Machine Learning, Market Structure & Competition

Carl Shapiro and Hal Varian

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Quick Review of Machine Learning
What is Machine Learning?

➢ Predict Labels as Function of Features
  ▪ Classic Approach: Construct Numerical Features, Construct Rules
  ▪ Deep Learning: Use Raw Data, Learn Directly
    • Images: Pixels
    • Translation: Paired Documents
    • Transcription: Voice and Text
  ▪ Requires Labeled Data (OpenImages), Hardware (GPU, TPU), Software (TensorFlow), Expertise

➢ Optimize Using Reinforcement Learning
  ▪ Multi-Armed Bandits
  ▪ Chess, Go, Atari Games etc.
What Can Machine Learning Do?

➢ Kaggle Predictions
  • Passenger Threats; Home Prices; Traffic to Wikipedia Pages; Personalized Medicine; ImageNet; Taxi Trip Duration; Product Purchases; Clustering Questions; Rental Listing Interest; Lung Cancer Detection; Click Prediction; Inventory Demand

➢ Demand: Match Customer & Product

➢ Supply: Reduce Cost and Waste

➢ Substitute and Complement Humans
  • Reduced Demand: Cashiers, Drivers, Translators
  • Increases Demand: Analytic Skills
What ML Inputs Are Scarce?

- Data Infrastructure: Critical Prerequisite
  - Collection, Manipulation, Storage & Retrieval
  - System Integrators Can Play Big Role
- Software: Open Source & In Cloud
- Hardware: Can Be Purchased in Cloud
- Expertise: Scarce But Growing Rapidly
- Firm-Specific Labeled Data: Key Input
Obtaining Labeled Data

➢ Multiple Ways to Obtain Needed Data
  ▪ As By-Product of Operations
  ▪ By Offering a Service (GOOG411, Flickr)
  ▪ Hiring Humans to Label Data
  ▪ Buying Data from Provider
  ▪ Sharing Data (Perhaps Mandated)
  ▪ Data from Governments and/or Consortia

➢ Data is Non-Rival, Partially Excludable
  ▪ Rights, Permissions, Licensing, Regulation
  ▪ “Ownership” Too Narrow a Concept for Policy
  ▪ Example: Who Control Driverless Car Data?
Big Data, ML and Public Policy

➢ Does Access to Data Give Incumbents a Major Competitive Advantage?
  ▪ Entrants Must Build or Acquire Necessary Data
  ▪ But: Entrants May Have Data From Adjacent Markets

➢ Incumbents Also Learn How to Improve Algorithms and Business Processes
  ▪ Shape of the “Machine Learning Learning Curve”
  ▪ Domain Knowledge Can Be Important

➢ Apply Essential Facility Doctrine to Data?
  ▪ Scope of “Essential” Data that Must be Shared?
  ▪ How to Regulate Terms & Conditions of Data Access?
Decreasing Returns to Scale

![Graph showing decreasing returns to scale with Mean Accuracy on the y-axis and Number of Training Images/class on the x-axis.

Higgs learning curves Accuracy graph with different models represented by different lines (Bayes, Lightning, Non-linear SVM, Tree, Random Forest, Gradient Tree Boosting).]
Machine Learning Meets Good Old Industrial Organization
Adoption of ML Technology

- Which Firms and Industries Will Successfully Adopt Machine Learning?
  - Large Heterogeneity in Timing of Adoption & Ability to Use ML Effectively
- Can Later Adopters Imitate Early Adopters?
  - Patents & Trade Secrets; Firm-Specific Routines
- Role of Geography in Adoption Patterns
- Very Large Competitive Advantage for Early, Successful Adopters
  - Large Firms? New Firms? Disruptive Aspects
Evidence on AI Adoption

- McKinsey Global Institute Survey
  - 3000 “AI Aware C-Level Executives” in 10 Countries
  - 20% Are “Serious Adopters”
  - 40% are Experimenting or are “Partial Adopters”
  - 28% Feel Their Firms Lack the Technical Capabilities to Implement AI

- Key Enablers of AI Adoption
  - Leadership, Technical Ability, Data Access
### AI Adoption by Industry (McKinsey)

<table>
<thead>
<tr>
<th>Industry</th>
<th>3 and more at scale</th>
<th>2 at scale</th>
<th>1 at scale</th>
<th>0 at scale</th>
<th>Total</th>
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<tr>
<td>Telecommunications</td>
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<td>High tech</td>
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<td>Energy and resources</td>
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<td>5</td>
<td>11</td>
<td>64</td>
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<tr>
<td>Automotive and assembly</td>
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<td>6</td>
<td>9</td>
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<tr>
<td>Media and entertainment</td>
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<td>11</td>
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<td>Financial services</td>
<td>14</td>
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<tr>
<td>Healthcare systems and services</td>
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<td>7</td>
<td>14</td>
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<tr>
<td>Retail</td>
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<td>2</td>
<td>6</td>
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<tr>
<td>Education</td>
<td>14</td>
<td>2</td>
<td>10</td>
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<tr>
<td>Consumer packaged goods</td>
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<td>5</td>
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<tr>
<td>Transport and logistics</td>
<td>11</td>
<td>5</td>
<td>9</td>
<td>75</td>
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<tr>
<td>Professional services</td>
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<td>4</td>
<td>8</td>
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<td>Construction</td>
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<td>3</td>
<td>10</td>
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<tr>
<td>Travel and tourism</td>
<td>6</td>
<td>3</td>
<td>10</td>
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<tr>
<td>Other</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>86</td>
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Key Research Question: Machine Learning & Vertical Integration

- How Will Machine Learning Tools and Data Be Combined to Create Value?
  - Within or Across Corporate Boundaries?
- Will ML Users Develop Their Own ML Capabilities or Purchase ML Solutions from ML Vendors?
  - Classic Make vs. Question, Key for Industry Analysis
- One-Stop Shopping in the Cloud is Happening
  - Data Labeling, Software, Algorithms, Consulting
  - Special-Purpose Hardware: Tensor-Processing Units (TPUs) Create Cost Advantage
Machine Learning and Vertical Integration: Some Public Policy Questions

- Privacy Regulations May Limit Ability of ML Vendors to Combine Data from Multiple Sources
  - Limits on Transfer of Data Across Corporate Boundaries and/or Sale of Data
  - Privacy Concerns vs. Growth of Markets for Data Used for Machine Learning

- Mandated Data Sharing May Promote Vertical Disintegration

- Treatment of Vertical Mergers Between ML Vendors and ML Users
Machine Learning Vendors
Structure of the ML Industry

- ML Vendors Offer Several Services
  - Data Centers, Containers, Dockers
  - Labeling Services, System Integration, Consulting
- ML Vendor Could Specialize in ML and Purchase Data Processing/Storage in Cloud
- Industry Structure is Oligopolistic
  - Leaders: Amazon, Google, Microsoft, Salesforce
  - Other Suppliers: IBM? Who Will Be Next?
- Will Industry Become More Fragmented?
  - Specialists by Industry?
Diminishing Returns to Scale

Source: Stanford Dogs dataset
ImageNet Progress: 2010-2015

Data Size Held Constant
Improvement Due to Hardware and Software
Source: Stanford ImageNet
Pricing of ML Services

- Large Fixed Costs, Low Marginal Cost
  - Undifferentiated Services & Bertrand Trap?
  - Size of Customer Switching Costs
  - Containers & Dockers
- Learning by Doing for ML Vendors
- Multi-Product Offerings and Bundling
## Pricing of ML Services: Google

<table>
<thead>
<tr>
<th>Feature</th>
<th>First 1000 units/month</th>
<th>Units 1001 - 5,000,000 / month</th>
<th>Units 5,000,001 - 20,000,000 / month</th>
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<tbody>
<tr>
<td>Label Detection</td>
<td>Free</td>
<td>$1.50</td>
<td>$1.00</td>
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<tr>
<td>Text Detection</td>
<td>Free</td>
<td>$1.50</td>
<td>$0.60</td>
</tr>
<tr>
<td>Safe Search (explicit content) Detection</td>
<td>Free</td>
<td>Now free with Label Detection</td>
<td>Now free with Label Detection</td>
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<td>Facial Detection</td>
<td>Free</td>
<td>$1.50</td>
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<td>Landmark Detection</td>
<td>Free</td>
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<td>$0.60</td>
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<td>Logo Detection</td>
<td>Free</td>
<td>$1.50</td>
<td>$0.60</td>
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<tr>
<td>Image Properties</td>
<td>Free</td>
<td>$1.50</td>
<td>$0.60</td>
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## Pricing of ML Services: Amazon

### Amazon Rekognition API Pricing

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<thead>
<tr>
<th>Region</th>
<th>US-East (N. Virginia)</th>
<th>US-West (Oregon)</th>
<th>EU (Ireland)</th>
<th>AWS GovCloud (US)</th>
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<tbody>
<tr>
<td><strong>Image Analysis Tiers</strong></td>
<td><strong>Price per 1,000 Images Processed</strong></td>
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<td></td>
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</tr>
<tr>
<td>First 1 million images processed* per month</td>
<td>$1.00</td>
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<td></td>
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<tr>
<td>Next 9 million images processed* per month</td>
<td>$0.80</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Next 90 million images processed* per month</td>
<td>$0.60</td>
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<tr>
<td>Over 100 million images processed* per month</td>
<td>$0.40</td>
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</table>
Impact of Machine Learning on Downstream Markets
Impact of ML on Minimum Efficient Scale?

- Will ML Generally Increase Minimum Efficient Scale by Transforming Variable Costs into Fixed Costs?
  - Fixed Cost of Developing a ML Solution
  - Substitutes for Variable Labor Costs

- Not if the Fixed Costs of ML are Small
  - Off-the-Shelf Generic ML Capabilities vs. Need to Develop a Specialized Solution
  - See: Pricing Structure for ML Solutions

- ML Could Lower Minimum Efficient Scale
  - Reduce or Eliminate Certain Fixed Costs
How to Start Up a Startup

- Fund Your Project on Kickstarter
- Hire Employees Using LinkedIn
- Purchase Cloud Computing Services from Amazon
- Use Open Source Software: Linux, Python, Tensorflow
- Set up a Kaggle Competition for Machine Learning
- Communicate Using Skype, Gmail, Google Docs
- Use Nolo for Legal Documents
- Market Your Product or Service Using AdWords
- User Support Provided by ZenDesk
Use of ML for Downstream Pricing

- Far Greater Price Discrimination?
  - Yield Management Goes Bananas
  - Auctions and Other Mechanisms
  - But: Customers Can Use ML Counterstrategies

- Group Discrimination – Many Groups!
  - More Data on Which to Condition Prices
  - Blurs Line Between Individual and Group Pricing

- Self-Selection & Product Differentiation
  - Customized Products
  - But: Competition + Low Consumer Search Costs
Algorithmic Collusion: Economist Catnip

- Classic Issue of Dynamic Oligopoly Pricing
- Rapid Response Equilibria
  - In Markets with Transparent Prices
  - Firms Move Far Faster Than Consumers
- Evolution of Machine Cooperation
  - Can Machines Find a Better Way to Coordinate?
  - Taking MFNs & MCCs to the Next Level?
- Instructive Examples
  - NASDAQ; ATPCO; Spectrum Auctions
  - Machines Learning Cryptographic Code
- Antitrust Implications: Who Goes to Jail?