Prediction Machines, Insurance and Protection

Ajay Agrawal, Joshua Gans, Avi Goldfarb: University of Toronto & NBER

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- Recent artificial intelligence (aka machine learning) is an advance in statistical prediction

- Predictions enable state-contingent decision-making

- State-contingent decision-making substitutes for rules/routines … AI is coming for your non-routine tasks

- State-contingent decision-making complements the acquisition of judgment about trade-offs and error costs

Chapter 6

ARTIFICIAL INTELLIGENCE TECHNOLOGIES AND AGGREGATE GROWTH PROSPECTS

Timothy Bresnahan

6.1 INTRODUCTION

This chapter examines the commercial application of Artificial Intelligence Technologies (AITs), seeking to address questions about these technologies specifically and about 21st century technical progress and its current and potential impact on economic growth. I focus on the highly valuable *applications* of AITs today, in production systems at the Internet Giants, in new User Interfaces, and elsewhere. My empirical conclusion about these applications is that the lazy idea of "Artificial Intelligence" — i.e. of computer systems that are able to perform productive tasks previously done by humans — is irrelevant to understanding how these technologies create value. Here "irrelevant" does not mean that substitution of machine for human tasks is less important than other determinants of the value in use of AITs. It means irrelevant: task level substitution of machine for human plays no role in these highly valuable systems.

What organisational changes are required to adopt AI?

Modularity

Bresnahan Conjecture: AI will be adopted in modular organisations
… so organisations will need to become more modular

AI Adoption and System-Wide Change

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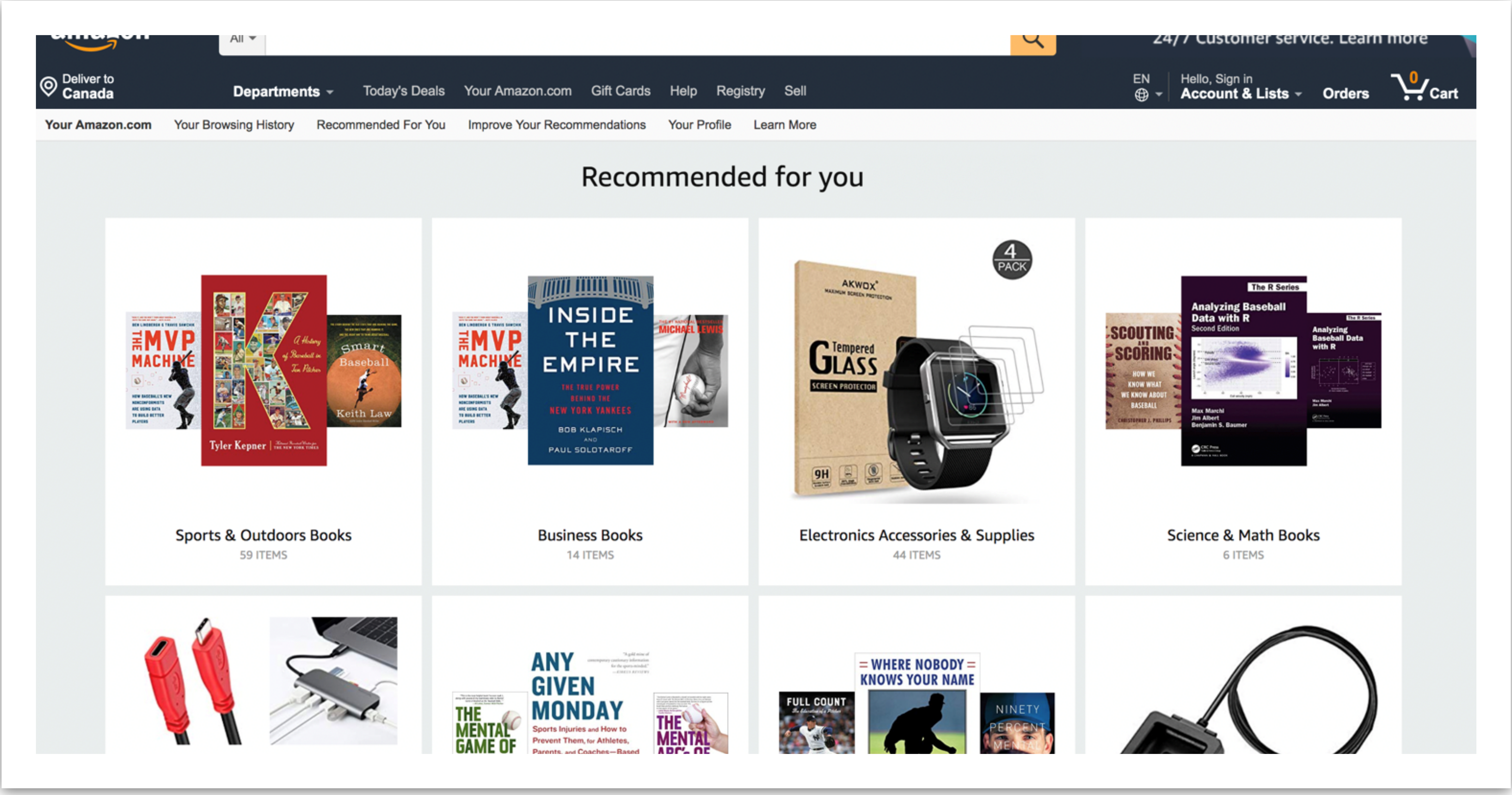
November 2022

Abstract

Analyses of AI adoption focus on its adoption at the individual task level. What has received significantly less attention is how AI adoption is shaped by the fact that organizations are composed of many interacting tasks. AI adoption may, therefore, require system-wide change which is both a constraint and an opportunity. We provide the first formal analysis where multiple tasks may be part of a loosely or strongly coupled system. We find that reliance on AI, a prediction tool, increases decision variation which, in turn, raises challenges if decisions across the organization interact. Loose coupling by reducing inter-dependencies between decisions softens that impact and can facilitate AI adoption. However, it does this at the expense of synergies. By contrast, when there are mechanisms for inter-decision coordination, AI adoption is enhanced in a tightly coupled environment. Consequently, we show that there are important cases where AI adoption will be enhanced when it can be adopted beyond tasks but as part of a designed organizational system.

Keywords: artificial intelligence, machine learning, coupling, systems

Retail



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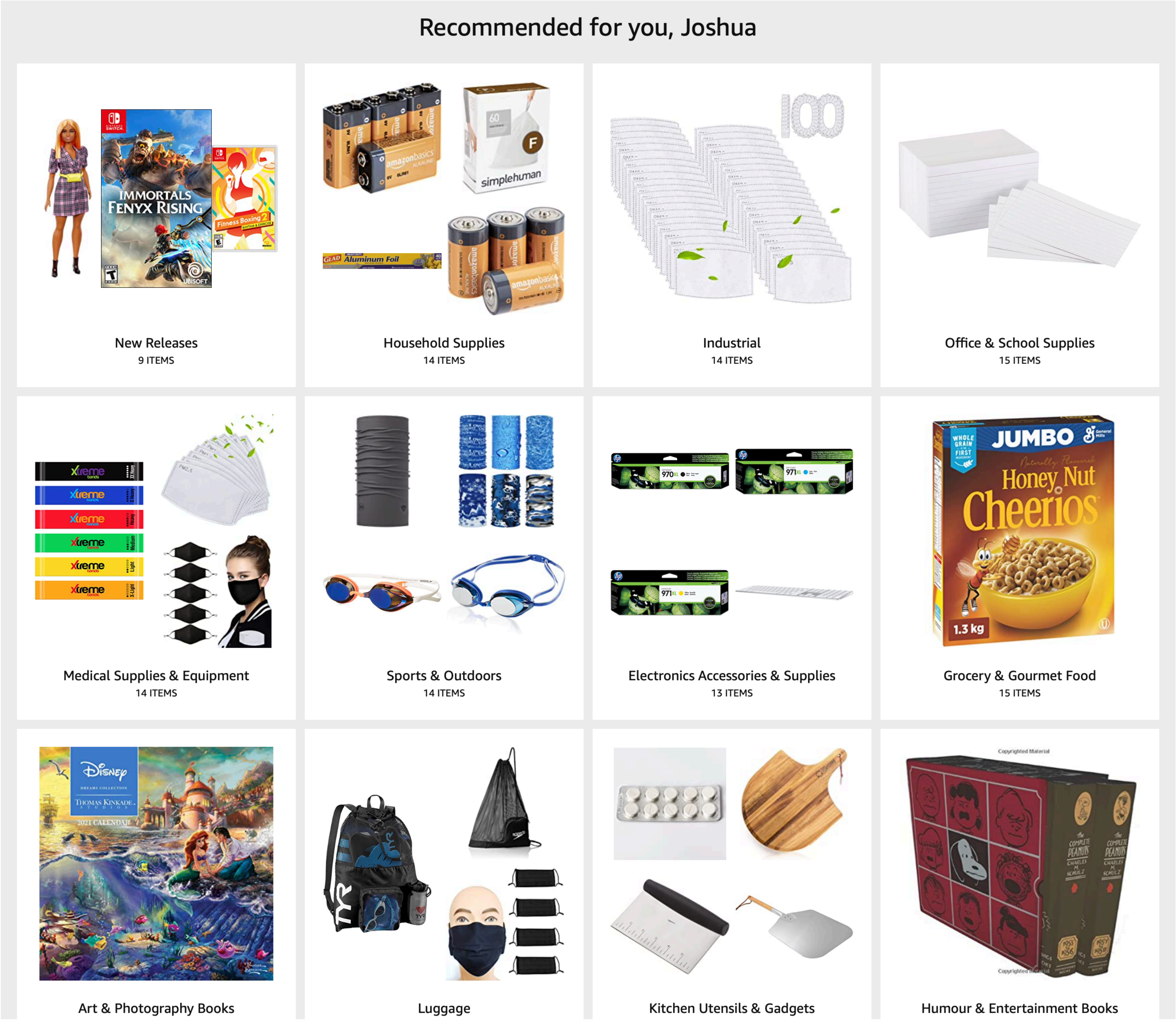

Recommendation Engine

AI Slots into Existing System

Ship without Shopping

AI Drives System

Main thesis: what was optimal prior to AI matters for AI adoption

Risk Management Activities

- Without AI prediction, there will be costs associated with uncertainty
- These costs can be mitigated:
  - Insurance: reduce the losses from “bad” outcomes
    - Retail inventory
    - Fire prevention
  - Protection: reduce the probability of “bad” outcomes
    - Brick houses
    - Hedgerows
    - Aircraft life vests

Market Insurance, Self-Insurance, and Self-Protection

Isaac Ehrlich

University of Chicago and Tel-Aviv University

Gary S. Becker

University of Chicago

The article develops a theory of demand for insurance that emphasizes the interaction between market insurance, "self-insurance," and "self-protection." The effects of changes in "prices," income, and other variables on the demand for these alternative forms of insurance are analyzed using the "state preference" approach to behavior under uncertainty. Market insurance and self-insurance are shown to be substitutes, but market insurance and self-protection can be complements. The analysis challenges the notion that "moral hazard" is an inevitable consequence of market insurance, by showing that under certain conditions the latter may lead to a reduction in the probabilities of hazardous events.

The incentive to insure and its behavioral implications have usually been analyzed by applying the expected utility approach without reference to the indifference curve analysis ordinarily employed in consumption

No insurance

No sprinkler system
No fire resistance treatment

All protection

Fire training
Dry pipe from river

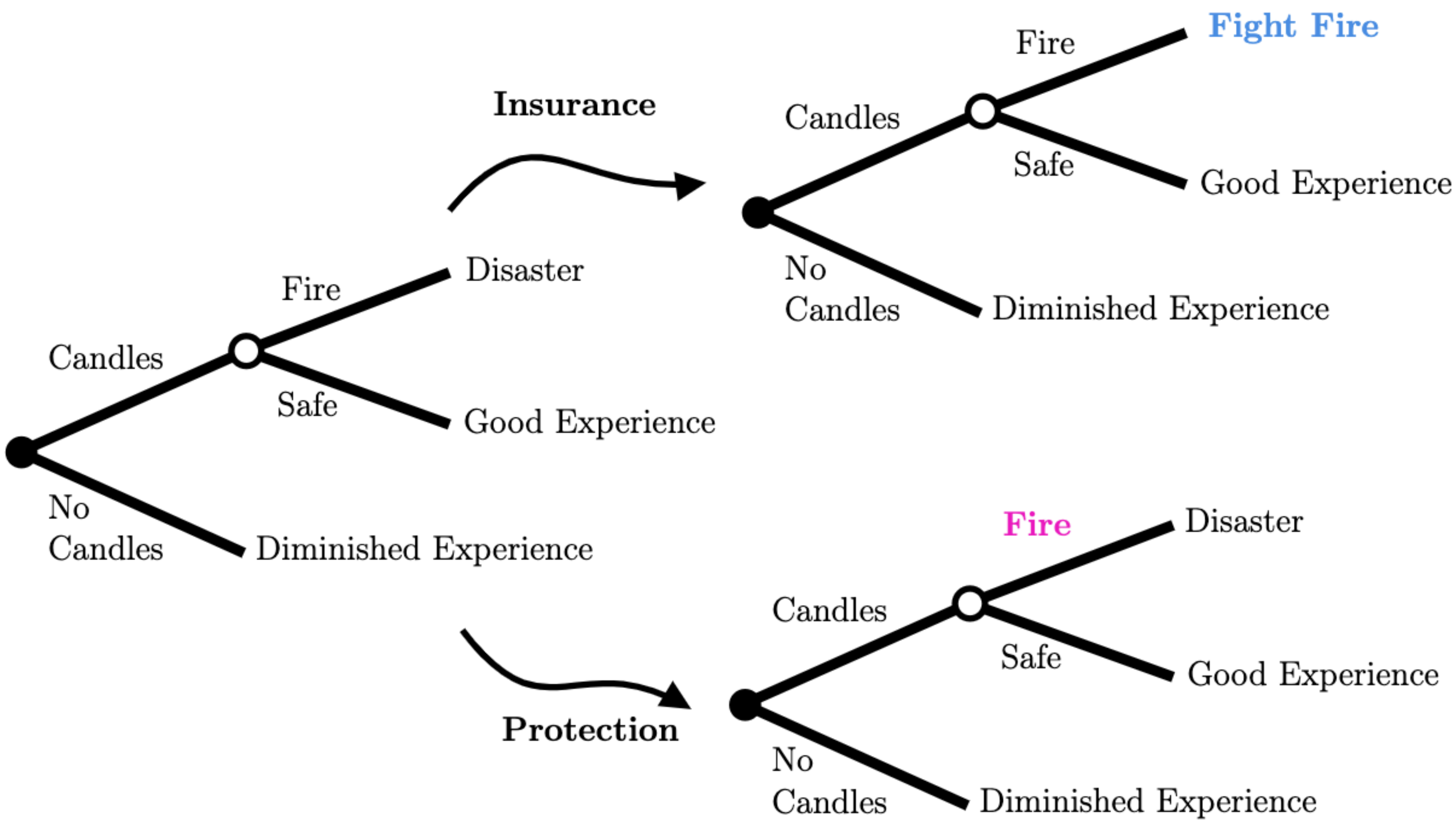

Figure 1: Insurance vs Protection under Fire Risk

Simple Model

Familiar state-matching setup:

- Two actions $a \in \{1,2\}$
- Two states $\theta \in \{1,2\}$
- If matches, get *R*
- If mismatched, get *r* (< *R*)
- 1 is the focal state, $\Pr[\theta = 1] = p > \frac{1}{2}$

If there is no prediction, optimal to choose *a* = 1

- This is called **"Following a Rule"**
- Payoff: $pR + (1-p)r$

If there is perfect prediction, optimal to match prediction

- This is called **"Making a Decision"**
- Payoff: R

Mitigation Options

Protection

- At a cost of $C(x)$ can change the probability of $\theta = 1$ to $p + x$
- (Assume $C'(1-p) = \infty$ so not optimal to eliminate uncertainty)

Insurance

- At a cost of $C(\Delta)$ the downside payoff becomes $r + \Delta$
- (Assume $c'(R-r) = \infty$ so it is not optimal to eliminate risk)

Prediction

- At cost of λ, acquire signal that yields the correct state with probability e
- If receive $s = \theta$ (predicted state is θ) then posteriors become:

$$p(1) = \frac{ep}{ep + (1-e)(1-p)} \text{ and } 1 - p(2) = \frac{e(1-p)}{(1-e)p + e(1-p)}$$

- Assume that $e > \frac{1}{2}$ (signals are informative

Information Processing Costs

- Suppose that $(x, \Delta) = (0{,}0)$
- If want to make a decision, obtain prediction.
- Expected payoff is $eR + (1 - e)r$
- Necessary condition to following prediction: $e > p$
- With information processing costs of λ, make a decision if:

$$e - p \geq \frac{\lambda}{R - r}$$

No prediction

- Optimal to **follow rule** with $a = 1$.
- Choose insurance and protection to solve:

$$\max_{x,\Delta} (p + x)R + (1 - p - x)(r + \Delta) - C(x) - c(\Delta)$$

- Suppose that $(x, \Delta) = (x^*_{RULE}, \Delta^*_{RULE})$

$$(R - r - \Delta) = C'(x^*_{RULE})$$
$$1 - p - x^*_{RULE} = c'(\Delta^*_{RULE})$$

Prediction

Proposition 1 *If the agent moves from a rule to a decision:*

1. *Protection is reduced; i.e.,* $x^*_{RULE} > x^*_{DEC} = 0$.
2. *Insurance is reduced (increased) if* e *is sufficiently high (low); i.e.,* $\Delta^*_{DEC} \leq (>) \Delta^*_{RULE}$ *if* $e \geq (<) p + x^*_{RULE}$

Corollary 1 *When* (x, Δ) *are endogenous, a necessary condition for making a decision to be preferred to a rule is that* $e > p$.

AI Adoption

- Suppose, however, that x^*_{RULE} and Δ^*_{RULE} are already locked-in.

Proposition 2 *AI prediction will be adopted if* $(e - p - x_{RULE})(R - r - \Delta_{RULE}) \geq \lambda$.

- AI adoption will be associated with a pressures to reduce insurance because *e* must exceed *p*

Hidden Uncertainty

Interesting thesis: when, without AI, firms rely on protection as a predominant risk management tool, the “errors” from following a rule are less visible. Consequently, the perceived opportunities for AI adoption are reduced.

AI Bullwhip Effect

Introduce a second task

- Two actions $b \in \{1,2\}$
- If $a = b$, get Γ
- If $a \neq b$, get $\gamma(< \Gamma)$
- At cost of Θ, *a* can be communicated to agent *B*

Suppose that *A* follows a rule

- Then *B* choose *b* = 1
- Payoff: $(p + x)R + (1 - p - x)(r + \Delta) + \Gamma - c(\Delta) - C(x)$

If *A* makes a decision

- Still optimal for *B* to choose *b* = 1
- Increases return to protection (relative to single task case)
- Bullwhip as returns to second task fall from Γ to

$$\Gamma - (e - (p + x)(2e - 1))(\Gamma - \gamma)$$

Managing Alignment Costs

Invest in communication

- Always ensure alignment so Γ is realised

Insurance for *B*'s task

$$e - (p + x)(2e - 1) = C_B'(\Delta_B^*)$$

- Note that *x* and Δ_B are complements

Some advertising

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RESEARCH ARTICLE

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Artificial intelligence adoption in a monopoly market

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Abstract
The adoption of artificial intelligence (AI) prediction of demand by a monopolist firm is examined. It is shown that, in the absence of AI prediction, firms face complex trade-offs in setting price and quantity ahead of demand that impact on the returns of AI adoption. Different industrial environments with differing flexibility of prices and/or quantity ex post also impact on AI returns as does the time horizon of AI prediction. While AI has positive benefits for firms in terms of profitability, its impact on average price and quantity, as well as consumer welfare, is more nuanced and critically dependent on environmental characteristics.

JEL CLASSIFICATION
D21, D81, O31

1 | INTRODUCTION

While certain themes have been explored in economics regarding the adoption of AI including its role in labour replacement (Acemoglu & Restrepo, 2018) and in potentially facilitating collusion (Calvano et al., 2020), there has been very little attention paid to how recent developments in AI will impact on the "meat and potatoes" operations of firms. That is, how will the adoption of AI change the price and quantity decisions of firms?

Usually, technological changes impact on those decisions through either process innovation (lowering the marginal costs of production and hence, reducing price and expanding quantity) or product innovation (improving demand and hence leading to price increases with

Here, we explore one canonical class of predictions that (a) are valuable to most firms and (b) have clear implications for price and quantity decisions made by those firms. We look at predictions of firm demand. Through the gathering of larger datasets on consumers and more sophisticated multicharacteristic demand forecasting models using AI methods such as machine learning, in the future, firms may be able to predict demand precisely and further in advance of having to make key price and quantity decisions. This motivates us to work through the theory of how that improvement in information will impact on firm behaviour.

In this paper, the implications of moving from uncertain to certain demand are explored for a single monopoly firm.[2] The technical challenge in exploring this is not modelling price and quantity outcomes

Artificial Intelligence Adoption in a Competitive Market

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November 7, 2022

Abstract

Economists have often viewed the adoption of artificial intelligence (AI) as a standard process innovation where we expect that efficiency will drive adoption in competitive markets. This paper models AI based on recent advances in machine learning that allow firms to engage in better prediction. Focussing on prediction of demand, it is demonstrated that AI adoption is a complement to variable inputs whose levels are directly altered by predictions and use is economised by them (that is, labour). It is shown that, in a competitive market, this increases the short-run elasticity of supply and may or may not increase average equilibrium prices. There are generically externalities in adoption with this reducing the profits of non-adoptees when variable inputs are important and increasing them otherwise. Thus, AI does not operate as a standard process innovation and its adoption may confer positive externalities on non-adopting firms. In the long-run, AI adoption is shown to generally lower prices and raise consumer surplus in competitive markets. *JEL Classification Numbers*: D21, D81, O31

Keywords: artificial intelligence, prediction, competition, externalities, variable input.

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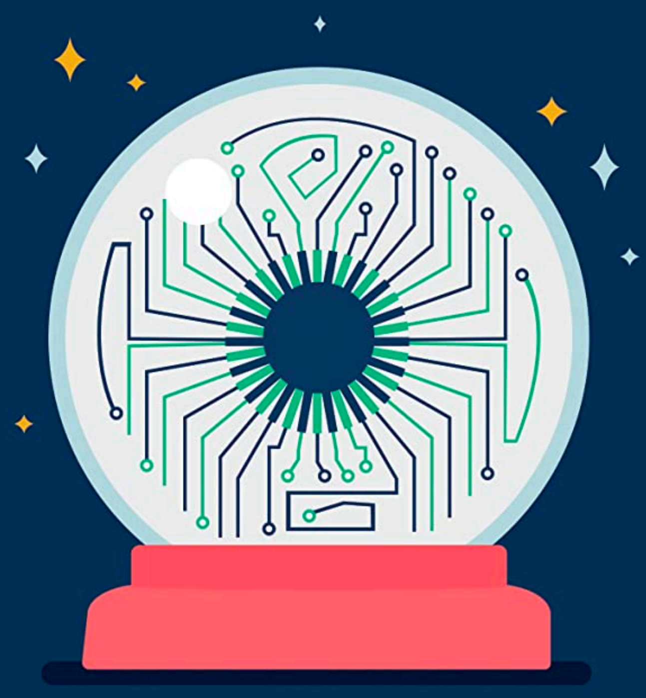
Power and Prediction



The Disruptive Economics of Artificial Intelligence

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