Week 4: Decisions in Settings with High Uncertainty

- Session 1 – Decision Trees
  - Example: Furniture maker IDEA Chooses a Supplier
- Session 2 – Using Simulation within Decision Trees
  - Example: More Complex Demand Distributions for IDEA
- Session 3 – Using Optimization Together with Simulation
  - Example: IDEA Chooses Order Quantities
- Session 4 – Wrap Up
  - Example: Back to the Newsvendor Problem

Original problem description for IDEA's Krusbär tent

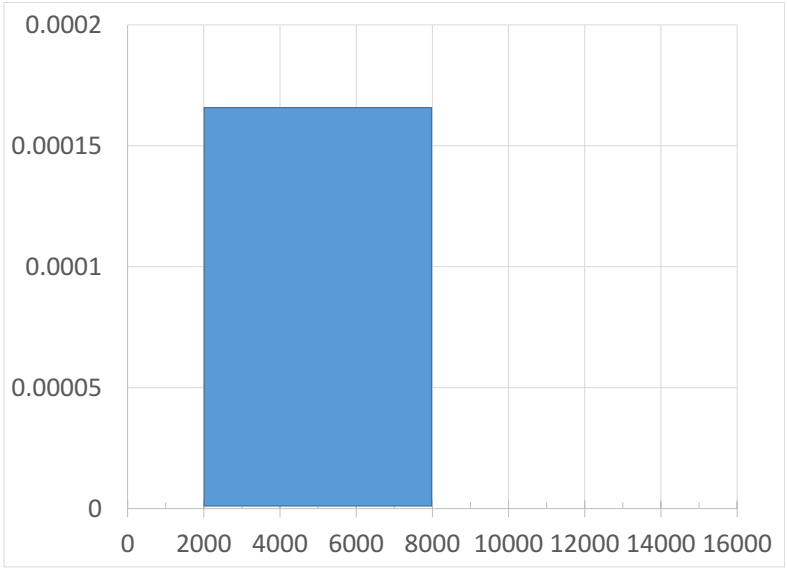
- Order quantities and costs, by supplier

	Sweden (S)	**Poland (P)**
Order Quantity	5,000 units	10,000 units
Fixed Charge	0€	50,000€
Unit Cost	120€	100€

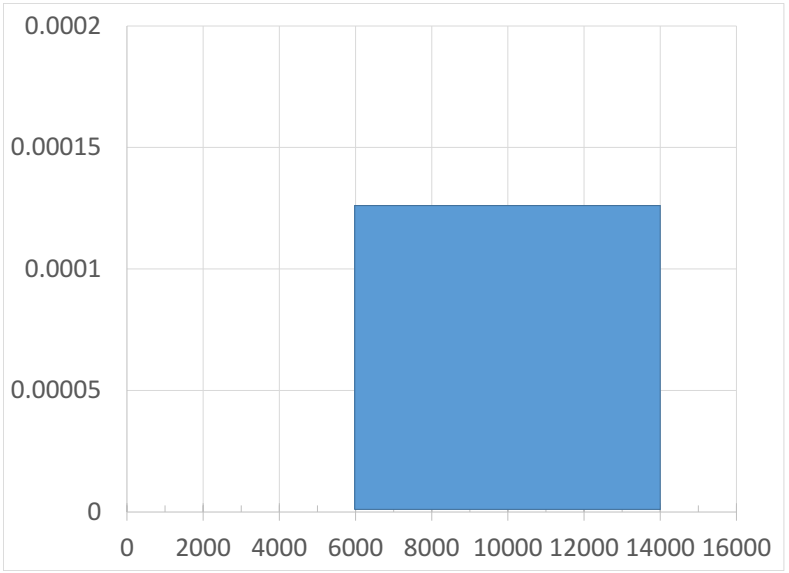
- Demand forecast given a unit price of 150€
  - 50% chance demand is strong: 10,000 units
  - 50% chance demand is weak: 5,000 units

But demand may be more complex

- Assume demand is uniformly distributed
  - Defined by a minimum outcome and a maximum outcome
  - Any outcome between a given minimum and maximum is equally likely
  - For example, see J. R. Evans, *Business Analytics*, Pearson, 2013.



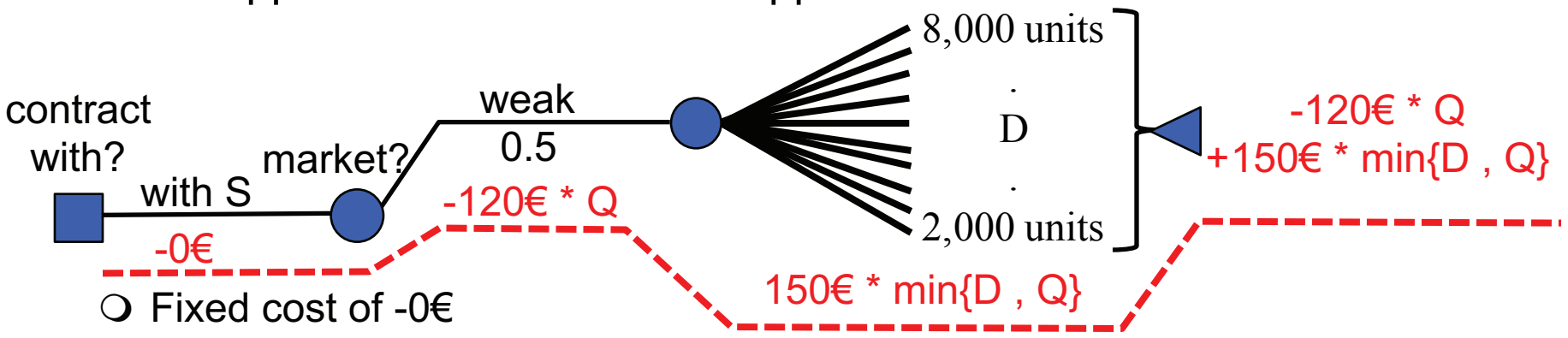
- More complex demand model
  - 50%-50% chance demand is weak or strong
  - Weak demand is uniformly distributed: 2,000-8,000 units
  - Strong demand is uniformly distributed: 6,000-14,000 units



- How can we represent this in a tree?

Consider the choice of Supplier S

- What happens if IDEA chooses supplier S and the market is weak?



  - Fixed cost of -0€
  - In a weak (or strong) market order Q = 5,000 units (100% of S's capacity)
    - Order cost = -120€ * Q (where Q=5,000)
  - Demand (D) is uniformly distributed between 2,000 and 8,000 units
    - If D ≤ Q, then revenue = 150€ * D
    - If D > Q, then revenue = 150€ * Q
    - For any D IDEA earns revenue = 150€ * min{D , Q}
  - Add the cash flows to determine IDEA's profit
    - Profit = - 120€ * Q + 150€ * min{D , Q}

- Set Q = 5,000 and simulate D to estimate IDEA's expected profit

Simulate Supplier S and a weak market (10 samples)

	A	B	C	D	E	F
1	**IDEA.xlsx**					
2						
3	**Order Quantity (Q) =**	5000	units			
4	**Fixed Cost =**	0	euros			
5	**Price =**	150	euros per unit			
6	**Unit Cost =**	120	euros per unit			
7						
8	**Sample**	**Demand**				
9	**Number**	**Sample (D)**	**Revenue**	**Fixed Cost**	**Variable Cost**	**Profit**
10	1	2,744.90	411,734.37	-	600,000.00	(188,265.63)
11	2	2,039.00	305,850.40	-	600,000.00	(294,149.60)
12	3	4,336.68	650,502.03	-	600,000.00	50,502.03
13	4	3,603.69	540,553.00	-	600,000.00	(59,447.00)
14	5	6,221.81	750,000.00	-	600,000.00	150,000.00
15	6	3,413.07	511,960.20	-	600,000.00	(88,039.80)
16	7	4,796.84	719,525.74	-	600,000.00	119,525.74
17	8	6,487.69	750,000.00	-	600,000.00	150,000.00
18	9	2,742.70	411,404.77	-	600,000.00	(188,595.23)
19	10	4,436.11	665,416.43	-	600,000.00	65,416.43
20						
21	**average =**	4,082.25				(28,305.31)
22	**std. deviation =**	1,471.92				158,788.93
23						

=$B$5*MIN($B$3,B10)

=$B$3*$B$6

=C10-D10-E10

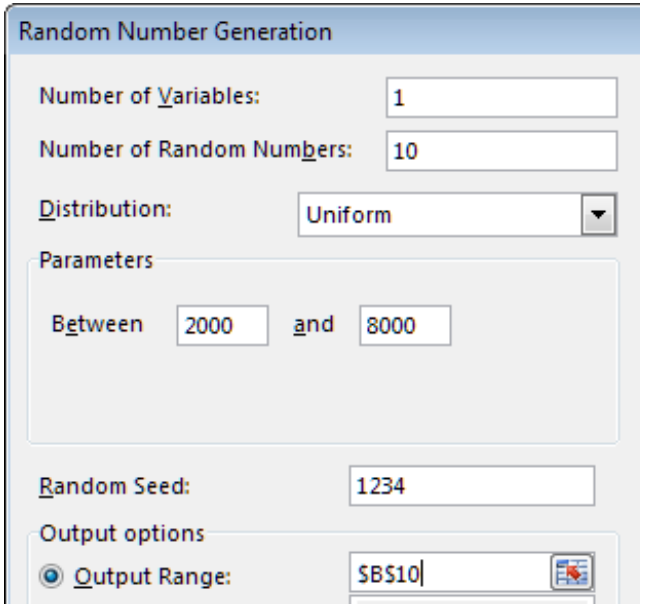
=$B$4

=AVERAGE(B10:B19)

=STDEV(B10:B19)

Notes on the simulation

- We used Excel's Random Number Generator (RNG)
  - 10 samples of 1 random variable (D)
  - Uniformly distributed from 2,000 to 8,000
  - Using random seed 1234
- Samples of the Uniformly distributed demand included fractional quantities
  - That's by definition in a uniform distribution
  - For simplicity, we'll use it in our example
  - There are other distributions that ensure that samples are whole numbers
  - See RJ Evans, *Business Analytics* Pearson, 2013
- The spreadsheet IDEA.xlsx has several worksheets, each with a different simulation



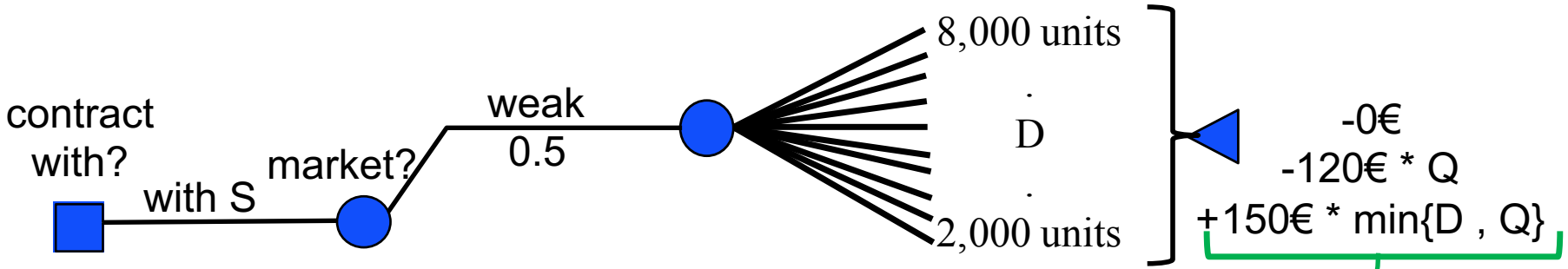
8	Sample	Demand
9	Number	Sample (D)
10	1	2,744.90
11	2	2,039.00
12	3	4,336.68
13	4	3,603.69
14	5	6,221.81
15	6	3,413.07
16	7	4,796.84
17	8	6,487.69
18	9	2,742.70
19	10	4,436.11

Supplier S and a weak market, with 1000 samples

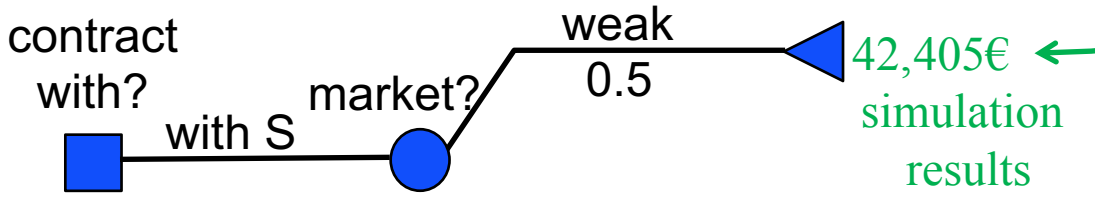
	A	B	C	D	E	F
1	**IDEA.xlsx**					
2						
3	**Order Quantity (Q) =**	5000	units			
4	**Fixed Cost =**	0	euros			
5	**Price =**	150	euros per unit			
6	**Unit Cost =**	120	euros per unit			
7						
8	**Sample**	**Demand**				
9	**Number**	**Sample (D)**	**Revenue**	**Fixed Cost**	**Variable Cost**	**Profit**
10	1	2,744.90	411,734.37	-	600,000.00	(188,265.63)
11	2	2,039.00	305,850.40	-	600,000.00	(294,149.60)
12	3	4,336.68	650,502.03	-	600,000.00	50,502.03
13	4	3,603.69	540,553.00	-	600,000.00	(59,447.00)
14	5	6,221.81	750,000.00	-	600,000.00	150,000.00
15	6	3,413.07	511,960.20	-	600,000.00	(88,039.80)
16	7	4,796.84	719,525.74	-	600,000.00	119,525.74
17	8	6,487.69	750,000.00	-	600,000.00	150,000.00
1008	999	2,642.54	396,380.50	-	600,000.00	(203,619.50)
1009	1000	3,713.92	557,087.92	-	600,000.00	(42,912.08)
1010						
1011	**average =**	5,044.06				42,404.97
1012	**std. deviation =**	1,712.70				145,039.38

We used the simulation to roll back a complex event

- Original event node with uniformly distributed demand



- Rolled back event node with expected value



- We also can simulate to estimate the expected profit in the other 3 cases

Simulate Supplier S and a strong market (1000 samples)

	A	B	C	D	E	F
1	**IDEA.xlsx**					
2						
3	**Order Quantity (Q) =**	5000	units			
4	**Fixed Cost =**	0	euros			
5	**Price =**	150	euros per unit			
6	**Unit Cost =**	120	euros per unit			
7						
8	**Sample**	**Demand**				
9	**Number**	**Sample (D)**	**Revenue**	**Fixed Cost**	**Variable Cost**	**Profit**
10	1	6,993.19	750,000.00	-	600,000.00	150,000.00
11	2	6,052.00	750,000.00	-	600,000.00	150,000.00
12	3	9,115.57	750,000.00	-	600,000.00	150,000.00
13	4	8,138.25	750,000.00	-	600,000.00	150,000.00
14	5	11,629.08	750,000.00	-	600,000.00	150,000.00
15	6	7,884.09	750,000.00	-	600,000.00	150,000.00
16	7	9,729.12	750,000.00	-	600,000.00	150,000.00
17	8	11,983.58	750,000.00	-	600,000.00	150,000.00
1008	999	6,856.72	750,000.00	-	600,000.00	150,000.00
1009	1000	8,285.23	750,000.00	-	600,000.00	150,000.00
1010						
1011	**average =**	10,058.75				150,000.00
1012	**std. deviation =**	2,283.61				0.00

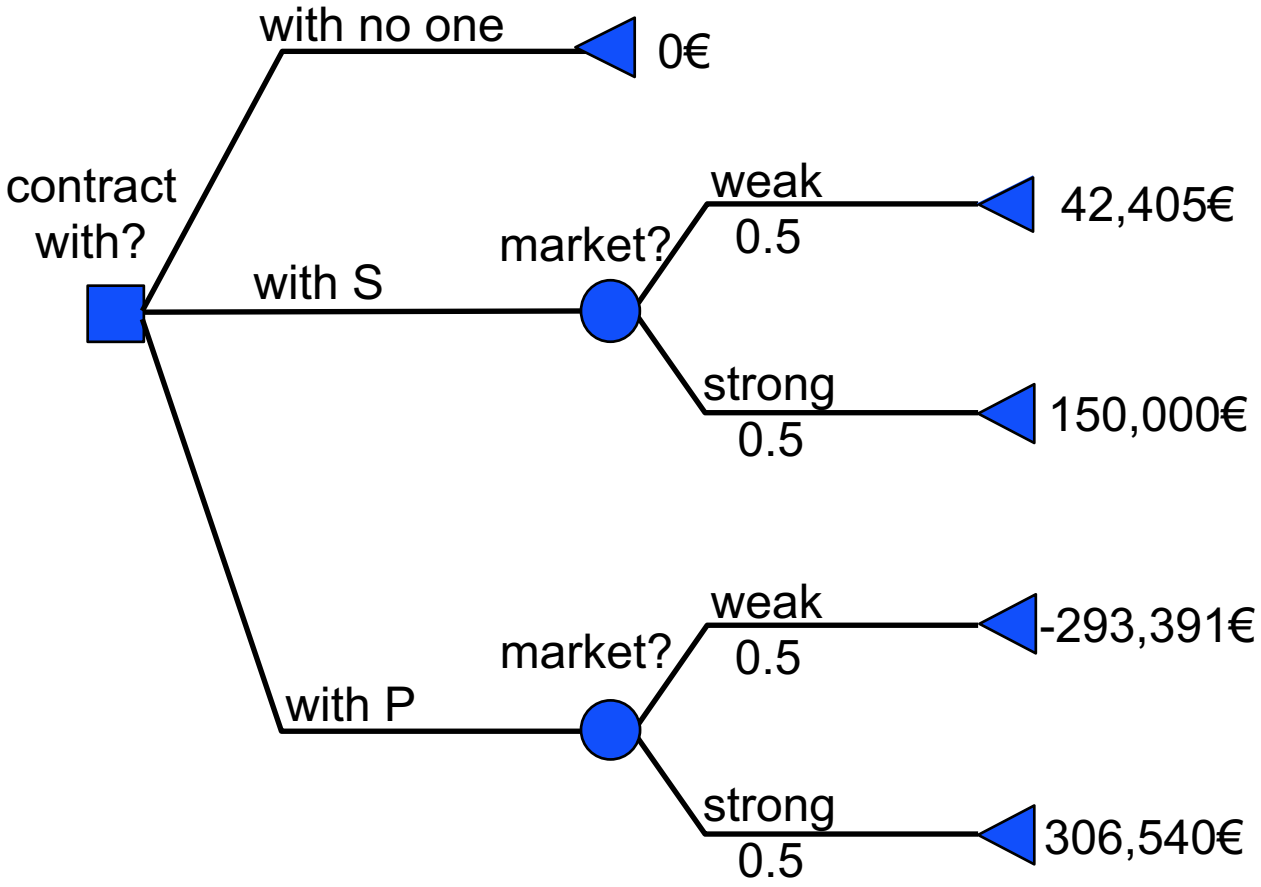
Simulate Supplier P and a weak market (1000 samples)

	A	B	C	D	E	F
1	**IDEA.xlsx**					
2						
3	**Order Quantity (Q) =**	10000	units			
4	**Fixed Cost =**	50000	euros			
5	**Price =**	150	euros per unit			
6	**Unit Cost =**	100	euros per unit			
7						
8	**Sample**	**Demand**				
9	**Number**	**Sample (D)**	**Revenue**	**Fixed Cost**	**Variable Cost**	**Profit**
10	1	2,744.90	411,734.37	50,000.00	1,000,000.00	(638,265.63)
11	2	2,039.00	305,850.40	50,000.00	1,000,000.00	(744,149.60)
12	3	4,336.68	650,502.03	50,000.00	1,000,000.00	(399,497.97)
13	4	3,603.69	540,553.00	50,000.00	1,000,000.00	(509,447.00)
14	5	6,221.81	933,271.28	50,000.00	1,000,000.00	(116,728.72)
15	6	3,413.07	511,960.20	50,000.00	1,000,000.00	(538,039.80)
16	7	4,796.84	719,525.74	50,000.00	1,000,000.00	(330,474.26)
17	8	6,487.69	973,152.87	50,000.00	1,000,000.00	(76,847.13)
1008	999	2,642.54	396,380.50	50,000.00	1,000,000.00	(653,619.50)
1009	1000	3,713.92	557,087.92	50,000.00	1,000,000.00	(492,912.08)
1010						
1011	**average =**	5,044.06				(293,391.16)
1012	**std. deviation =**	1,712.70				256,905.74

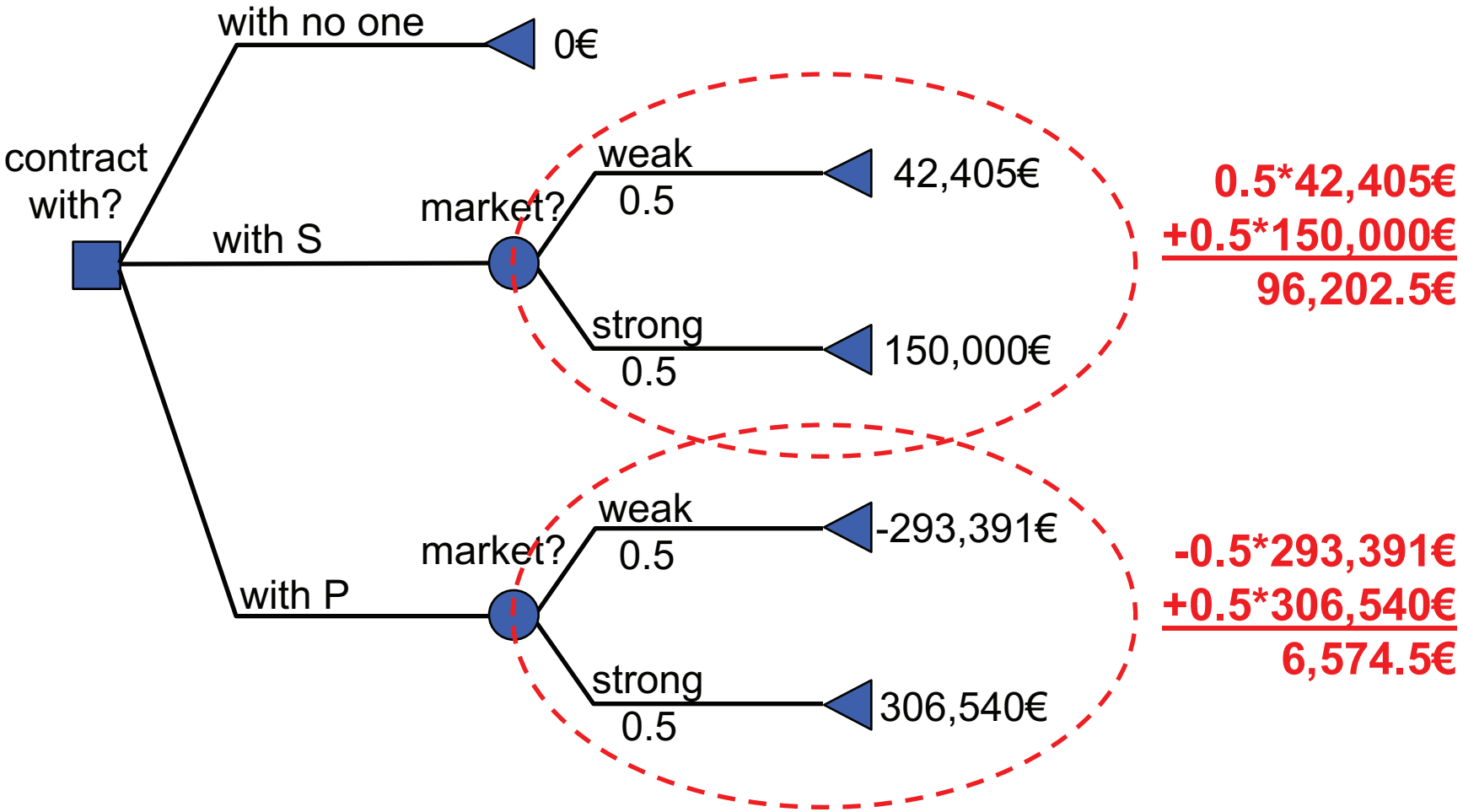
Simulate Supplier P and a strong market (1000 samples)

	A	B	C	D	E	F
1	**IDEA.xlsx**					
2						
3	**Order Quantity (Q) =**	10000	units			
4	**Fixed Cost =**	50000	euros			
5	**Price =**	150	euros per unit			
6	**Unit Cost =**	100	euros per unit			
7						
8	**Sample**	**Demand**				
9	**Number**	**Sample (D)**	**Revenue**	**Fixed Cost**	**Variable Cost**	**Profit**
10	1	6,993.19	1,048,979.16	50,000.00	1,000,000.00	(1,020.84)
11	2	6,052.00	907,800.53	50,000.00	1,000,000.00	(142,199.47)
12	3	9,115.57	1,367,336.04	50,000.00	1,000,000.00	317,336.04
13	4	8,138.25	1,220,737.33	50,000.00	1,000,000.00	170,737.33
14	5	11,629.08	1,500,000.00	50,000.00	1,000,000.00	450,000.00
15	6	7,884.09	1,182,613.61	50,000.00	1,000,000.00	132,613.61
16	7	9,729.12	1,459,367.66	50,000.00	1,000,000.00	409,367.66
17	8	11,983.58	1,500,000.00	50,000.00	1,000,000.00	450,000.00
1008	999	6,856.72	1,028,507.34	50,000.00	1,000,000.00	(21,492.66)
1009	1000	8,285.23	1,242,783.90	50,000.00	1,000,000.00	192,783.90
1010						
1011	**average =**	10,058.75				306,539.96
1012	**std. deviation =**	2,283.61				193,385.84

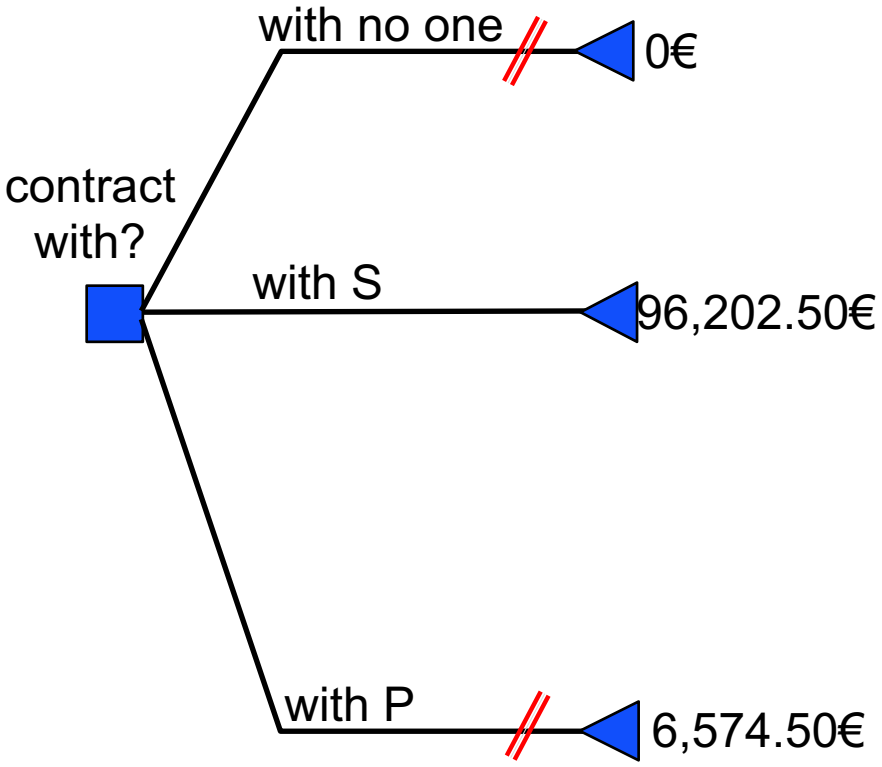
IDEA's tree with simulated estimates of expected profit



We then calculate the expected values for Supplier S, P



The exp. profit maximizing choice remains Supplier S



- Estimate for supplier S drops by >1/3
  - From 150,000€ to ~96,200€
- Estimate for supplier P drops by >90%
  - From 75,000€ to ~6,600€
- To maximize expected profit still contract with supplier S

Wrap-up for Session 2 of Week 4

- How did IDEA's problem change from last session to this one?

- The overall structure of the decision problem did not change
  - First decide on a supplier: S, P, or none
    - Fixed costs and order quantities same as before
  - Then see if the market is weak or strong
    - Same 50%/50% probabilities as before

- But the outcomes for weak and strong markets did become more complex
  - In the initial model they were fixed numbers, 5000 or 10,000
    - In either case we could simply calculate IDEA's profits
  - In the updated model demand in weak and strong markets was still random
    - We used simulation to estimate IDEA's expected profits

- Simulations let us evaluate the outcomes of a more complex event
  - Next session: we'll use optimization to help evaluate more complex decisions