Learning and Forgetting: The Dynamics of Aircraft Production

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Motivation

Learning: Unit cost decreases with cumulative production.
Forgetting: Firm's production experience depreciates over time.

Question: Is there organizational forgetting in aircraft production? And if so what are dynamics of its technology?

What this paper does:
(a) Discuss the industry learning, forgetting and experience spillovers process.
(b) Develope a model of firm learning and forgetting and estimate it.

Why is this important: Organizations can forget!

Key take away: Organizational forgetting add a degree of dynamic complexity to industries where learning is present.

The commercial aircraft industry

- Massive entry costs.
- Dynamically increasing returns.
- Imperfect competition.
- Because the unit of output is so large, production is highly labor intensive.
- Production rates are very low.

The Lockheed L-1011

The most technologically advanced commercial jet of its era. Produced at a time when the commercial aircraft market was extremely volatile, 1970–1984. There were four basic models of L-1011 in only 250 units produced and production rates varied widely.

Learning

- In labor-intensive industries workers becoming more efficient through multiple repetition.
- Learning can also be thought of as the accumulation of human capital.
- Learning results from a more experienced workforce.

$\implies$ Aircraft producers are very careful to maintain stability in their manufacturing process over time.

Organizational Forgetting

Forgetting at the organizational level without accounting for what fraction is due specifically to individuals.

- Aircraft firm's experience is embodied in its workers.
  - $\implies$ Turnover and layoffs may lead to losses of experience.
- Experience may depreciate in times of falling production rates (Δ^+ layoffs).
- Recent production is more important than more-distant past production in determining a firm's current efficiency.
- The industry labor union secures that as employees attain seniority, they have the option of requesting an upgrade into a higher-level job, generating a Domino effect.
  - $\implies$ turnover rates are high, which leads to greater organizational forgetting

Experience Spillovers

- The skills required to build a new model of an existing aircraft might do not transfer over completely from past production.
- By introducing a new model, a firm might experiences a setback in learning and higher production costs for the whole aircraft program.
- If learning does not spill over completely between these models, then production costs for the whole program are higher as a result.

$\implies$ Production costs are likely to increase when firms introduce new models of a product.

Direct labor requirements and yearly output
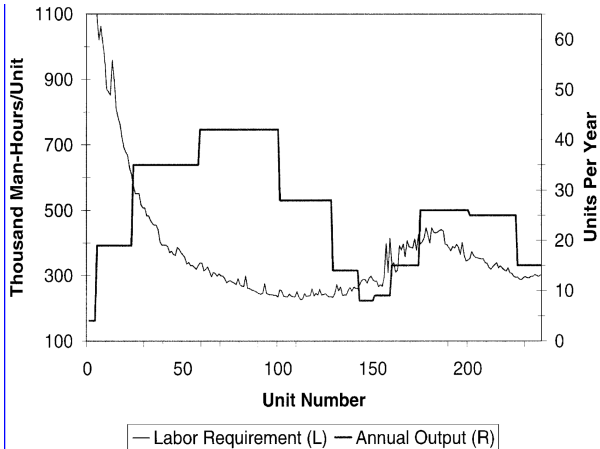
Model (1)

Firms adjust the variable inputs at the unit level (isoquant $q = 1$), thus labor hours (L) used in the production of unit i:

$$\ln L_i = \ln A(\bar{K}) + \theta \ln \underbrace{E_i}_{\text{Experience}} + \gamma_0 \ln \underbrace{S_i}_{\text{Line speed}} + \epsilon_i$$

θ measures the rate of learning ($LR = 1 - 2^\theta$), γ_0 measures the within-period returns to production rate.

Experience:

Traditional model (cumulative past output): $E_i = E_{i-1} + 1$

Using a depreciation factor: $E_t = \delta E_{t-1} + q_{t-1}$

$\implies$ Learning can take place only by producing planes, and unless production rates are maintained, experience begins to depreciate.

Model (2)

The model allows experience spillovers to be incomplete across models buding two groups of types:

$$E_i = \begin{cases} E_{1,t} & \text{if } i \text{ is type -1,-100,-200} \\ E_{500,t} & \text{if } i \text{ is type -500} \end{cases}$$

Then using λ as the experience spillover parameter:

$$E_{1,t} = \delta E_{1,t-1} + q_{1,t-1} + \lambda q_{500,t-1}$$
$$E_{500,t} = \delta E_{500,t-1} + q_{500,t-1} + \lambda q_{1,t-1}$$

Results

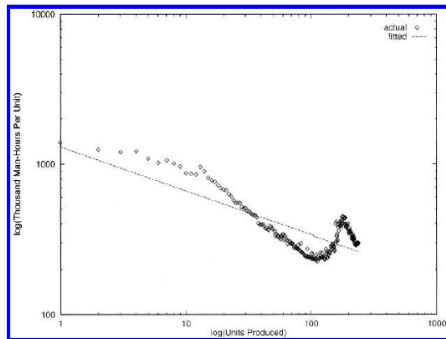Estimation using 2SLS for the traditional model and GMM for the nonlinear model.

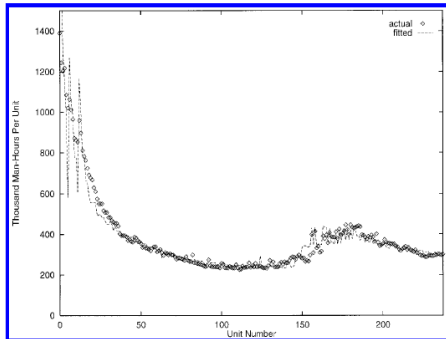FIGURE 3. TRADITIONAL LEARNING CURVE: ALL 238 UNITS (LOG-LOG)

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

Depretiation factor might explain organizational forgetting

61% of the firm's stock of experience existing at the beginning of a year survives to the end of the year (!!).

- Depreciation in a firm's stock of a very specific kind of human capital.
- High turnover due to "displacement rights".
- Given that the two L-1011 models are quite similar and were produced in the same plants together, the spillover parameter estimates were surprisingly low (around 70% overlap between the two models)
  $\implies$ aircraft production experience is very specific.

Industry executives confirm that disruption in production is highly costly.
$\implies$ Organizational forgetting may also explain the lack of technological change itself.

Personal comments

Amazing stuff:

- Very clean, smart, even simple estimation strategy to bring to light a HUGE concept.
- Even tough is a very specific and unique industry, and the robustness checks we not really exhaustive, from now on I am convinced that if an organization can learn it can also forget.

Just one thing:

Forgetting might just be a fancy term for workers turnover.