The Macroeconomic Implications of the AI economy

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Boston College Macro-Labor-AI Workshop

AI and Economic Activity

- AI transformative innovation of our time
  - potential importance multitude of economic activities
  - we are still in the process of determining how broad is the impact

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  ○ how does it spill over to aggregate economy?
    some industry estimates: 7% (GS) and 14% (PwC) over next decade

  ○ capital and labor allocation across sectors

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  - capital and labor allocation across sectors

- Use: quantitative macro model

  - parameterized input-output linkages

  - model and calibrate role of AI

What is Special about AI?

- Many things, some of them modeled in literature
  - automation and task replacement, skill-biased technical change
    Acemoglu & Autor (2011), Acemoglu & Restrepo (2018, 2020), ...
- Our focus: AI in marketing
  - customer base management, acquisition, management, product design, advertising

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- Current/future use in these applications?
  - customer support improvements of 14%-34%
    Brynjolfsson et al. (2023)
  - gen-AI could lead to $30\% - 50\%$ increase in productivity in customer service
    Bamberger et al. (BCG 2023)
  - organizations utilizing generative AI in marketing, sales, product development, and service operations
    Chui et al. (McKinsey 2023)
  - multiple marketing applications explored in industry
    reviewed in Ma, Sun (2020), Verma et al. (2021), Haleem et al. (2022)

Nvidia CEO Jensen Huang Said, "This Is the Beginning of a New World" Thanks to Artificial Intelligence (AI). 1 Stock to Buy If He's Right

By Danny Vena – Apr 16, 2024 at 3:09PM

KEY POINTS
- The chipmaker-in-chief thinks AI will change the world as we know it.
- Generative AI can streamline time-consuming tasks.
- Microsoft has been working behind the scenes to develop digital helpers.

Motley Fool Issues Rare "All In" Buy Alert

Generative AI could raise global GDP by 7%

Published on 05 APR 2023
Topic: ARTIFICIAL INTELLIGENCE

Goldman Sachs

The four companies say they launched the Frontier Model Forum to ensure 'Responsible' AI models' © FT montage

Advertising + Add to myFT

AI advertising start-up valued at $4bn after fundraising

The Brandtech Group will use funds to disrupt industry with machine-generated content and artificial intelligence

CIO JOURNAL

At Moderna, OpenAI's GPTs Are Changing Almost Everything

'People literally talk about how AI is going to cure diseases someday, and I think this is a very meaningful first step,' said OpenAI CEO Sam Altman

+14%

PwC research shows global GDP could be up to 14% higher in 2030 as a result of AI – the equivalent of an additional $15.7 trillion – making it the biggest commercial opportunity in today's fast changing economy.

INCREASE IN AI PRODUCTIVITY

- Setup: multi-sector model with customer markets
  - customer base crucial for generating sales
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- Study effect of increase in marketing productivity

  - 10% increase in productivity in AI-service sector $\rightarrow$ 6% increase in aggregate GDP

  - customer market friction drives more than half of the response, I-O the rest

  - large spillover effect of customer market friction:
    small marketing sector (20% of VA) but large aggregate effects
    Bai, Storesletten, Ríos-Rull (2024) demand shocks $\rightarrow$ productivity shocks

  - reallocation of labor towards traditional sectors ($-4.4\% \rightarrow +1.5\%$)

MODEL: FLOW OF GOODS
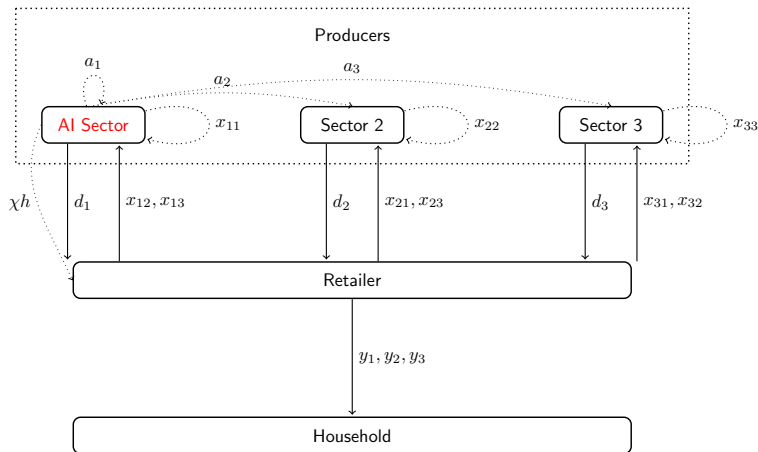
MODEL: FRICTION AND PRICES
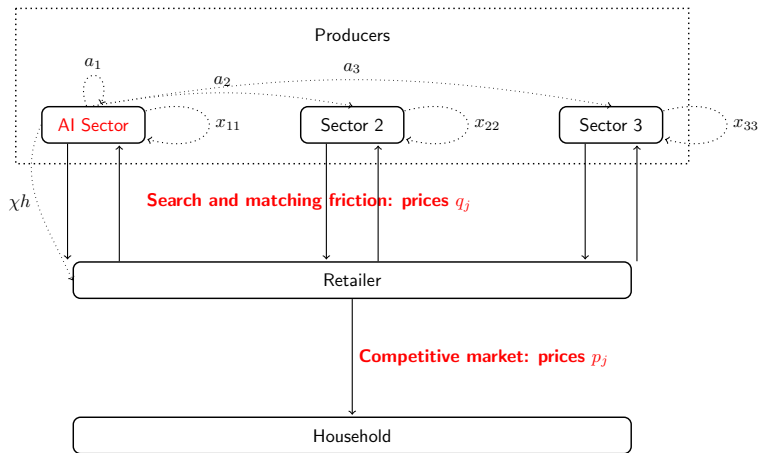
PRODUCTION

- Sector j production Cobb-Douglas: $z_j F(k_j, l_j, \{x_{jm}\})$

  - x_{jm} intermediate use of sector m output in sector j

  - productivity $\ln z_{jt} = (1 - \rho_z^j)\ln z_j^* + \rho_z^j \ln z_{jt-1} + \varepsilon_{jt}$

- Marginal cost v given factor prices and productivity:

$$v_{jt} \equiv \min_{k, \ell} \left\{ w_t \ell_{jt} + r_t k_{jt} + v_{jt} x_{jjt} + \sum p_{mt} x_{jmt} \mid z_{jt} F(\cdot) = 1 \right\}$$

INTERMEDIATE PRODUCERS

- **Customer market friction** based on double-sided search and matching
  Drozd and Nosal (2012)

- Mass 1 of intermediate producers
  - each with customer base H_j, and marketing capital m_j
  - producers need customer base to sell goods: sales $d_j \leq H_j$
  - marketing helps get new customers: $H_{jt} = (1 - \delta_H)H_{jt-1} + \frac{m_j}{\sum_j \bar{m}_j}h_t$
  - h_t is the mass of searching retailers

- Marketing services a_j accumulate marketing capital

$$m_{jt} = (1 - \delta_m^j)m_{jt-1} + a_{jt} - \Psi_j(m_{jt-1}, a_{jt})$$

INTERMEDIATE PRODUCERS

- Producers maximize the present value of discounted profits

$$\Pi_{jt} = (q_{jt} - v_{jt})d_{jt} - v_{1t}a_{jt}$$

subject to

$\rightarrow$ $m_{jt} = (1 - \delta_m)m_{jt-1} + a_{jt} - \Psi(m_{jt-1}, a_{jt})$

$\rightarrow$ $H_{jt} = (1 - \delta_H)H_{jt-1} + \frac{m_{jt}}{\sum_j \bar{m}_{jt}}h_t$

$\rightarrow$ $d_{jt} \leq H_{jt}$

Retailers

- Retailers h search for producers at cost $\chi v_1 h$

  - undirected search $h \rightarrow$ probabilities π_j

  - matching consistent with producer problem: buys H_j from j

  $$H_{jt} = (1 - \delta_H)H_{jt-1} + h_t \pi_j$$

- In equilibrium

  $$\pi_j = \frac{\bar{m}_j}{\sum_j \bar{m}_j}$$

- Marketing services a_{jt}, h_t produced by sector impacted by AI (Sector 1)

Retailers: Search

- Measure of searching retailers endogenously determined by

$$\sum_j \pi_{jt} J_{jt} \leq \chi v_{1t} \qquad \text{(with equality when } h > 0\text{)}$$

where

$$J_{jt} = \max\{0, p_{jt} - q_{jt}\} + (1 - \delta_H)\mathbb{E}_t[\Omega_{t,t+1} J_{jt+1}]$$

p_j: retail price

q_j: wholesale price

WHOLESALE PRICES: NASH BARGAINING

- Producer and retailer bargain over the wholesale price (q_j)

- At each date and state, the price q_j satisfies

$$q_j \in \arg\max_q J_{jt}(q)^{1-\theta} V_{jt}(q)^{\theta}$$

value of the match to retailer

$$J_{jt} = \max\{0, p_{jt} - q\} + (1 - \delta_H)\mathbb{E}_t[\Omega_{t,t+1} J_{jt+1}]$$

value of the match to the producer

$$V_{jt} = \max\{0, q - v_{jt}\} + (1 - \delta_H)\mathbb{E}_t[\Omega_{t,t+1} V_{jt+1}]$$

- Result

$$q_j = \theta p_{jt} + (1 - \theta)v_{jt}$$

Households

- Maximize expected discounted lifetime utility:

$$U = \mathbb{E}_0 \left[\sum_{t=0}^{\infty} \beta^t u(c_t, \ell_t) \right]$$

- Aggregate sectoral goods y_j into composite $G(\{y_j\})$:

$$G(\{y_j\}) = \left(\sum_j \omega_j^{\frac{1}{\gamma}} (y_j)^{\frac{\gamma-1}{\gamma}} \right)^{\frac{\gamma}{\gamma-1}}$$

- Composite good used for consumption and investment:
  $c_t + i_t = G(\{y_j\})$

- Capital accumulation with adjustment cost ϕ:

$$k_t = (1-\delta)k_{t-1} + i_t - \phi(i_t, k_{t-1})$$

- Budget constraint includes income from labor, capital, profits, and bonds

- Industry information at the 3-digit level and group industries in 3 sectors
  - services impacted by AI in marketing (Sector 1)
  - other services (Sector 2)
  - the rest (Sector 3)
- Idea: industries exposed to AI, related to marketing/management services
  - use AI Industry Exposure measure from Felten et al. (2021)
  - abilities exposed to AI (based on survey) $\rightarrow$ occupations $\rightarrow$ 4-digit exposure
  - 4-digit $\rightarrow$ 3-digit using labor compensation weigths
  - select highest index marketing/management services

CALIBRATION

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- Baseline Calibration (20% of aggregate value added)
  - Publishing industries, except internet (includes software)
  - Data processing, internet publishing, and other information services
  - Computer systems design services
  - Miscellaneous professional, scientific, and technical services
  - Management of companies and enterprises

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- Alternative Calibration
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  - Motion picture and sound recording industries
  - Broadcasting and telecommunication
  - Data processing, internet publishing, and other information services
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- **Conservative Calibration**

- Weights in demand aggregator (PCE): NIPA and PCE Bridge tables

$$\left(\sum_j \omega_j^{\frac{1}{\gamma}} \left(y_j \right)^{\frac{\gamma-1}{\gamma}} \right)^{\frac{\gamma}{\gamma-1}}$$

- Factor shares: 'use tables' of the I-O accounts from BEA

$$F(k_j, l_j, \{x_m^j\}) = k_{jt}^{\alpha_k^j} l_{jt}^{\alpha_l^j} \prod_m x_{jmt}^{\alpha_m^j}$$

- BEA-BLS Integrated Industry-level Production Accounts $\rightarrow$ Solow residuals
- Sectoral PPI: BEA's use tables

- Marketing friction
  - $m_{jt} = (1 - \delta_m^j)m_{jt-1} + a_{jt} - \Psi_j(m_{jt-1}, a_{jt})$
  - makes retail prices less volatile than wholesale prices
  - adjustment cost to match the volatility of PPI to CPI in aggregate data
- $\delta_m^j \leftarrow$ marketing expenditures/sales of 7%

- Spillovers in the model due to customer market friction

- Essential element of output (sales)

    ○ $z_j F(k_j, l_j, \{x_m^j\})$ – production

    ○ $H_{jt} = \frac{m_j}{\sum_j m_j} h_t$ – customers

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- z_1 shock increases efficiency of customer acquisition in all sectors
  - $\rightarrow$ to sell more, need $k_j, l_j, \{x_m^j\} \uparrow$
  - $\rightarrow$ short run in Sector 1: $k, l \downarrow$, long run: $l \downarrow$
  - $\rightarrow$ output in all sectors goes up
  - $\rightarrow$ output in Sector 1 by less than implied by just the productivity shock
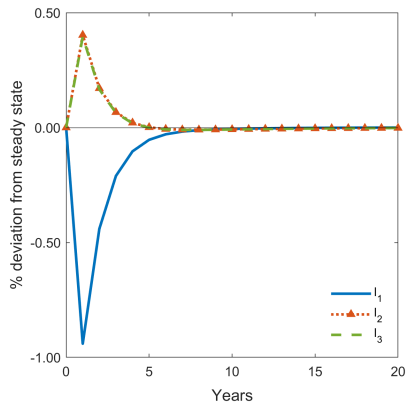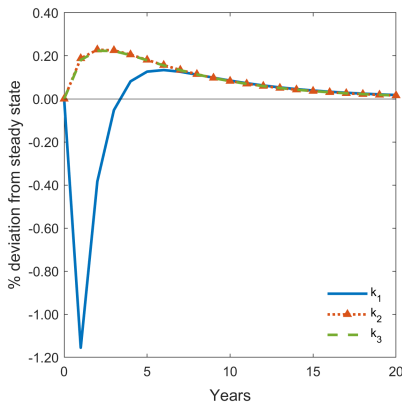
- 1% positive productivity shock in Sector 1
→ Large impact on Sector 2-3 output
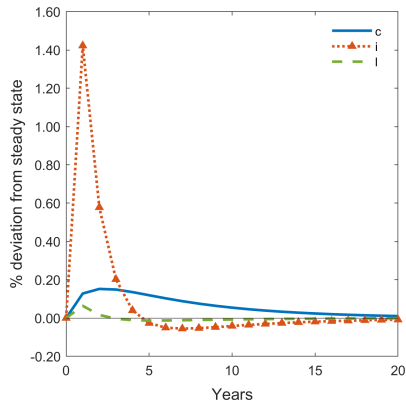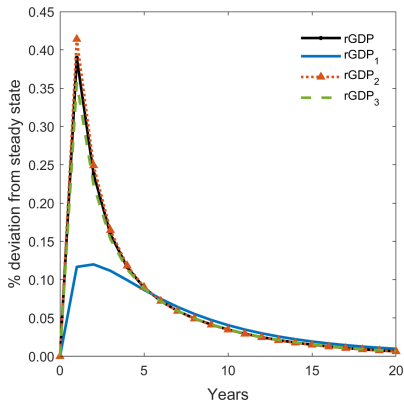
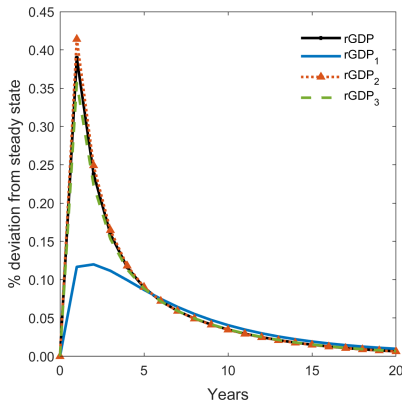# IMPULSE RESPONSE FUNCTION: TRANSITORY AI SHOCK

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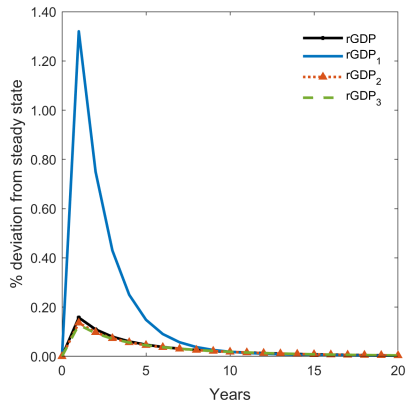- → Relocation of factors from Sector 1

- 1% positive productivity shock in Sector 1
→ **Customer market responsible for spillovers**
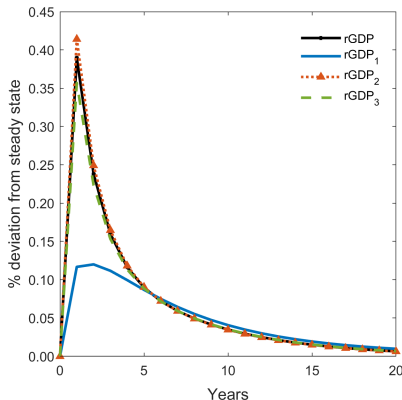

BASELINE   NO CUSTOMER MARKET

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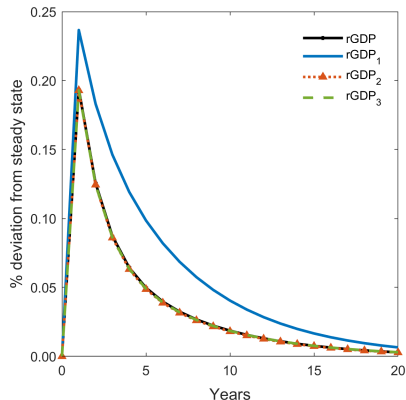
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- → **Input-output increases impact of customer market**

BASELINE   NO INPUT-OUTPUT

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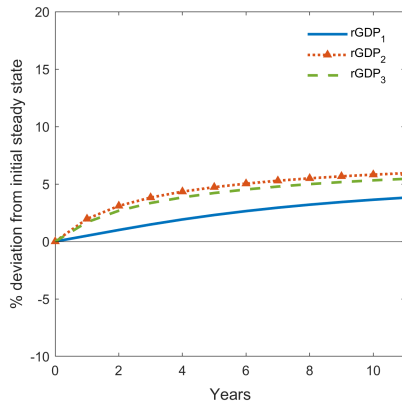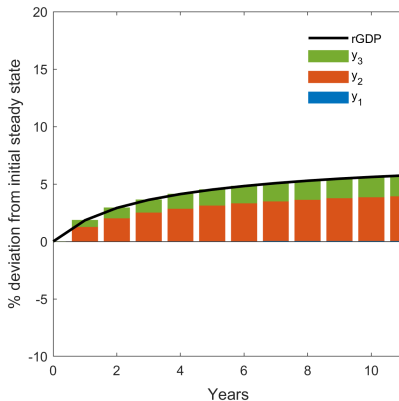
LONG-RUN IMPACT: PERMANENT AI SHOCK

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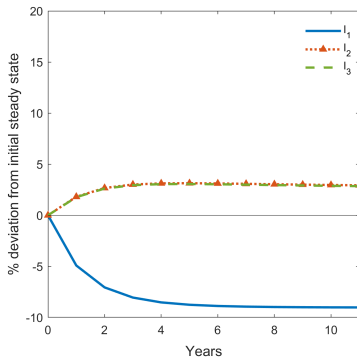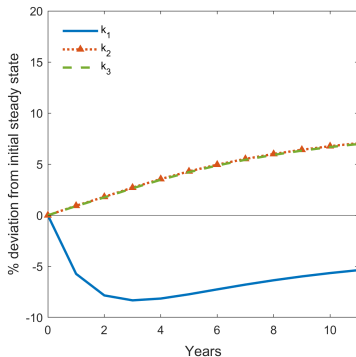
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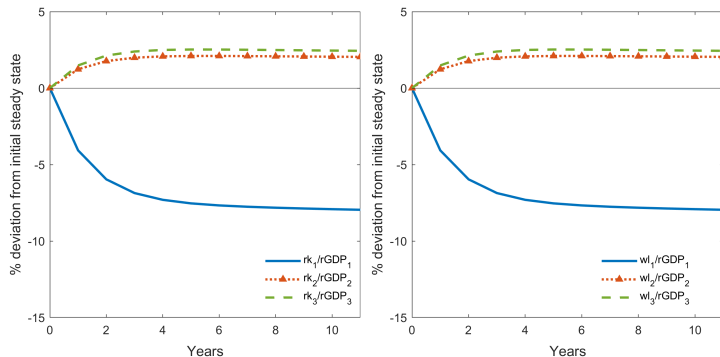
BASELINE CALIBRATION

- Aggregate GDP effects: **Baseline** calibration

Variable	**Baseline**	No I-O	No Customer Market	No I-O No CM
$rGDP$	**5.9**	**3.3**	**2.5**	**0.3**
$rGDP_1$	15.8	12.0	14.1	11.1
$rGDP_2$	5.8	3.1	2.3	0.1
$rGDP_3$	5.6	3.1	2.2	0.1
$rGDP/l$	5.9	3.3	2.5	0.3
$rGDP_1/l_1$	21.1	19.5	13.9	10.1
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$\rightarrow$ Labor productivity goes up across sectors

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Long-run Impact: Decomposition

- Aggregate GDP effects: **Baseline** calibration

$\rightarrow$ Consumption, investment, wages go up

$\rightarrow$ Relocation of labor, capital driven by customer markets

Variable	**Baseline**	No I-O	No Customer Market	No I-O No CM
c	5.8	3.1	2.5	0.3
i	6.5	3.8	2.5	0.3
w	5.8	3.1	2.5	0.3
l_1	-4.4	-6.2	0.1	0.9
l_2	1.5	1.6	0.0	0.0
l_3	1.5	1.6	0.0	0.0
k_1	1.2	-3.4	2.6	1.3
k_2	7.4	4.7	2.4	0.3
k_3	7.4	4.7	2.4	0.3

CONCLUSIONS

- Multi-sector model with I-O and customer market friction
  - calibrated input-output structure
  - customer market friction implies strong spillover effect of AI shock
  - consistent with findings on the impact of TV marketing on sales
    Kim (2022) – TV introduction impacts sales by 3-4%

- Other predictions
  - labor, capital reallocation away from AI sector
  - spillover of labor productivity

- Other outcomes and potential questions
  - speed of transition ← depends on marketing friction
  - effect on income distribution and labor reallocation: capital and labor shares
  - flexible and tractable framework