# Learning Curves

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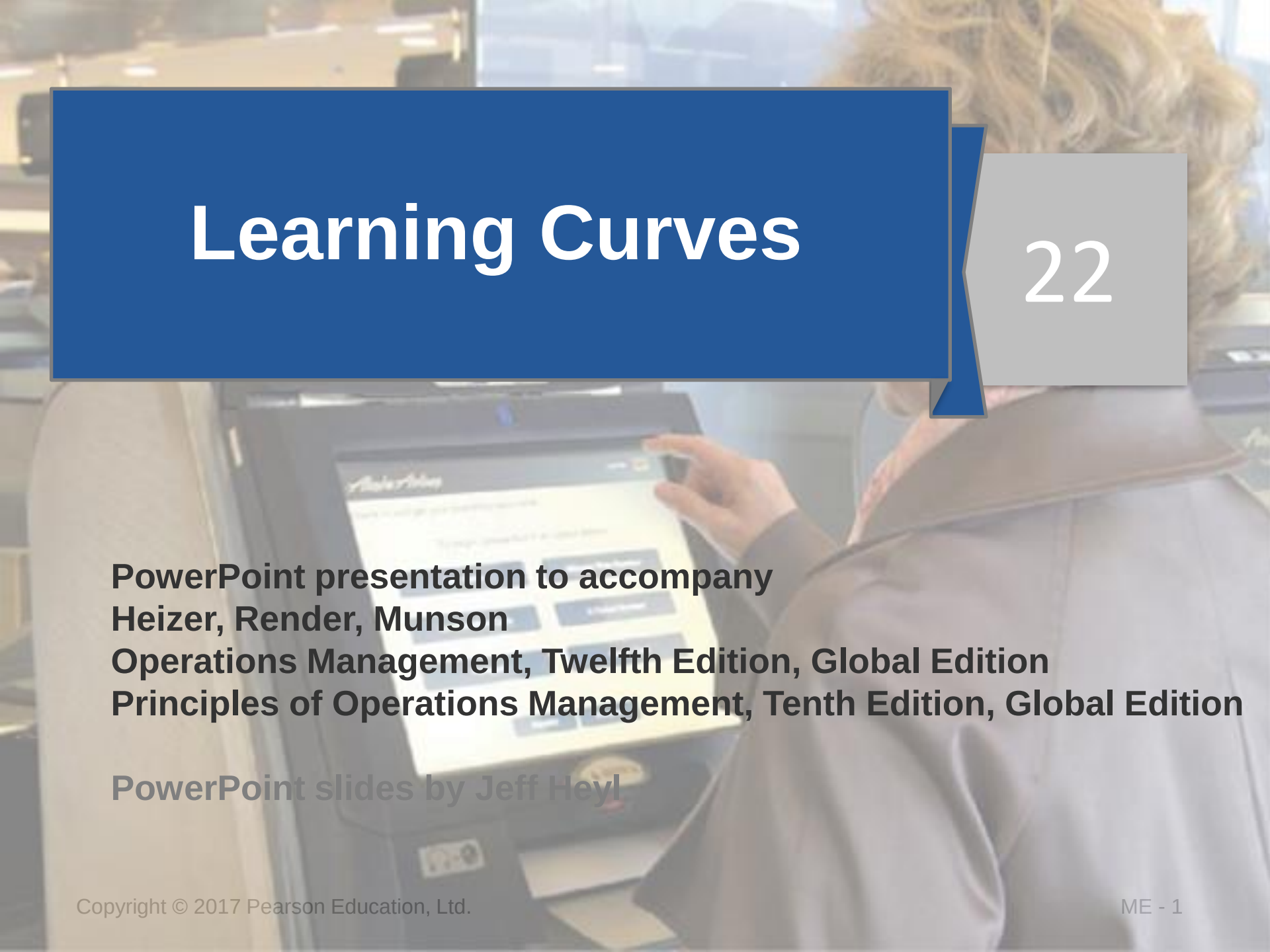

**PowerPoint presentation to accompany**
**Heizer, Render, Munson**
**Operations Management, Twelfth Edition, Global Edition**
**Principles of Operations Management, Tenth Edition, Global Edition**

**PowerPoint slides by Jeff Heyl**

# Outline

- What Is a Learning Curve?
- Learning Curves in Services and Manufacturing
- Applying the Learning Curve
- Strategic Implications of Learning Curves
- Limitations of Learning Curves

# Learning Objectives

**When you complete this chapter you should be able to:**

- **E.1** ***Define*** learning curve
- **E.2** ***Use*** the doubling concept to estimate times
- **E.3** ***Compute*** learning-curve effects with the formula and learning-curve table approaches
- **E.4** ***Describe*** the strategic implications of learning curves

# What Is a Learning Curve

- Based on the premise that people and organizations become better at their tasks as the tasks are repeated
- Time to produce a unit decreases as more units are produced
- Learning curves typically follow a negative exponential distribution
- Time savings per unit decreases over time

# Learning Curve Effect

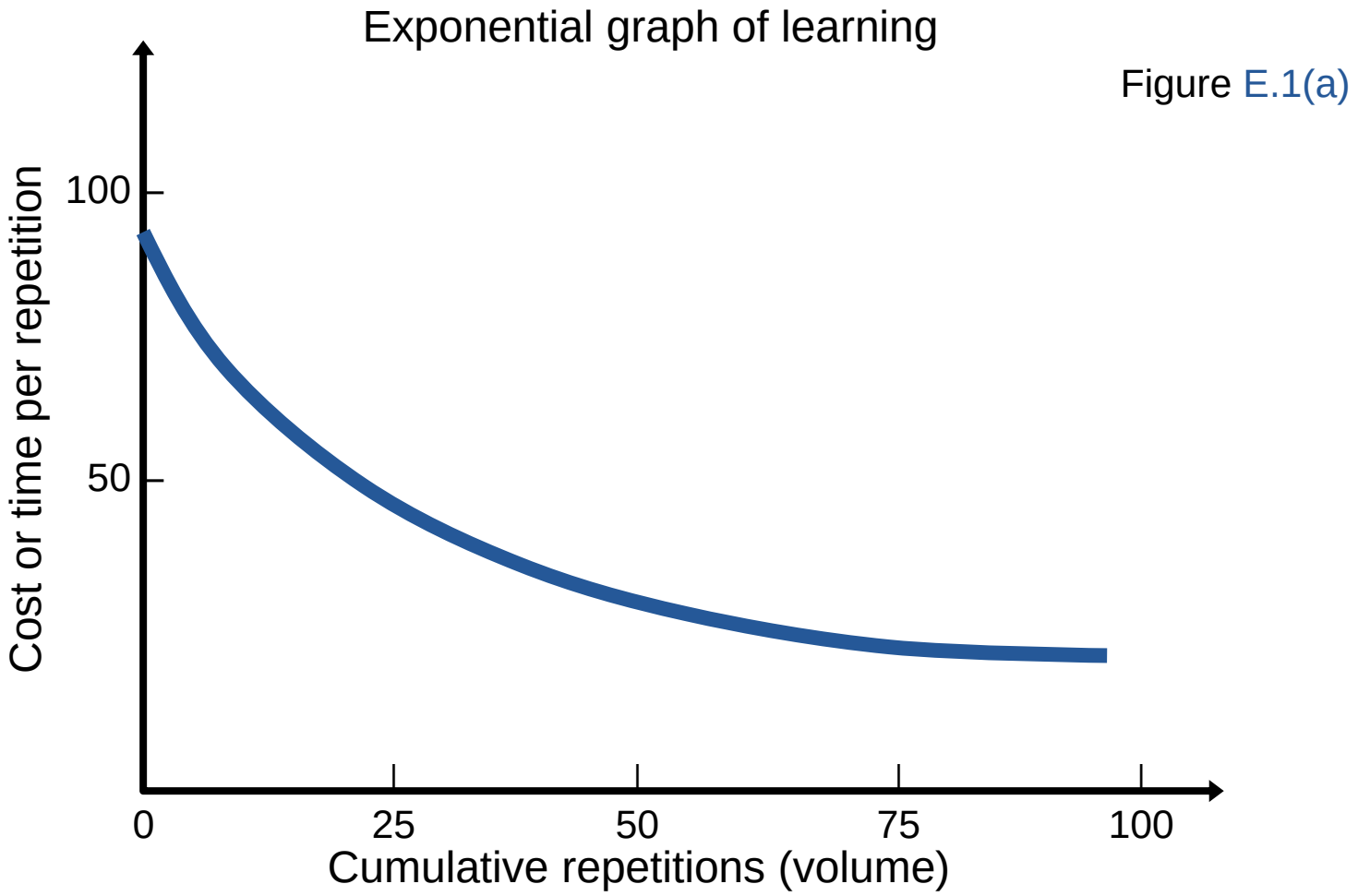


Figure E.1(a)

# Learning Curve Effect

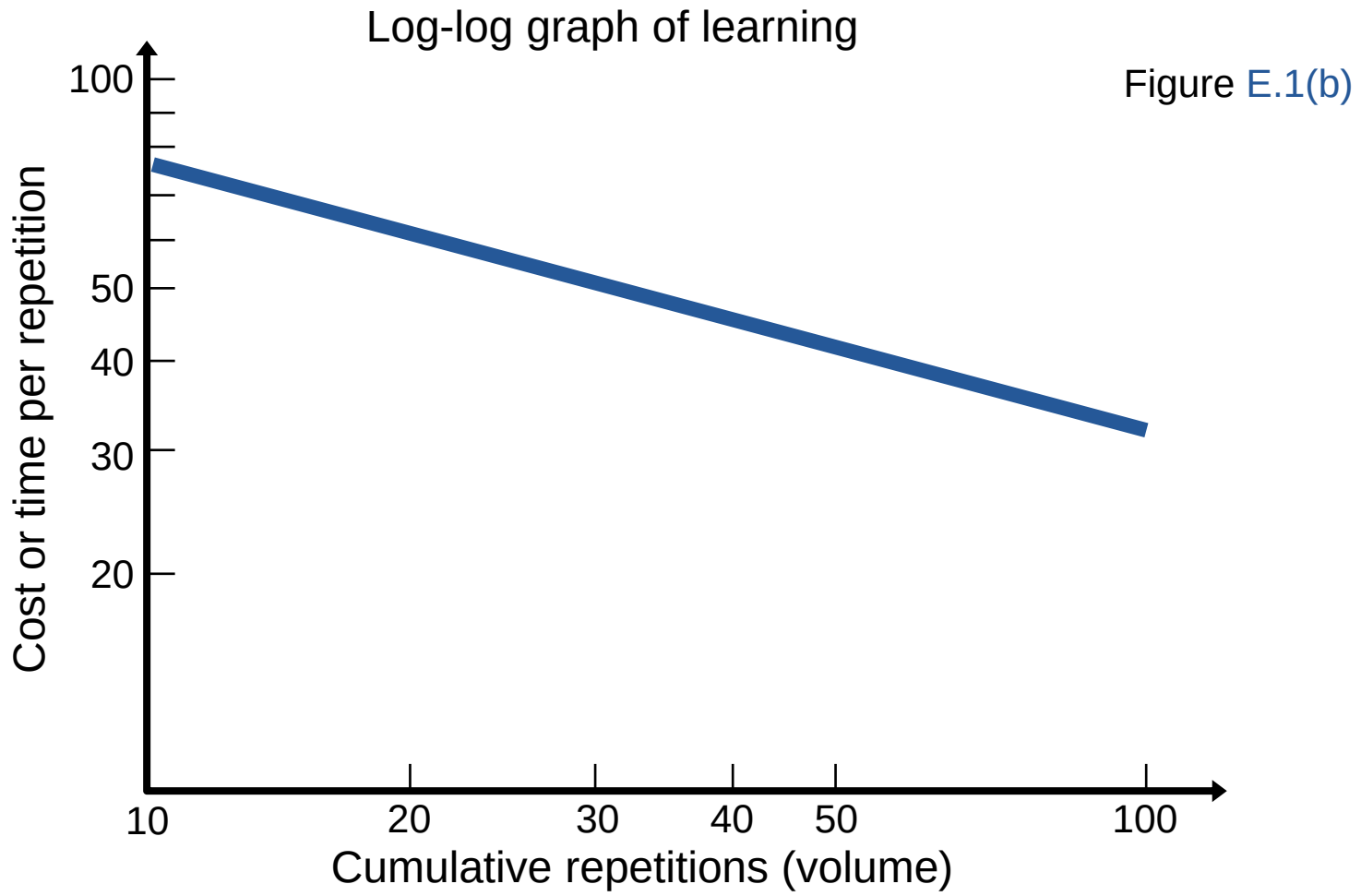


Figure E.1(b)

# Learning Curves

$T$ x $L^n$ = Time required for the $n^{th}$ unit

where $T$ = unit cost or unit time of the first unit
$L$ = learning curve rate
$n$ = number of times $T$ is doubled

First unit takes 10 labor-hours
70% learning curve is present
Fourth unit will require doubling twice — 1 to 2 to 4

Hours required for unit 4 = 10 x $(.7)^2$ = 4.9 hours

# Learning Curve Examples

TABLE E.1 Examples of Learning-Curve Effects

| EXAMPLE | IMPROVING PARAMETER | CUMULATIVE PARAMETER | LEARNING-CURVE SLOPE (%) |
|---|---|---|---|
| 1. Model-T Ford production | Price | Units produced | 86 |
| 2. Aircraft assembly | Direct labor-hours per unit | Units produced | 80 |
| 3. Equipment maintenance at GE | Average time to replace a group of parts | Number of replacements | 76 |

# Learning Curve Examples

TABLE E.1 Examples of Learning-Curve Effects

| EXAMPLE | IMPROVING PARAMETER | CUMULATIVE PARAMETER | LEARNING-CURVE SLOPE (%) |
|---|---|---|---|
| 4. Steel production | Production worker labor-hours per unit produced | Units produced | 79 |
| 5. Integrated circuits | Average price per unit | Units produced | 72[a] |
| 6. Handheld calculator | Average factory selling price | Units produced | 74 |

[a] Constant dollars

# Learning Curve Examples

TABLE E.1 Examples of Learning-Curve Effects

| EXAMPLE | IMPROVING PARAMETER | CUMULATIVE PARAMETER | LEARNING-CURVE SLOPE (%) |
|---|---|---|---|
| 7. Disk memory drives | Average price per bit | Number of bits | 76 |
| 8. Heart transplants | 1-year death rates | Transplants completed | 79 |
| 9. Caesarean section baby deliveries | Average operation time | Number of surgeries | 93 |

# Learning Curves in Services and Manufacturing

- Different organizations have different learning curves
- Any change in process, product, or personnel disrupts the learning curve

# Learning Curves in Services and Manufacturing

**Internal**: Labor forecasting, scheduling, establishing costs and budgets

**External**: Supply-chain negotiations

**Strategic**: Evaluation of company and industry performance, including costs and pricing

# Applying the Learning Curve

- Doubling approach
  - Simplest approach
  - Labor cost declines at a constant rate, the learning curve rate, as production doubles
  - Does not work for other production quantities

# Applying the Learning Curve

- For an 80% learning rate

| *N*TH UNIT PRODUCED | HOURS FOR *N*TH UNIT | |
|---|---|---|
| 1 | 100.0 | |
| 2 | 80.0 | = (.8 x 100) |
| 4 | 64.0 | = (.8 x 80) |
| 8 | 51.2 | = (.8 x 64) |
| 16 | 41.0 | = (.8 x 51.2) |

# Formula Approach

Determine labor for any unit, $T_N$, by

$$T_N = T_1(N^b)$$

where $T_N$ = time for the $N^{\text{th}}$ unit
$T_1$ = time to produce the first unit
$b$ = (log of the learning rate)/(log 2)
= slope of the learning curve

# Formula Approach

Determine labor for any unit,

$$T_N = T_1(N^b$$

where $T_N$ = time for the $N$
$T_1$ = time to produ
$b$ = (log of the lea
= slope of the le

TABLE E.2

Learning-Curve Values of *b*

| LEARNING RATE (%) | *b* |
|---|---|
| 70 | – .515 |
| 75 | – .415 |
| 80 | – .322 |
| 85 | – .234 |
| 90 | – .152 |

# Using Logs

Learning rate = 80%
First unit took 100 hours

$$T_N = T_1(N^b)$$
$$T_3 = (100 \text{ hours})(3^b)$$
$$= (100)(3^{\log .8/\log 2})$$
$$= (100)(3^{-.322})$$
$$= 70.2 \text{ labor hours}$$

# Learning Curve Table Approach

$$T_N = T_1 C$$

where $T_N$ = number of labor-hours required to produce the $N^{th}$ unit

$T_1$ = number of labor-hours required to produce the first unit

$C$ = learning-curve coefficient found in Table E.3

# Learning-Curve Coefficients

| TABLE E.3 | Learning-Curve Coefficients, Where Coefficient $C = N^{(\text{LOG OF LEARNING RATE/LOG 2})}$ | | | |
|---|---|---|---|---|
| | 70% | | 85% | |
| UNIT NUMBER (N) | UNIT TIME COEFFICIENT | TOTAL TIME COEFFICIENT | UNIT TIME COEFFICIENT | TOTAL TIME COEFFICIENT |
| 1 | 1.000 | 1.000 | 1.000 | 1.000 |
| 2 | .700 | 1.700 | .850 | 1.850 |
| 3 | .568 | 2.268 | .773 | 2.623 |
| 4 | .490 | 2.758 | .723 | 3.345 |
| 5 | .437 | 3.195 | .686 | 4.031 |
| 10 | .306 | 4.932 | .583 | 7.116 |
| 15 | .248 | 6.274 | .530 | 9.861 |
| 20 | .214 | 7.407 | .495 | 12.402 |

# Coefficient Example

First boat required 125,000 hours
Labor cost = $40/hour
Learning factor = 85%

$T_N = T_1 C$
$T_4$ = (125,000 hours)(.723)
= 90,375 hours for the 4th boat

90,375 hours x $40/hour = $3,615,000

$T_N = T_1 C$
$T_4$ = (125,000 hours)(3.345)
= 418,125 hours for all four boats

# Coefficient Example

Third boat required 100,000 hours
Learning factor = 85%

New estimate for the first boat

$$\frac{100{,}000}{.773} = 129{,}366 \text{ hours}$$

# Strategic Implications

If a firm's strategy is to follow a steeper curve than the rest of the industry, they can do this by:

1. Following an aggressive pricing policy
2. Focusing on continuing cost reduction and productivity improvement
3. Building on shared experience
4. Keeping capacity ahead of demand

# Industry and Company Learning Curves

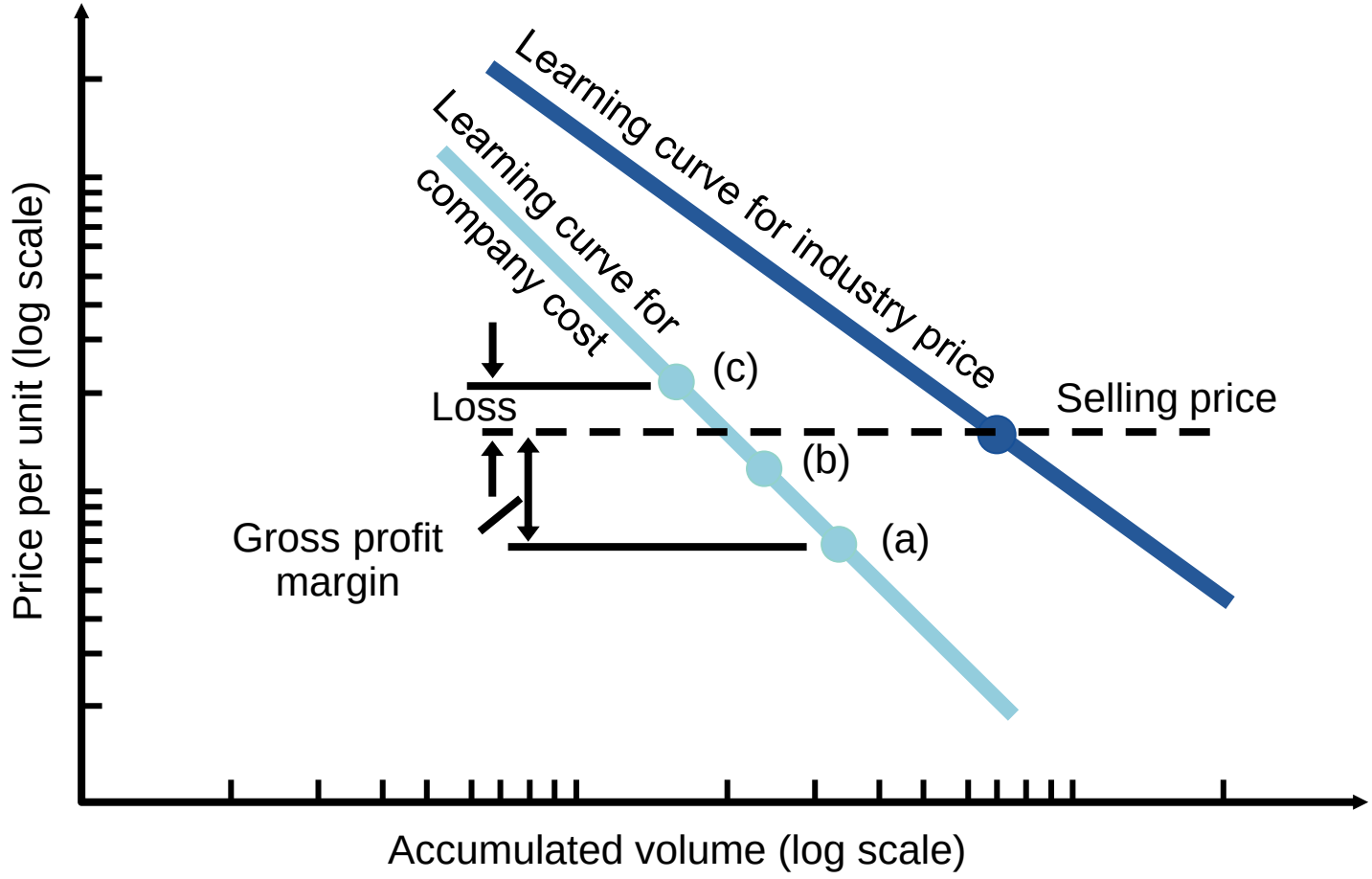


Figure E.2

# Limitations of Learning Curves

- Learning curves differ from company to company as well as industry to industry so estimates should be developed for each organization
- Learning curves are often based on time estimates which must be accurate and should be reevaluated when appropriate

# Limitations of Learning Curves

- Any changes in personnel, design, or procedure can be expected to alter the learning curve
- Learning curves do not always apply to indirect labor or material
- The culture of the workplace, resource availability, and changes in the process may alter the learning curve