposed to mitigate the monopsony hypothesis?

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Problème IV : La tarification des demandes de pointe (peak load pricing)

Ce problème s'intéresse aux choix tarifaires d'une firme privée produisant des biens périssables (que nous définissons comme étant non stockables), confrontée à des demandes fluctuantes au cours du temps[6].

Nous nous intéressons ici au cas d'une firme placée en situation de monopole privé (un exemple parmi d'autres : la production d'électricité sur une île assurée par une unique centrale détenue par un opérateur privé).

Afin de simplifier l'analyse, on suppose que la firme fait face à deux types de demandes indépendantes notées 1 et 2 :

- la demande "hors-pointe" (off peak): $q_1 = D_1(p_1)$
- la demande "de pointe" (peak) : $q_2 = D_2(p_2)$.

Lorsque $p_1 = p_2 = p$, $D_1(p) < D_2(p)$ (d'où la dénomination pointe et hors pointe).

La fonction de coût de la firme intègre deux éléments : le coût de production et le coût d'investissement :

- pour l'investissement, on supposera que la capacité est adaptée, c'est-à-dire que cette capacité est exactement égale au maximum des quantités consommées sur chaque période (absence de surcapacité). Le coût marginal d'investissement dans une unité supplémentaire de capacité est supposé égal à γ.
- Concernant la production stricto sensu, le coût marginal de production est supposé constant au cours du temps et égal à c.

Situation 1 : la demande "hors-pointe" est strictement inférieure à la demande de "pointe"

Nous nous plaçons dans le cas où $\forall p_1, p_2 \in R^+$, $D_1(p_1) < D_2(p_2)$:

1. Donnez la fonction de profit du monopole.
2. Montrez que lorsque la demande hors-pointe reste « petite » par rapport à la demande de pointe, le monopole va choisir une politique tarifaire (ou un niveau de production) tel que le revenu marginal s'égalise respectivement à c et $c+\gamma$. Quelle est la condition de validité d'un tel résultat ?

Situation 2 : la demande "hors-pointe" est potentiellement supérieure à la demande de "pointe"

Nous nous plaçons dans le cas général où les fonctions de demande sont telles qu'il est possible de trouver au moins un couple de prix (p_1, p_2) tel que $D_1(p_1) > D_2(p_2)$. Dans une telle situation, il est clair que la capacité doit alors être dimensionnée sur la demande observée en période 1.

[6] Ce type de problème est fréquent dans des industries telles que le transport aérien, l'hôtellerie, la production d'électricité, le transport ferroviaire...

Par souci de simplicité, nous admettrons qu'une étude économétrique a permis d'estimer les élasticités-prix $\left(\left|\varepsilon_i\right|\right)_{i=1,2}$ (où $\varepsilon_i = \frac{p_i}{D_i\left(p_i\right)} \frac{dD_i\left(p_i\right)}{dp_i} < 0$, *i=1,2*) de ces deux demandes. Supposons que chacune de ces deux fonctions de demandes présente une élasticité prix-constante : $D_i\left(p_i\right) = k_i . p_i^{-\left|\varepsilon_i\right|}$ où $\left(k_i\right)_{i=1,2}$ sont deux constantes. Dans la suite de ce problème, nous allons supposer que <u>l'entreprise souhaite conserver un dimensionnement de son installation calé sur la demande de pointe</u>.

3. Quel est l'objectif de l'entreprise ? A quelle contrainte se trouve t'elle confrontée ? Donnez l'expression mathématique de ce programme d'optimisation[7].
4. En utilisant les conditions d'optimalité de Kuhn et Tucker, pouvez-vous mettre en évidence une relation qui lie la politique tarifaire optimale $\left(p_1^*, p_2^*\right)$ aux paramètres du problèmes : c, γ, $\left(\left|\varepsilon_i\right|\right)_{i=1,2}$.

Nous supposons désormais que les deux fonctions de demande ont la même élasticité prix : $\varepsilon_1 = \varepsilon_2 = \varepsilon$. L'objectif est de calculer les prix optimaux.

5. Partant d'une expression de p_1^* en fonction de p_2^*, c, γ et ε ; déduisez l'expression de la politique tarifaire optimale aux heures de pointe p_2^* en fonction de c, γ, $\left(k_i\right)_{i=1,2}$ et ε. Déduisez-en le tarif p_1^* pratiqué en dehors des heures de pointe ?
6. Interprétation économique : discutez brièvement les leçons susceptibles d'être tirées de ce raisonnement pour des industries telles que l'hôtellerie ou le transport aérien.

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[7] Notons, qu'une formulation en quantité sera ensuite plus aisée à manipuler. Quel que soit votre choix (prix ou quantités), merci de respecter les formulations standards...

Problem VI: Getting confidence in market equilibriums – an agent-based perspective

The aim of this work is to compare the classic Cournot oligopoly equilibrium (computed with optimality first order conditions) with results obtained with a simple iterative process during which market players are progressively discovering their optimal strategies.

We are studying a stylized industry where marginal cost of production is supposed to be constant and equal to zero. The market demand is well described by the inverse demand function: P(Q)=600 – Q.

Case 1 : traditional Cournot equilibriums

1. Compute the market equilibrium (price and quantity sold by each firm) when the market is served by: a) a monopoly; b) a symmetric duopoly and c) a symmetric triopoly.

Case 2 : Roth & Erev, a Reinforcement learning process

The goal of this problem is to build a Cournot one-sided auction. It is based on a set of stylised agent-based simulations with computational learning based on the Roth and Erev (1995) algorithm. This market will be simulated for several hundred periods until it reaches a stationary state. This exercise will be repeated many times for different market concentration (monopoly, duopoly and triopoly) before results will be compared to the traditional Cournot equilibriums.

We are assuming that producers are involved in a Cournot one-sided auction. In this kind of auction, each individual firm freely select its output (quantity). All the firms are then offering (simultaneously) their quantities to the market. A clearing process is then applied to compute a uniform price (price is the same for all the market participants) given all those submitted quantities. Taking this price information, market players can compute their profits and are allowed to adjust their output decision. Firms can then submit a new quantity to the market (simultaneously). A market clearing is then organized and so on (this iterative process is repeated)...

Market rules

We are studying an oligopoly wholesale commodity market linking a total of *n* "producers"[8] (i.e. wholesaler sellers), and an inverse demand function: P(Q)=600 – Q where $Q = q_1+...+q_i+...+q_n$ where *i* name player *i*. All players are homogeneous (cost = 0).

The simulations consist of supply bidding made by each individual producer. Each bid represents the quantity that will be produced by the firm who selected it. At each iteration, firms can freely selects a bid (also named a supply strategy) that is bounded between zero excluded, and a maximum capacity: K = 5×integer_part(120/*n*). In this framework, all the firms have identical capacities so that K will be the same for all the market players.

To simplify, let us suppose that for each individual firm, the set of allowable bids is discrete and can easily be indexed by an integer number *s*=*1, . . ., S* bounded between 1 and *S*=integer_part(120/n) so that bids can only take discrete values such as 5-units increments: 5, 10, ..., K-5, K with K= 5×*S*. Thus, players choose their supply strategies (supply quantity) from the set of *S* values described in Table 2.

Table 2: correspondence between index value and the supplied quantity

Bid index *s*	Quantity produced q_i
1	5
...	...
s	5.*s*
...	...
S = integer_part(120/n)	K =5×integer_part(120/n)

[8] In case of a Monopoly, n=1; in case of a duopoly, n=2 and n=3 in case of a triopoly...

Behavioural rules

The way market participant are updating their previous bid is called a behavioural assumption. In this case, we are focussing on a simple method called "**reinforcement learning**". At the beginning of every period the agents choose quantity strategies, and at the end of it they try to learn how to improve their bidding behaviour.

We are building a framework where each firm selects randomly a supply strategy in the discrete set, indexed by *s*. At the beginning of the simulation process (time t=1), all the strategies have a uniform initial probability to be played. In every period (time indexed as t), the interactions follows this pseudo-code:

> (1) Each Producer *i* selects **randomly** and independently a bid index. This corresponds to a bid: a quantity $q_i(t)$ proposed to the market in the period *t.*
>
> (2) All the bids are submitted to the market. The market clears, determining the uniform market price p(t) ;
>
> (3) Producers calculate their profits (for producer *i* : $\Pi_i(t) = p(t).q_i(t)$) ;
>
> (4) Producers reinforce strategies (which means: re-calculate the probabilities of playing each of them) in the next period;
>
> (5) Back to (1) and time t = t + 1.

We now describe in detail how a player can "reinforce" its strategies. To do so, we rely on the concept of propensity which is related to that of probability. Each producer *i* plays each possible action *s*=1, ..., *S* with a given "propensity", $r_s^i(t)$. The probability $p_s^i(t)$ that *i* plays *s* is given by its propensity divided by the sum of the propensities of all possible actions:

$$p_s^i(t) = \frac{r_s^i(t)}{\sum_{s=1}^{S} r_s^i(t)} .$$

The algorithm actualises the propensities assigned to each quantity strategy $r_s^i(t)$ and increases the probability of those that yield better results. We now describe how the propensity of each strategy at *t* + 1 is established as a function of $\Pi_i(t)$. Propensities are initialised to a given value (i.e. $r_s^i(1) = constant$ for all *s*), so that all actions have the same initial probability. At the end of each round, producers update their propensities according to the results obtained by the actions played using a version of the R&E reinforcement rule. This rule follows these steps:

i. Namely, traders reinforce the selected action, λ, through an increase in its propensity by $\Pi_i(t)$. Therefore, chosen strategies resulting in a positive payoff are reinforced to some extent, and there is a strong incentive for firms to trade. Those that do not place firms "in the money" will not be reinforced.

ii. Moreover, actions that are similar (i.e. $\lambda-1$ and $\lambda + 1$), are also reinforced, but to a lesser extent, through an increase in their propensity by $(1-\delta).\Pi_i(t)$ where $0 < \delta < 1$ ("persistent local experimentation").

iii. Independent of trading performance, the importance of past experience is reduced by discounting all propensities by γ ("gradual forgetting").

iv. Finally, actions whose probability falls below a certain threshold are removed from the choice space ("μ, extinction in finite time").

The propensities are computed in two steps. First, the pre-extinction propensities $r_s^i(t)'$ are:

$$r_s^i(t)' = \begin{cases} (1-\gamma) r_s^i(t)(t-1) + \Pi_i(t) & \text{if } s = \lambda, \\ (1-\gamma) r_s^i(t-1) + (1-\delta)\Pi_i(t) & \text{if } s = \lambda - 1 \text{ or } s = \lambda + 1, \\ (1-\gamma) r_s^i(t-1) & \text{if } s \neq \lambda - 1,\ s \neq \lambda \text{ and } s \neq \lambda + 1. \end{cases}$$

Second[9], the propensities are corrected when the "extinction in finite time" feature is binding:

$$r_s^i(t) = r_s^i(t)' I_{\left\{ (r_s^i(t)') / \left(\sum_{s=1}^{Si} r_s^i(t)' \right) > \mu \right\}}$$

where I is an indicator function that takes value 1 if the condition is satisfied and 0 otherwise. The algorithm is used analogously on the buyers' side with the corresponding indices.

The probabilities are then determined for each agent with: $p_s^i(t) = \dfrac{r_s^i(t)}{\sum_{s=1}^{S} r_s^i(t)}$

__Building a Matlab framework and running simulations__

The aim of this part is to build a useful toolbox that will be intensively used to run several simulations. This will be realised on the Matlab platform (available on the IFP School network. To access Matlab on the Intranet, use login **Ext14** and password **Ext114** and then with the explorer open P:\Logiciels_IS\Matlab).

__Note : MATLAB__
MATLAB is a language for technical computing. Information about MATLAB can be obtained at the MathWorks Website. An extensive list of Online MATLAB Resources has also been compiled by Jerod Parker of George Mason University (http://bass.gmu.edu/matlab/matlab.html). A series of MATLAB Tutorials prepared by members of the Department of Mathematics at Southern Illinois University at Carbondale are also available online (http://www.math.siu.edu/matlab/tutorials.html). You can obtain a license by contacting the SMILE team at IFP School.

VERY IMPORTANT: This is just a suggestion. Feel free to use Python or alternative environment if you feel ill at ease with Matlab.

All of the following questions imply the development of a clear and well commented procedure. Of course, students are also invited to furnish a separate answer sheet where the main part of the algorithm is written in pseudo code.

2. Write your own code to simulate an iterative Cournot one-sided auction with R&E reinforcement learning process with parameters : γ, δ, μ. Does it converge to a stationary outcome in a reasonable computational time?

Cournot equilibrium vs simulation outcomes: a comparison

Three different market structures will be scrutinized (a monopoly, a duopoly and an oligopoly case). Each of the three cases will be simulated. All the simulations will be done with the following set of parameters: initial propensities set equal to 90000, δ = 0.3, μ= 0.002 and γ=0.01).

3. For each of the three market structures, plot the market price p(t) as a function of time for t=1 to t= 2000. Please give a short comment regarding a possible convergence to stationary outcomes?

[9] When λ=1 or λ=S, there is only one neighbouring strategy. If that is the case, the experimentation parameter is applied only to s = λ+1=1 or s = λ−1 = S−1, respectively.

To get confidence in the results of this random mechanism, each of the three market structure case will be simulated 50 times (all those 50 simulations will be realised with the following set of parameters[10]: initial propensities set equal to 90000, $\delta = 0.3$, $\mu = 0.002$ and $\gamma = 0.01$).

The number of observations (simulation runs) for each market structure assumption will be 50, with 2000 trading periods in each run. As a result, a total of 3×20×2000 = 120 000 markets clearings will be computed.

The simulations should normally converge to stationary outcomes in approximately 1000 periods. Our attention will focus on the price average for periods [1001, 2000] in each run.

As a result, those 20 experiments per crossholding will give us a sample of 20 equilibrium prices. This sample will be analysed using basic statistical techniques (both the mean and the unbiased estimator of standard deviation will be computed).

4. Display your own simulation results as in Table 2.

Table 2: Simulation results

Market structure	Results Price average for periods [1000, 2000] in run number *r* $\overline{P}_r = \frac{1}{200}\sum_{t=301}^{500} P_r(t)$			Interpretation	
	Run #1 $\overline{P}_1$	...	Run #20 $\overline{P}_{20}$	Mean estimation for a given market structure $Price = \sum_{r=1}^{20} \overline{P}_r$	Unbiased estimation of standard deviation $\sigma = \sqrt{\frac{1}{19}\sum_{r=1}^{20}\left(\overline{P}_r - Price\right)^2}$
Monopoly n=1					
Duopoly n=2					
Triopoly n=3					

Note: Special Matlab functions such as xlswrite and xlsread could be useful to save Matlab results in a .dat format (those kind of format can be used with MSExcel).

5. Compare those results with those computed in Part 1. What can you conclude?
6. You have just built an "agent-based simulation" experiment. What do you think about the "cleverness" of those agents? How do you qualify their learning mechanism (compared to the one classically exhibited by real human confronted to the same problem)? Can this kind of experiment bring confidence in the use of classic equilibriums concepts based on optimization conditions (in this case: a Monopoly and a Cournot oligopoly)?

[10] As quantities are randomly selected, note that these 20 runs can possibly converge to different stationary outcomes.