

Technological Learning - Answers

Exercise 1) (12 points)

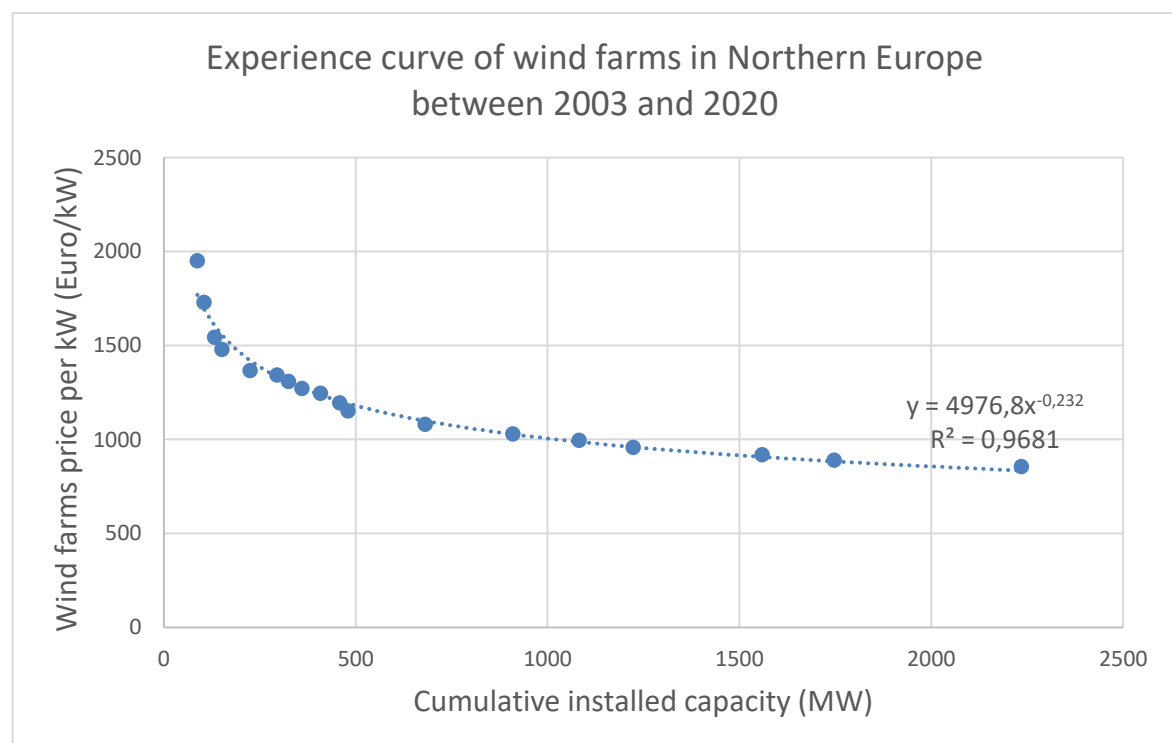
a) *Experience curves (8 points)*

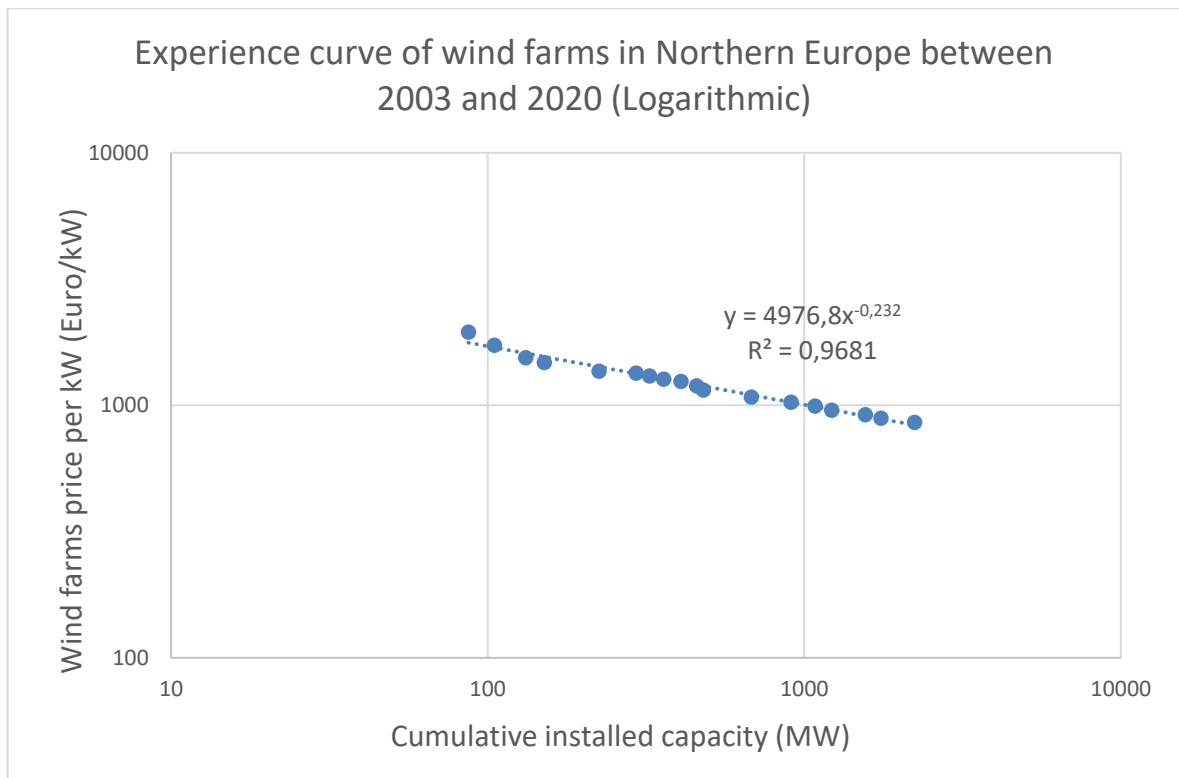
Converting to Euro₂₀₂₀

$$Price_{2020} = Price_{year} \left(\frac{CPI_{2020}}{CPI_{year}} \right)$$

Year	Cum cap. (MW)	Corrected mean price (€ ₂₀₂₀ /kW)	Year	Cum cap. (MW)	Corrected mean price (€ ₂₀₂₀ /kW)
2003	87	1951	2012	458	1196
2004	105	1730	2013	480	1152
2005	132	1544	2014	681	1080
2006	151	1479	2015	910	1030
2007	225	1368	2016	1082	996
2008	295	1342	2017	1223	957
2009	325	1310	2018	1559	918
2010	360	1271	2019	1747	891
2011	408	1246	2020	2235	856

Graphs





Calculation PR

$$b = 0.232$$

$$PR = 2^b = 85.7\%$$

Number of doublings

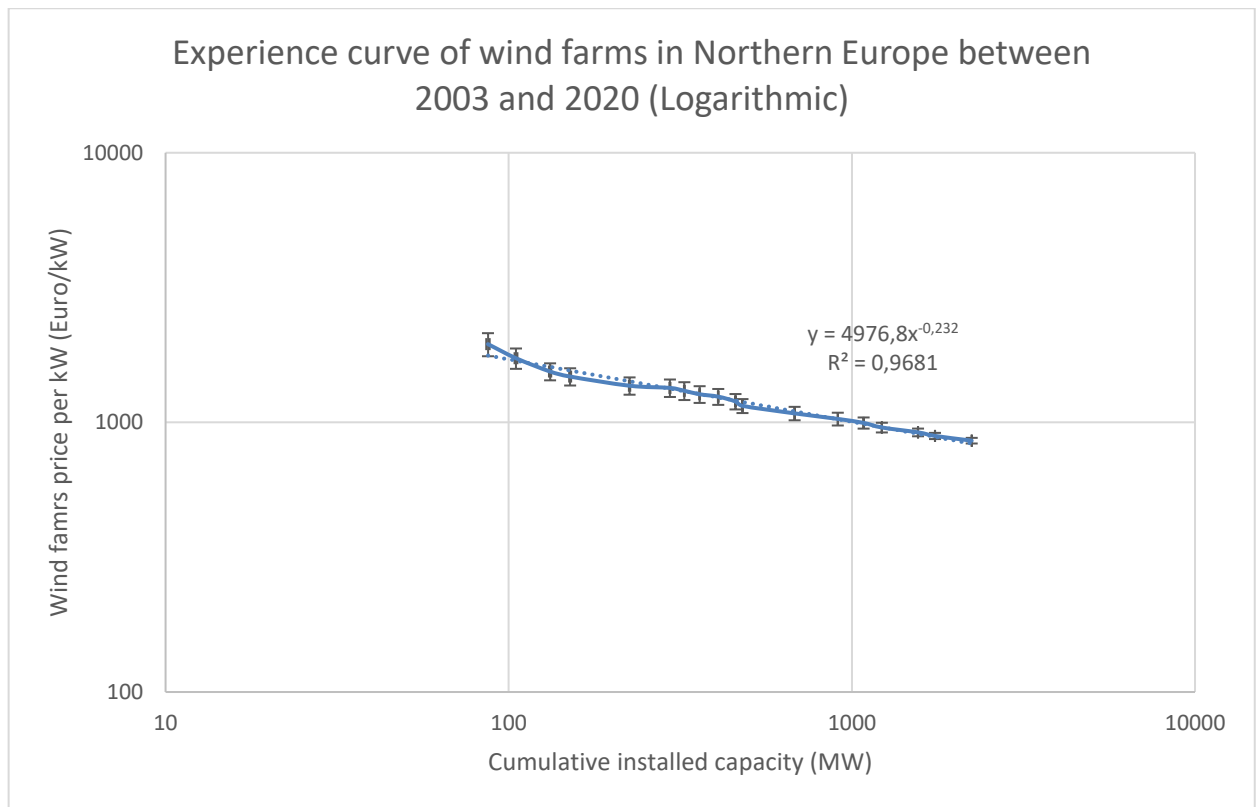
$$n = \log_2 \left(\frac{CAP_{2020}}{CAP_{2003}} \right) = \frac{\log \left(\frac{CAP_{2020}}{CAP_{2003}} \right)}{\log 2} = 4.68$$

Average annual growth

$$i = \left(\frac{CAP_{2020}}{CAP_{2003}} \right)^{\frac{1}{17}} - 1 = 0.210$$

Average growth is 21.0 % per year.

b) *Uncertainty (4 points)*

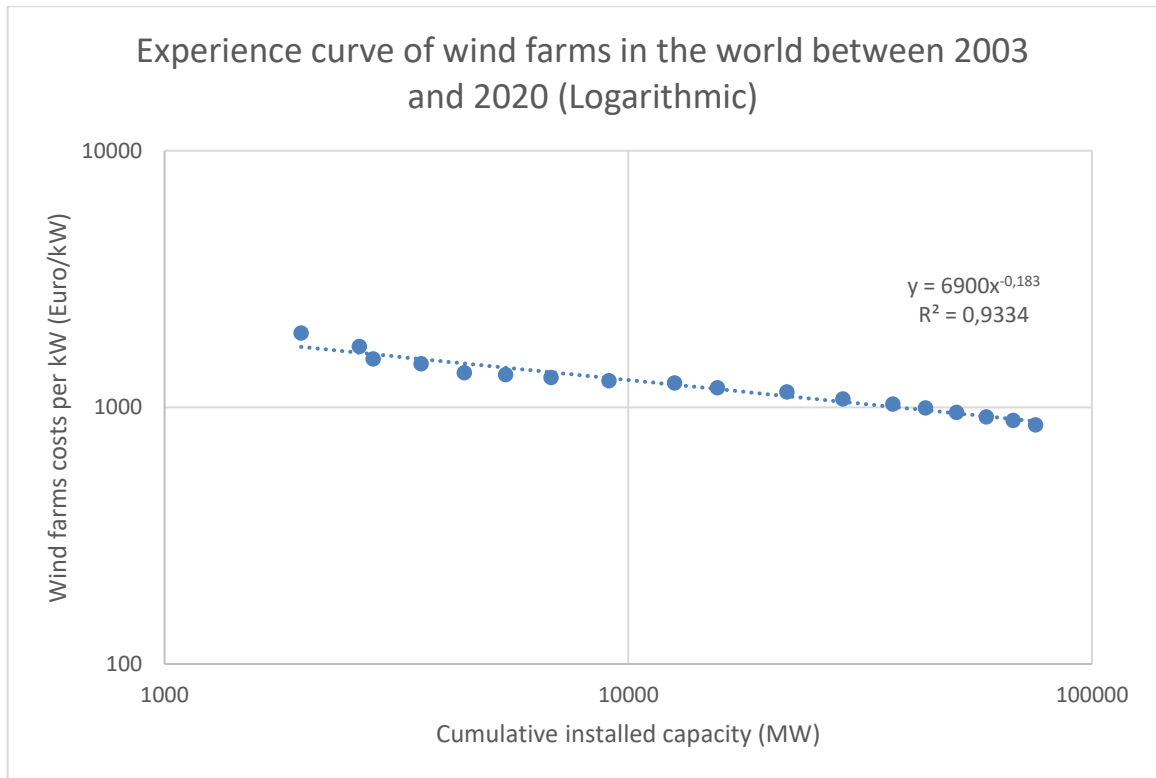


Standard uncertainty has continuously decreased from 2003 to 2020. In other words, the prices for a wind system given by different manufacturers are converging to a similar value.

Exercise 2) (10 points)

2a) (8 points)

b	-0.183
Progress ratio	0.88
Number of doublings	5.26
Growth rate	23.9%



2b) Differences between PRs in exercise 1) and 2) (2 points)

The prices remain identical, but the global and national **growth rate** is different. This is the basis of the different PRs.

Exercise 3) (8 points)

Discussed in class.

Exercise 4) (30 points)

a) Calculation break-even year (10 points)

Due to the variety in PR and growth rate, the table below gives the answers to the most used values.

Progress ratio PR	Learning index b (unitless)	Global breakeven capacity	Swiss breakeven capacity	Time period until global breakeven is reached	Breakeven year
%		MW	MW	years	
63	-0.667	364,043	728	7.1	2019
75	-0.415	796,611	1,593	11.4	2023
86	-0.218	5,236,628	10,473	21.7	2033

b) Will it fit on our roofs? (5 points)

→ Yes, it will fit but not with a high PR i.e. 86%, because $21.94 > 12.5 \text{ m}^2$ for PR=86% (if the average household size in Switzerland is assumed to be 125 m^2 the roof area should be at least 10%, i.e. $12.5 \text{ m}^2/\text{household}$). However, it will be challenging if we take into account roof orientation, apartments (which have on average only a limited roof surface), etc.

PR	# of years	b/e year	Required roof surface (m ²)	Req. Avg. roof surface with 3.58 million HH (m ²)
63	7.1	2019	5,460,643	1.53
75	11.4	2023	11,949,160	3.34
86	21.7	2033	78,549,421	21.94

c) Total costs for break-even (10 points)

In the table below, the total costs, the non-profitable part and the profitable part are given for the PR values.

PR	Costs (MCHF)	Competitive share (MCHF)	Government cost (M CHF)
63	1,357	937	419
75	3,398	2,473	925
86	22,686	18,235	4,451

d) The total costs for the Swiss government (5 points)

The non-profitable part of the solar cells is anything above the Break-even cost=1775 CHF/kW.