Immigration in the Age of Automation

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July 6, 2026

Outline of the Talk

1. Introduction
2. Model
3. Calibration
4. Results
5. Mechanism
6. Sensitivity Analysis
7. Welfare Analysis
8. Conclusion

Research Question

How does the **skill composition of immigration** interact with **endogenous automation** to shape:

- Output
- Labor market
- Wage inequality
- Welfare

Key idea: Immigration changes firms' incentives to automate.

Why This Question Matters

Two major structural trends

- Rising immigration
- Rapid adoption of automation

Usually studied separately.

Research Gap

The macroeconomic consequences of immigration may depend critically on its interaction with automation.

Contribution

1. Distinguish between **HS and LS immigration**, along with **endogenous automation capital** in a DSGE model.
2. Show **automation drives asymmetric effects** of HS and LS immigration on output per capita.
3. **Quantify** aggregate and distributional effects.

Findings

HS immigration

- Larger aggregate output gains
- Encourages automation
- **Raises** output per capita
- Compresses the skill premium

LS immigration

- Smaller aggregate output gains
- Discourages automation
- **Lowers** output per capita
- Widens the skill premium

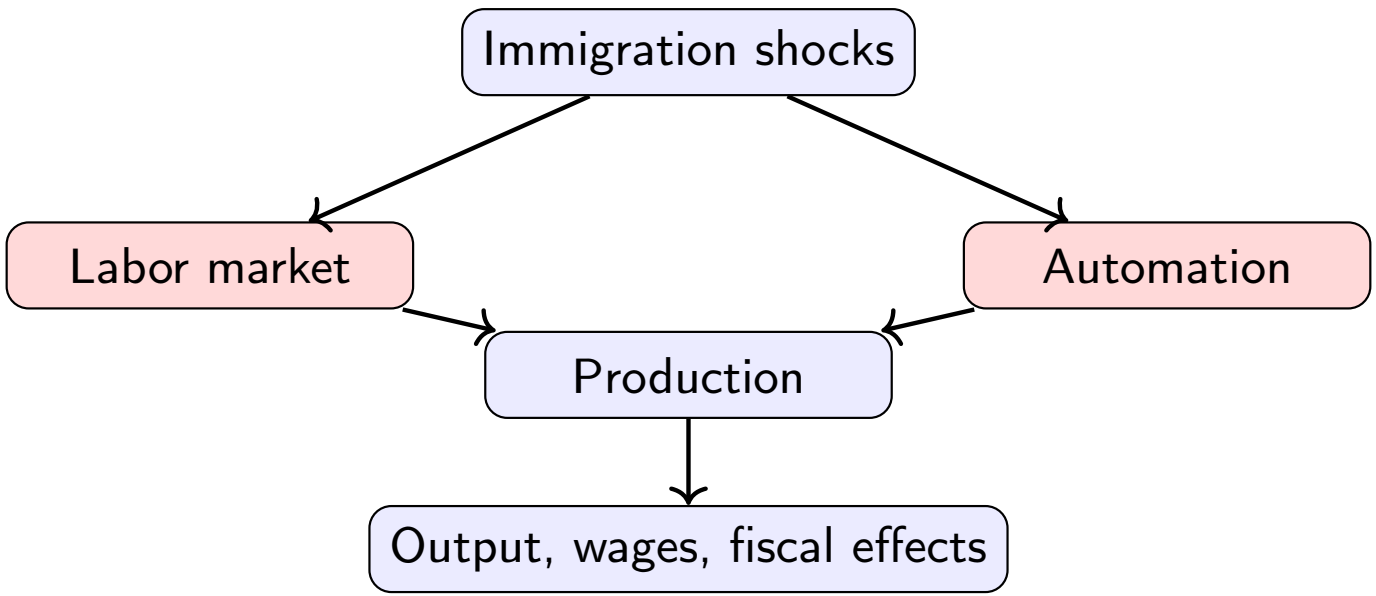
Automation is the key transmission mechanism.

Model Overview

Environment

DSGE model with:

- 4 worker types: native/immigrant $\times$ high-/low-skilled
- search-and-matching frictions
- traditional & automation capital
- labor taxes & unemployment benefits



Worker Types and Immigration

Worker heterogeneity

Workers differ by nativity and skill:

$$n \in \{N, I\}, \qquad s \in \{H, L\}$$

Four worker types:

$$N_t^{N,H}, \quad N_t^{I,H}, \quad N_t^{N,L}, \quad N_t^{I,L}$$

Immigration shocks

Immigrant populations evolve as:

$$N_t^{I,s} = \rho^{imm} N_{t-1}^{I,s} + \varepsilon_t^{I,s}, \qquad s \in \{H, L\}$$

Set $\rho^{imm} \approx 1$: no return migration

Representative Household Assumption

Simplification

- Perfect insurance against idiosyncratic labor-market risk

Why Appropriate Here?

- Focus on **production side:** (immigration & automat adoption)
- **Worker heterogeneity is preserved**: $(n, s) \in \{N, I\} \times \{H, L\}$ with different wages, unempl risks, and exposure to automation.

Distributional Analysis

- Capital ownership heterogeneity is introduced *ex-post* using **SOEP ownership shares**.
- Welfare decomposition captures both labor-market and capital-ownership effects.

Representative Household

Preferences

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \frac{C_t^{1-\gamma}}{1-\gamma}$$

Capital accumulation

The household owns traditional and automation capital:

$$K_t^T = (1-\delta_T)K_{t-1}^T + I_t^T + AC_t^T$$

$$K_t^A = (1-\delta_A)K_{t-1}^A + I_t^A + AC_t^A$$

Production Technology

Production process

Combines capital, HS labor and LS labor–automation composite

$$Y_t = A_t (K_{t-1}^T)^{b_1} (E_t^H)^{b_2} (X_t)^{b_3}, \qquad b_1 + b_2 + b_3 = 1 \quad (CRS)$$

Labor Aggregation

Native–immigrant labor aggregation

For each skill group $s \in \{H, L\}$:

$$E_t^s = \left[a_s (E_t^{N,s})^{\frac{\gamma^s - 1}{\gamma^s}} + (1 - a_s)(E_t^{I,s})^{\frac{\gamma^s - 1}{\gamma^s}} \right]^{\frac{\gamma^s}{\gamma^s - 1}}$$

- a_s: native productivity advantage
- γ^s: natives-immigrants elasticity of substitution
  - higher γ^s implies greater substitutability
  - assume **imperfect substitutes**

Automation–Labor Composite

Low-skilled labor and automation

$$X_t = \left[a(E_t^L)^{\frac{\sigma-1}{\sigma}} + (1-a)(K_{t-1}^A)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$$

- $\sigma > 1$: **substitutes** (Acemoglu and Restrepo, 2020)
- $\uparrow$ LS labor $\Rightarrow \downarrow$ incentive to automate

Frictional Labor Market

Employment and unemployment

$$N_t^{n,s} = E_t^{n,s} + U_t^{n,s}, \qquad n \in \{N, I\},\ s \in \{H, L\}$$

Matching technology

Firms post vacancies in skill-specific labor markets:

$$M_t^s = \mu^s (S_t^s)^{\alpha^s} (v_t^s)^{1-\alpha^s}, \qquad s \in \{H, L\}$$

Allocation of Matches

Searchers and matches

- Natives and immigrants compete within each skill market s.
- Matches are allocated according to their shares in searchers S_t^s:

$$\phi_t^s = \frac{S_t^{N,s}}{S_t^s}, \qquad M_t^{N,s} = \phi_t^s M_t^s, \qquad M_t^{I,s} = (1 - \phi_t^s) M_t^s.$$

- Endogenous ϕ_t^s: empl dynamics differ across groups due to
  1. immigration shocks
  2. asymmetric S&M frictions

Hiring Probabilities

Job-finding probabilities

For each type, the hiring prob is given by:

$$p_t^{n,s} = \frac{M_t^{n,s}}{S_t^{n,s}}, \qquad n \in \{N, I\}, \qquad s \in \{H, L\}$$

Depends on composition of searchers' pool, which evolves over time.

Employment Dynamics and Immigration

Employment law of motion

$$E_t^{n,s} = (1 - s^{n,s})E_{t-1}^{n,s} + M_t^{n,s}$$

Instantaneous hiring: new immigrants may be matched immediately

Searchers

Searchers include unemployed, newly separated, and new immigrants:

$$S_t^{n,s} = N_t^{n,s} - (1 - s^{n,s})E_t^{n,s}$$

An immigration shock increases $N_t^{n,s}$ and so $S_t^{n,s}$.

Government

Tax revenue

$$TR_t = \tau_H \left(w_t^{N,H} E_t^{N,H} + w_t^{I,H} E_t^{I,H} \right) + \tau_L \left(w_t^{N,L} E_t^{N,L} + w_t^{I,L} E_t^{I,L} \right)$$

Unemployment benefits

Using average wage (natives & immigrants) within skill s:

$$B_t = \rho_b^H \bar{w}_t^H (U_t^{N,H} + U_t^{I,H}) + \rho_b^L \bar{w}_t^L (U_t^{N,L} + U_t^{I,L})$$

Fiscal balance

$$T_t = TR_t - B_t$$

Equilibrium

Competitive equilibrium

Given initial conditions and shocks, equilibrium consists of:

- household choices: C_t, I_t^T, I_t^A, K_t^T, K_t^A
- firm choices: factor inputs & vacancies
- labor-market outcomes: $E_t^{n,s}$, $U_t^{n,s}$, $M_t^{n,s}$
- prices: $w_t^{n,s}$, R_t^T, R_t^A
- government policy: taxes, benefits, transfers

Goods-market clearing

$$C_t + I_t^T + I_t^A + AC_t^T + AC_t^A = Y_t$$

Calibration: German Data

Why Germany? Worldwide:

- 2nd-largest destination for immigrants
- 3rd-highest adoption of industrial robots

Data Sources

- **German Socio-Economic Panel (SOEP)**
  - Worker characteristics
  - Employment and unemployment
  - Wages
  - Native/immigrant status
- **EU KLEMS**
  - Factor income shares
  - Capital and investment
- **Destatis microcensus**
  - Population shares by skill and nativity

Calibration year: 2019 (pre-COVID, post-2015 refugee wave)

Calibration: Key Parameters

Standard

- $\beta = 0.96$
- $\delta_T = 0.08$
- $\delta_A = 0.10$
- $\phi_T = \phi_A = 3$
- $\rho_A = 0.9$

Production

- $b_1 = 0.30$
- $b_2 = 0.25$
- $b_3 = 0.45$
- $\sigma = 2$

Labor Market

- Matching elasticity: $\alpha = 0.5$
- Bargaining: $\varphi = 0.6$
- Matching efficiencies & separation rates match SOEP employment & unemployment rates

Fiscal Block

- Labor taxes: 30% (HS), 25% (LS)
- Replacement rates: 60% (HS), 50% (LS)
- Earnings-related unemployment benefits

Calibration Targets and Model Fit

Parameters calibrated to match

- Employment rates
- Unemployment rates
- Native–immigrant wage gaps
- Skill premia

Model fit

- Matches 8 out of 12 moments within 2 pp
- Slightly understates unemployment rates (typical in DMP)

Model reproduces the key labor-market and wage moments used in the quantitative analysis.

Calibration: Model Fit

Moment	Data	Model
Employment Rates		
Native HS	98.2%	99.3%
Immigrant HS	90.6%	92.5%
Native LS	92.6%	95.8%
Immigrant LS	82.6%	84.2%
Wage Gaps (log points)		
Native premium (HS)	0.227	0.228
Native premium (LS)	0.155	0.232
Skill premium (natives)	0.544	0.469
Skill premium (immigrants)	0.472	0.474
Unemployment Rates		
Native HS	1.8%	0.7%
Immigrant HS	9.4%	7.6%
Native LS	7.4%	4.2%
Immigrant LS	17.4%	15.8%

Quantitative Exercise: HS vs LS Immigration

Compare two shocks:

- 1% increase in HS immigrants
- 1% increase in LS immigrants

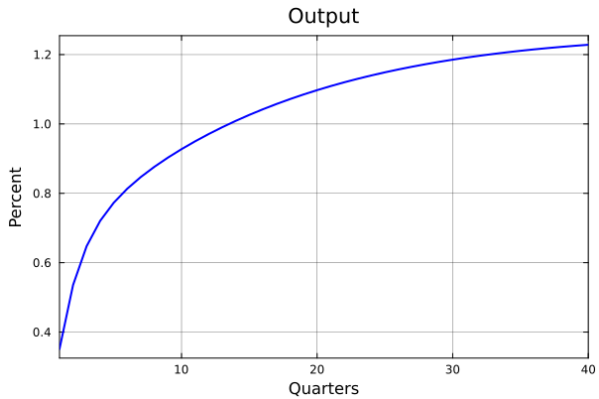
Question:

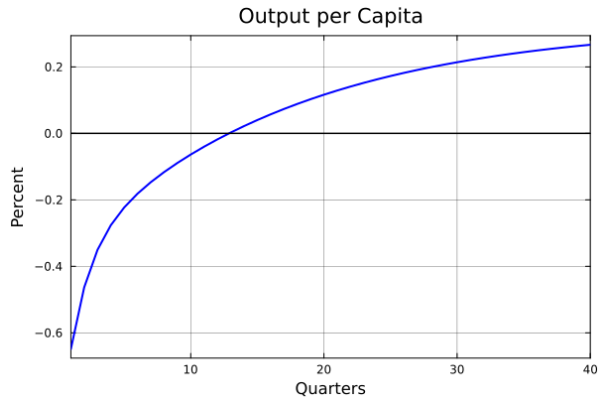
How does the skill composition of immigration affect **output**, **automation**, **income distribution**?

Aggregate vs Per Capita Output Effects

HS immigration

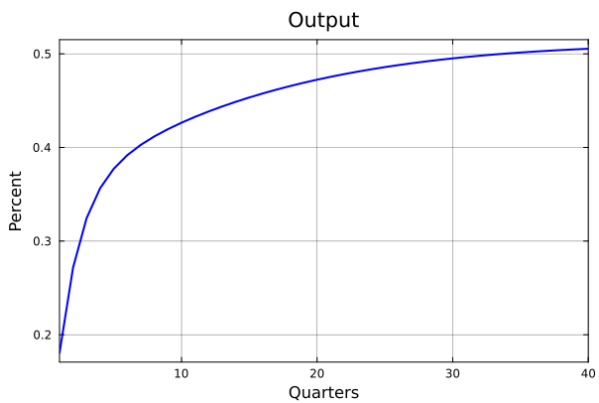
Aggregate output increases by **1.2%**. Output pc eventually **increases**.

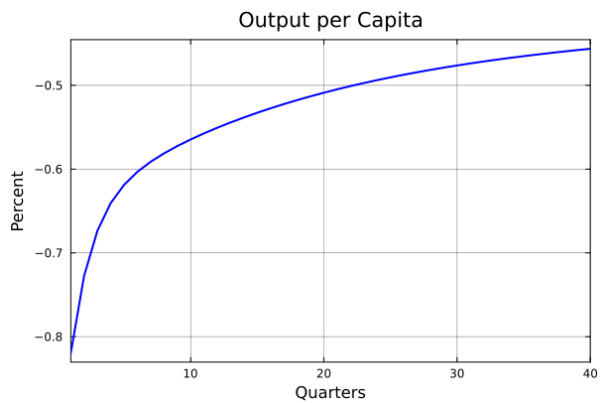




LS immigration

Aggregate output increases by **0.5%**. Output pc persistently **declines**.

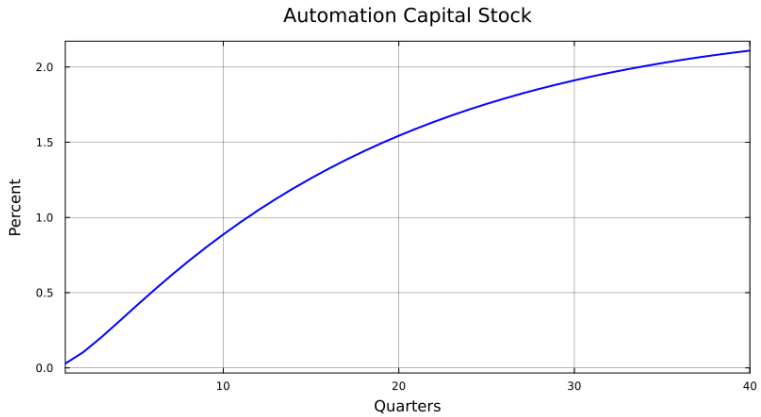


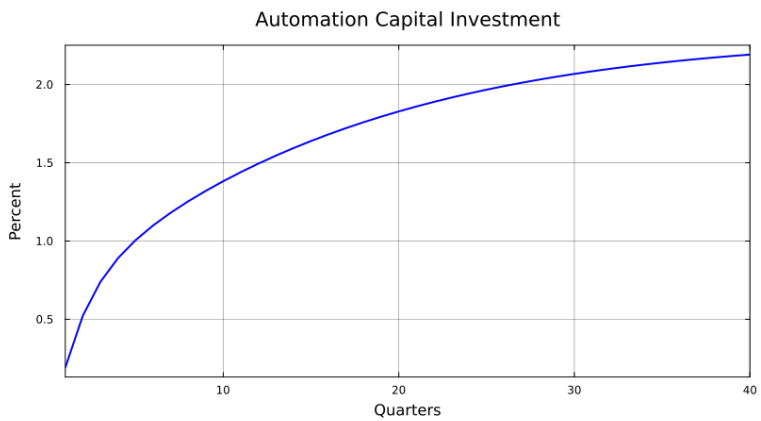


Automation Responds Asymmetrically

HS immigration

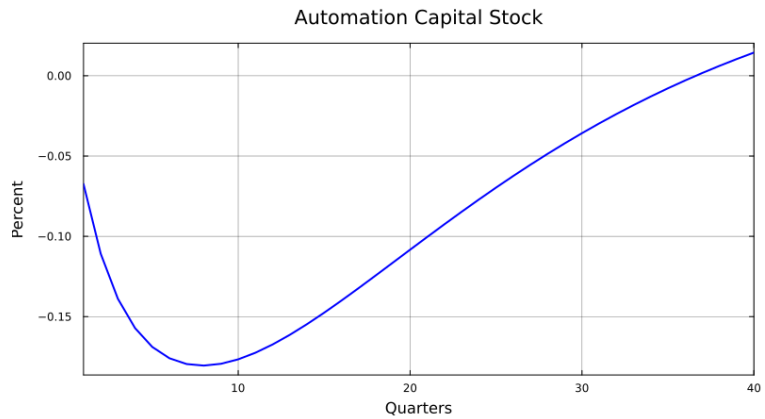
Stimulates autom investment

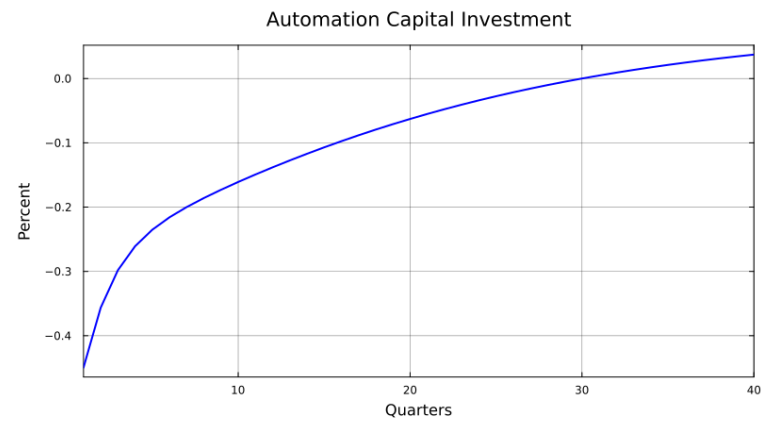




LS immigration

Discourages autom investment





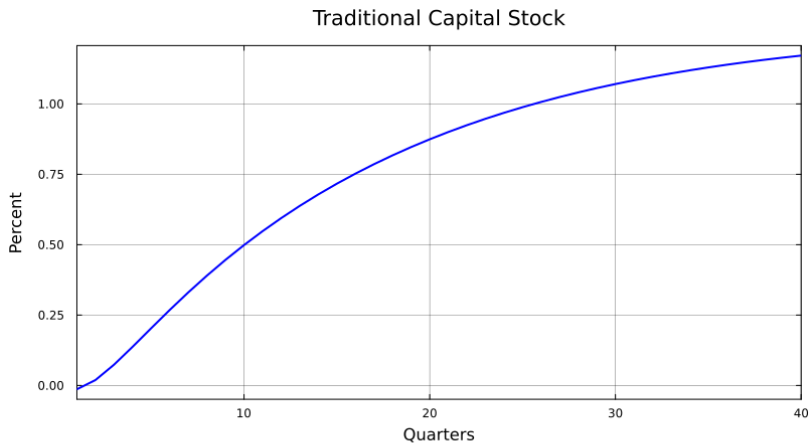
Key mechanism

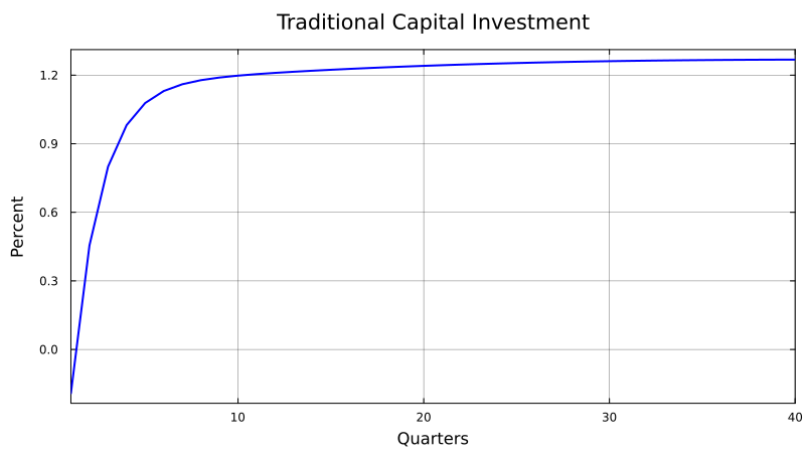
HS labor complements automation, LS labor substitutes for it.

Traditional Capital Responses: Symmetric

HS immigration

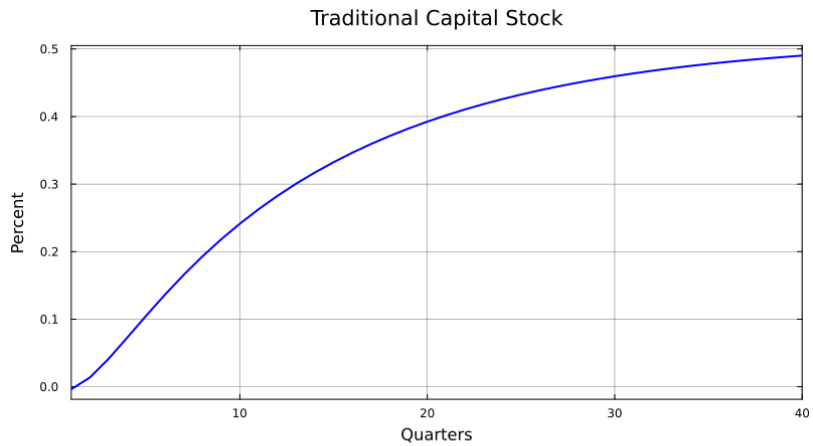
Stimulates traditional investment

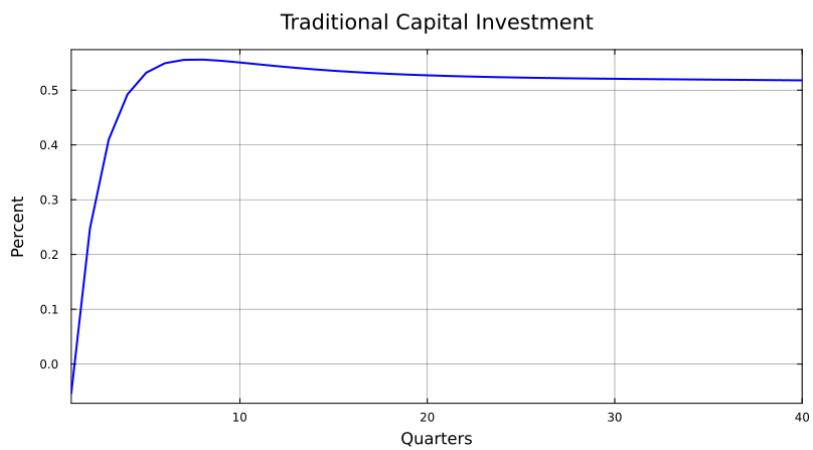




LS immigration

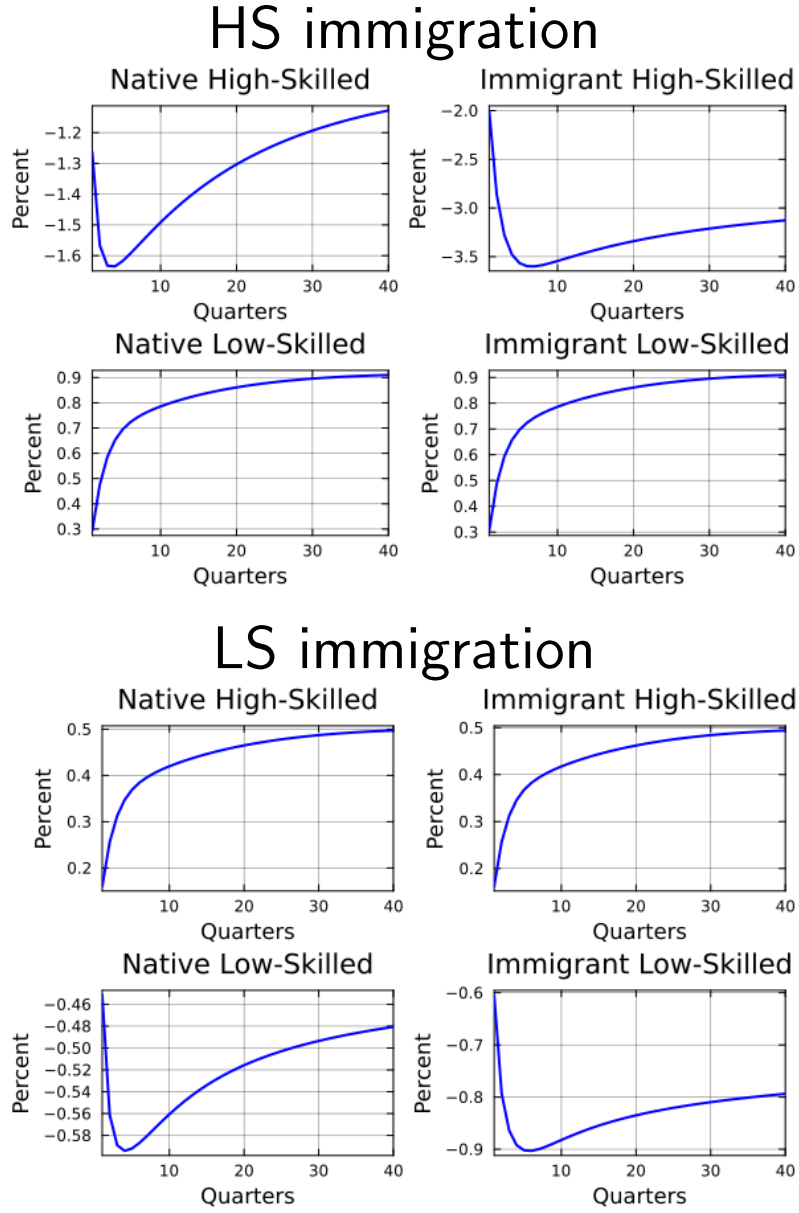
Stimulates traditional investment





Labor-Market Responses

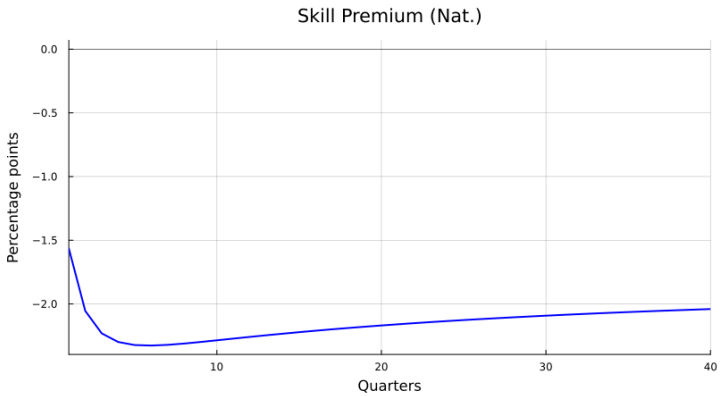
- Within-skill competition lowers wages for group receiving immigrants.
- Cross-skill complementarities increase wages of other skill group.
- Unemployment responses confirm job-competition effect on immigrants, job-creation effect on natives
- see also SVAR evidence for Germany (Maffei-Faccioli and Vella, 2021)

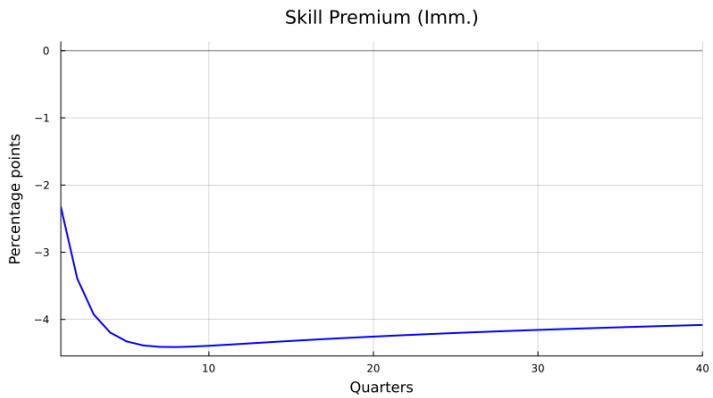


Skill Premium Responds Asymmetrically

HS immigration

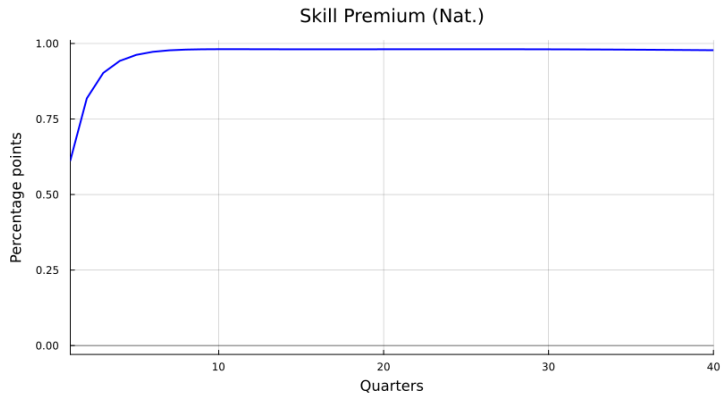
Compresses the skill premium

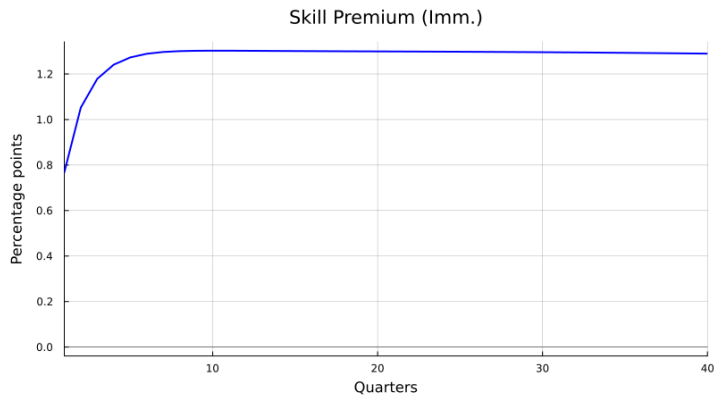




LS immigration

Widens the skill premium





Takeaways

1. HS immigration: larger output gains, lower wage inequality

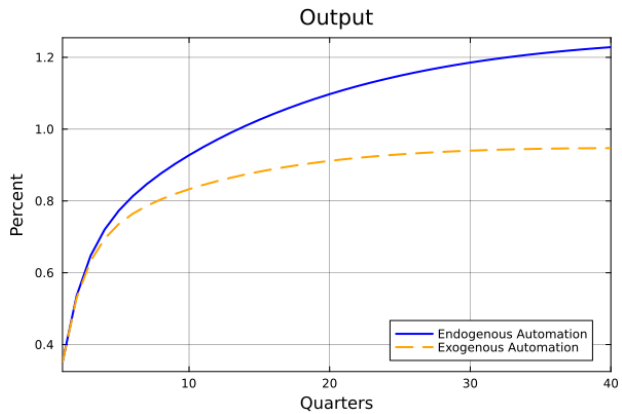
2. Automation responds asymmetrically to HS, LS immigration

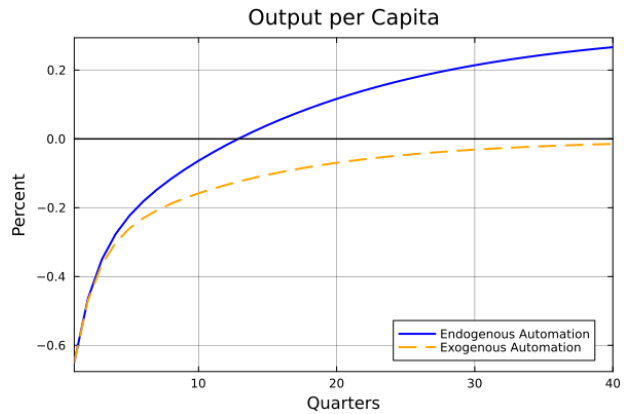
3. Next: inspect the mechanism by comparing
   - **Baseline**: Automation adjusts endogenously
   - **Counterfactual:** automation capital is held fixed

Role of Endogenous Automation: Output

HS immigration

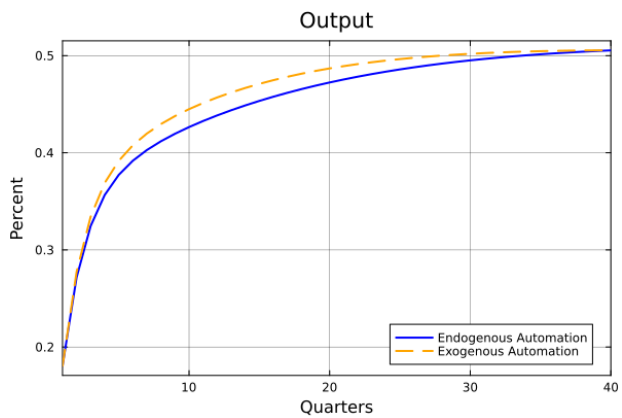
Automation amplifies output gains, **turning positive** the pc effect.

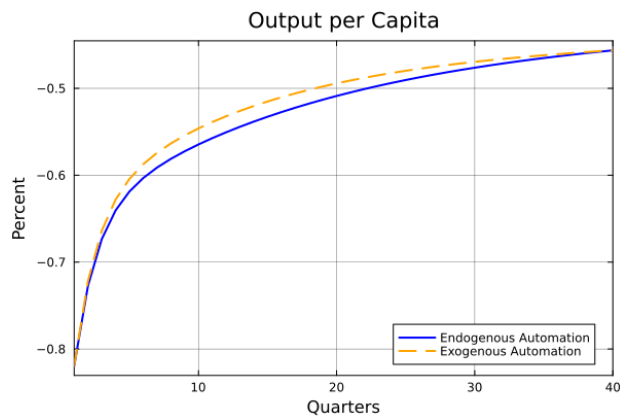




LS immigration

Automation dampens output gains, pc effect remains negative.

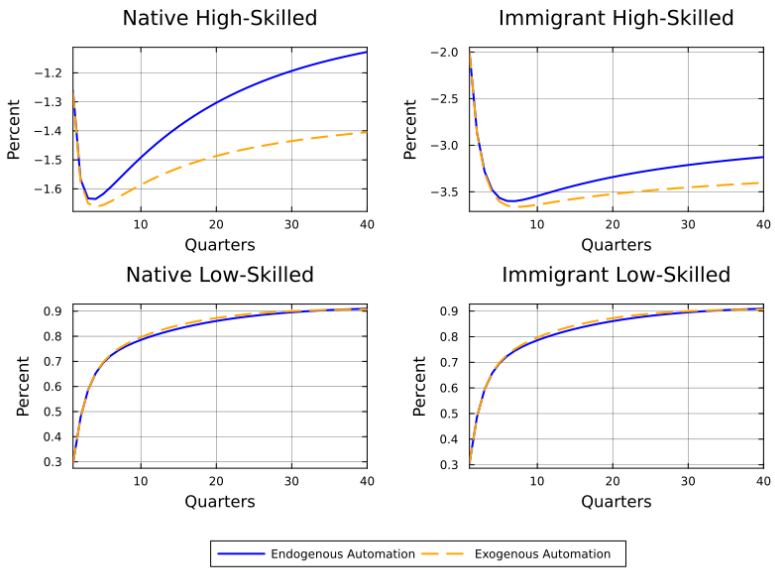




Role of Endogenous Automation: Wages

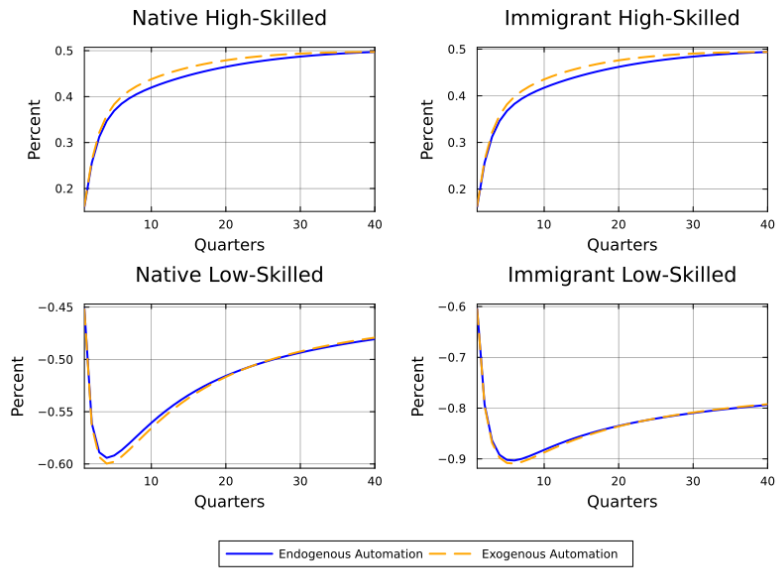
HS immigration

- Automation cushions wage losses.
- Firms adjust the production mix.



LS immigration

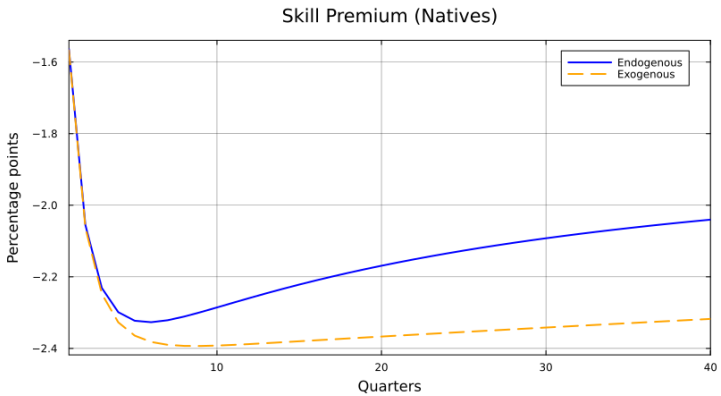
- Automation hardly affects wage losses.
- Limited role in shaping wage dynamics.

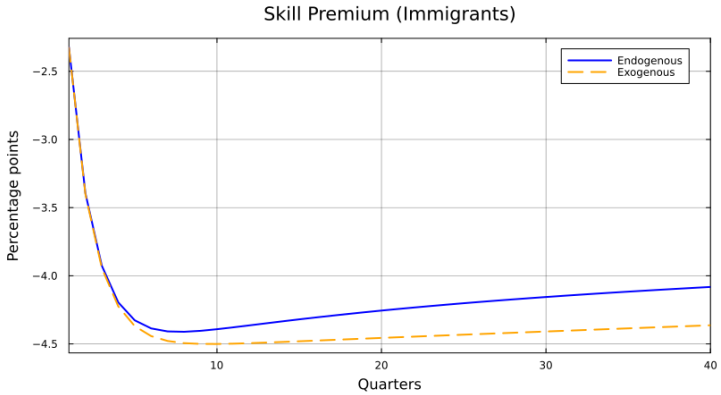


Role of Endogenous Automation: Skill Premium

HS immigration

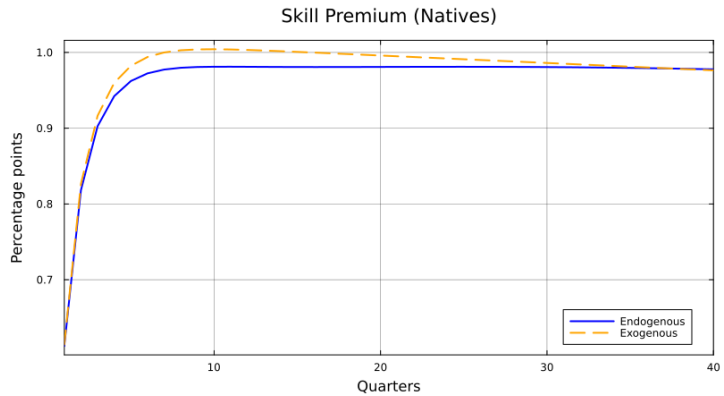
Automation attenuates decline in skill premium.

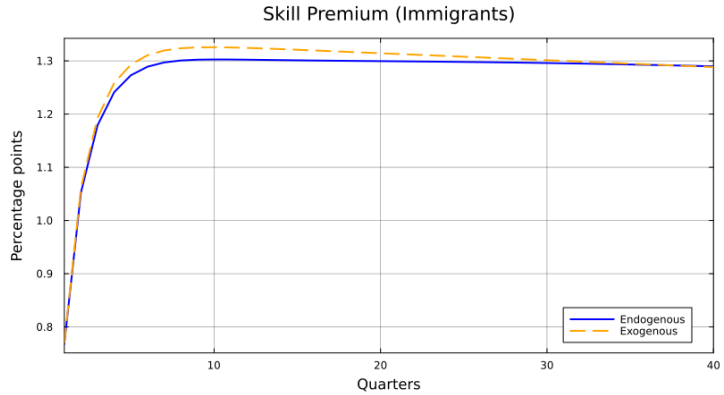




LS immigration

Automation moderates increase in skill premium.





Sensitivity Analysis

Robustness checks

Vary key production- and labor-market parameters:

$\sigma \in [1.1, 5.0], \qquad a \in [0.5, 0.9], \qquad \gamma_H \in \{3, 5, 8\}, \quad \gamma_L \in \{8, 15, 25\}$

- Automation-LS labor substitution
- LS labor share
- Native–immigrant substitution

Result

The key findings are robust.

Welfare Analysis

Approach

- Representative household
- Distributional effects recovered *ex post*
- Steady-state consumption equivalents
- Capital income allocated using SOEP ownership shares
- Welfare computed separately for the 4 groups
- Welfare decomposition captures both labor-market and capital-ownership effects.

Capital ownership is the key determinant of welfare gains from immigration.

Welfare Effects

	HS Imm.	LS Imm.
Native HS	+1.23	+1.22
Native LS	+1.50	+0.10
Immigrant HS	-2.67	+1.12
Immigrant LS	+0.75	-1.88
Aggregate	**+1.16**	**+0.30**

- Aggregate welfare increases more for HS imm
- Immigrants suffer welfare losses (job competition)

Why Do Welfare Effects Differ?

Labor-market channel

- Within-skill competition
- Cross-skill complementarity

Capital-income channel

- Native HS own most capital
- Capture automation gains
- Protected from wage competition

$$\text{Welfare} = \text{Labor Income} + \text{Capital Income}$$

Automation amplifies the importance of capital ownership.

Summary

HS immigration

- Larger output gains
- Accelerates automation adoption
- Compresses wage inequality
- Raises wealth inequality through capital gains

LS immigration

- Smaller aggregate gains
- Reduces incentives to automate
- Increases wage inequality
- Capital owners remain main beneficiaries

Conclusion

- We provide a framework for analyzing immigration-automation interactions and their implications for growth and inequality.
- These feedback effects fundamentally alter immigration's economic impact.
- The asymmetric automation response explains the contrasting effects on output per capita of HS and LS immigration.
- Capital ownership—not labor-market position alone—is central to who benefits.
- Policy implication: Not independent domains. Design policies that harness combined potential while ensuring shared prosperity.