Rethinking Firm Dynamics: Labor Allocation, Financial Frictions, and Automation

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The New Reality in Tech Firms

“Maintenance” Is Now Core High-Skill Work: ***lets call it Services!***

1. Modern “Maintenance” ≠ Wrench-Turning

Continuous product upkeep: Bug-fixes, security patches, DevOps → same software engineers who build the product

2. Share of High-Skill Maintenance Is Rising

- FAANG* reports: ≈ 35 % of engineering head-count now Services / Infra / DevOps
- GitHub sample: ≈ 40 % of commits on mature repos are maintenance-type

3. Financing Makes It Costly = Labor costs must be financed up-front

- ≈ 60 % of start-up payroll financed with short-term credit or VC bridge loans (Crunchbase 2022)
- Recent rate hikes ⇒ wage “carry” cost spiked in 2022-23

Key Questions Raised

Financing Wedge:

- How do higher wage-financing costs alter the optimal allocation between labor devoted to production and labor devoted to upkeep / services?

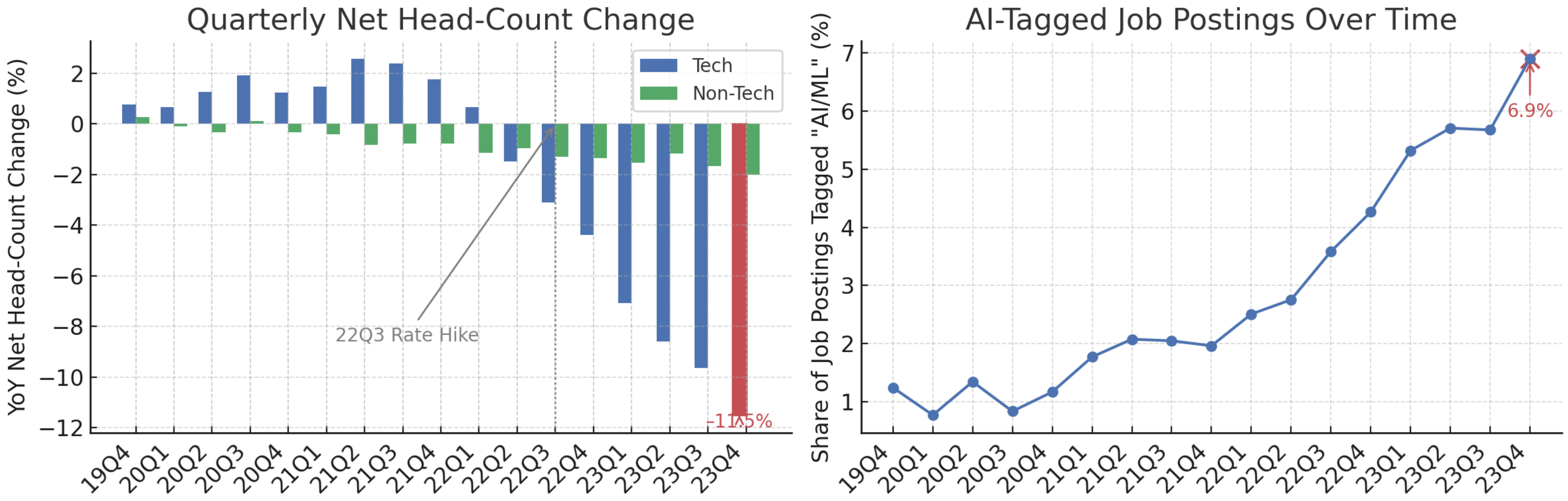
Cyclical Talent Reallocation:

- When upkeep roles draw on the same high-skill engineers as new-feature development, what happens to staffing decisions in booms vs. busts?

Automation Margin:

- Can AI tools substitute for (or complement) costly human maintenance labor—especially when financing conditions tighten?

Macro Fallout: Layoffs & the AI Hiring Spike (2020 – 2023)



Left: Grouped bar chart showing quarterly year-over-year net head-count changes for Tech vs. Non-Tech (2019Q4–2023Q4).
Right: Line chart of the share of job postings tagged "AI/ML" over the same period.

- Even as tech firms cut head-count overall, they ramped up hiring for AI & Services

Hypothesis: financing costs + automation option jointly drive this paradox

A need for a model with the ingredients

Two Human Labor Margins

1. h_t^{prod}: new-product engineering
2. h_t^{serv} : high-skill maintenance & DevOps

Working-Capital Wedge

- Payroll must be financed ⇒ Working Capital Constraints (WKC) in the resource constraint (Christiano et al., 2005)

Automation Margin (AI)

- AI-capital ai_t as a third input to maintenance: can substitute or complement

Next: We'll build this model step-by-step, starting from a simple RBC benchmark

Benchmark Model

The representative agent solves:

$$max_{c_t, h_t^{prod}, h_t^{maint}, i_t, k_{t+1}} E_0 \sum_{t=0}^{\infty} \beta^t U\big(c_t - G(h_t)\big)$$

- With: U strictly increasing and concave, U'(c)>0, U''(c)<0 and disutility of total labor, G'(h)>0, G''(h)>0

Subject to:

1. Resource Constraint:

$$c_t + i_t = A_t f(k_t, h_t^{prod})$$

2. Capital Law of Motion:

$$k_{t+1} = k_t(1 - \delta(\mu(h_t^{maint}))) + (1 + \varepsilon_t) i_t$$

3. Labor Market:

$$h_t = h_t^{prod} + h_t^{maint}$$

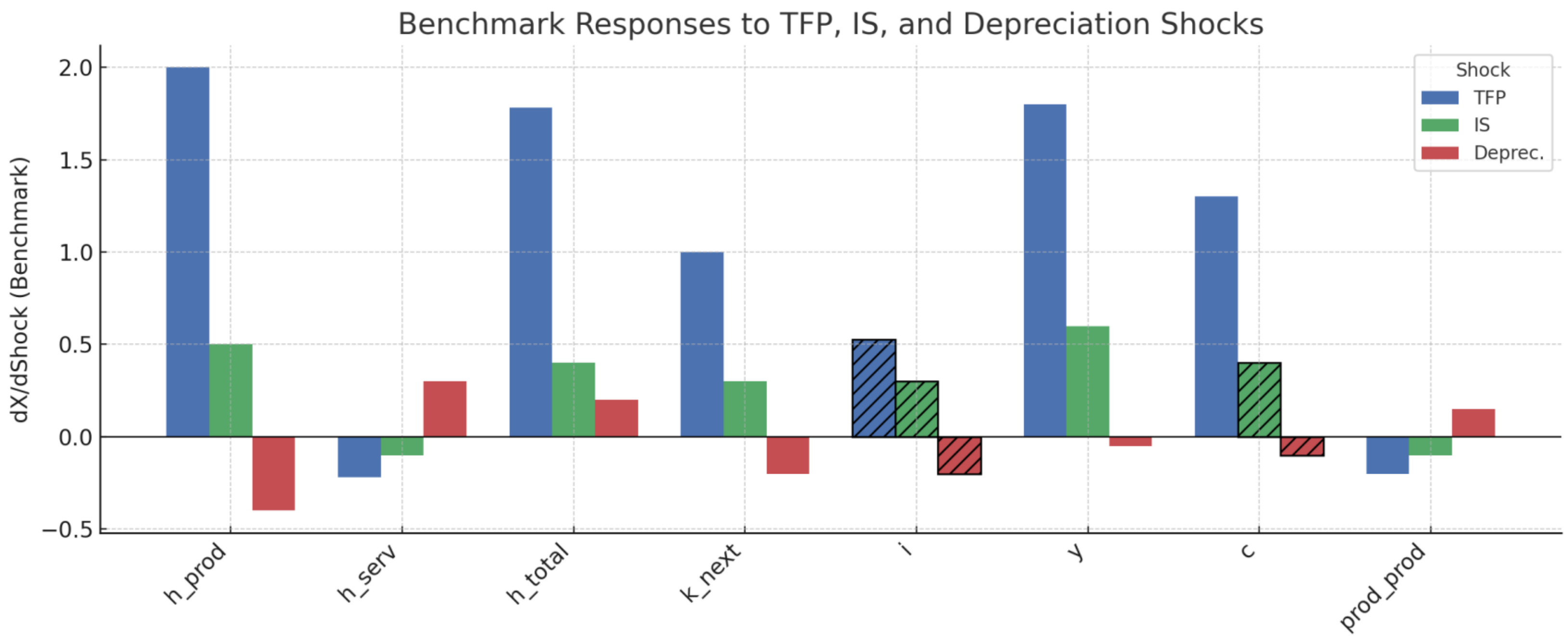
4. Maintenance and depreciation:

$$m_t = \mu\big(h_t^{maint}\big), \delta_t = \delta(m_t)$$

Table 2.1: Short-run effects due to technology shocks with labor intensive maintenance.

	TFP	IS	Depreciation Shock
$\frac{dh_t^y}{dx_t}$	$-\frac{F_2(G''+k_t\delta''(m')^2+k_t\delta' m'')}{A(t)}>0$	$\frac{G''(t)\delta'(t)m'(t)k_t}{\varepsilon_t^2 B(t)}>0$	$-\frac{k_t\delta' m' G''}{\Gamma(t)}<0$
$\frac{dh_t^m}{dx_t}$	$\frac{G''F_2}{A(t)}<0$	$\frac{(F_{22}-G'')\delta'(t)m'(t)k_t}{\varepsilon_t^2 B(t)}<0$	$-\frac{k_t\delta' m'(F_{22}-G'')}{\Gamma(t)}>0$
$\frac{dm}{dx_t}$	$m'\frac{dh_t^m}{d\alpha_t}<0$	$m'\frac{dh_t^m}{d\varepsilon_t}<0$	$m'\frac{dh_t^m}{d\eta_t}>0$
$\frac{d\delta}{dx_t}$	$\delta' m'\frac{dh_t^m}{d\alpha_t}>0$	$\delta'(t)m'(t)\frac{dh_t^m}{d\varepsilon_t}>0$	$\delta' m'\frac{dh_t^m}{d\eta_t}<0$
$\frac{dk_{t+1}}{dx_t}$	$\frac{U''F}{U''+\beta E_t[V_{11}(t+1)\|t]}>0$	$i_t\frac{U''}{U''+\varepsilon_t^2\beta E_t[V_{11}\|t]}-\frac{U'}{U''+\varepsilon_t^2\beta E_t[V_{11}\|t]}>0$	$-\frac{U''k_t\delta}{U''+\beta E_t[V_{11}\|t]}<0$
$\frac{dc_t}{dx_t}$	$-\frac{G'F_2k_t(\delta''(m')^2+\delta' m'')}{A(t)}$ $+\frac{\beta E_t[V_{11}(t+1)\|t]F}{U''+\beta E_t[V_{11}(t+1)\|t]}>0$	$\frac{G'F_{22}k_t\delta' m'}{\varepsilon_t^2 B(t)}+i_t\frac{\beta\varepsilon_t E_t[V_{11}\|t]}{U''+\varepsilon_t^2\beta E_t[V_{11}\|t]}$ $-U'\frac{\beta\varepsilon_t E_t[V_{11}\|t]}{U''+\varepsilon_t^2\beta E_t[V_{11}\|t]}\gtrless 0$	$-\frac{k_t\delta' m' G' F_{22}}{\Gamma(t)}$ $-\frac{\beta E_t[V_{11}\|t]k_t\delta}{U''+\beta E_t[V_{11}\|t]}\gtrless 0$
$\frac{dF_2}{dx_t}$	$F_{22}\frac{dh_t^y}{d\alpha_t}<0$	$F_{22}\frac{dh_t^y}{d\varepsilon_t}<0$	$F_{22}\frac{dh_t^y}{d\eta_t}>0$
$\frac{dy_t}{dx_t}$	$F+\alpha_t F_2\frac{dh_t^y}{d\alpha_t}>0$	$F_2\frac{dh_t^y}{d\varepsilon_t}>0$	$F_2\frac{dh_t^y}{d\eta_t}<0$
$\frac{di_t}{dx_t}$	$\frac{dk_{t+1}}{d\alpha_t}-\delta' m'\frac{dh_t^m}{d\alpha_t}\gtrless 0$	$\frac{1}{\varepsilon_t}[\frac{dk_{t+1}}{d\varepsilon_t}-k_t\delta' m'\frac{dh_t^m}{d\varepsilon_t}-i_t]\gtrless 0$	$\frac{dk_{t+1}}{d\eta_t}+k_t\delta+\eta_t k_t\delta' m'\frac{dh_t^m}{d\eta_t}\gtrless 0$
$\frac{dh}{dx_t}$	$-F_2k_t\frac{\delta''(m')^2+\delta' m''}{A(t)}>0$	$\frac{F_{22}k_t\delta'(t)m'(t)}{\varepsilon_t^2 B(t)}<0$	$-\frac{F_{22}k_t\delta'(t)m'(t)}{\Gamma(t)}>0$
$\frac{d(F_2+m')}{dx_t}$	$F_{22}\frac{dh_t^y}{d\alpha_t}+m''\frac{dh_t^m}{d\alpha_t}\gtrless 0$	$F_{22}\frac{dh_t^y}{d\varepsilon_t}+m''\frac{dh_t^m}{d\varepsilon_t}\gtrless 0$	$F_{22}\frac{dh_t^y}{d\eta_t}+m''\frac{dh_t^m}{d\eta_t}\gtrless 0$
with	$A(t)=\alpha_t F_{22}(G''(t)$ $+k_t\delta''(m')^2+k_t\delta' m'')$ $-G''(k_t\delta''(m')^2+k_t\delta' m'')<0$	$B(t)=B(t)=F_{22}(\frac{k_t}{\varepsilon_t}\delta''(m')^2$ $+\frac{k_t}{\varepsilon_t}\delta' m''+G'')$ $-G''\frac{k_t}{\varepsilon_t}(\delta''(m')^2+\delta' m'')<0$	$\Gamma(t)=F_{22}(\eta_t k_t\delta''(m')^2$ $+\eta_t k_t\delta' m''+G'')$ $-G'' k_t\eta_t(\delta''(m')^2+\delta' m'')<0$

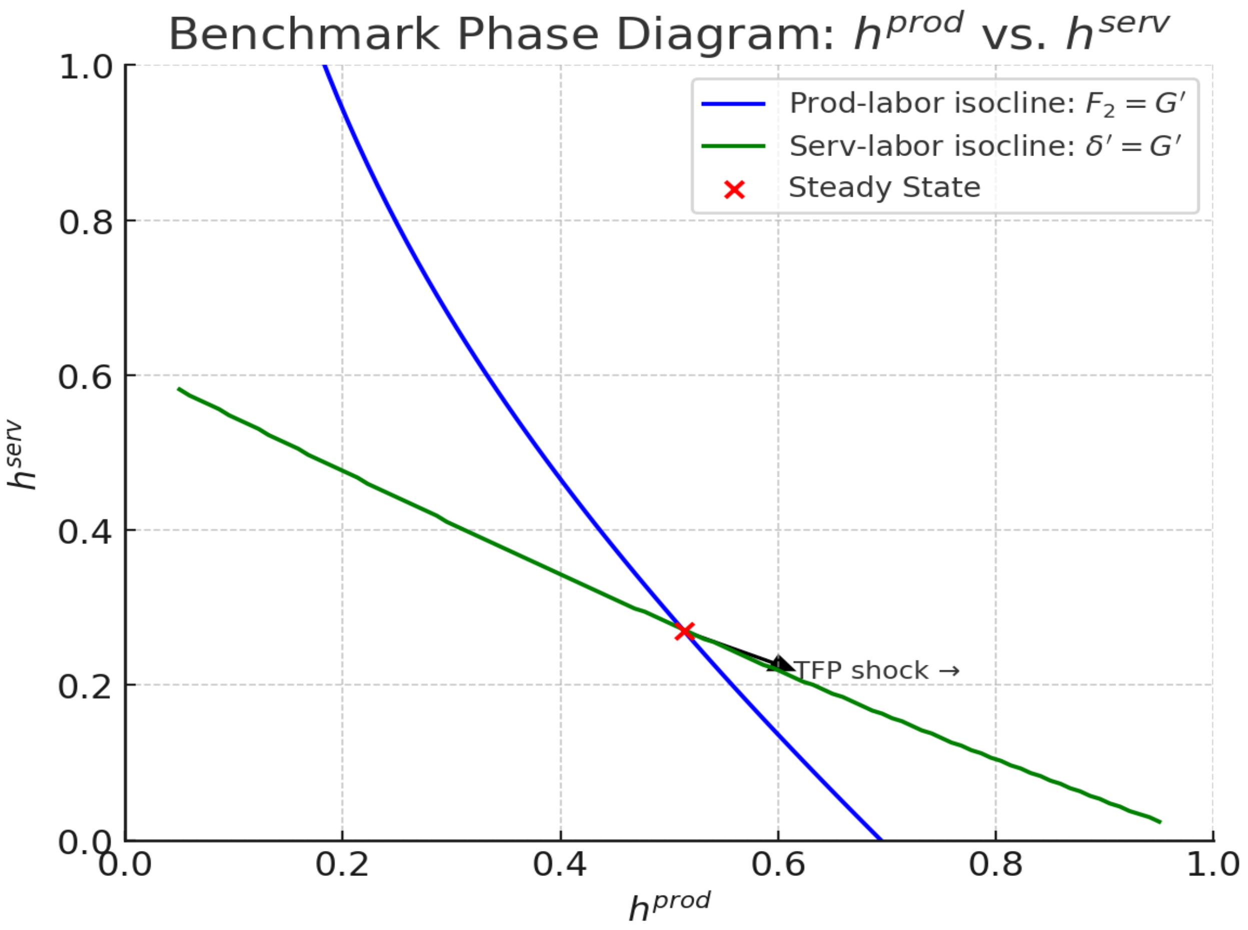
Numerical responses



Magnitudes: Responses are computed from the closed-form comparative statics using standard calibration: $\beta = 0.98, \alpha = 0.4, \delta = 0.09,\ standard\ GHH\ preferences$

Note: The allocation of labor to production and services is important in distinguishing an IS and a depreciation shock

Reallocation Dynamics: Production vs. Services Labor



A positive TFP shock triggers an immediate reallocation:

- h_t^{prod} →↑and h_t^{serv} →↓

Mechanism: The TFP shock raises marginal product of h_t^{prod} → reallocate hours away from services

Introducing Working Capital Constraints

Why?

- Tech firms often pre-finance payroll via short-term credit or VC
- Rising policy rates sharply increase the cost of high-skill labor

Resource Constraint:

$$c_t + i_t + \phi r_t h_t = A_t f\left(k_t, h_t^{prod}\right)$$

- We assume the firm must **pre-finance its labor cost** using internal funds or borrowing
- ϕ affects the **tightness** of the constraint: higher ϕr_t→ easier to finance labor
- r_t: is a time-varying exogenous process to model **financial shocks**

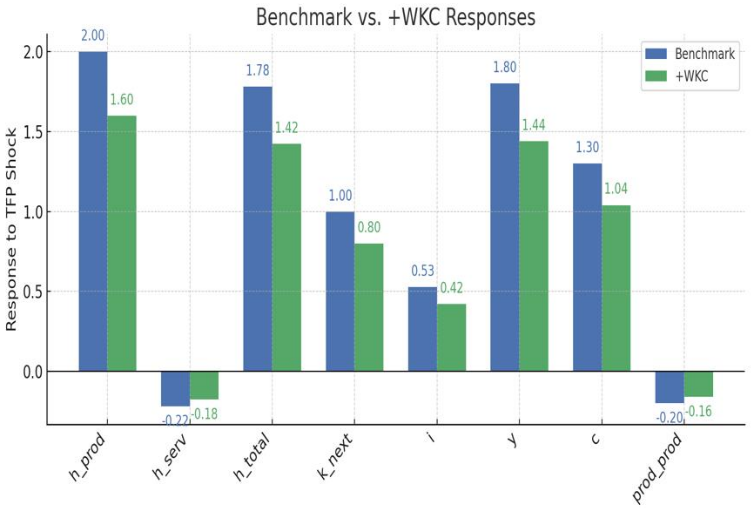
Key Intuition:

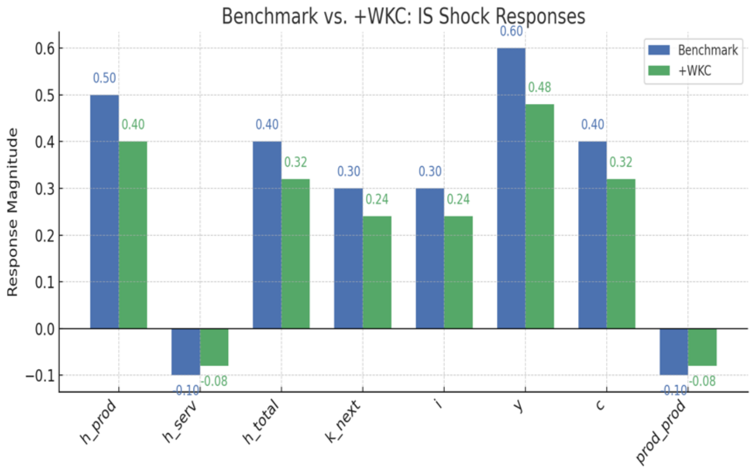
- **Labor "tax":** Every extra hour of high-skill labor now carries a financing cost ϕr_t
- **Dampened Responses:** Shocks that would normally boost h_t^{prod}, i now partially offset
- **Sharper Cutbacks:** In downturns (e.g. higher r_t), h_t^{serv}, which is a large fraction, gets cut more when financing dries up

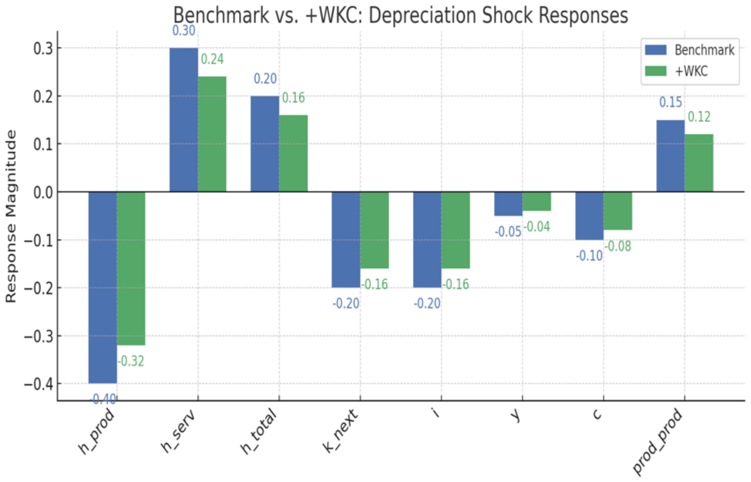
Impact of WKC in the Short-Run Responses I

Variable	Δ-Term
h^{prod}	$-F_2 M\Big[\frac{1}{A_S - \phi G"} - \frac{1}{A_S}\Big]$
h^{serv}	$G" F_2 k\Big[\frac{1}{A_S - \phi G"} - \frac{1}{A_S}\Big]$
h	Sum of the two Δ-terms above
k_{t+1}	$\Delta_{k'} = N_k\Big[\frac{1}{A_S - \phi G"} - \frac{1}{A_S}\Big]$
i	$\Delta_i = N_i\Big[\frac{1}{A_S - \phi G"} - \frac{1}{A_S}\Big]$
y	$\Delta_y = F_1\,\Delta_{k'} + F_2\,\Delta_{h^{prod}}$
c	$\Delta_c = \Delta_y - \Delta_i$
F_2	$\Delta_{F_2} = F_{22}\,\Delta_{h^{prod}}$

Impact of WKC in the Short-Run Responses II



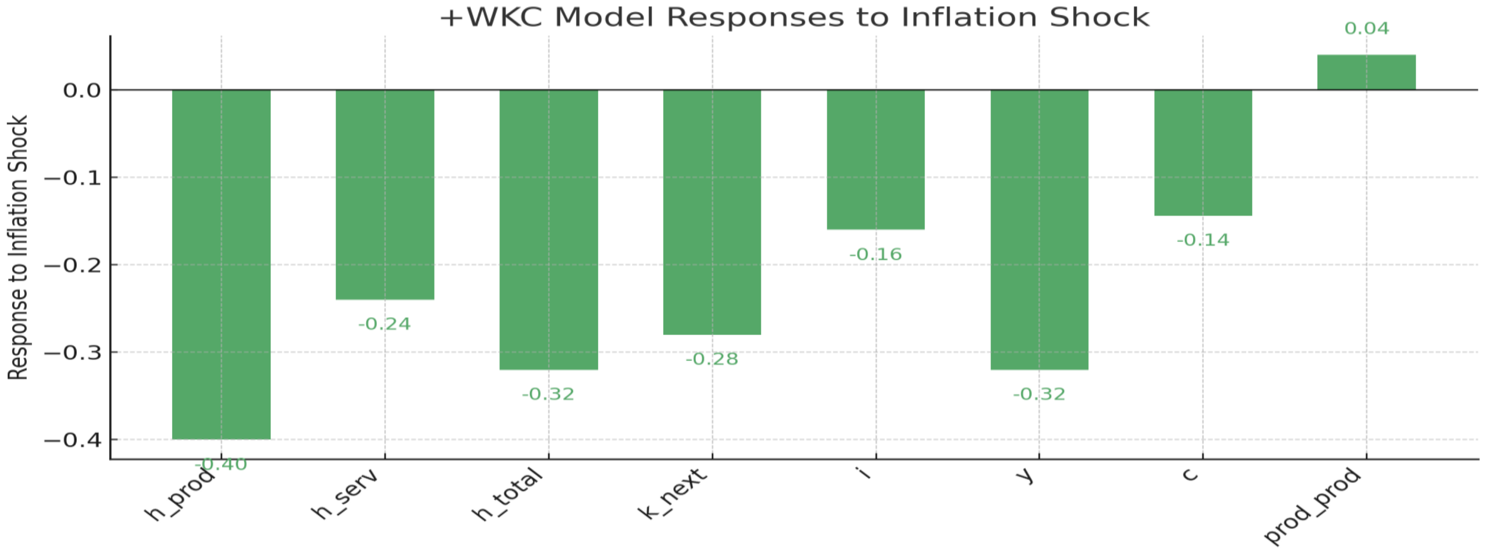




- **Consumption and labor productivity** following IS & Dep. shocks sees a dampened cut
- Credit constraints cushions the intertemporal trade-off between $c\ and\ i$
- TFP-shock responses are uniformly attenuated (~20 %)
- **Policy**: Tight credit conditions make tech firms **less responsive** to both positive opportunities (innovation, expansion) and negative shocks, leading to **sluggish adjustment** in labor

*Introducing WPC uniformly **attenuates** the model's responses to all shocks. Firms temper both hiring and investment when wages carry a financing cost.*

Responses to an Inflation Shock



$\beta = 0.98$
$\alpha = 0.4$
$\delta = 0.088$
GHH risk aversion =2
disutility of labor =1
WKC: $\varphi = 0.6$
Surveys of high-growth tech firms (e.g. Crunchbase 2022) show that roughly 60 % of monthly payroll is paid out of revolving lines or debt

- A higher **credit friction** raises firms' effective cost of human labor
- Under an inflation-like jump high-skill both h_t^{prod} and h_t^{serv} contract sharply
- **WKC** amplify the consumption-smoothing Euler effect: consumption drops less than output, indicating a shift into precautionary saving

Introducing Automation (AI) Margin

AI as a separate input:

- **AI substitution**: human-labor and AI are **imperfect substitutes**
- In production: as a substitute or complement to labor
- In services/depreciation: requires high-skilled labor to function and improve
- AI has **zero marginal wage** but entails **fixed up-front adoption cost** (we capture in depreciation function)

Resource Constraint:

$$c_t + i_t + i_t^{ai} + \phi r_t h_t = A_t f(k_t, h_t^{prod}, ai_t))$$

Capital Law of Motion:

$$k_{t+1} = k_t(1 - \delta(\mu(h_t^{maint}))) + (1 + \varepsilon_t) i_t$$

- **Labor Market**:

$$h_t = h_t^{prod} + h_t^{maint}$$

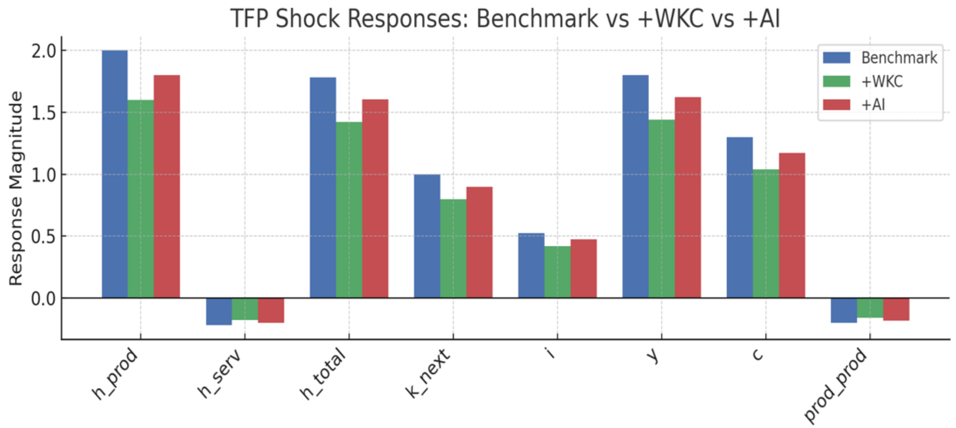
- **Maintenance and depreciation**:

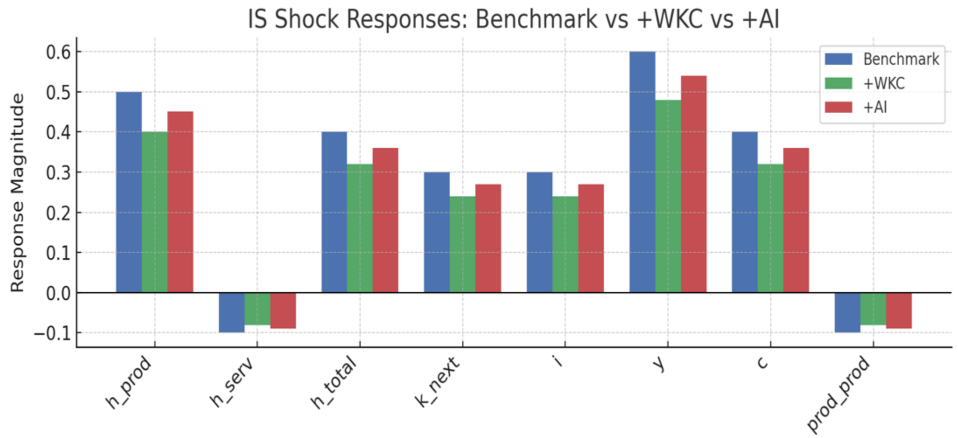
$$m_t = \phi\left(h_t^{maint}, ai_t^{maint}\right) = \mu\left(h_t^{maint}\right) + \psi(ai_t)$$

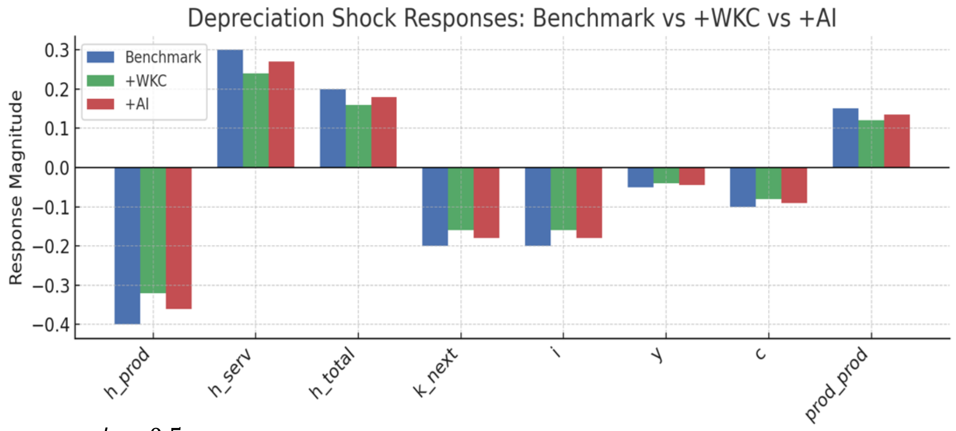
- **Law-of-Motion: Automation Capital**

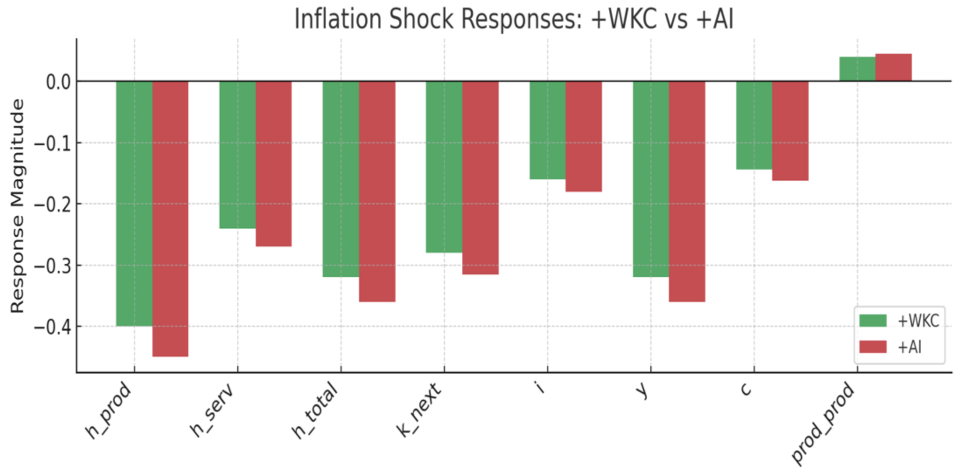
$$ai_{t+1} = ai_t(1 - \delta^{ai}) + i_t^{ai}$$

Impact of AI in the Short-Run Responses I





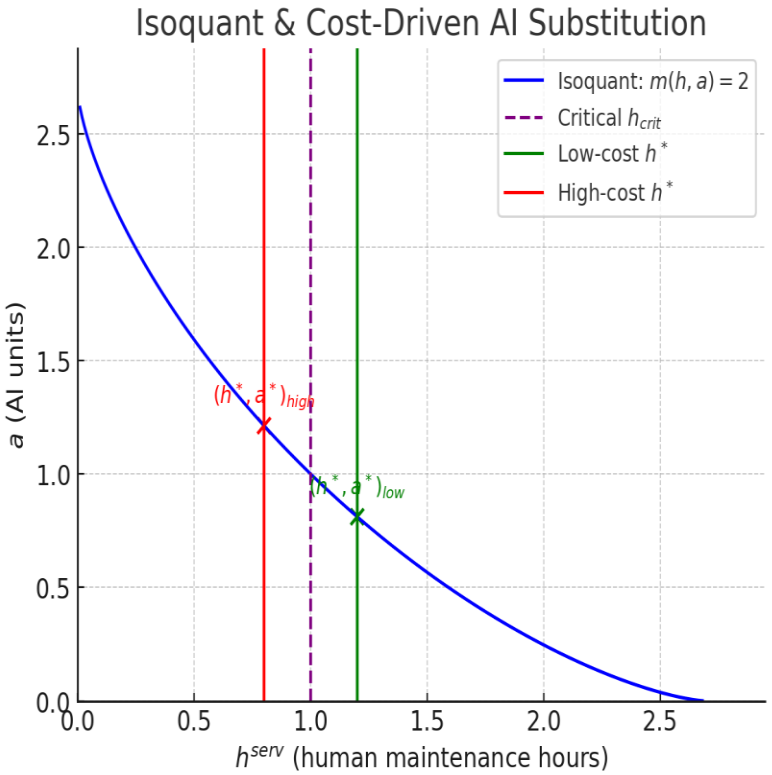




$\psi = 0.5$

- For TFP, IS, and depreciation shocks WKC attenuates responses while adding AI partially restores them toward the benchmark
- For inflation shocks AI substitution **mitigates** the hit to human labor, investment, and output

Critical Tipping Point: Human vs. AI Services



Blue curve: maintenance isoquant m(h,a)=2
Purple dashed: critical human-hour threshold
Green & red: equilibrium human hours under low vs *high-financing-cost scenarios, with corresponding* critical points

*This "cliff-like" reallocation helps explain why many tech firms **simultaneously** cut DevOps positions and ramp up AI tooling when financing conditions worsen or AI capabilities improved*

- When financing costs rise (green to red), optimal solution **left, higher AI**
- **Marginal-Productivity vs. Marginal-Cost:** On the isoquant, every point yields the same services output
- As the effective wage-carry rate ↑, **dollar cost** of one more human hour ↑

Movement Along the Isoquant

- **Low financing cost (green)**: human hours are relatively cheap, equilibrium **right** of the critical line, AI plays a supporting role
- **High financing cost (red)**: human hours become too expensive, forcing a jump to a **high-AI, low-human** solution

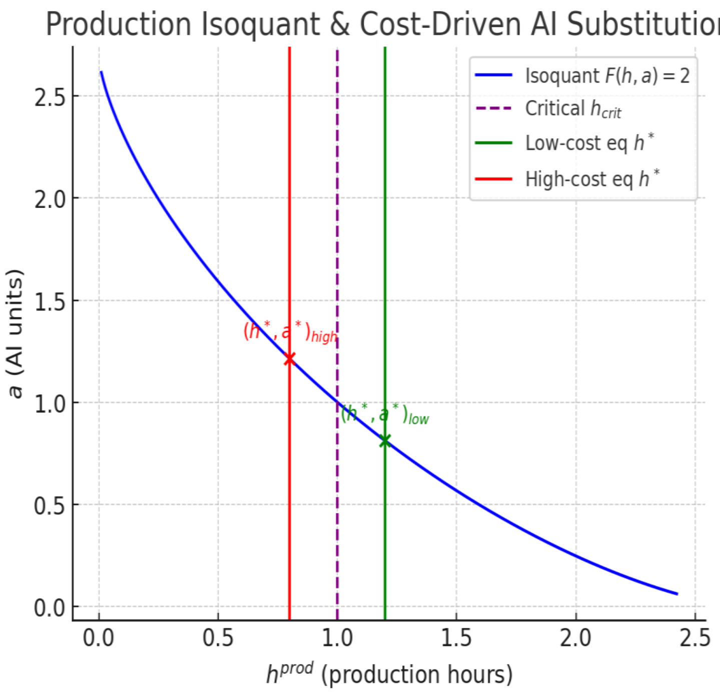
Discrete "Cliff"

- Because AI has **zero marginal wage**, once the relative cost of humans crosses the threshold, it is **always** optimal to drop human hours to (near) zero
- This generates a **non-smooth switch,** small inflation shock around the critical value leads to a **large jump** in the human/AI allocation

Managerial Take-Away

- **Credit-tightening** (higher r) or **expensive human capital** can trigger mass automation **overnight**
- Conversely, improvements in **AI productivity** shift the isoquant inward, lowering the critical threshold and making AI takeover even more likely

Production Labor vs. AI Substitution

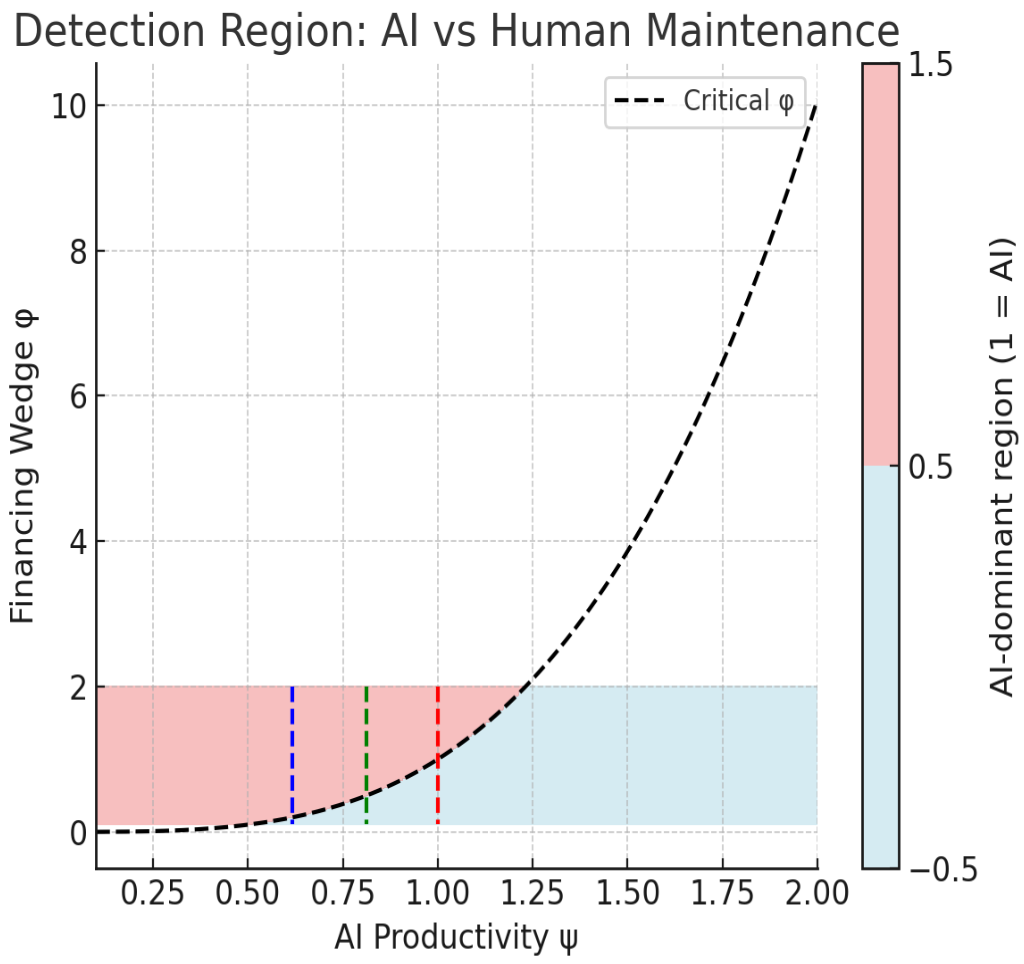


Blue curve: Isoquant for production technology
Purple dashed: Critical human-hour threshold
Green line & marker: Low financing-cost equilibrium, human-heavy.
Red line & marker: High financing-cost equilibrium, AI-heavy

- **Production Isoquant** shows all combinations yielding the same output
- A **vertical isocost** line (green or red) gives the cheapest human-AI mix for different financing costs
- When financing is cheap (green), firms use **more human hours** and less AI; the tangency lies **right** of the critical
- When financing cost jumps (red), the optimal labor is **left** of causing a **cliff-like** jump to a **high-AI** solution

If AI enters production, there is a ***tipping point*** *where firms* ***fully substitute*** *production labor with AI*

AI-Human Tipping Surface



Black dashed line: separating **human-dominant** (below curve, light blue) from **AI-dominant** (above curve, light red)

Vertical dashed lines:

Blue: $\psi = 0.5$(benchmark calibration)

Green: $\psi = 0.7$

Red: $\psi = 1$

- At those ψ values, **higher φ** (right of the line) triggers full automation; **lower** keeps human maintenance
- **Below** the curve → human labor remains cheaper (even with credit wedge)
- **Above** the curve → AI's marginal productivity makes it strictly cheaper; firms **zero out** human hours
- This explains why many tech firms went straight to AI automation in 2022–23

Conclusions

- **Rethinking Labor Allocation:** Traditional RBC models miss that modern tech firms devote a large share of **high-skill labor** to maintenance. We introduce a **services-labor** margin alongside production
- **Financing Frictions Matter: Simple working capital constraints** uniformly **attenuate** firms' hiring, investment, and output responses to TFP, IS, depreciation, and inflation shocks, making adjustment **sluggish** under tight credit
- **Automation as a Flexible Margin: AI input** (in both production & services) partially **restores** cyclicality and can, above a sharp **tipping point**, fully **displace** human labor when AI's productivity or financing costs cross critical thresholds
- **Managerial & Policy Implications**: **Tech firms** facing high wage-carry costs will automate **maintenance** (and potentially **production**) almost overnight
- **Policy tools** that ease payroll financing can prolong human-labor employment and slow headcount volatility

"Automation is not just a technology story, it's a financial-structure story. Credit costs can flip the switch from full-time engineers to AI overnight."

Work in progress: Stylized Facts & Empirical Validation

1. Assemble Stylized Facts

- **Labor composition:** DevOps/SRE share over time: Compustat, FAANG reports, AI-specialist postings; GitHub commit tags
- **Credit financing intensities:** Payroll financed by short-term debt; Crunchbase survey, Compustat leverage ratios. Credit-spread series: Fed H.15 (corporate yields)
- **Layoff & hiring dynamics:** Quarterly tech layoffs (BLS JOLTS, ADP payroll data) vs. AI-job ads

2. Empirical Strategies: Structural GMM / Bayesian estimation, match model moments

3. Extensions

- **Micro-survey** of CFOs/CTOs of startups on payroll financing
- **Sectoral comparisons** (software vs. biotech vs. manufacturing)

Goal: Rigorously test the model's key predictions, credit-driven dampening, AI tipping points

Thank you!