Production Planning with Flexible Production

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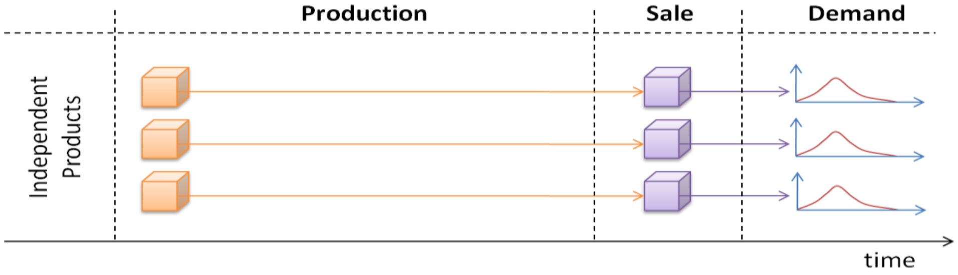
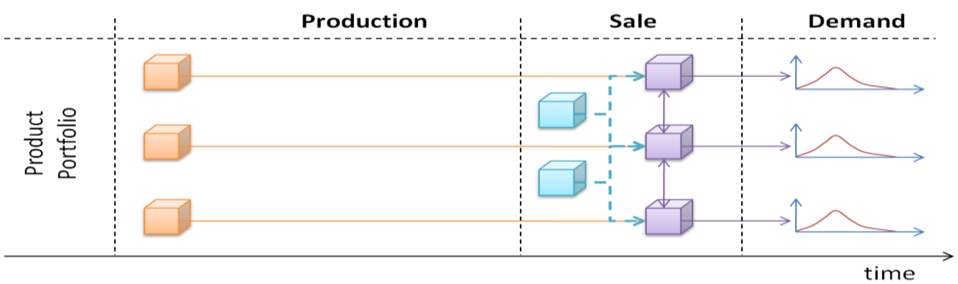
What is the value of flexibility in a product supply chain?

- **Base Design:** Produce everything before the start of the season at low-cost, long lead-time facilities.

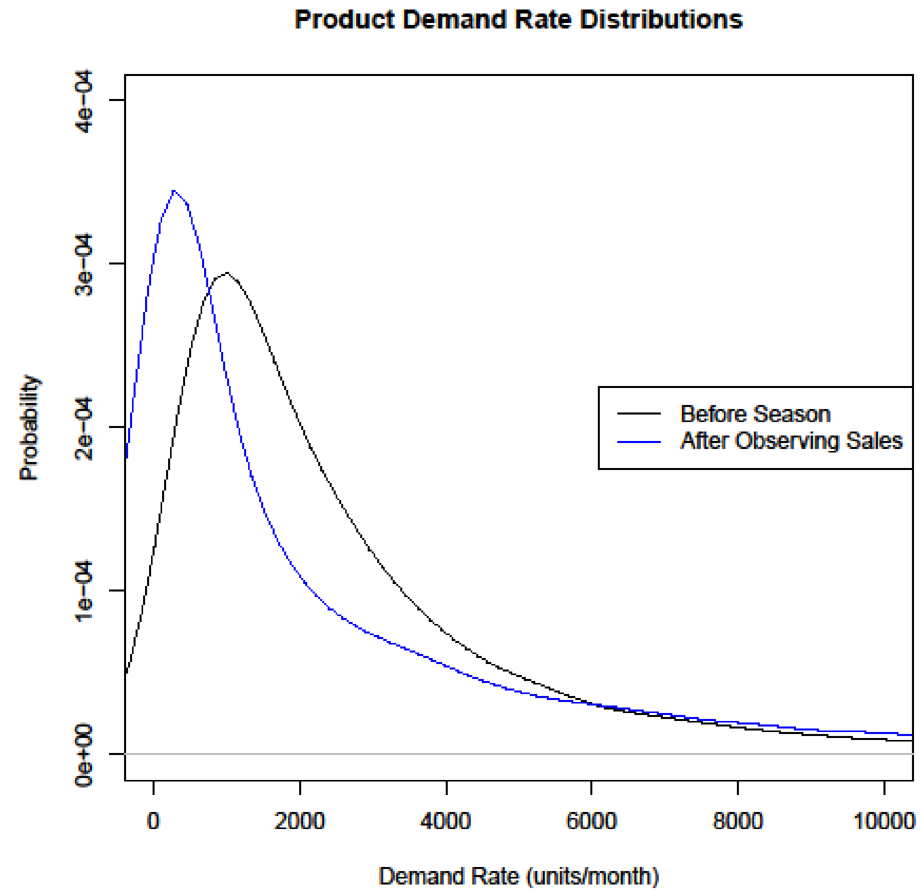


- **Flexible Design:** Produce some additional units in high-cost, short lead-time facilities

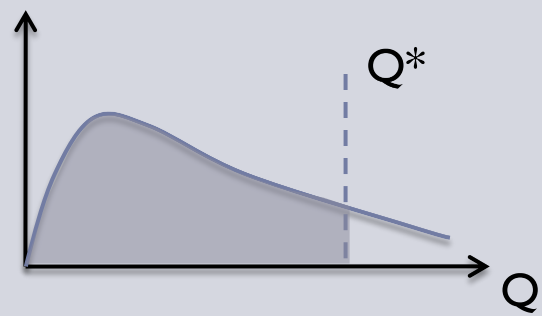
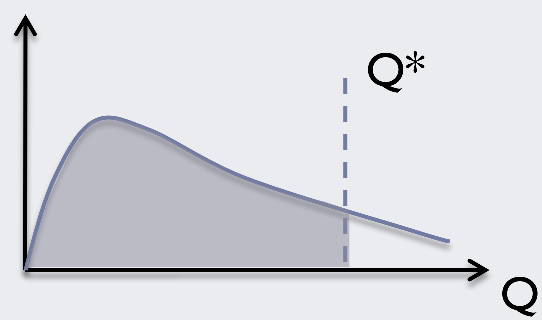
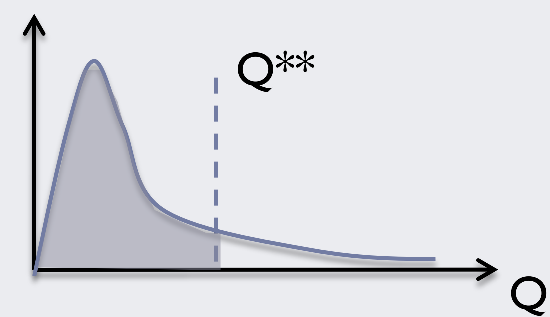


The key uncertainty is the demand for each product…

- Non-negative
- Long right-hand tails
- Learning



Decision rules are designed to determine optimal production quantities…

	Before Season	During Season
Base Design		N/A
Flexible Design		

Determining the optimal quantity for each case is a classic newsvendor problem…

- **Profit Function:**

$$\Pi = \begin{cases} q(r-p) & \text{if } d > q \\ q(r-p) + (q-d)(s-p) & \text{if } d \le q' \end{cases}$$

- **Marginal Profit:**

$$\frac{\partial \Pi}{\partial q} = \mathbf{P}(d > q)(r-p) + \mathbf{P}(d \le q)(s-p) = 0$$

$$\left(1 - \mathbf{P}(d \le q)\right)(r-p) + \mathbf{P}(d \le q)(s-p) = 0$$

$$\mathbf{P}(d \le q)\left((s-p) - (r-p)\right) = -(r-p)$$

- **Optimal Quantity:**

$$\mathbf{P}(d \le q) = \frac{r-p}{(r-p)-(s-p)} = \frac{c}{c+h},$$

Simulation used 1M trials for each set of product, system design and decision rule…

- **Base Design:**

$$\mathrm{NPV_{Base}} = \left(\frac{\min(D, Q/T)R}{r}\right)\left(1 - \frac{1}{(1+r)^T}\right) - QP^L,$$

- **Flexible Design:**

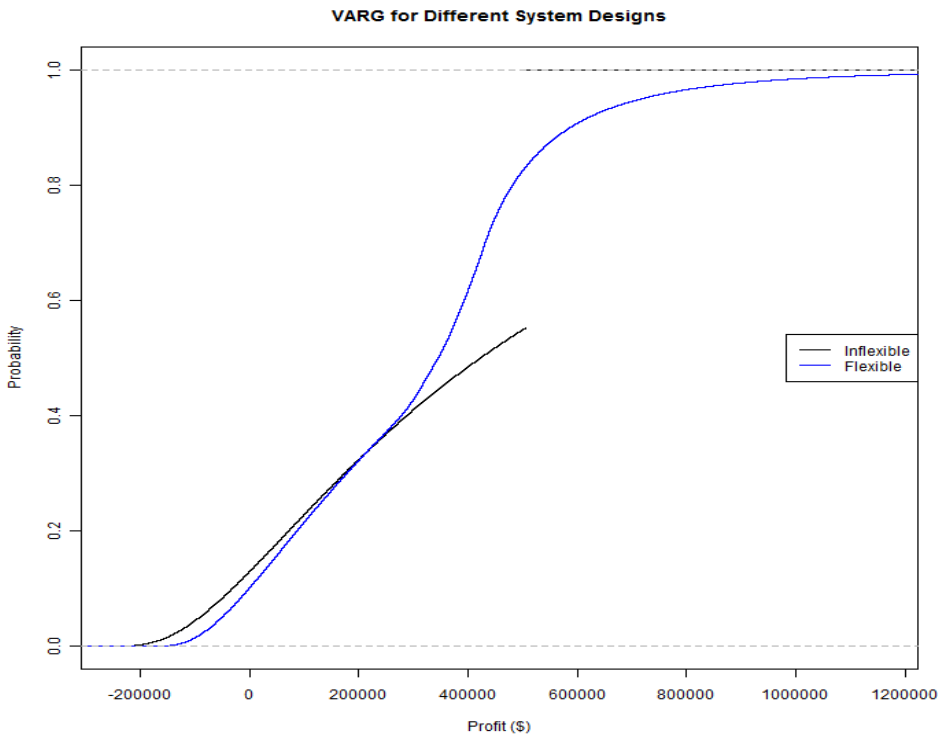
$$\mathrm{NPV_{Flexible}} = \left(\frac{\min\left(D, \frac{Q}{T(1-E)}\right)R}{r}\right)\left(1 - \frac{1}{(1+r)^{T(1-E)}}\right) - QP^L$$
$$+ \left(\frac{\min\left(\hat{D}, \frac{Q^* + \ddot{Q}}{TE}\right)R}{r(1+r)^{T(1-E)}}\right)\left(1 - \frac{1}{(1+r)^{TE}}\right) - \frac{\hat{Q}P^S}{(1+r)^{T(1-E)}},$$

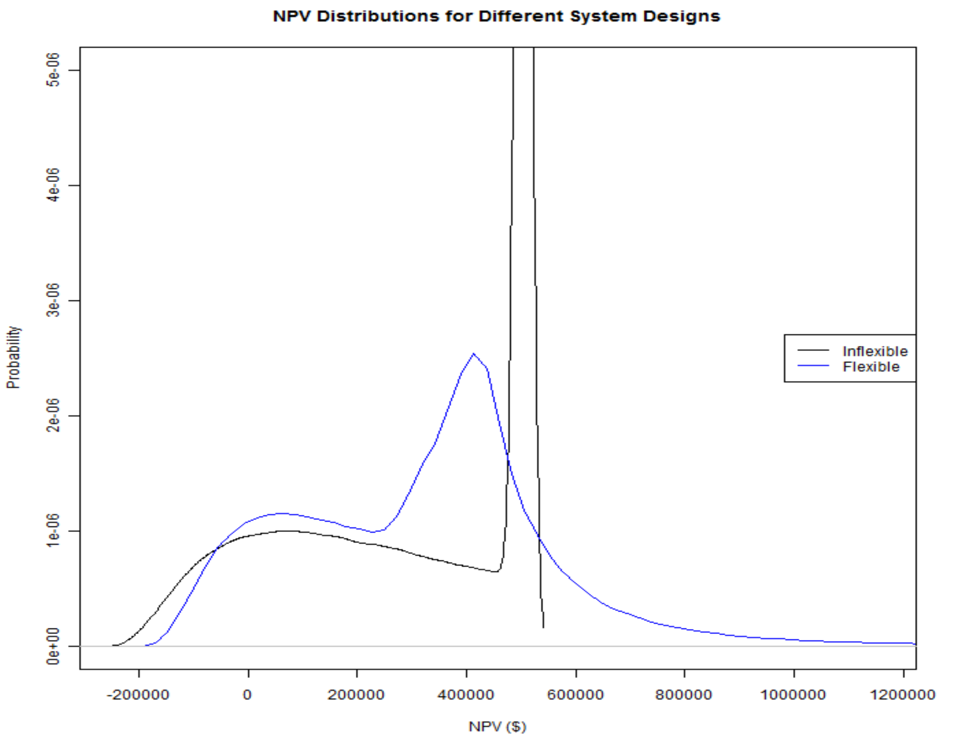
The results show that the flexible design outperforms the base design…

	E[NPV]	STD[NPV]	CAPEX	E[NPV]/CAPEX
Base Design (Inflexible)	$313,085.60	$219,461.20	$265,680.00	1.18
Flexible Design	$325,979.20	$270,032.50	$185,976.00	1.75

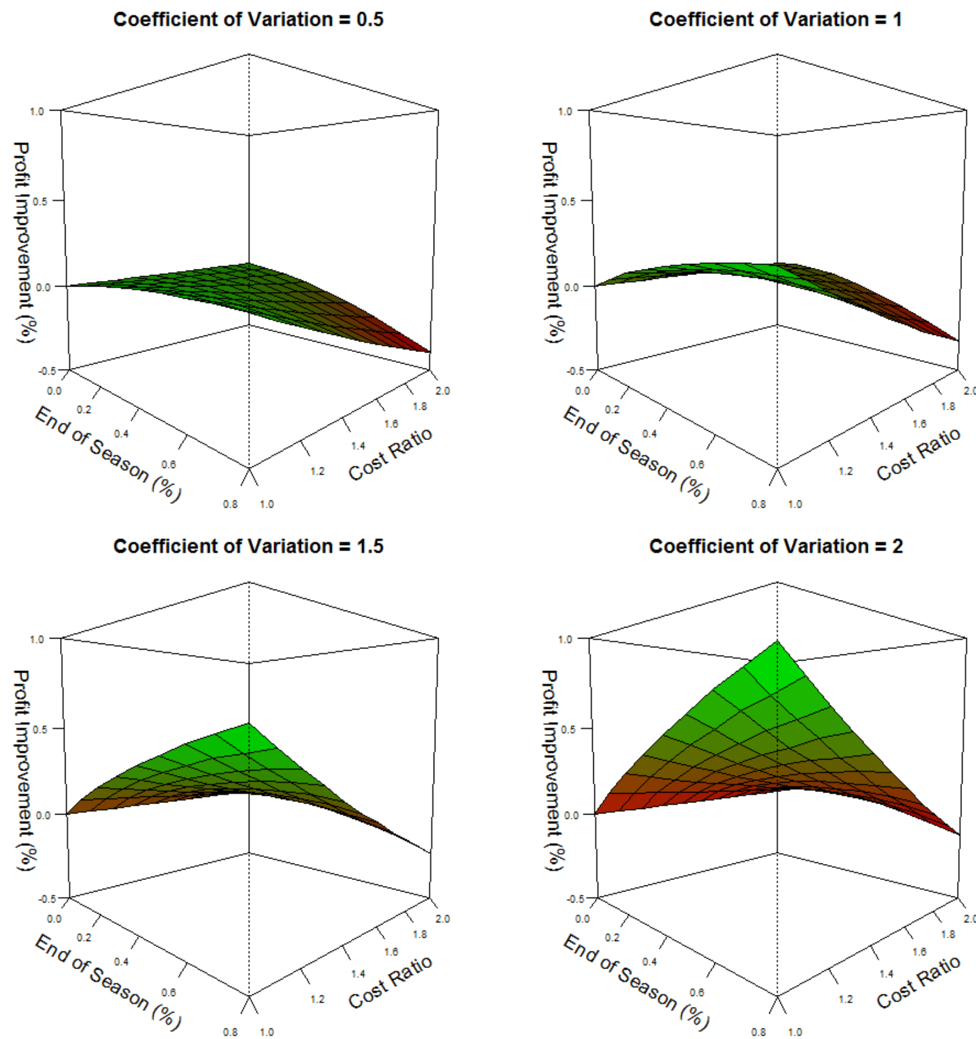
	P5	P95	Min(NPV)	Max(NPV)
Base Design (Inflexible)	$(91,701.71)	$504,191.10	$(258,937.60)	$504,191.10
Flexible Design	$(50,923.83)	$722,381.20	$(181,233.00)	$13,056,468.70

THE RESULTS SHOW THAT THE FLEXIBLE DESIGN OUTPERFORMS THE BASE DESIGN…



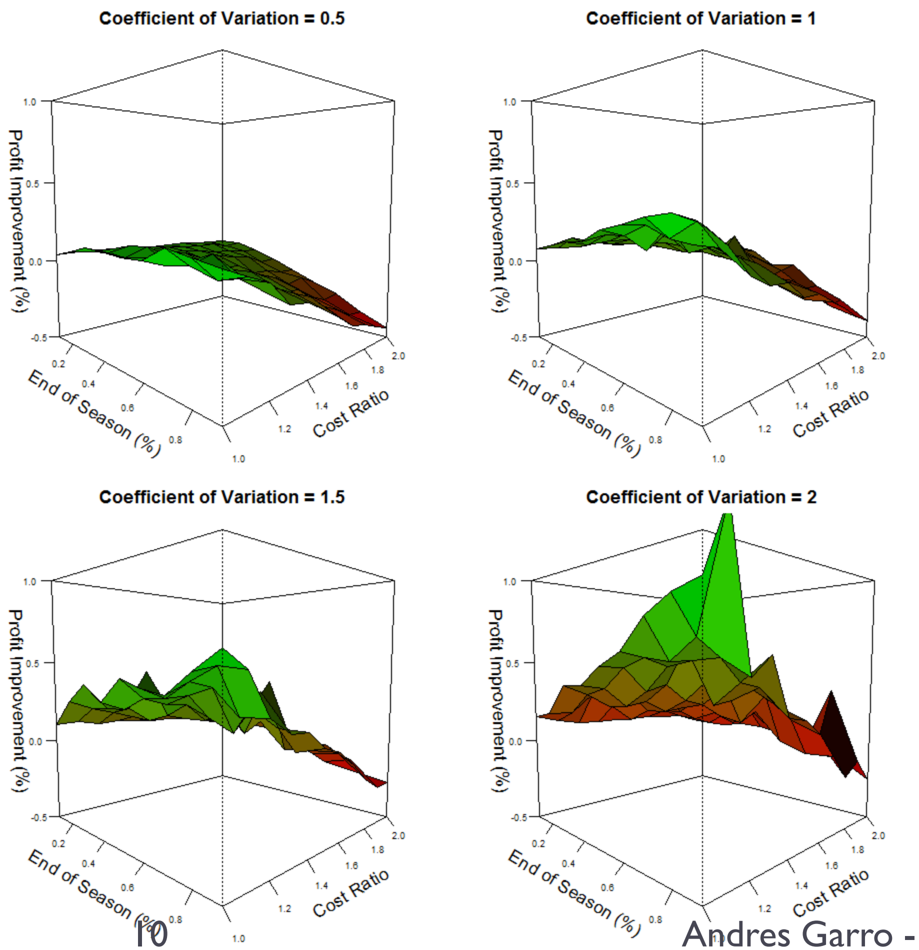


THE VALUE OF FLEXIBILITY DEPENDS ON THE UNCERTAINTY AND THE PRODUCTION COSTS…

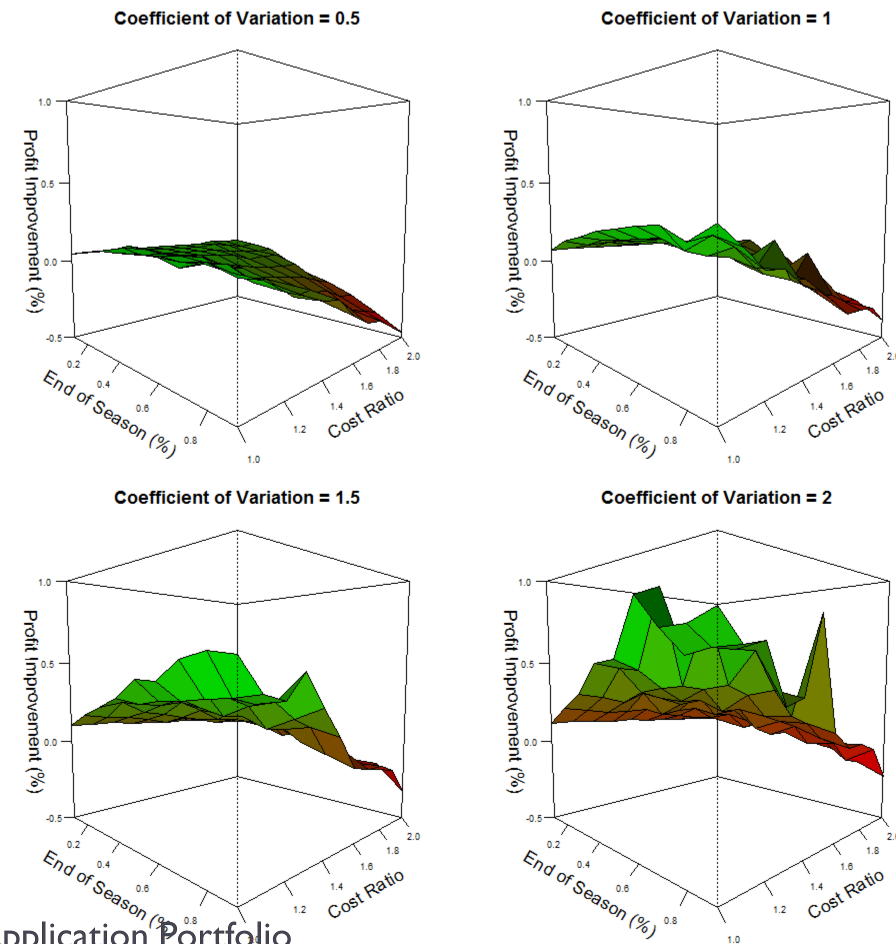


The value of flexibility increases with the number of products…

5 Products



10 Products



Summary of findings…

- The flexible design reduced the potential losses, significantly improved the potential gains, and had an average net present value increase of over 4% for a typical set of operating conditions.
- The benefit of the flexibility increases dramatically as the cost of short lead-time production goes down or the demand uncertainty goes up.
- As the number of products increases, the flexible design becomes progressively more attractive.