Knowledge and Skills for Enterprise Transformation.

Modeling & Managing Complex Systems
A Case Study of Healthcare Delivery

William B. Rouse

Overview

- Complex Adaptive Systems
- Healthcare Delivery
- Complexity of Healthcare
- Case Study – Cost Control
- Healthcare Enterprise
- Summary

Complex Adaptive Systems

Georgia Tech Tennenbaum Institute

- They are nonlinear, dynamic and do not inherently reach fixed equilibrium points. The resulting system behaviors may appear to be random or chaotic.
- They are composed of independent agents whose behavior can be described as based on physical, psychological, or social rules, rather than being completely dictated by the dynamics of the system.
- Agents' needs or desires, reflected in their rules, are not homogeneous and, therefore, their goals and behaviors are likely to conflict -- these conflicts or competitions tend to lead agents to adapt to each other's behaviors.
- Agents are intelligent, learn as they experiment and gain experience, and change behaviors accordingly. Thus, overall systems behavior inherently changes over time.
- Adaptation and learning tends to result in self-organizing and patterns of behavior that emerge rather than being designed into the system. The nature of such emergent behaviors may range from valuable innovations to unfortunate accidents.
- There is no single point(s) of control – systems behaviors are often unpredictable and uncontrollable, and no one is "in charge." Consequently, the behaviors of complex adaptive systems usually can be influenced more than they can be controlled.

Healthcare

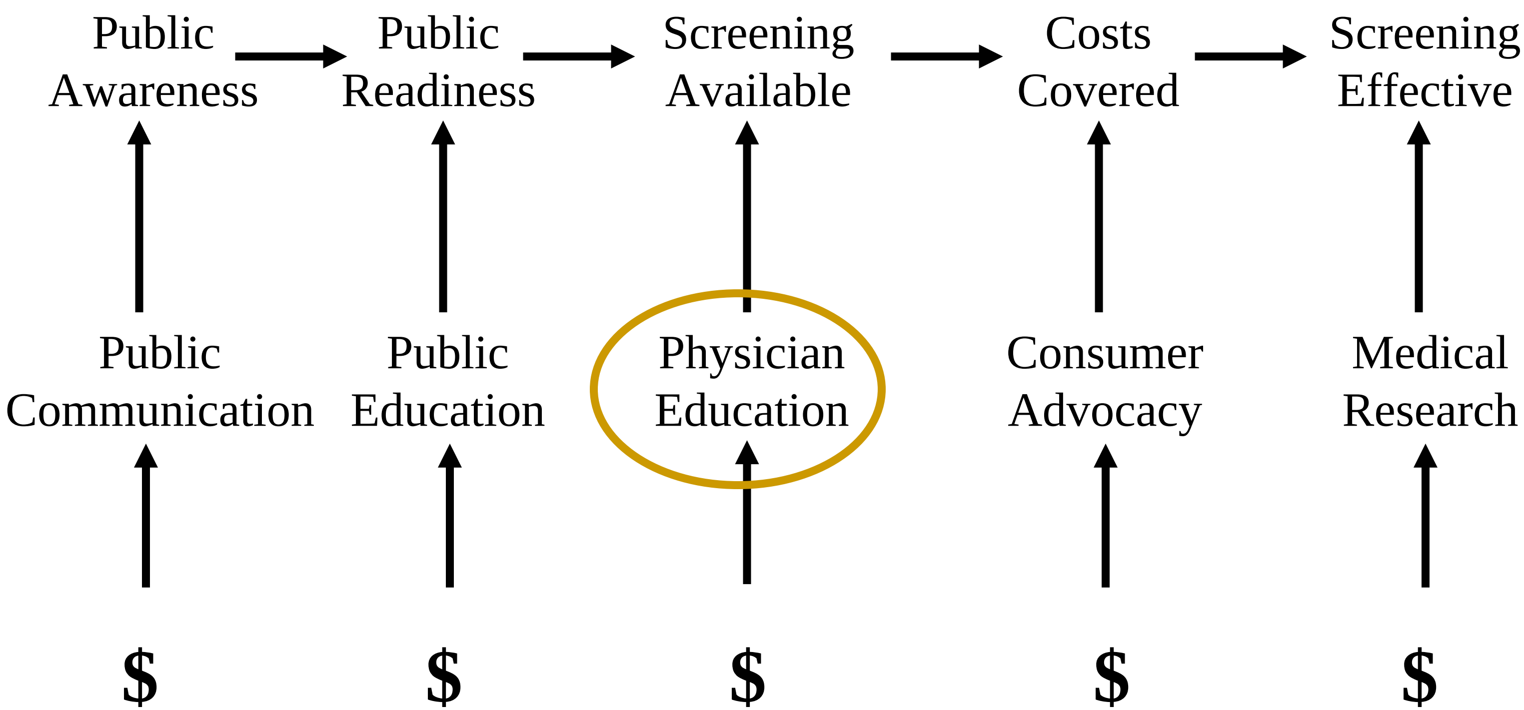
- Stakeholders & Interests
- Example of Disease Detection
- Network of Networks

Stakeholders & Interests

Georgia Tech Tennenbaum Institute

Stakeholder	Risk Mgt.	Prevention	Detection	Treatment
Public	e.g., Buy Insurance	e.g., Stop Smoking	e.g., Get Screened	
Delivery Sys			Physicians	Physicians & Hospitals
Government	Medicare, Medicaid, Congress	NIH, CDC, DoD, et al.		
Non-Profits		American Cancer Society, American Heart Association, et al.		
Academia	Business Schools	Basic Science Disciplines	Technology & Medical Schools	Medical Schools
Business	Employers, Insurance Companies, HMOs		Guidant, Medtronic, et al.	Lilly, Merck, Pfizer, et al.

Disease Detection



Public, Delivery System, Government, Non-Profits, Academia, Business

Networks of Networks

Accreditation & Licensing

- American Board of Medical Specialties
- Accreditation Council for Graduate Medical Educ.
- Accreditation Council for Continuing Medical Educ.
- AOA Council on Postdoctoral Training
- Federation of State Medical Boards
- Joint Commission on Accreditation of Healthcare Org.
- Liaison Committee on Medical Education

Professional Associations

- American Academy of Family Physicians
- American Medical Association
- American Osteopathic Association (AOA)
- Council of Medical Specialty Societies
- Etc.

Examples of Other Stakeholders

- American Assoc of Retired Persons
- Leapfrog Purchasing Group
- National Business Group on Health
- Etc.

Complexity

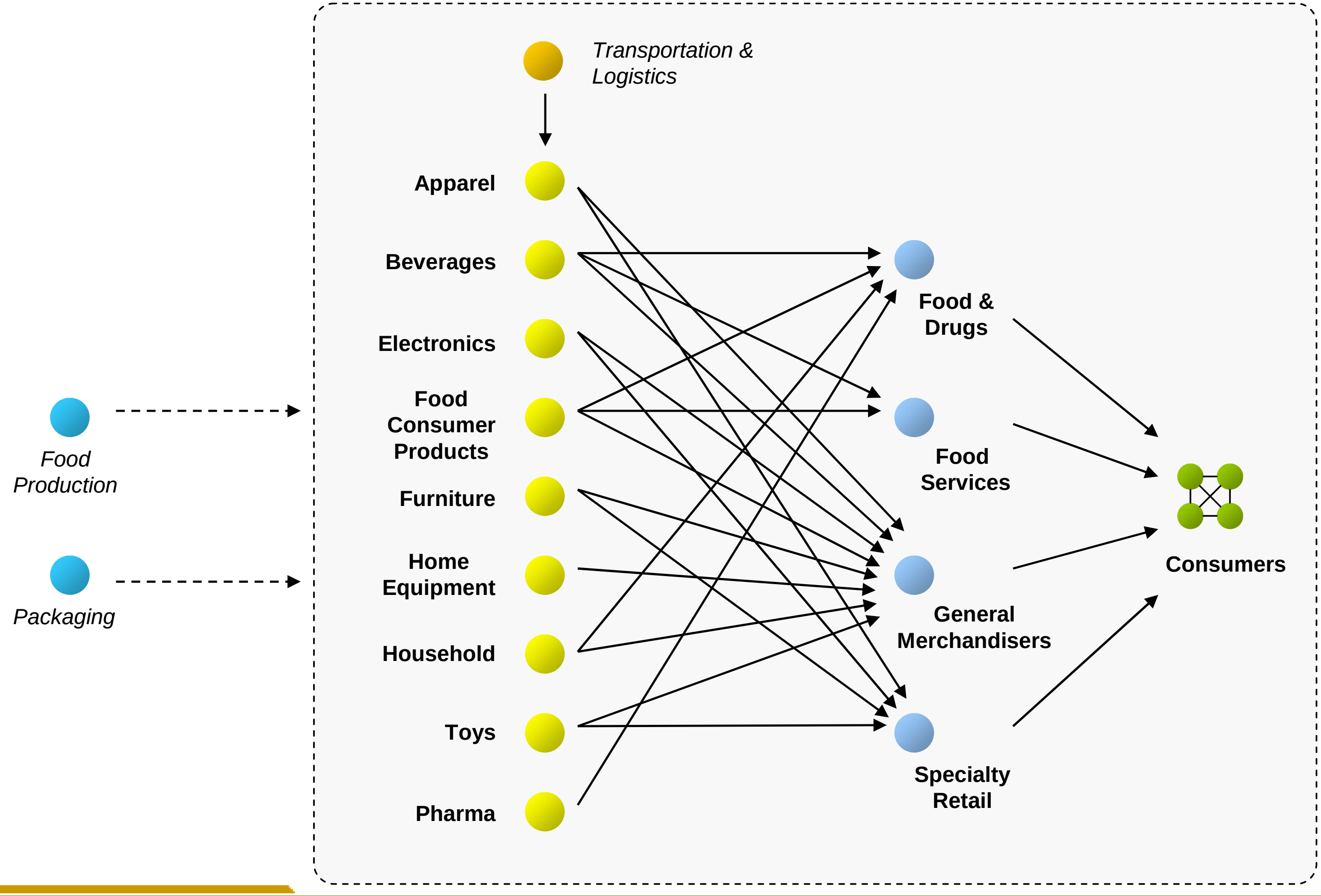
- Market Complexity
- Studying Complexity
- Design Implications
- Management Implications

Market Complexity

Georgia Tech Tennenbaum Institute

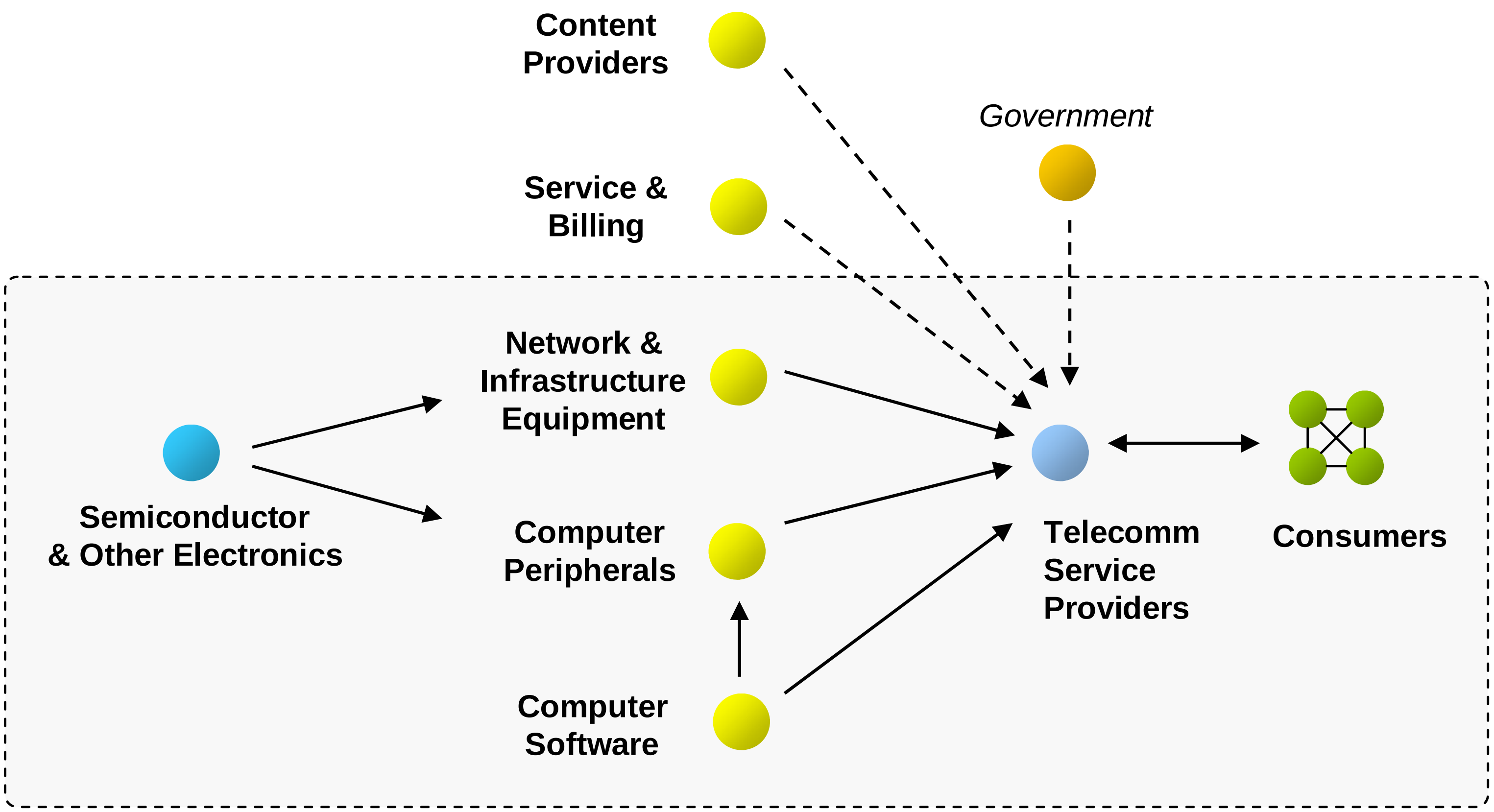
- Retail
- Telecom
- Healthcare
- Complexity Model
  - Network Model
  - Calculating Complexity
  - Complexity Surface
- Complexity Assessment

Retail

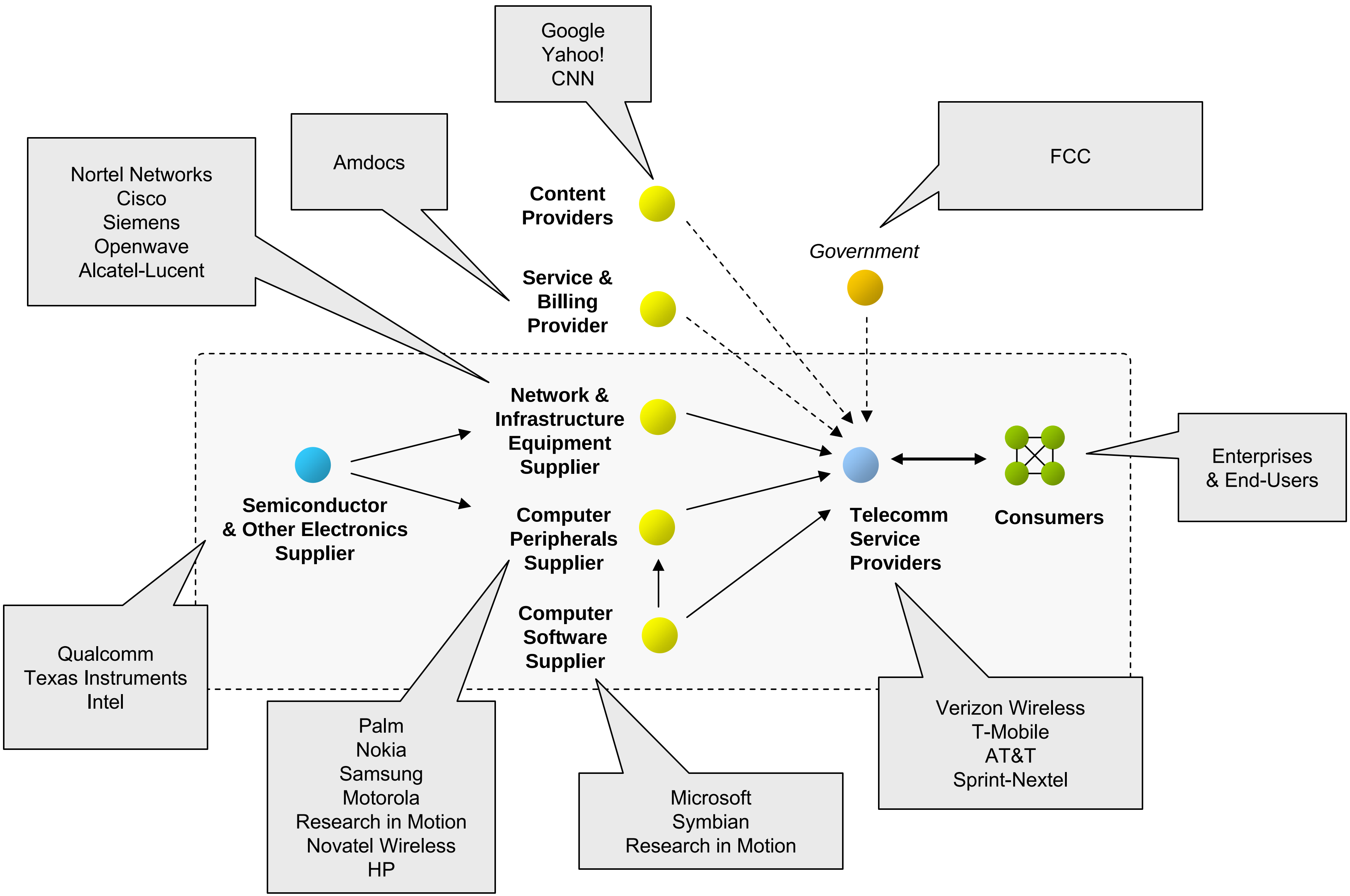


Transportation & Logistics
Apparel
Beverages
Electronics
Food Consumer Products
Furniture
Home Equipment
Household
Toys
Pharma
Food Production
Packaging
Food & Drugs
Food Services
General Merchandisers
Specialty Retail
Consumers

Telecom

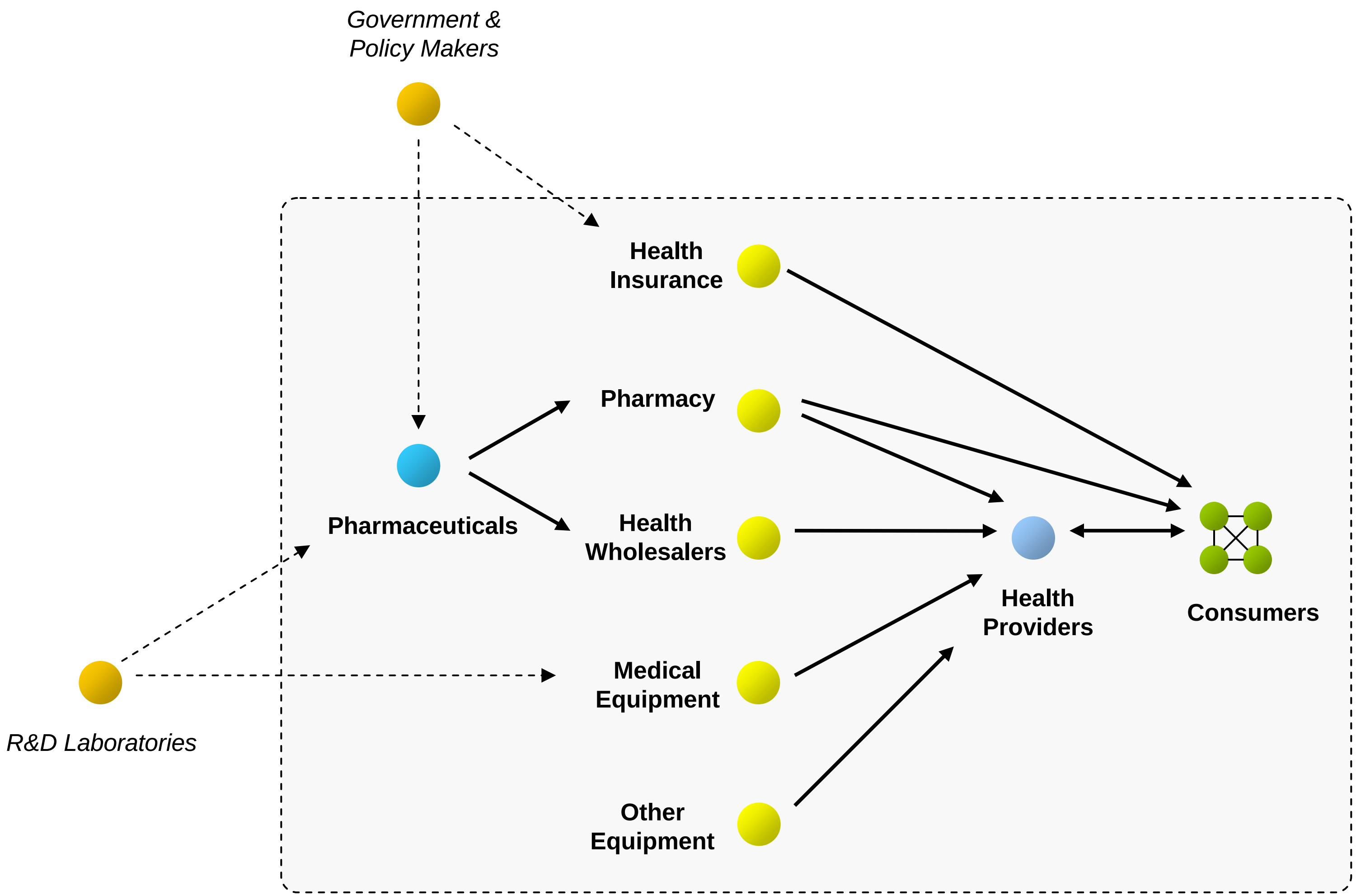


Content Providers
Government
Service & Billing
Network & Infrastructure Equipment
Semiconductor & Other Electronics
Computer Peripherals
Telecomm Service Providers
Consumers
Computer Software



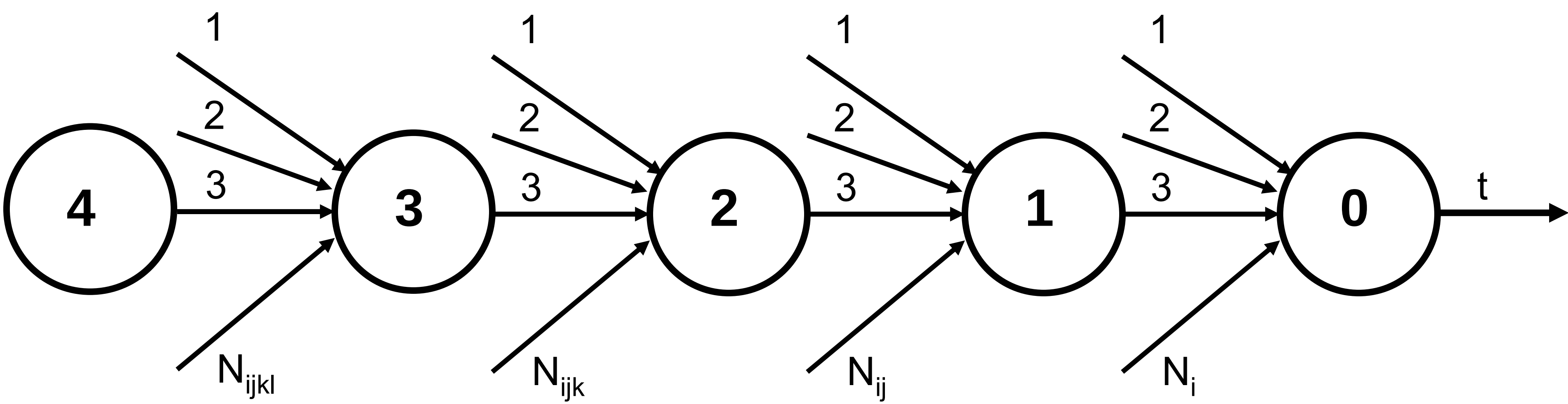
Google
Yahoo!
CNN
Amdocs
Nortel Networks
Cisco
Siemens
Openwave
Alcatel-Lucent
FCC
Content Providers
Service & Billing Provider
Government
Network & Infrastructure Equipment Supplier
Semiconductor & Other Electronics Supplier
Computer Peripherals Supplier
Computer Software Supplier
Telecomm Service Providers
Consumers
Enterprises & End-Users
Qualcomm
Texas Instruments
Intel
Palm
Nokia
Samsung
Motorola
Research in Motion
Novatel Wireless
HP
Microsoft
Symbian
Research in Motion
Verizon Wireless
T-Mobile
AT&T
Sprint-Nextel

Healthcare



Government &
Policy Makers
Health
Insurance
Pharmacy
Pharmaceuticals
Health
Wholesalers
Health
Providers
Consumers
Medical
Equipment
R&D Laboratories
Other
Equipment

Network Model



N_i = No. of 1st tier suppliers to ith product/service outlets

N_{ij} = No. of 2nd tier suppliers to ijth Tier 1 supplier, e.g., OEM

N_{ijk} = No. of 3rd tier suppliers to ijkth Tier 2 supplier

N_{ijkl} = No. of 4th tier suppliers to ijklth Tier 3 suppliers

Calculating Complexity

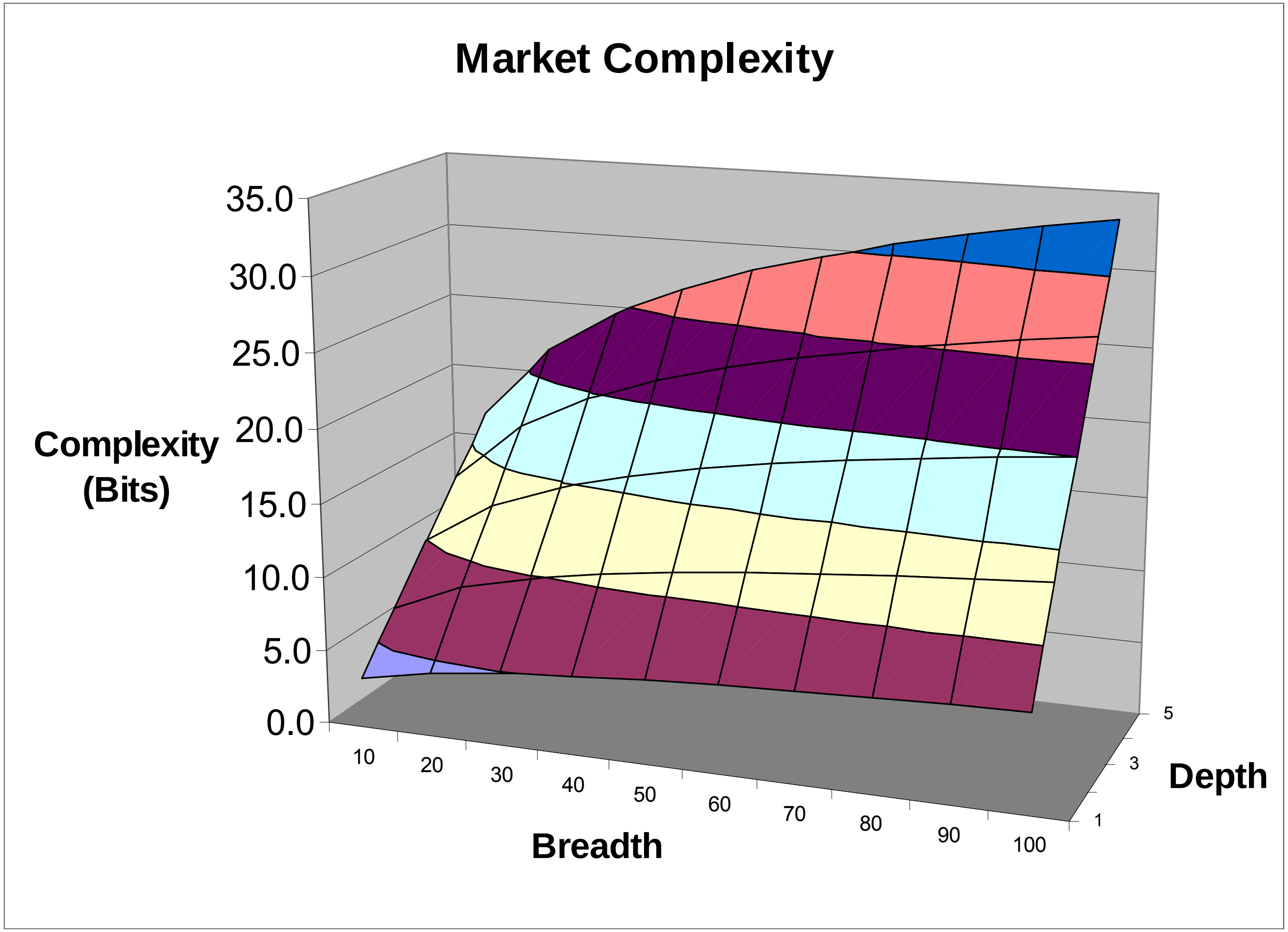
$$C = \sum_{m=1}^{T} pt_m \{ \sum_{i=1}^{N_i} -p(n_i \mid t) \log [p(n_i \mid t_m)] +$$

$$\sum_{j=1}^{N_{ij}} -p(n_j \mid n_i\, t) \log [p(n_j \mid n_i\, t_m)] +$$

$$\sum_{k=1}^{N_{ijk}} -p(n_k \mid n_i\, n_j\, t) \log [p(n_k \mid n_i\, n_j\, t_m)] +$$

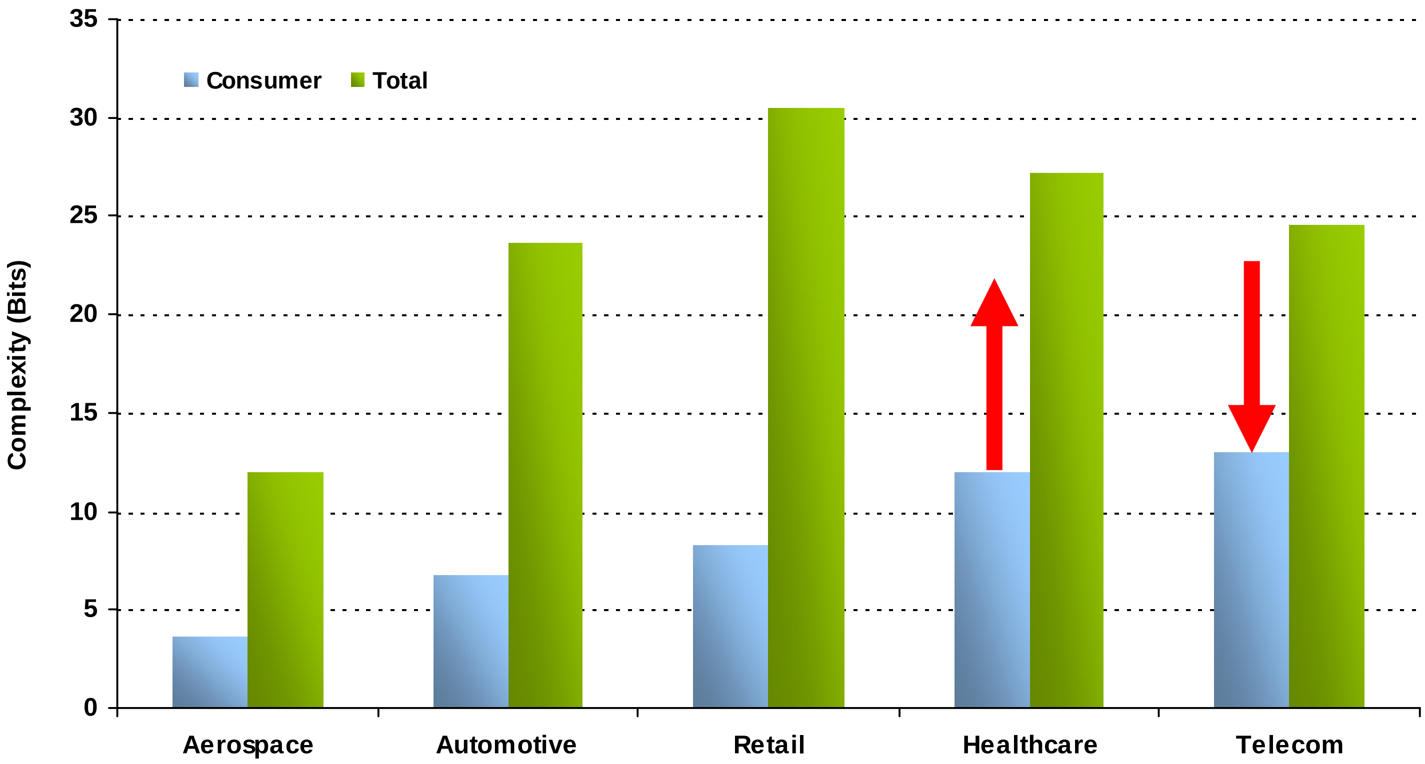
$$\sum_{l=1}^{N_{ijkl}} -p(n_l \mid n_i\, n_j\, n_k\, t) \log [p(n_l \mid n_i\, n_j\, n_k\, t_m)] \}$$

Complexity Surface



Complexity Assessment

Georgia Tech Tennenbaum Institute



Design Implications

- Two Design Principles
- Designed Complexity
- Enterprise Agility
- Enterprise Architectures

Two Design Principles

- The nature and extent of B2C service value determines B2B service value, as well as the value of products and other value enablers.
- The magnitude of B2C complexity, relative to total market complexity, reflects market maturity
  - Both B2C and B2B complexity are expressed in terms of information theory binary digits (bits),
  - B2B complexity is often increased, in turn increasing total complexity, in order to reduce B2C complexity.

B2C = Business to Consumer
B2B = Business to Business

Designed Complexity

- The enterprise as a system includes all stakeholder organizations whether they are your partners, collaborators, channels, competitor, or regulators
- Increase complexity where you can best manage it, in order to decrease complexity to end users, i.e., patients and physicians
  - You can manage design, development, manufacturing, sustainment
  - You cannot manage economies, markets, competitors, end users
- Support managing complexity by providing means to monitor and influence system state, performance, and stakeholders – see Managing Complexity

Enterprise Agility

- Optimization Within Design Assumptions
  - Objective is to balance performance and costs
  - Assure robust allocation of resources
- Adaptation Beyond Design Assumptions
  - Objective is to balance opportunities and risks
  - Assure ability to reallocate resources
- Tradeoffs Between Optimization vs. Adaptation
  - Options for contingencies enhance agility
  - Costs of options undermine optimality
- Architectures That Enable Ongoing Tradeoffs

Enterprise Architectures

Strategic Processes
Operational Processes
Information Systems
Information Technology

Management Implications

- Value Philosophy
- Organizational Behaviors
- Managing Complexity

Value Philosophy

Georgia Tech Tennenbaum Institute

- Value focuses on organizational outputs (or outcomes), rather than inputs.
  - Health states of patients vs. budgets of providers
- Value relates to benefits of outcomes, rather than outcomes themselves.
  - Productivity improvements due to wellness
- Value implies relevant, usable, and useful outcomes.
  - Stakeholders have to understand and appreciate

Organizational Behaviors

	Traditional System	Complex Adaptive System
Roles	Management	Leadership
Methods	Command & Control	Incentives & Inhibitions
Measurement	Activities	Outcomes
Focus	Efficiency	Agility
Relationships	Contractual	Personal Commitments
Network	Hierarchy	Heterarchy
Design	Organizational Design	Self Organization

Managing Complexity

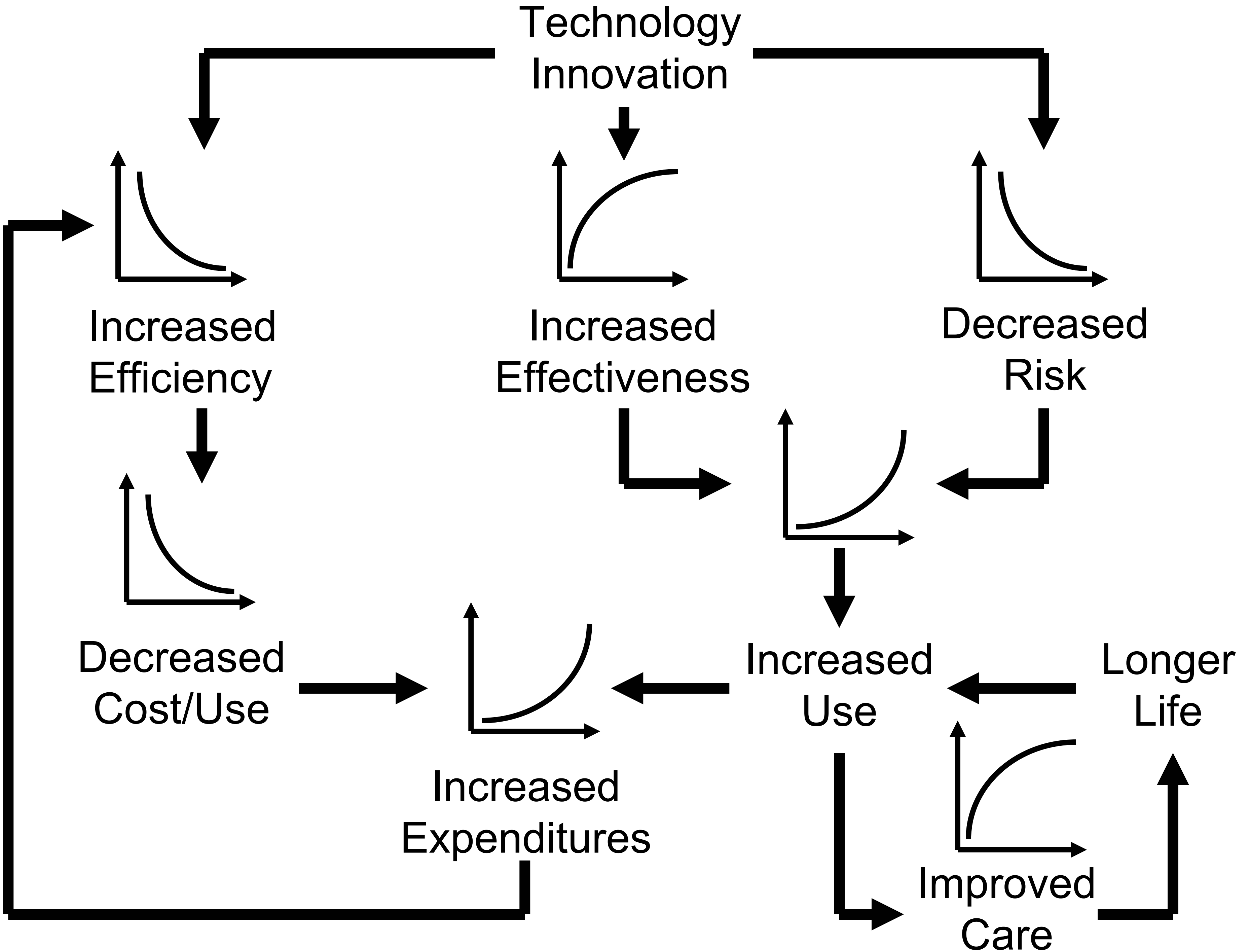
- System State
  - Current and projected value flows
  - Current and projected problems
- System Performance
  - Current and projected value, costs & value/cost
  - Current and projected options for contingencies
- System Stakeholders
  - Involvement of each stakeholder group
  - Performance of each stakeholder group
- Information Systems
  - Measurement, modeling & display of system state
  - Agile “What If?” experimentation & adaptation

Case Study

- Motivation
  - Tripled %GDP for real healthcare costs for 1965-2005
  - 50% of cost growth attributable to technological innovation
  - “Running on Empty”
- Approach
  - Growth Model
  - Learning Model
  - Process Model
- Conclusions

Approach

- Overall Phenomenon
- Model No. 1 & Results
- Model No. 2 & Results
- Model No. 3 & Results
- Implications


Technology
Innovation
Increased
Efficiency
Increased
Effectiveness
Decreased
Risk
Decreased
Cost/Use
Increased
Expenditures
Increased
Use
Longer
Life
Improved
Care

Model No. 1 -- Growth

$$\text{Cost}\,(1 - \alpha)\ \text{Use}\,(1 + \beta) = \text{Total}\,(1 + \delta)$$

where α = Annual rate of cost reduction
β = Annual rate of usage growth
δ = Annual allowable total growth

$$\alpha = (\beta - \delta)/(\beta + 1)$$

Results No. 1

Treatment	Annual Rate of Usage Growth	Minimum Annual Rate of Cost Reduction
Angiography	10%	9%
Angioplasty	15%	13%
Dialysis	12%	11%
Hip Replacement	10%	9%
Knee Replacement	11%	10%

Limitations

Georgia Tech Tennenbaum Institute

- Model Provides No Mechanism for Achieving Cost Reductions
- Model Does Not Differentiate Elements of Healthcare Delivery Process

Model No. 2 -- Learning

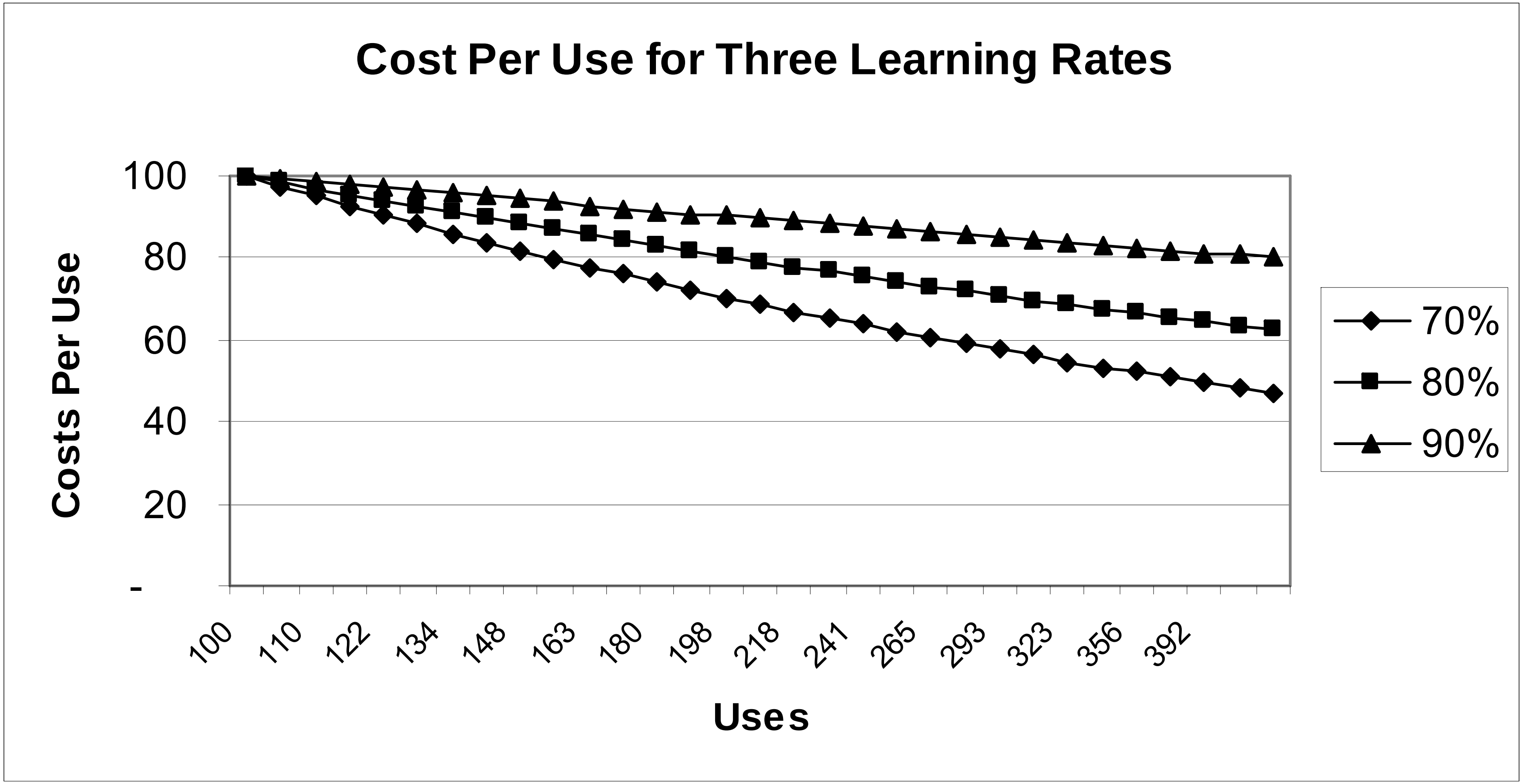
Georgia Tech Tennenbaum Institute

$$\text{Cost } (t=T) = \text{Cost } (t=0) \text{ No. Uses } (t=T)^{-\text{Rate}}$$

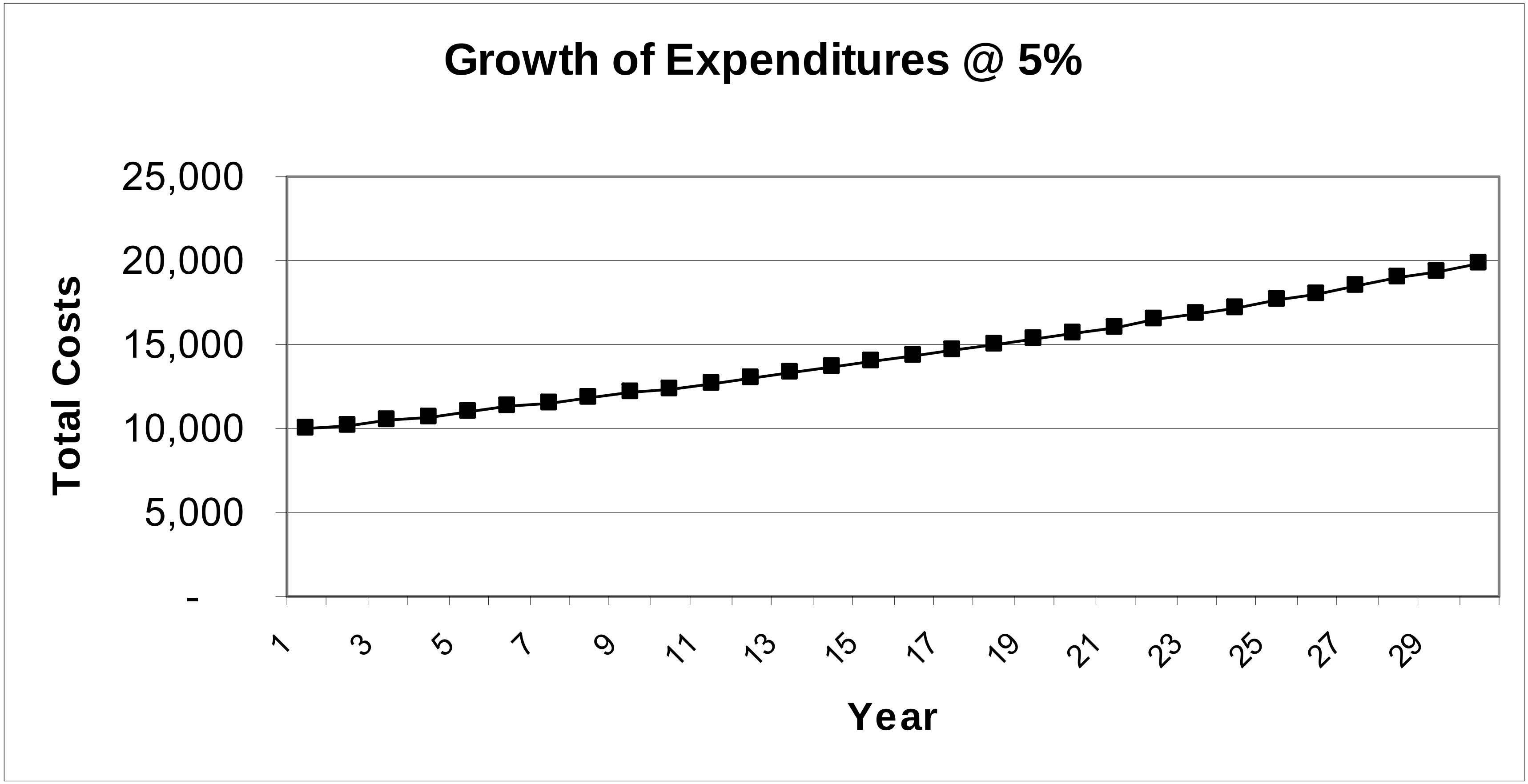
Note: This is a well-developed concept in a wide range of production processes.

Percent Cost Per Use for Each Doubling of Uses	Rate for Learning Model
70%	0.515
80%	0.322
90%	0.152

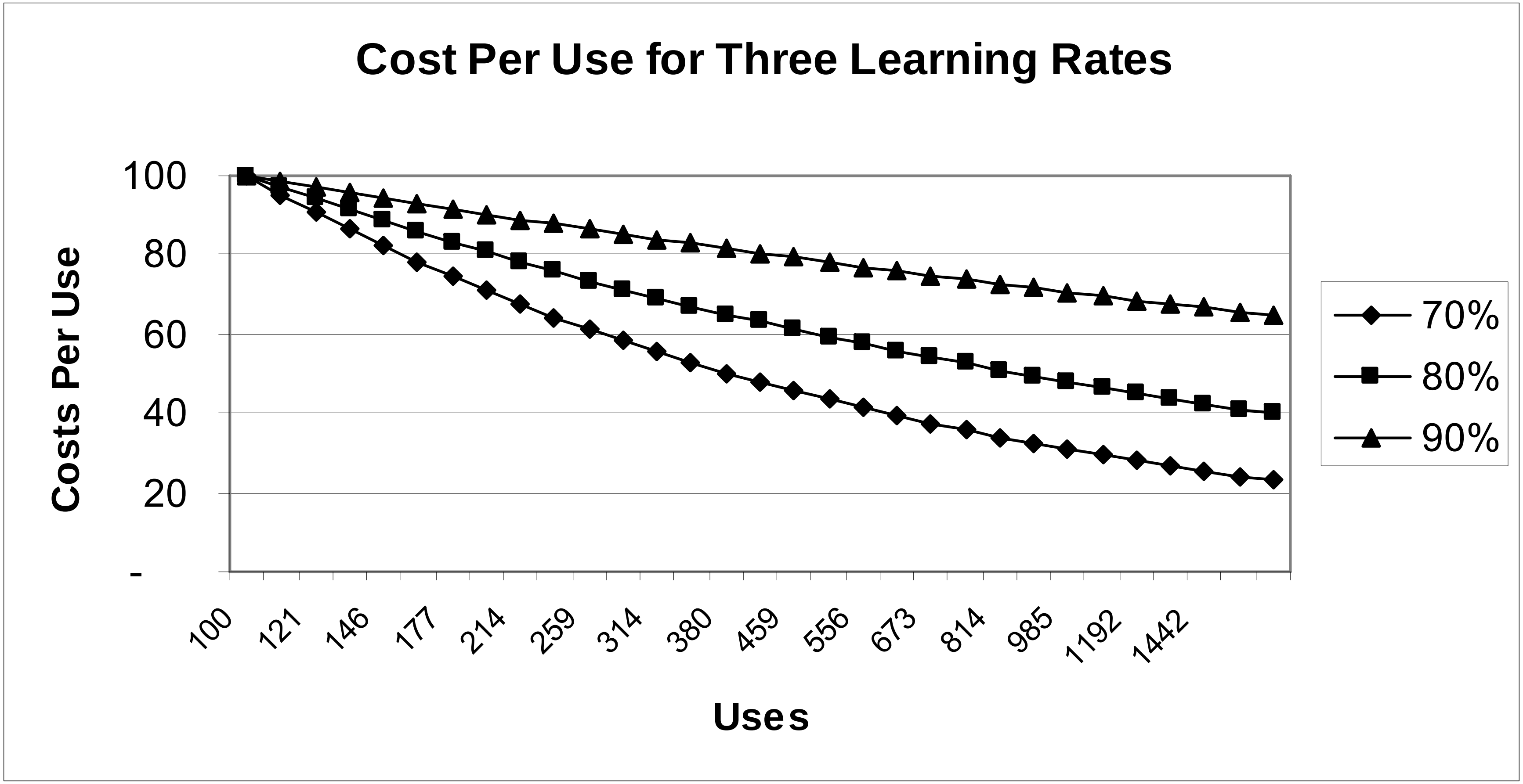
Cost Reductions @ 5% Growth



Expenditure Growth @ 5%

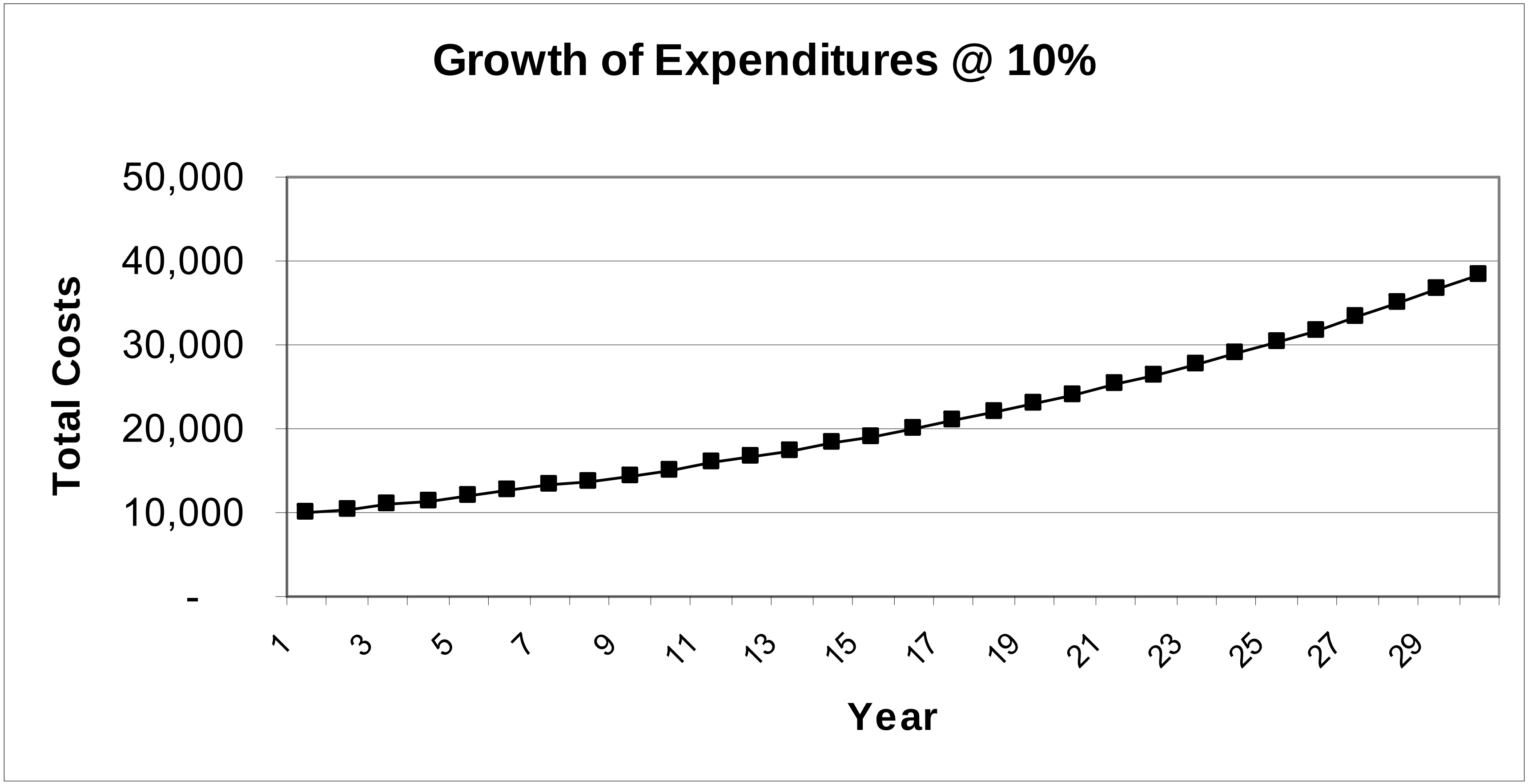


Cost Reductions @ 10% Growth



Expenditure Growth @ 10%

Georgia Tech | Tennenbaum Institute



Results No. 2

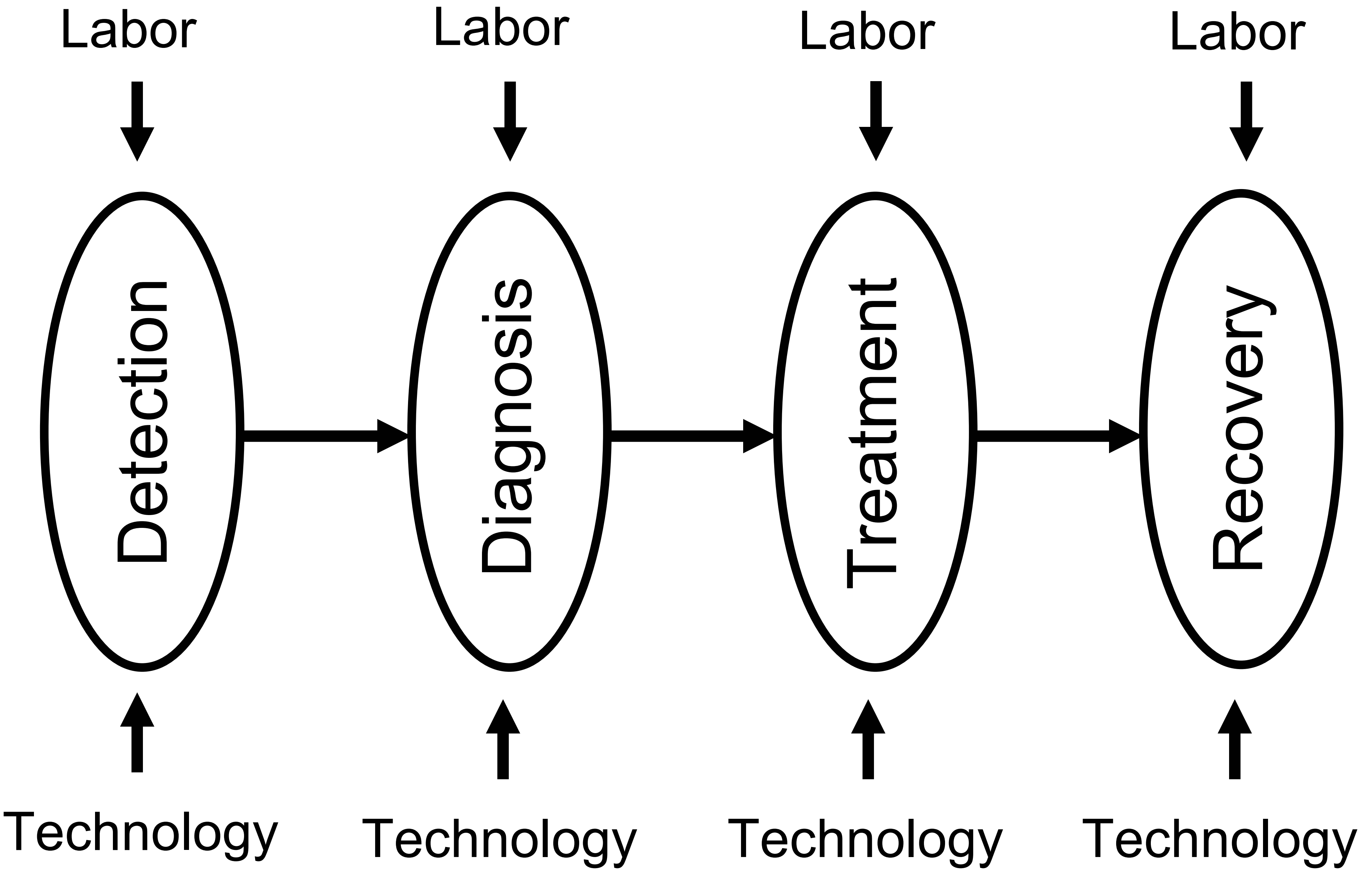
	Results at 30 Years		
Rate	No. of Uses	Cost/Use	Total Expenditures
5%	412	$48/use	$19,874
10%	1586	$24/use	$38,256

Note: Uses = 100, Cost/Use = $100, Total = $10,000 at Year =1

Limitations

- Model Exhibits Impressive Cost Reductions Due to Production Learning, But It Does Not Suggest Where & How This Learning Happens
- Model Does Not Reflect the Process Whereby Healthcare Is Delivered

Model No. 3 -- Process



Expanded Cost Model

Georgia Tech Tennenbaum Institute

$$\text{Cost}(t) = \text{Cost of Labor}(t) + \text{Cost of Tech.}(t)$$

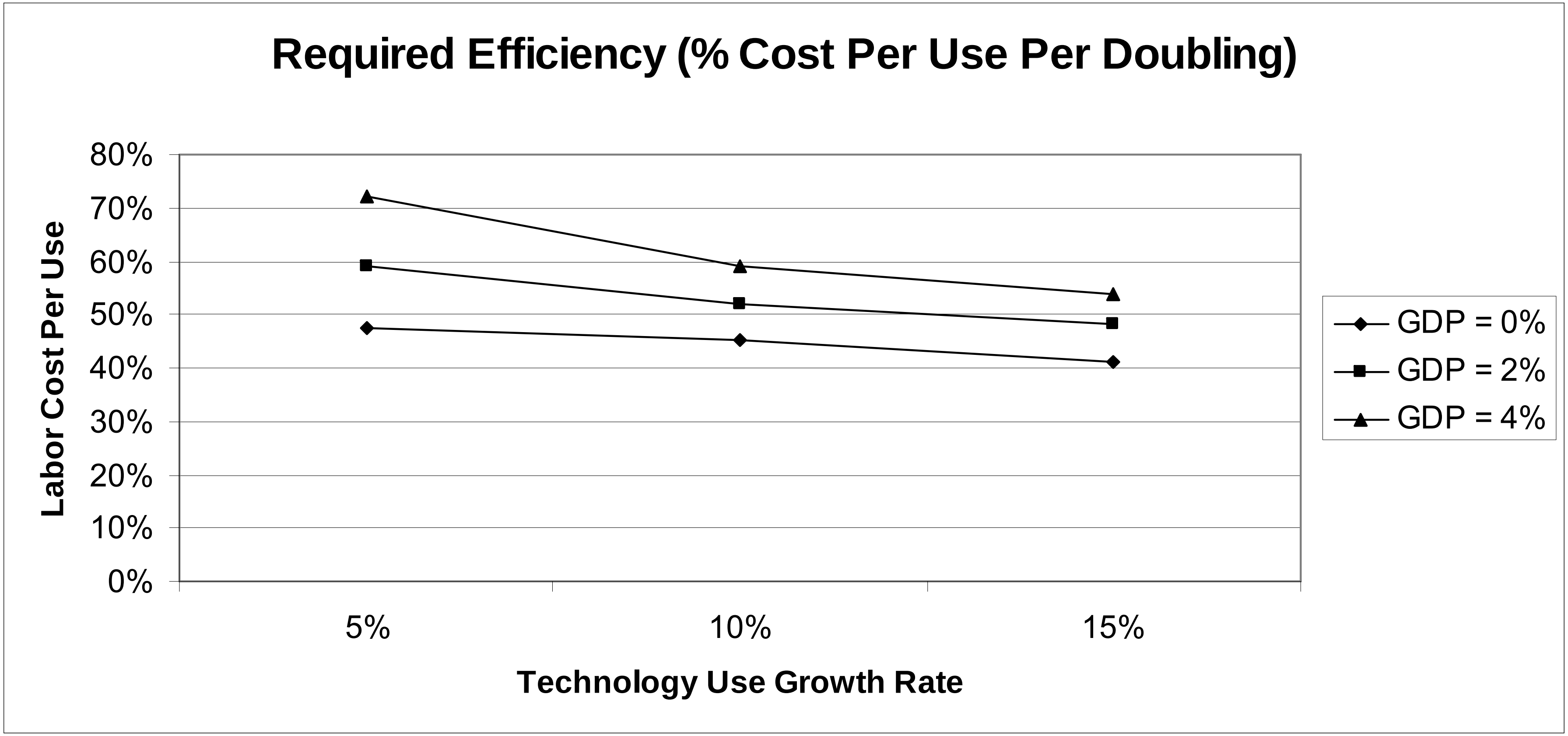
$$C_{TOT}(t) = CPU_L(t)\,NU(t) + CPU_T(t)\,NU(t)$$

$$CPU_L(t) = CPU_L(1)\,NU(t)^{-Rate_L}$$

$$CPU_T(t) = CPU_T(1)\,NU(t)^{-Rate_T}$$

$$NU(t) = NU(1)\,(1+\beta)^{t-1}$$

Results No. 3



Required Efficiency (% Cost Per Use Per Doubling)
80%
70%
60%
50%
40%
30%
20%
10%
0%
Labor Cost Per Use
5%
10%
15%
Technology Use Growth Rate
GDP = 0%
GDP = 2%
GDP = 4%

Implications

- In order to limit the growth of total healthcare spending to the growth of the GDP, some combination of three things is needed
  - Limiting the growth of technology use
  - Limiting the cost of technology use
  - Decreasing the cost of labor associated with use
- Overall, savings due to learning are the key to affordability
  - Learning rates of < 70% are very difficult to achieve

Sources of Learning

- Labor efficiency, changes in personnel mix, standardization, specialization, methods improvements, better use of equipment, changes in the resource mix, product and service redesign, and shared best practices.
  - Less Labor Per Use: Achievable via individual learning and productivity enhancements.
  - Less Expensive Hours Per Use: Achievable by, for example, substituting assistant physicians or nurse practitioners for physicians. In this case, the experts can be used as orchestrators of cadres of much less expensive clinicians.
  - No Labor Per Use: Often technology enabled. For example, web-based scheduling and account management can enable patients to substitute their labor for that of providers, as has been experienced in the airline, banking, and retail industries.

"Bending the Curve"

1. Producing and Using Better Information
   1. Promoting Health Information Technology
   2. Center for Medical Effectiveness & Health Care Decision Making
   3. Patient Shared Decision Making
2. Promoting Health and Disease Prevention
   1. Public Health: Reducing Tobacco
   2. Public Health: Reducing Obesity
   3. Positive Incentives for Health
3. Aligning Incentives with Quality and Efficiency
   1. Hospital Pay-for-Performance
   2. Episode-of-Care Payment
   3. Strengthening Primary Care and Care Coordination
   4. Limit Federal Tax Exemptions for Premium Contributions
4. Correcting Price Signals in the Health Care Market
   1. Reset Benchmark Rates for Medicare Advantage Plans
   2. Competitive Bidding
   3. Negotiated Prescription Drug prices
   4. All-Payer Provider Payment Methods and Rate
   5. Limit Payment Rate Updates in High-Cost Areas

Interpretation

- Seven of these recommendations would tend to reduce use rates
  - 1.2, 1.3, 2.1, 2.2, 2.3, 3.1, 3.2
- Nine of these recommendations focus on reducing costs by
  - Increased efficiency (1.1, 1.2, 3.3)
  - Increased market-based competition (3.4, 4.1-4.5)

Conclusions

Georgia Tech Tennenbaum Institute

- Successful Technology Innovation Leads to Growing Markets and Increased Revenues
  - Revenue to Innovator → Cost to Payer
- Such Growth Is Viewed More Favorably When Individuals Pay, Rather Than Third Parties
  - Possible Market-Based Mechanisms?
- Increasing System Efficiency Is Needed to Assure the Affordability of Technology Innovation
  - Required Improvements Are Very Substantial

Healthcare Enterprise

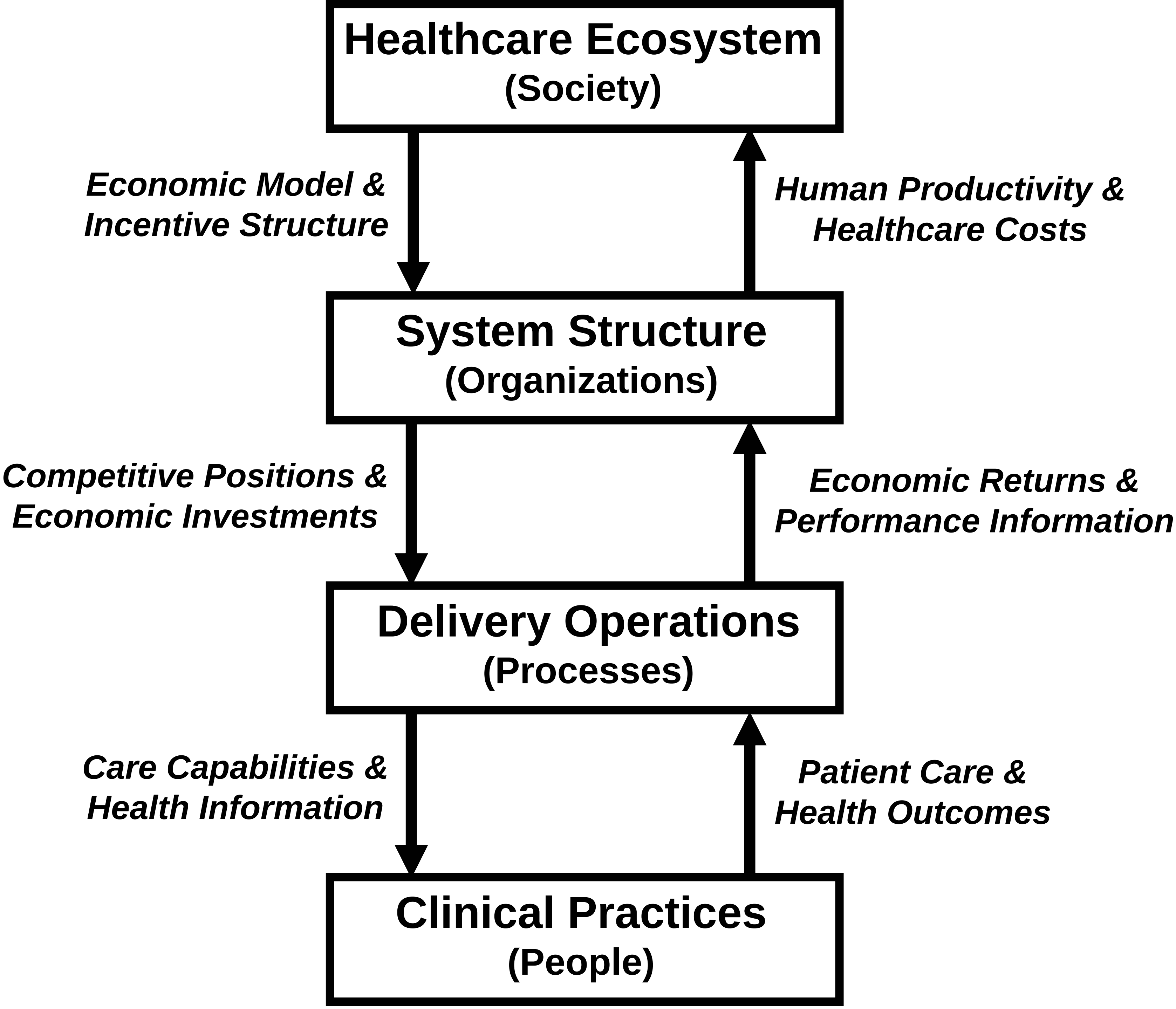
Georgia Tech Tennenbaum Institute

- Entities & Context
- Enterprise Architecture
- Implications for Change
- Hierarchical Network

Entities & Contexts

Georgia Tech Tennenbaum Institute

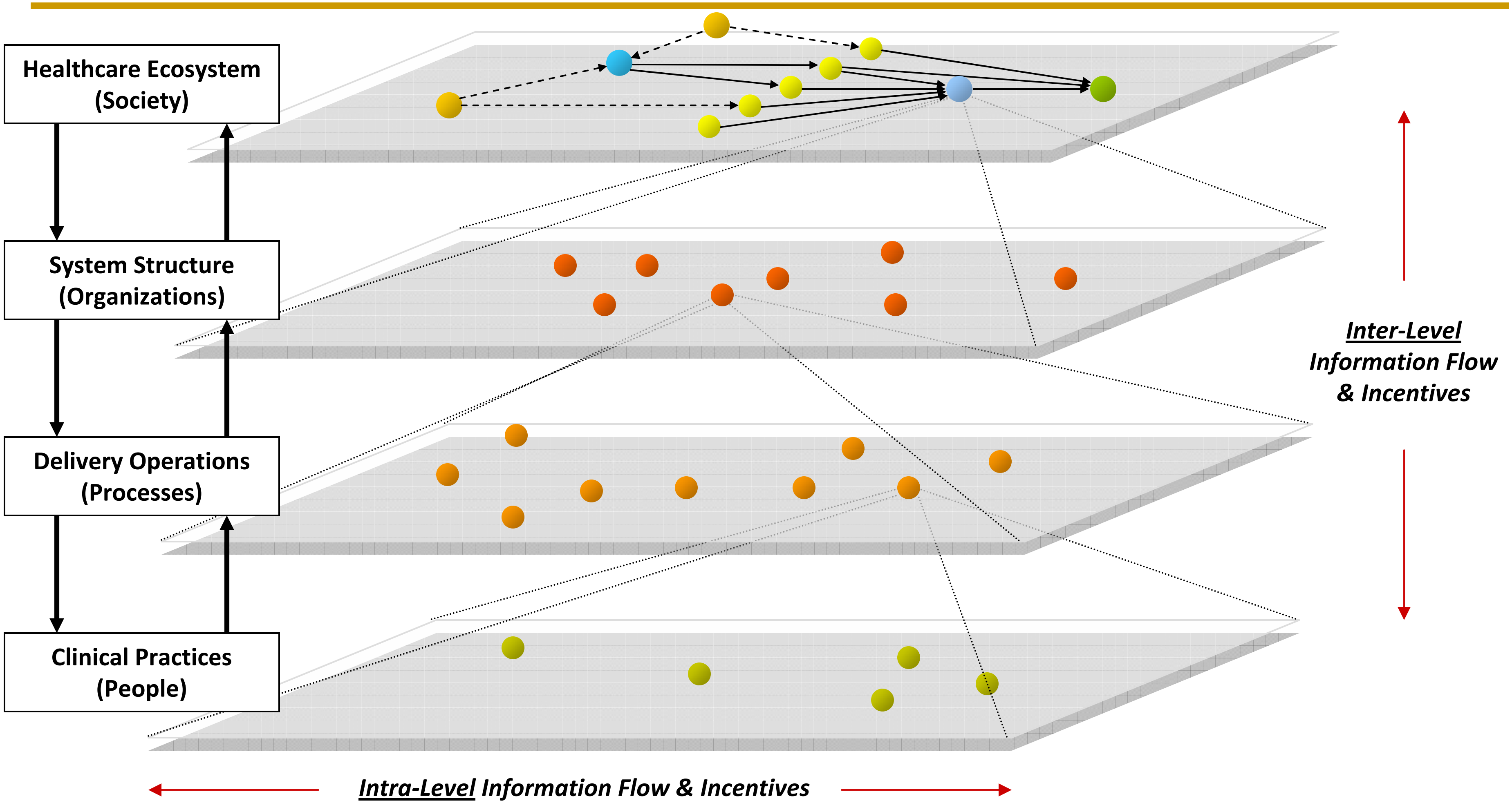
Entities Interacting	Context of Interactions
People	Processes
Processes	Organizations
Organizations	Society


Healthcare Ecosystem
(Society)
Economic Model &
Incentive Structure
Human Productivity &
Healthcare Costs
System Structure
(Organizations)
Competitive Positions &
Economic Investments
Economic Returns &
Performance Information
Delivery Operations
(Processes)
Care Capabilities &
Health Information
Patient Care &
Health Outcomes
Clinical Practices
(People)

Implications for Change

- Value can be increased in two ways
  - Increase the health outcomes
  - Decrease the cost of outcomes
- Increasing value provided by Clinical Practices
  - Constrained by the nature of Delivery Operations
- Increasing value provided by Delivery Operations
  - Constrained by System Structure
- Increased value provided by System Structure
  - Constrained by the Ecosystem

Hierarchical Network



Summary

- Complex Adaptive Systems
- Healthcare Delivery
- Complexity of Healthcare
- Case Study – Cost Control
- Healthcare Enterprise

Georgia Tech Tennenbaum Institute