Learning and Forgetting: The Dynamics of Aircraft Production

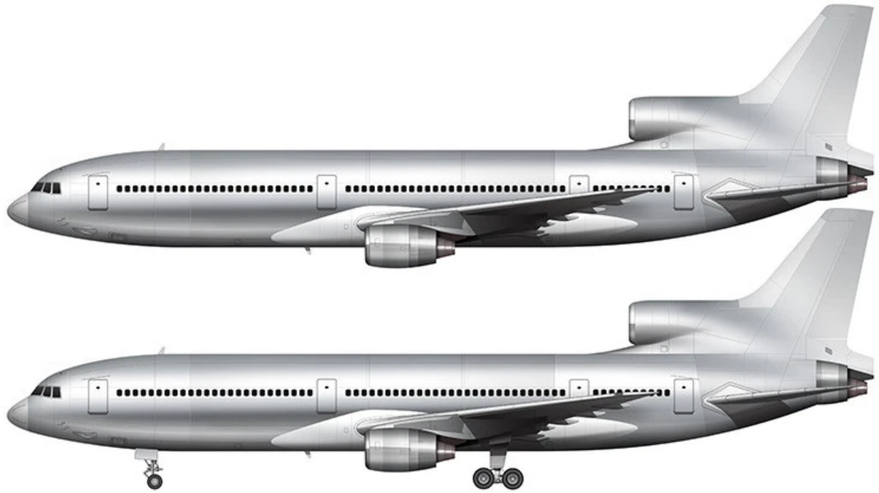
Benkard (AER, 2000)

Introduction

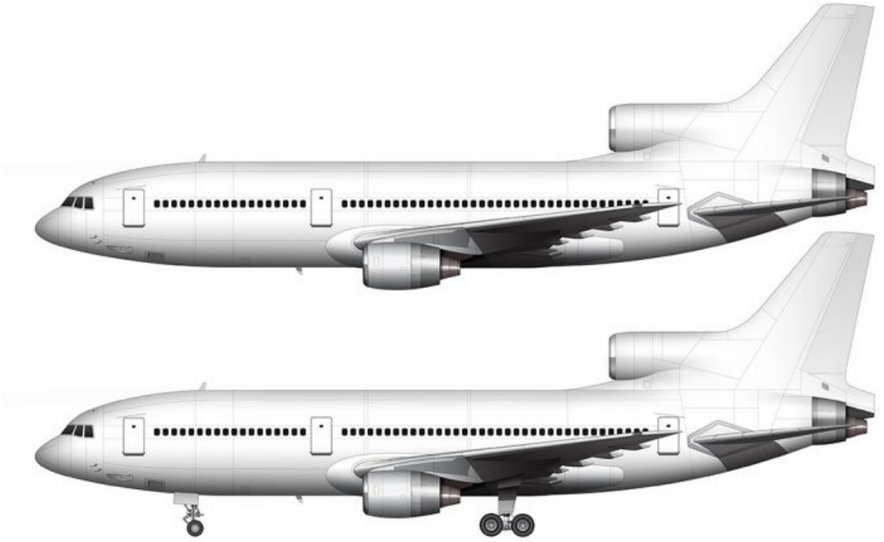
- Research Questions:
  - Draw a distinction between traditional firm learning (“learning-by-doing”) and a general learning model that allows for organizational forgetting
  - Document the presence of organization forgetting and understand the dynamics of technology in commercial aircraft production
- Approach:
  - Estimate the labor requirement function with unit-level production data from Lockheed for the Lockheed L-1011 (models: -1, -100, -200, -500), to understand learning/forgetting and experience spillovers
- Why is this important?
  - Understanding how organizational forgetting occurs can inform policies to reduce forgetting and increase productivity

L-1011 models

Lockheed produced a total of 250 units over the production run of the L-1011, which comprised 4 models of the “same” plane



Lockheed L-1011-1
65% of total production
Produced from 1970-1984



Lockheed L-1011-500
20% of total production
Produced from 1978-1984

L-1011 production

Production exhibits increasing returns to scale

Labor requirements fall as output increases

Consistent with traditional learning model

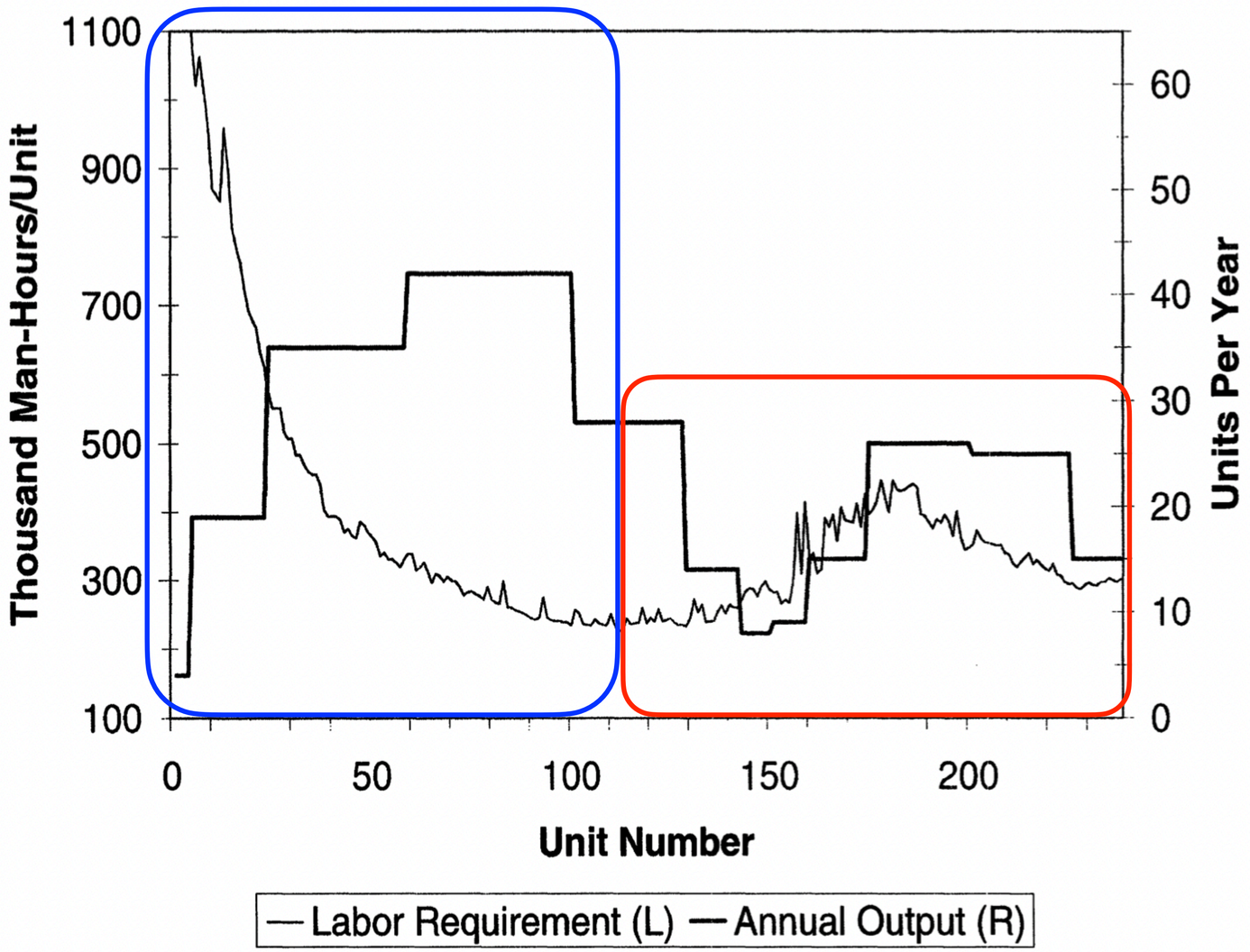


FIGURE 1. L-1011 PRODUCTION: DIRECT LABOR REQUIREMENT AND YEARLY OUTPUT

Possible decreasing returns to scale

Labor requirements increase as output increases

Want to understand whether organizational forgetting occurred

Firm experience

- Established literature shows that the aircraft industry has strong learning effects; input requirements decline with cumulative production
- Experience can be modeled or quantified in the following ways:
  - Traditional learning: experience accrues with cumulative output

$$E_i = E_{i-1} + 1 \text{ with } E_1 = 1$$

  - Organizational forgetting: experience is dynamic and depreciates over time

$$E_t = \delta E_{t-1} + q_{t-1} \text{ with } E_1 = 1$$

Model

The firm's labor requirement takes the Cobb-Douglas form:

$$ln(L_i) = ln(A_{\bar{K}}) + \theta ln(E_i) + \gamma_0 ln(S_i) + \epsilon_i$$

Where A is constant, E_i measures firm experience, S_i measures production line speed, and ϵ_i captures the unobserved

E_i: accommodate parameters for traditional learning model: "θ" organizational forgetting "δ" and production spillovers "λ"

ϵ_i is correlated with E_i and $S_i \rightarrow$ use demand and cost shifters as instruments

Organizational forgetting and spillovers

$E_i = E_{1,t} = \delta E_{1,t-1} + q_{1,t-1} + \lambda q_{500,t-1}$ if i is type -1, -100, -200

$E_i = E_{500,t} = \delta E_{500,t-1} + q_{500,t-1} + \lambda q_{1,t-1}$ if i is type -500

Where $E_{1,1} = E_{500,1} = 1$

δ measures the rate of experience depreciation (organizational forgetting)

λ measures experience spillovers across the production of different models

Traditional learning model

$$ln(L_i) = ln(A) + \theta ln(E_i)$$

	ln A	θ
Basic regressions		
1. Units 1–112	7.90	−0.51
	(0.06)	(0.01)
2. Units 1–238	7.16	−0.29
	(0.08)	(0.02)

Traditional learning model explains the first half of the production run adequately but does not fit the full sample well

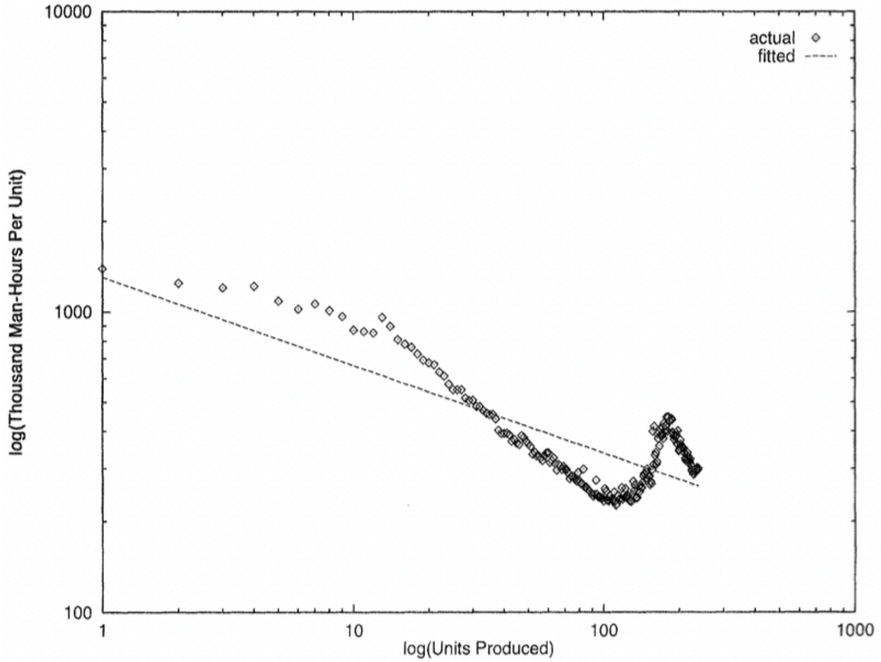


FIGURE 3. TRADITIONAL LEARNING CURVE: ALL 238 UNITS (LOG-LOG)

General learning model

	ln A	θ	γ_0	δ	λ
OF only					
9. $[S_N^* = 9.3]$	7.63	−0.65	0.14	0.952	—
	(0.01)	(0.02)	(0.12)	(0.003)	
Spillovers					
10. $[S_N^* = 6.9]$	7.73	−0.63	0.11	0.960	0.70
	(0.01)	(0.03)	(0.17)	(0.003)	(0.07)
$N = 238$	$TSS = 33.7$				

$\delta < 1 \rightarrow$ Reject H_0: no organizational forgetting

$\lambda < 1 \rightarrow$ Reject H_0: complete spillovers

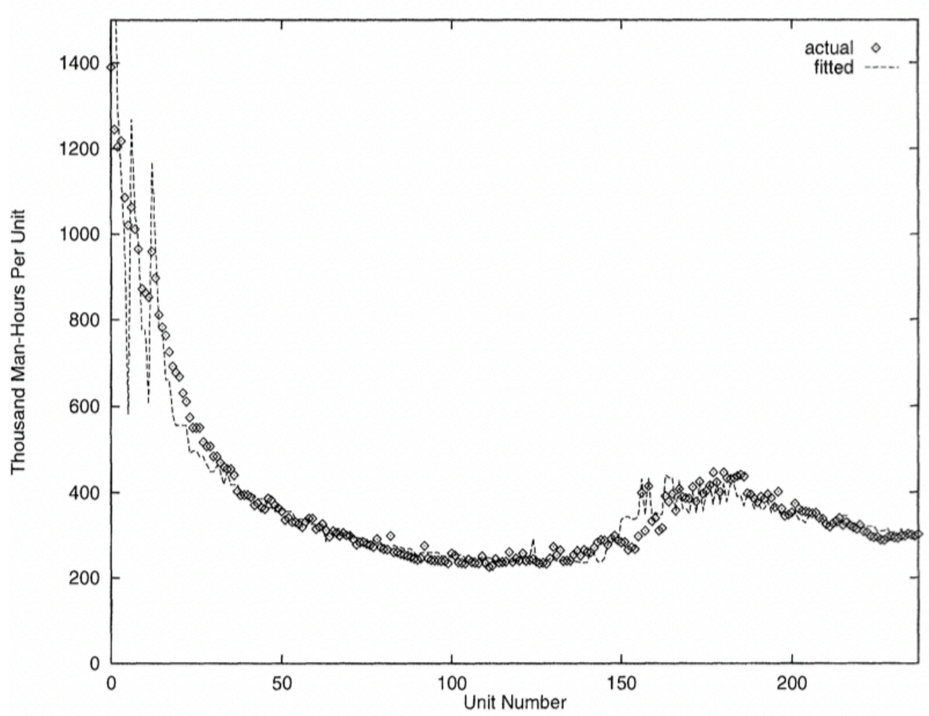


FIGURE 4. ORGANIZATIONAL FORGETTING AND INCOMPLETE SPILLOVERS (REGRESSION 10)

Summary and conclusion

- The dynamics of aircraft production are more complex than what traditional firm learning (experience accruing from cumulative output) can explain
- Using detailed unit-level production data from Lockheed, support is found for organizational forgetting and incomplete spillovers of firm experience
- Implications for: job turnover rates, firm management practices, infant industry protection and antitrust policies