645 – Computational Economics
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October 22, 2025

HW1 – Part B

Question 1

Indices

- $s \in S$: scenarios for permitting and construction outcomes (delay, overrun, abandonment), with probabilities π_s and $\sum_s \pi_s = 1$
- $t \in \{1,\ldots,T\}$: operating years after COD.

Parameters

- C_{base} [$]: baseline EPC capital (include soft costs unless noted separately).
- ϕ_s [decimal]: cost overrun multiplier in scenario s (e.g., 0.25 means +25%).
- Δt_s [years]: time from FID to COD in scenario s.
- r [%]: risk-adjusted discount rate (WACC plus risk premium).
- p_t [$/MWh]: expected real price in year t.
- Q_t [MWh]: expected energy in year t (e.g., 8760 × Cap × CF, adjusted for outages if desired).
- T [years]: financial lifetime for operating cash flows.

Variables

- $x \in \{0,1\}$: binary build decision (1 = build, 0 = do not build)

Objective Function

$$min_x\ E\left[\frac{C_{base}(1+\phi)(1+r)^{\Delta t}}{\sum_{t=\Delta t+1}^{T} \frac{E[P_t Q_t]}{(1+r)^t}}\right]$$

The model minimizes the expected levelized cost of electricity (LCOE), as expressed in the objective function. The numerator represents the effective capitalized cost of construction, which increases with higher baseline costs (C_{base}), cost overruns (ϕ), financing rates (r), and delays (Δt). The denominator reflects the present value of expected electricity revenues over the plant's operating life, discounted by the same rate r. Permitting reform shifts the probability distributions of these uncertain parameters by shortening and stabilizing construction timelines, reducing cost overruns, and lowering financing risk. These changes decrease interest during construction (IDC), reduce the risk premium embedded in r, and cut soft costs through simpler regulatory processes. By improving predictability and reducing the likelihood of abandonment, reform lowers the expected LCOE and, equivalently, increases the project's expected net present value (NPV).

Constraints

- *Scenario probabilities*

$$\sum_{s \in S} \pi_s \, , \pi_s \geq 0$$

Each scenario s represents a possible realization of delay (Δt_s) and cost overrun (ϕ_s) outcomes. The probabilities π_s weight each scenario in the expected value of the objective function.

- *Delay and cost overrun bounds*

$$\Delta t_{min} \leq \Delta t_s \leq \Delta t_{max}, \; \phi_{min} \leq \phi_s \leq \phi_{max}$$

These constraints ensure delays and overruns remain within realistic limits (e.g., truncating extreme values). Under reform, both the mean and variance of these parameters decrease.

- *Policy shift relationships*

$$R_{reform} < r_{baseline}, \; E[\Delta t_s]_{reform} < E[\Delta t_s]_{baseline}, \; E[\phi_s]_{reform} < E[\phi_s]_{baseline}$$

These comparative conditions represent the effect of permitting reform, which shortens timelines, reduces uncertainty, and lowers financing risk. They are not strict optimization constraints but define how parameter inputs differ between policy cases.

- <u>Feasibility condition for construction and operation</u>

$$C_{base}(1 + \phi_s)(1 + r) > 0, \sum_{t=\Delta t_s+1}^{\Delta t_s+T} \frac{E[P_t Q_t]}{(1 + r)^t} > 0$$

Both the capitalized cost (numerator) and the discounted revenue term (denominator) must be positive to ensure a valid LCOE value. These implicit constraints keep the model well-defined without binary build or completion variables.

Sample Code

```
* --- variables ---
positive variables
   pi(s)     "scenario probability π_s"
   dlt(s)    "construction delay Δt_s (years)"
   phi(s)    "cost overrun rate ϕ_s"
;

* global scalars for bounds
scalar dt_min, dt_max, phi_min, phi_max, r, Cbase ;
```

```
* present value of expected revenue by scenario
parameter pv_revenue(s) ;

dlt.lo(s) = dt_min ;    dlt.up(s) = dt_max ;
phi.lo(s) = phi_min ;   phi.up(s) = phi_max ;

* --- equations ---
equation
   prob_sum1       "scenario probabilities sum to one"
   prob_nonneg(s)  "scenario probabilities are nonnegative"
   delay_lower(s)  "delay at least Δt_min"
   delay_upper(s)  "delay at most Δt_max"
   overrun_lower(s)"overrun at least ϕ_min"
   overrun_upper(s)"overrun at most ϕ_max"
   feas_num_pos(s) "capitalized cost (numerator) strictly positive"
   feas_den_pos(s) "PV of revenues (denominator) strictly positive"
;

* --- probability normalization ---
prob_sum1..      sum(s, pi(s)) =e= 1 ;
prob_nonneg(s).. pi(s)         =g= 0 ;

* --- delay and overrun bounds ---
delay_lower(s)..    dlt(s) =g= dt_min ;
delay_upper(s)..    dlt(s) =l= dt_max ;
overrun_lower(s)..  phi(s) =g= phi_min ;
overrun_upper(s)..  phi(s) =l= phi_max ;

* --- feasibility (use tiny epsilon to force strict positivity) ---
scalar eps /1e-6/ ;

feas_num_pos(s)..
   Cbase * (1 + phi(s)) * power(1 + r, dlt(s)) =g= eps ;

* pv_revenue(s) should already reflect the delay window and discounting
feas_den_pos(s)..
   pv_revenue(s) =g= eps ;

* --- policy shift relationships (implemented in data, not as constraints) ---
* For the reform case, set lower r, and choose scenario inputs with lower E[Δt_s] and E[ϕ_s]
* e.g., r = r_reform; dlt.lo/up and phi.lo/up can be tightened; pi(s) can be reweighted.
```

Question 2

<u>Data Sources</u>

- *Portugal-Pereira et al. (2018), "Better Late Than Never, but Never Late is Better: Risk Assessment of Nuclear Power Construction Projects," Energy Policy 120, 158–166*

This paper compiles global data on cost overruns and construction delays for 180 reactor projects. I will use the reported mean delay (approximately 7 years) and the estimated 20 percent cost escalation per additional year to calibrate the baseline delay and overrun distributions (Δt_s, ϕ_s) in the stochastic model. These data provide the foundation for modeling how permitting reform shortens delays and tightens uncertainty ranges.

- *Guaita, Spangler & Hansen (2025), "Parametric and Nonparametric Models of U.S. Cost Overruns for Nuclear Power Plants," Idaho National Laboratory*

This forthcoming INL study provides updated U.S. parameters for cost growth, financing burden, and schedule risk after 2000. I will use its reported probability density functions for cost overruns to validate the Monte Carlo sampling and to benchmark U.S. project performance against international experience. The data help distinguish "status-quo" versus "reform" variance in project outcomes.

- *Jacobs, Jantarasami & Fishman (2024), Licensing and Permitting Reforms to Accelerate Nuclear Energy Deployment, Bipartisan Policy Center*

This policy report provides estimated reductions in permitting duration (25 to 40 percent) and administrative costs (10 to 15 percent) under proposed NRC process reforms. I will apply these values to define the "moderate" and "comprehensive reform" scenarios that shift the delay and soft-cost parameters in the model.

Assumptions

1. Scenarios and Uncertainty
The model includes different possible permitting and construction outcomes. Each one (called a "scenario") has its own chance of happening and includes a unique delay and cost overrun. These probabilities must add up to 100%.

2. Scenario Probabilities
The model decides how likely each scenario is by assigning weights (probabilities) that are positive and sum to one. These aren't fixed in advance; they're part of the model setup.

3. Limits on Delay and Overrun
Delays and cost overruns are only allowed within a reasonable range (minimum and maximum). For reform scenarios, I assume that both the average delay and the amount of variation are lower.

4. Construction Cost Grows with Delay and Overrun

Construction costs go up if the project takes longer or faces overruns. These increases are compounded by the financing rate (r), meaning the longer it takes, the more expensive it gets.

5. Revenues Start After Construction Is Done
   The plant doesn't earn anything until it starts running. Once it's built, it sells power each year for a set price and amount. Future revenue is discounted using the same rate r. This revenue stream is calculated in advance for each scenario.

6. Feasibility Check
   The model makes sure that both the total cost and total revenue are greater than zero, to avoid dividing by zero or getting meaningless results. It does this with a tiny lower limit (like 0.000001).

7. How Reform Affects the Model
   Reform isn't enforced by a rule in the model. Instead, it's reflected by changing inputs:
   - Lower financing rate (r)
   - Shorter and more predictable delays
   - Smaller cost overruns
   - Different scenario probabilities to reflect more confidence in better outcomes

8. No Operating or Maintenance Costs Modeled
   The model only tracks revenue, not the costs of running the plant. It assumes that either those are minor or already included in the electricity price used.

9. Project Runs for a Fixed Number of Years
   Once construction is done, the plant operates for a fixed time (like 60 years). There's no salvage value or cash flow after that.

10. Simplified for Calculation
    To keep things manageable:
    - I assume annual discounting
    - All costs are in today's dollars (real terms)
    - Reform is reflected only in the numbers I feed into the model, not in new equations