Does Pandemic-Induced Uncertainty Increase Automation and Income Inequality?

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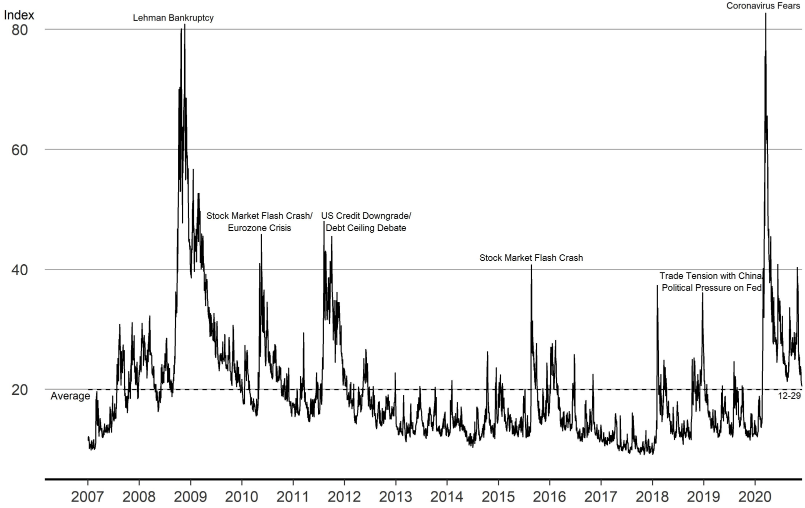
COVID-19 created massive uncertainty



Source: Bloomberg

Could job uncertainty stimulate automation?

- Should pandemic recur, workers might be exposed to health risks: an important source of uncertainty
- Unlike workers, robots are not susceptible to health risks, creating incentive for automation
- But uncertainty depresses aggregate demand (Leduc-Liu, 2016), reducing incentive for hiring and automation spending
- Through automation, job uncertainty may affect income inequality (skill premium)
- To study the macro and distributional impact of job uncertainty requires a GE model with automation decisions and heterogenous workers

A GE framework with automation and heterogeneous skills

- Final good a CES composite of 2 types of intermediate goods
  - One produced by unskilled workers, and the other by skilled workers combined with automation equipment (robots)
- Unskilled workers face search frictions, skilled workers face spot labor market
- Firms create vacancies at a fixed cost (unlike textbook DMP model with free entry)
- Firms can automate unfilled vacancies at a fixed cost
  - Adopt robot if fixed cost below benefit: automation prob endogenous

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Model implications

- Job uncertainty raises unemployment in models with labor market frictions (Leduc-Liu, 2016)
- Job uncertainty creates two opposing effects on automation (new)
  1. Uncertainty reduces NPV of robots (option-value channel): automation $\downarrow$
  2. Job uncertainty boosts incentive to substitute robots for workers (technology shifting): automation $\uparrow$
- Under calibrated parameters, job uncertainty reduces automation initially and then raises it persistently
  - Increases in automation boost labor productivity and skilled wages but reduce unskilled wages
  - Through automation channel, job uncertainty increases income inequality (skill premium) and reduces labor share

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Representative household

- Two types of members: skilled (inelastically supplied in spot market) and unskilled (face search frictions)
- Family utility function

$$\mathbb{E}\sum_{t=0}^{\infty}\beta^t\Theta_t\left(\ln C_t-\chi N_t\right)$$

- Budget constraint

$$C_t+\frac{B_t}{r_t}=B_{t-1}+w_{nt}N_t+w_{st}\bar{s}+\phi(1-N_t)+d_t-T_t$$

- Employment surplus (for unskilled)

$$S_t^H=w_{nt}-\phi-\frac{\chi}{\Lambda_t}+\mathbb{E}_tD_{t,t+1}(1-q_{t+1}^u)(1-\delta_{t+1})S_{t+1}^H$$

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Labor market for unskilled workers

- Job seekers

$$u_t = 1 - (1 - \delta_t)N_{t-1}$$

where δ_t denotes job separation rate and N_{t-1} is beginning-of-period employment

- Vacancies

$$v_t = (1 - q^v_{t-1})(1 - q^a_t)v_{t-1} + \delta_t N_{t-1} + \eta_t$$

where q^v_t denotes job filling rate, q^a_t denotes automation probability, and η_t denotes newly created vacancies

  - Vacancy is a slow-moving state variable, different from standard DMP

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Labor market for unskilled workers

- Matching technology

$$m_t = \mu u_t^{\alpha} v_t^{1-\alpha}$$

- Employment dynamics

$$N_t = (1-\delta_t)N_{t-1} + m_t$$

- End-of-period unemployment rate

$$U_t = u_t - m_t = 1 - N_t$$

- Job filling and finding rates

$$q_t^v = \frac{m_t}{v_t}, \quad q_t^u = \frac{m_t}{u_t}$$

Intermediate goods producers

- Two intermediate good sectors: one with unskilled workers, the other with skilled workers and robots
  - Production of a firm with one unskilled worker:

$$y_{nt} = Z_t \zeta_{lt}$$

  - Production of a firm with one robot:

$$y_{at} = Z_t \zeta_{at}^{\alpha_a} s_t^{1-\alpha_a}$$

  where s_t denotes input of skilled labor

- Aggregate intermediate goods:

$$Y_{nt} = Z_t \zeta_{lt} N_t, \quad Y_{at} = Z_t \zeta_{at} A_{t-1}$$

- Final consumption good:

$$Y_t = \left[\alpha_n Y_{nt}^{\frac{\sigma-1}{\sigma}} + (1-\alpha_n) Y_{at}^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$$

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Vacancy creation

- Creating a new vacancy incurs an entry cost e drawn from i.i.d. distribution $F(e)$
- Benefit of creating a vacancy is the vacancy value J_t^v
- New vacancy created if net value of entry is non-negative ($e \leq J_t^v$)
- Number of new vacancy being created

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Automation decision

- Adopting robot incurs fixed cost x drawn from i.i.d. distribution $G(x)$
- Value of a robot

$$J_t^a = (1-\rho^o)\mathbb{E}_t \beta \theta_{t+1} \frac{\Lambda_{t+1}}{\Lambda_t} \left[\alpha_a p_{a,t+1} \frac{Y_{a,t+1}}{A_t} - \kappa_a + J_{t+1}^a \right]$$

where κ_a is flow cost of operating robots and $D_{t,t+1}$ is SDF

- Automate iff $x \leq x_t^* \equiv J_t^a - J_t^v \Rightarrow$ prob of automating

$$q_t^a = G(x_t^*)$$

- Stock of robots/automatons (A_t)

$$A_t = (1-\rho^o)A_{t-1} + q_t^a(1-q_{t-1}^v)v_{t-1}$$

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Values of an open vacancy and a filled position

- Value of an open vacancy (J_t^v)

$$J_t^v = -\kappa + q_t^v J_t^e + (1 - q_t^v)\mathbb{E}_t D_{t,t+1}\left[q_{t+1}^a J_{t+1}^a + (1 - q_{t+1}^a) J_{t+1}^v\right]$$

where κ is vacancy posting cost

- Value of a filled position (J_t^e)

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Wage determination

- Unskilled wages are determined by Nash bargaining

$$\max_{w_{nt}} \quad \left(S_t^H\right)^b (J_t^e - J_t^v)^{1-b}$$

- Steady state wage

$$w_n^N = \phi + \frac{\chi}{\Lambda} + \frac{b}{1-b}[1-\beta(1-q^u)(1-\delta)](J^e - J^v)$$

  - Wage increases with both worker reservation value $\phi + \frac{\chi}{\Lambda}$ and worker bargaining weight b
  - Wage decreases with firm reservation value $J^v \rightarrow$ threat of automation (q^a) raises J^v and thus lowers wage (Leduc-Liu, 2019)
- Skilled wage determined in competitive labor market

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Government policy and market clearing

- Government policy

$$\phi(1 - N_t) = T_t$$

- Bond market clearing

$$B_t = 0$$

- Skilled labor market clear

$$\bar{s} = s_t A_{t-1}$$

- Final goods market clearing

$$C_t + \kappa v_t + \kappa_a A_{t-1} + (1 - q^v_{t-1}) v_{t-1} \int_0^{x_t^*} x dG(x) + \int_0^{J_t^v} e dF(e) = Y_t$$

Steady state and calibration

- Steady-state targets:
  - Average unemployment rate from 1985-2018: $U = 0.06$
  - Quarterly average job separation rate (JOLTS): $\bar{\delta} = 0.1$
  - Quarterly job filling rate (den Haan et al, 2000): $q^v = 0.71$
  - Vacancy posting costs (Leduc-Liu, 2019): $\kappa v = 0.01Y$
  - Skill premium: $w_s/w_n = 1.54$, ratio of median earnings of bachelor's or higher to those with some college
  - Steady state share of jobs performed by robots and skilled workers: $p_a Y_a/Y = 0.19$ (Nedelkoska and Quintini, 2018)
- Vacancy creation and robot adoption cost distributions

$$F(e) = \left(\frac{e}{\bar{e}}\right)^{\eta_v} \quad G(x) = \left(\frac{x}{\bar{x}}\right)^{\eta_a}$$

  - Focus on uniform distribution: $\eta_v = \eta_a = 1$ (Leduc-Liu, 2019)

Calibrated parameters

	Parameter Description	value
β	Subjective discount factor	0.99
ϕ	Unemployment benefit	0.25
α	Elasticity of matching function	0.50
b	Nash bargaining weight	0.50
ρ^o	Automation obsolescence rate	0.03
κ_a	Flow cost of automated production	0.98
$\bar{\delta}$	Job separation rate	0.10
μ	Matching efficiency	0.66
κ	Vacancy posting cost	0.03
χ	Disutility of working	0.73
$\bar{e}$	Scale of vacancy creation cost	8.39
$\bar{x}$	Scale of robot adoption cost	1.86
α_n	Share of intermediate goods produced by unskilled workers	0.5
σ	Substitution elasticity between intermediate goods	3
α_a	Share of robots in skilled worker sector	0.3

Job uncertainty shocks

- Focus on labor-specific productivity shock ζ_{lt}
- First-moment shock:

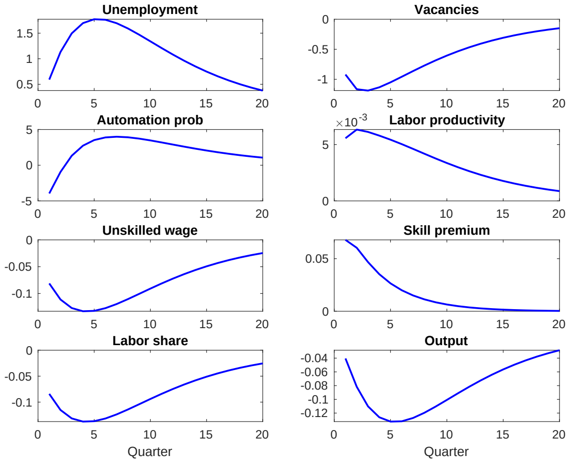
$$\ln(\zeta_{lt}) = 0.95 \ln(\zeta_{l,t-1}) + \exp(\sigma_{\zeta t}/2)\varepsilon_{\zeta t}$$

  where $\varepsilon_{\zeta t} \sim N(0,1)$
- Second-moment shock (uncertainty):

$$\sigma_{\zeta t} = (1 - 0.76)0.01 + 0.76\sigma_{\zeta,t-1} + 0.39\varepsilon_{\sigma t}$$

  where $\varepsilon_{\sigma t} \sim N(0,1)$ and independent of $\varepsilon_{\zeta t}$
- Second-moment shock processes calibrated based on VAR in Leduc and Liu (2016)

IRFs following a job uncertainty shock



Macro and distributional effects of job uncertainty shock

- Uncertainty reduces NPV of employment and vacancies, raising U and reducing v: recessionary
- Job uncertainty produces opposing effects on automation
  1. Recessionary effect discourages automation (J^a falls)
  2. Technology substitution effect: opportunity cost of automation (J^v) declines $\rightarrow$ boosts automation incentive
- Under calibrated parameters, uncertainty initially reduces automation and then raises it persistently, boosting labor productivity
- Increased threat of automation depresses unskilled wages and raises skill premium: increasing inequality
- Aggregate labor share declines despite higher skilled wage income

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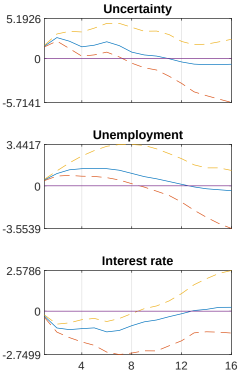
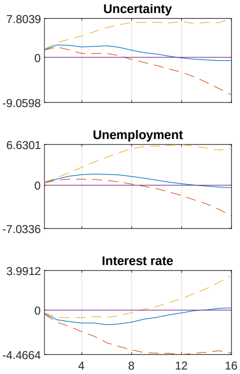
VAR evidence: uncertainty boosts computer investment



VAR evidence: uncertainty lowers labor share



Conclusion

- Pandemic-induced job uncertainty reduces employment but may stimulate automation
- By stimulating automation, job uncertainty reduces employment and wages of unskilled workers
- Through the automation channel, job uncertainty increases labor productivity and skill premium while lowering labor share
- Model predictions broadly in line with VAR evidence