NTNU
Department of Industrial Economics and Technology Management
Spring 2021

TIØ4285 Production and Network Economics

Deliverable 4

This deliverable counts for 70% of the final grade. Please note that there will not be an individual score for this deliverable.

Out: Monday, 26 April
In: Monday, 10 May 6pm

Late answers are not accepted.

General Advice

- You can work together in groups of up to 3 students. Collaboration between groups is not allowed and considered cheating.
- Please read the questions carefully and answer to what is asked. Keep you answer short (but as long as necessary) and concise.
- Base your answers on the contents taught in this course (or previous courses).
- If you make any assumptions that are necessary to reproduce your results, make sure you mention them in your report.
- Document how you find your results. You have to provide either calculations or sound logical reasoning.
- Any models and/or programs you implement as part of your answer have to be uploaded to Blackboard (providing log files is not sufficient). If you upload more than 1 file to Blackboard, please upload a single zip-file containing all files. Make sure that the group number is part of the filename. Ensure that the main report is clearly identifiable. Check that the zip-file can be unpacked before uploading.
- Make sure you mention the names of all group members and the group number on the first page of the report.
- Use a font size of at least 11pt for the report.

Exercise 1 (25%)

Jackson & Jackson have developed and produced a vaccine against a potentially life-threatening disease. As they are the first to do so, there is no market price for the vaccine. The Board of Directors of Jackson & Jackson has therefore decided to auction off the first batch to the highest bidder.

The CFO of Jackson & Jackson is an avid user of online auctions and therefore familiar with the overall concept. Still, he wants you to help him refresh his memory of auction theory. What he can tell you is that all bidders are symmetric, risk-neutral, and have independent private values. The bidders' reservation prices are drawn from the same distribution and are between 0.5 and 1 billion NOK.

a) Explain the Revenue Equivalent Theorem.
b) How can auctioning off the vaccine help with determining a single market price for the future? Which auction type should you use for this purpose? Briefly discuss the four different auction types introduced in the lecture.
c) What is the expected revenue of an English auction, given that Jackson & Jackson are able to attract 10 bidders? Assume that the probability density function for the bidders' reservation prices is given as $f(x) = 2x$.

For the following questions, consider you are a bidder rather than the seller. You do not have to calculate to answer these questions. Answer short and concise.

d) Given the severe consequences of not having access to the vaccine, you consider yourself to be risk-averse. In a first-price, sealed-bid auction, how would that change your bidding behavior? How do you define "risk" and "risk premium" in your case?
e) You cannot attend the auction yourself and therefore send your best friend to attend the auction and bid on your behalf. What is the least amount of information you have to give your friend before you send him to bid in
    I. an English auction?
    II. a Dutch auction?

    Explain your answer.

Exercise 2 (30%)

Paula owns a company that has the profit function $\pi(\mathrm{x}) = \mathrm{R}(\mathrm{x}) - \mathrm{C}(\mathrm{x})$, where $R(x)$ is revenues and $C(x)$ are costs; x is the amount sold. Demand for the product of the company is $Q = 48 - 2P$, where Q is demand given price P. Paula cannot manage to do all work in the company by herself and therefore hires Arthur. His cost function is given by $C(x) = 12x$, and there are no other costs to the firm.

a) What is the optimal output level?
b) Assume Arthur leases the company. Which lease price will Paula ask for?
c) Assume Paula pays 12 monetary units for each sold product x as a wage to Arthur. How many units will Arthur produce and sell if he is not (or cannot) be observed?
d) Assume Paula pays 14 monetary units for each sold product x as a wage to Arthur. How many units will Arthur produce and sell if he is not (or cannot) be observed? How many units will be produced and sold if Paula can (and will) observe him and give clear instructions?
e) Assume now that Paula offers Arthur a revenue share of ¾ rather than a wage. How many units are now produced and sold? What is the joint profit?
f) Assume now that Paula offers Arthur a profit share of $\frac{1}{3}$ rather than a wage. How many units are now produced and sold? What is the joint profit?

Exercise 3 (5%)

One insight from economic analysis suggests that firms will make a trade-off between motivation for hard work and efficiency in risk sharing. Explain in not more than 500 words.

Exercise 4 (40%)

Country Y relies strongly on coal and natural gas fired generation for its electricity supply. Coal-fired generation is mainly used for base load, and gas-fired generation is used to provide flexibility and cover peak loads.

As a consequence of a recent international climate agreement, Country Y has committed to reduce its CO_2 emissions per unit of supplied electricity by 90% (linearly) over a thirty year period. The main alternatives for reducing emissions are demand reduction and replacing fossil-fueled power generation by renewable generation. Due to its geographical location, country Y has one main option for renewable generation: offshore wind farms. Two policy instruments are considered; see below.

Assume that all coal-fired power generation is owned by one single company CFP, and that all gas-fired power generation is owned by another single company GFP. Both companies can invest in wind farms.

In this exercise you will investigate the development of the energy system over time under different policy options and market power assumptions, ensuring that supply covers demand, and that the CO_2 emissions in the years 2030, 2040, and 2050 do not exceed the emission targets.

Generation technologies g have capacity limits cap_g, investment costs c_g^I per unit of capacity, operational costs per unit of production, and CO_2 emissions per unit of production. Production costs for producer *i* depend on produced amount Q_{igy} via cost function $f_g(Q_{igy}) = c_g Q_{igy} + d_g {Q_{igy}}^2$. The electricity price in year y depends on the total amount of electricity via the inverse demand function $p_y = a_y - b_y Q_y^C$.

Quantities are scaled to MWh/year, and prices and costs to NOK / MWh.

Consider only one year per decade in your analysis and model.

Input data demand, import prices and emission permit prices

Year	Demand by year		Emission tax (if applicable)	Investment costs^			Reduction factor emissions per kWh produced
	Intercept	Slope	NOK/kg CO_2	c_g^I			
y	a_y	b_y	p_y^{CO2}	Coal	Gas	Wind	
2020	1,000	5	0	120	180	360	
2030	1,200	6	40	80	120	240	0.7
2040	1,400	7	70	40	60	120	0.4
2050	1,600	8	100				0.1

^Investment costs are scaled to be representative in the perspective of one year per decade and end-of- horizon effects.

Input data Supply

Technology	Initial capacity		Operational costs		Emission factor
	cap_ig		NOK/MWh		kg CO_2/kWh
i,g	*CFP*	*GFP*	c_g^P	d_g^P	e_g
Coal	200		100	0.5	1.1
Gas		200	200	0.4	0.4
Wind			10	0.1	0

Discount rate: 50% per decade (!).

Input data Policy options

- Wait and See: implement the emission tax and hope for the best.
- Hard Target: suppliers are responsible that their average emissions per kWh produced meet country targets.

Develop and implement a model (in GAMS, XPRESS or Python) to compute the multi-period equilibrium for all four combinations of:

- Market structure: Perfect competition or Duopoly
- Policy options: Wait and See or Hard Target

a) Derive the model. Present the full model formulation including an overview of symbols used and a brief description of all model equations. (It is allowed to include clearly legible picture(s) of a hand-written formulation in your pdf file.)

b) Implement the model in a way so that you can easily change the input parameter values and market power assumptions. *As a stepping stone in your model development and analysis, first establish the base line CO_2 emissions in 2020 for both market structures before doing the multi-period analysis.*

c) For all four combinations, report in tables:
   1. Yearly production and emissions - by technology
   2. Yearly sales, revenues, producion costs, investment cost, CO_2 tax), profit, average emission per kWh - by producer
   3. Yearly consumption, prices, consumer surplus, producer profits, emissions, average emission per kWh - aggregate

   In the tables, report monetary values in multiples of 1,000. Additionally, to maintain comparability between years do report undiscounted values.

d) Discuss how market power affects prices, emissions, profits, investment, and consumer surplus (max 250 words)

e) Verify the profit optimality condititon “Marginal Cost (MC) equals Marginal Revenues (MR)” by computing both terms MC and MR for company CFP for the following three combinations
   - Year 2020, perfectly competitive
   - Year 2020, duopoly
   - Year 2050, perfectly competitive, Wait and See

f) Discuss advantages and disadvantages of both policy instruments (max. 250 words).