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OPTIMAL GRADUALISM

IS GRADUALISM DESIRABLE?

- **Technology, trade, and reforms** are desirable in the long run…
- But workers who fail to adjust might experience income declines in short run.

Question 1: Does society benefit from more gradual tech advances?

Question 2: Should gradualism be encouraged via temporary taxes?

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Yes. Less adverse distributional effects.

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Yes. Positive optimal tax in short run and zero tax in long run.

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Yes. Less adverse distributional effects.

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Yes. Positive optimal tax in short run and zero tax in long run.

…so long as temporary assistance programs "imperfect"

THIS PAPER

- **Theory:** model of adjustment to technological disruptions / reforms
  - formulas for optimal taxes (positive in short run, zero in long run)
  - formulas for gains from more gradual technological advances
- **Applications:** quantitative evaluation of formulas
  - **routine jobs automation** (Cortes, 2016) and **china shock** (Autor et al. 2014)
  - calibrate model to match large income decline for exposed workers
  - optimal policy calls for temporary taxes of 10%, phased out over time
  - **Colombia's 1990 trade liberalization**: optimal reform more gradual

A MODEL OF TECHNOLOGICAL DISRUPTIONS

- Mass 1 of workers with ℓ_x allocated to island $x \in \mathscr{X}$ (jobs, products, occupation)
- Final good produced from $y = f(\{\ell_x\}_{x \in \mathscr{X}})$ with cost function c^f
- Initial steady state with common wage $\bar{w} = 1$ across islands
- At time $t = 0$, new technology arrives. For $x \in \mathscr{D}$, good x can be replaced by k_x produced (or exchanged) for $1/A_{x,t}$ units of final good
- Government sets tax $\tau_{x,t}$ on new technology and does lump-sum rebate T_t
- Workers in $x \in \mathscr{D}$ reallocate at Poisson rate α_x to highest paying islands

A MODEL OF TECHNOLOGICAL DISRUPTIONS

Final good	$y_t = f(\{y_{x,t}\}_{x \in \mathscr{A}})$
Disrupted islands	$y_{x,t} = \ell_{x,t} + k_{x,t}$ if $x \in \mathscr{D}$
Other islands	$y_{x,t} = \ell_{x,t}$ if $x \notin \mathscr{D}$
Resource constraint	$y_t = c_t + \sum_{x \in \mathscr{A}} (k_{x,t}/A_{x,t}), \qquad m_{x,t} = k_{x,t}/A_{x,t}$
Reallocation	$\dot{\ell}_{x,t} = -\alpha_x \cdot \ell_{x,t}$ if $x \in \mathscr{D}, \qquad \ell_t = 1 - \sum_{x \in \mathscr{A}} \ell_{x,t} \to_t 1$

A MODEL OF TECHNOLOGICAL DISRUPTIONS

Proposition 1: Assume that $\bar{w} > (1+\tau_{x,t})/A_{x,t}$ so that technology adopted. Under regularity and symmetry conditions on f, equilibrium given by

Wage disrupted islands $w_{x,t} = (1+\tau_{x,t})/A_{x,t}$ if $x \in \mathcal{D}$

Wage at other islands $w_{x,t} = w_t$ if $x \notin \mathcal{D}$

Iso-cost curve $1 = c^f(\{w_{x,t}\}_{x \in \mathcal{A}}, w_t)$

Total output $y_t = \ell_t \cdot 1/c^f_w$

New technology utilization $k_{x,t} = \ell_t \cdot c^f_x / c^f_w - \ell_{x,t}$

OPTIMAL POLICY

- Indirect utility of households from undisrupted islands

$$U_0 = \mathscr{U}\left(\{w_t + T_t\}_{t=0}^{\infty}, a_0\right)$$

- Indirect utility of households from disrupted islands

$$U_{x,0} = \mathscr{U}_x\left(\{w_{x,t} + T_t, w_t + T_t\}_{t=0}^{\infty}, a_{x,0}; \alpha_x\right) - \kappa(\alpha_x)$$

- Assume shock not insured ($a_{x,0} = a_0$) and open economy (r_t fixed)
- Policy objective: maximize welfare function with marginal welfare weights $g = \mathscr{W}'(U_0)$ and $g_x = \mathscr{W}'(U_{x,0})$ for $x \in \mathscr{D}$
- Example: utilitarian benchmark $g = g_x = 1$

VARIATIONAL FORMULA

Lemma 1: Consider a variation in taxes $\tau_{x,t}$ that induces a change in wages $\{dw_t, dw_{x,t}\}$ and capital utilization $dk_{x,t}$. This variation changes tax revenue by

$$dT_t = -\sum_{x \in \mathcal{A}} \ell_{x,t} \cdot dw_{x,t} - \ell_t \cdot dw_t + \sum_x \tau_x \cdot \frac{dk_{x,t}}{A_{x,t}}$$

and, letting $P_{x,t} = e^{-\alpha_x t}$, we can express the change in social welfare as

$$d\mathcal{W} = \int_0^\infty \left[\sum_{x \in \mathcal{A}} \ell_{x,0} \cdot \boxed{g_x} \Big(P_{x,t} \cdot \boxed{\lambda_{x,d,t}} \cdot \left(dw_{x,t} + dT_t\right) + (1 - P_{x,t}) \cdot \boxed{\lambda_{x,r,t}} \cdot \left(dw_t + dT_t\right) \Big) + \ell_0 \cdot g \cdot \boxed{\lambda_t} \cdot (dw_t + dT_t) \right] dt$$

Pareto weights

Marginal utility of consumption at t for households that have not reallocated

Marginal utility of consumption at t for households that already reallocated

Marginal utility of consumption at t for unaffected households

MARGINAL UTILITIES

- Welfare change depends on marginal utilities of consumption λ
- Papers estimate future path of income, not consumption, for affected households
- Map from income to marginal utilities depends on households' behavior:

	Risk of transition time	Risk of transition time shared or insured
No saving nor borrowing outside island		
Saving and borrowing outside island		

MARGINAL UTILITIES

- Welfare change depends on marginal utilities of consumption λ
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- Map from income to marginal utilities depends on households' behavior:

	Risk of transition time	Risk of transition time shared or insured
No saving nor borrowing outside island	$\lambda_{x,d,t} = e^{-\rho t} \cdot u'(w_{x,t} + T_t)$ $\lambda_{x,r,t} = e^{-\rho t} \cdot u'(w_t + T_t)$ $\lambda_t = e^{-\rho t} \cdot u'(w_t + T_t)$	$\lambda_{x,d,t} = e^{-\rho t} \cdot u'(P_{x,t} \cdot (w_{x,t} - w_t) + w_t + T_t)$ $\lambda_{x,r,t} = e^{-\rho t} \cdot u'(P_{x,t} \cdot (w_{x,t} - w_t) + w_t + T_t)$ $\lambda_t = e^{-\rho t} \cdot u'(w_t + T_t)$
Saving and borrowing outside island	Solved numerically: two-state problem in Achdou et al. (2021)	$\lambda_{x,d,t} = e^{-rt} \cdot u'(c_{x,0})$ $\lambda_{x,r,t} = e^{-rt} \cdot u'(c_{x,0})$ $\lambda_t = e^{-rt} \cdot u'(c_0)$

OPTIMAL TAX WITH EXOGENOUS REALLOCATION

Definition: let χ_t be the social value of income at undisrupted islands at t, $\chi_{x,t} \geq \chi_t$ the social value of income in $x \in \mathscr{D}$ at time t, and $\bar{\chi}_t$ their average. In particular:

$$\chi_{xt} = g_x \cdot \lambda_{x,d,t}, \qquad \chi_t = \frac{\ell_0}{\ell_t} \cdot g \cdot \lambda_t + \sum_{x \in \mathscr{D}} (1 - P_{x,t}) \cdot \frac{\ell_{x,0}}{\ell_t} \cdot g_x \cdot \lambda_{x,r,t}$$

Proposition 1: Optimal tax sequence satisfies

$$\tau_{x',t} = \sum_{x \in \mathscr{D}} \frac{\ell_{x,t} \cdot w_{x,t}}{m_{x',t}} \cdot \underbrace{\left(\frac{\chi_{x,t}}{\bar{\chi}_t} - 1\right)}_{>0} \cdot \underbrace{\boxed{\left(-\frac{d \ln w_{x,t}}{d \ln k_{x',t}}\right)}}_{>0} + \frac{\ell_t \cdot w_t}{m_{x',t}} \cdot \underbrace{\left(\frac{\chi_t}{\bar{\chi}_t} - 1\right)}_{<0} \cdot \underbrace{\boxed{\left(-\frac{d \ln w_t}{d \ln k_{x',t}}\right)}}_{<0}$$

Intuition: Reducing $k_{x,t}$ leads to **decline in revenue (LHS)** vs **change in wages (RHS)**

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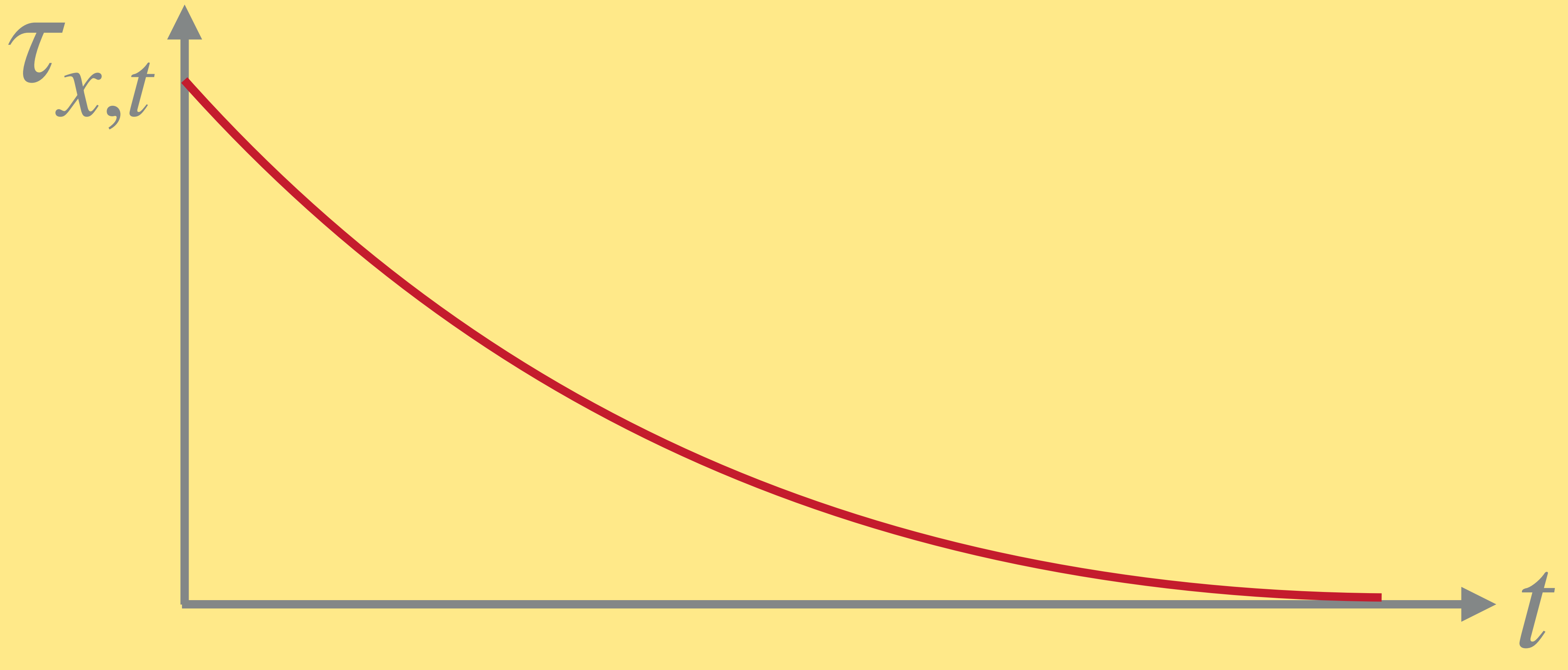
Force towards gradualism: benefits from reducing future use of new tech small; affect income of a small share of workers

Long run: $\ell_{x,t} \to 0$ implies $\tau_{x,t} \to 0$

Optimal tax for immediate shock



OPTIMAL TAX WITH ENDOGENOUS REALLOCATION EFFORT

Proposition 2: Optimal tax sequence satisfies

$$\tau_{x',t} = \sum_{x \in \mathcal{D}} \frac{\ell_{x,t} \cdot w_{x,t}}{m_{x',t}} \cdot \left(\frac{\chi_{x,t}^{end}}{\bar{\chi}_t^{end}} - 1 \right) \cdot \left(-\frac{d \ln w_{x,t}}{d \ln k_{x',t}} \right) + \frac{\ell_t \cdot w_t}{m_{x',t}} \cdot \left(\frac{\chi_t^{end}}{\bar{\chi}_t^{end}} - 1 \right) \cdot \left(-\frac{d \ln w_t}{d \ln k_{x',t}} \right)$$

Social values of income account for the GE effects of **induced reallocation effort**:

$$\chi_{x,t}^{end} = \chi_{x,t} + \boxed{\sum_{x'' \in \mathcal{D}} (\ell_{x'',0}/\ell_{x,t}) \cdot \mu_{x''} \cdot \varepsilon_{x'',x} \cdot \mathcal{U}_{x,\alpha,d,t}}$$

$$\chi_t^{end} = \chi_t + \boxed{\sum_{x,x'' \in \mathcal{D}} (\ell_{x'',0}/\ell_t) \cdot \mu_{x''} \cdot \varepsilon_{x'',x} \cdot \mathcal{U}_{x,\alpha,r,t}}$$

- $\mathcal{U}_{x,\alpha,r,t} > 0$ and $\mathcal{U}_{x,\alpha,d,t} < 0$: adverse incentives from redistribution
- $\varepsilon_{x'',x}$: cross-partial elasticity of change in incentives on reallocation effort $\alpha_{x''}$
- $\mu_{x''} \geq 0$: social value of higher reallocation rate

OPTIMAL TAX WITH ENDOGENOUS REALLOCATION EFFORT

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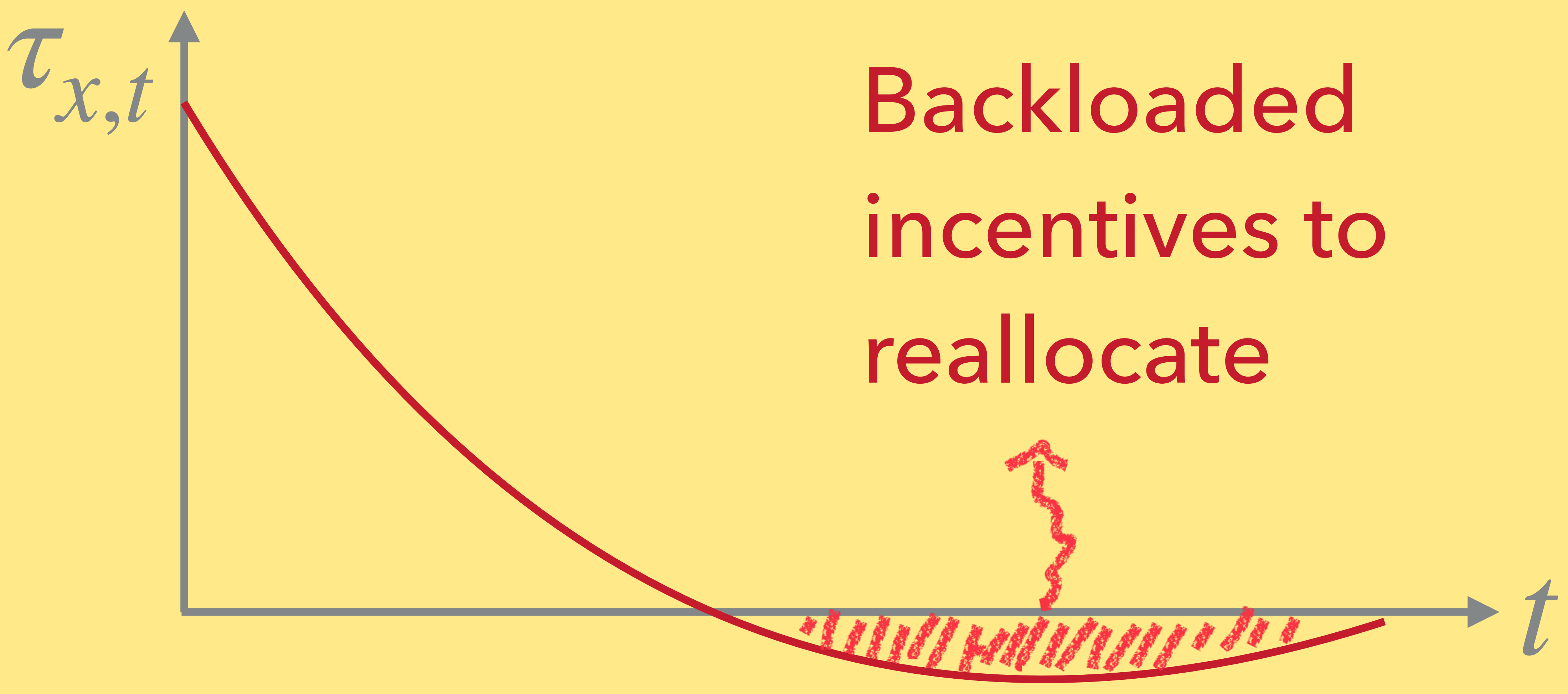
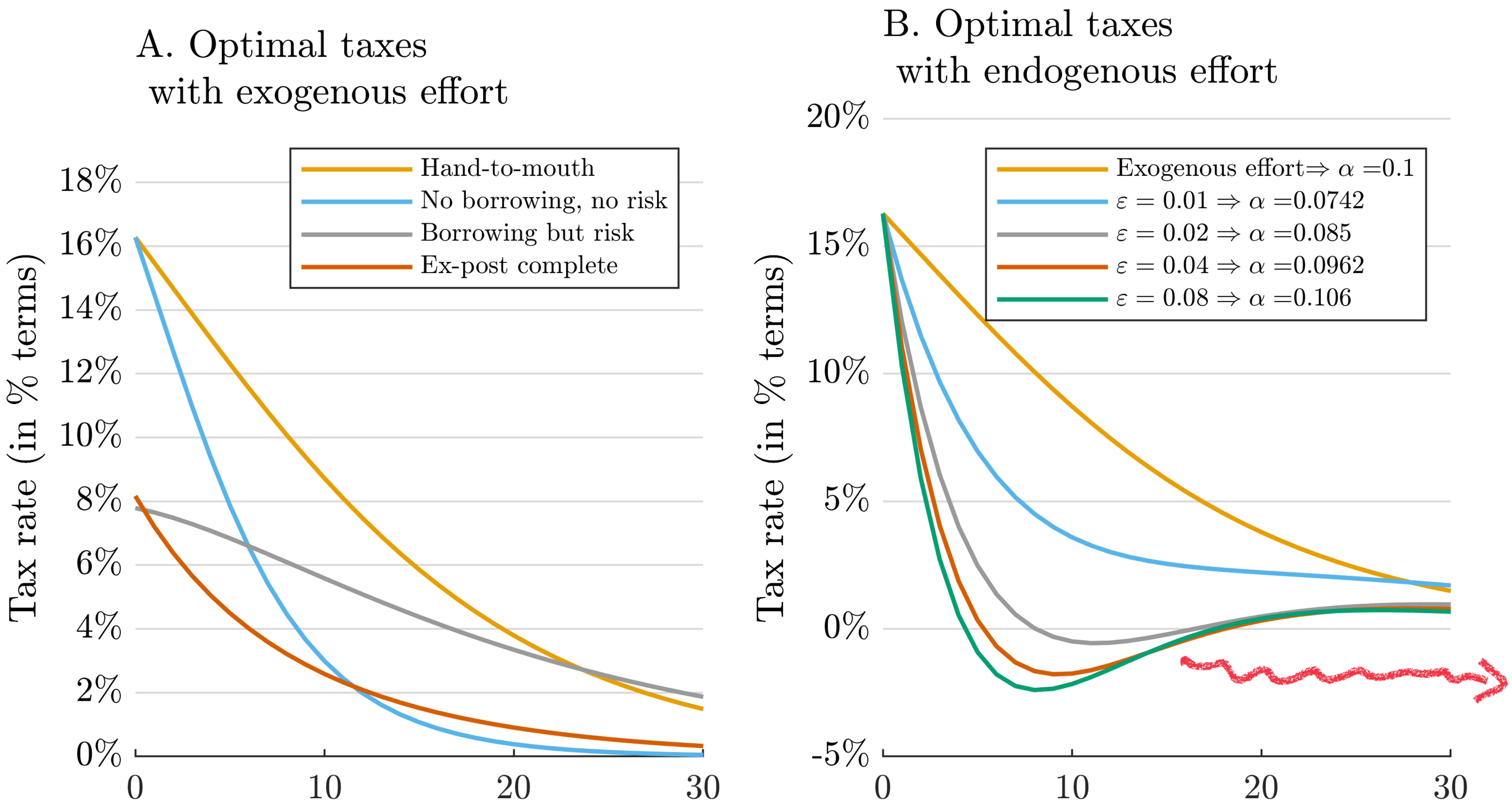
Optimal tax for immediate shock



A NUMERICAL EXAMPLE

Optimal response to 2.5% of jobs disrupted by technology 30% more productive than labor, with $\alpha = 10\,\%$ per year.



Backloaded incentives to reallocate

OPTIMAL TAX WITH OTHER GOVERNMENT TOOLS

- Assistance program with replacement rate $\mathscr{R}_t \in [0,1]$ depending on income
- Endogenous work effort $n_{x,t}$ unobserved and responds with elasticity ε_ℓ
- If $\varepsilon_\ell > 0$, program imperfect substitute to taxing technology (Naito,1999)

Proposition 3: Optimal tax sequence satisfies

$$\tau_{x',t} = (1 - \mathscr{R}_t^*) \cdot \left[\sum_{x \in \mathscr{A}} \frac{\ell_{x,t} \cdot n_{x,t} \cdot w_{x,t}}{m_{x',t}} \cdot \left(\frac{\chi_{x,t}}{\bar{\chi}_t} - 1 \right) \cdot \left(- \frac{d \ln w_{x,t}}{d \ln k_{x',t}} \right) + \frac{\ell_t \cdot n_t \cdot w_t}{m_{x',t}} \cdot \left(\frac{\chi_t}{\bar{\chi}_t} - 1 \right) \cdot \left(- \frac{d \ln w_t}{d \ln k_{x',t}} \right) \right]$$

$$- \mathscr{R}_t^* \cdot \varepsilon_\ell \cdot \frac{d \ln \text{average wage}}{d \ln k_{x',t}}$$

Dampened distributional considerations

Fiscal externality

Note: formula for $\mathscr{R}_t^* \in (0, 1/(1 + \varepsilon_\ell)]$ in paper

GAINS FROM NATURAL GRADUALISM

- Natural gradualism: benefits from slowing down passage of time… Instead of facing technology $\{A_{x,t}\}_{x\in\mathscr{A}}$, face $\{A_{x,(1-\gamma)t}\}_{x\in\mathscr{A}}$ for $\gamma < 0$.

Proposition 4: Suppose there are no taxes on new technologies.

- Starting from $\gamma = 0$, welfare gains from increasing γ are

$$\mathscr{W}_\gamma = \int_0^\infty \left[\sum_{x\in\mathscr{D}} \left(\ell_{x,t} \cdot \chi_{x,t} \cdot w_{x,t} - \ell_t \cdot \chi_t \cdot w_t \cdot \frac{s_{x,t}}{s_t} \right) \cdot \frac{\dot{A}_{x,t}}{A_{x,t}} \cdot t \right] dt$$

- With optimal taxes $\tau_{x,t}$ in place, no gains from natural gradualism.

Note: here, $s_{x,t}$ denotes the share of good x in GDP; and $s_t = 1 - \sum_{x\in\mathscr{D}} s_{x,t}$

APPLICATIONS

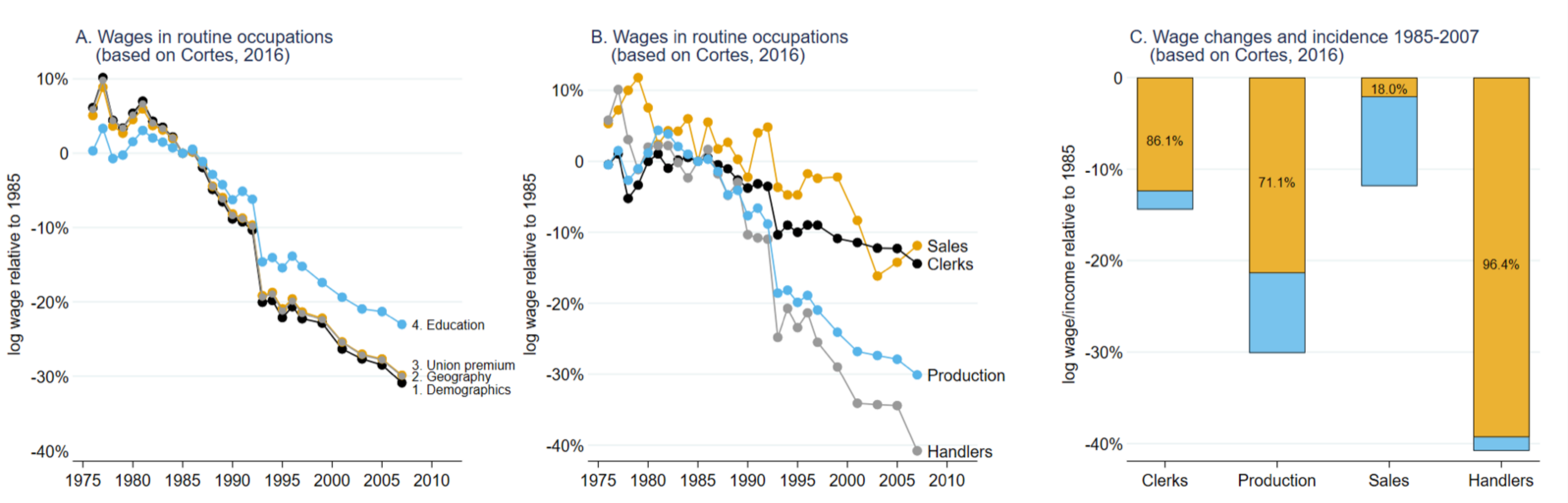
Automation of routine jobs

The China Shock

Colombia's trade liberalization

THE AUTOMATION OF ROUTINE JOBS

- Using PSID, **Cortes (2016)** documents large decline in occupational wages in routine jobs since 1985.
- And large incidence on workers who held these jobs in 85, as implied by a sizable drop in their future income 20 years after relative to others.

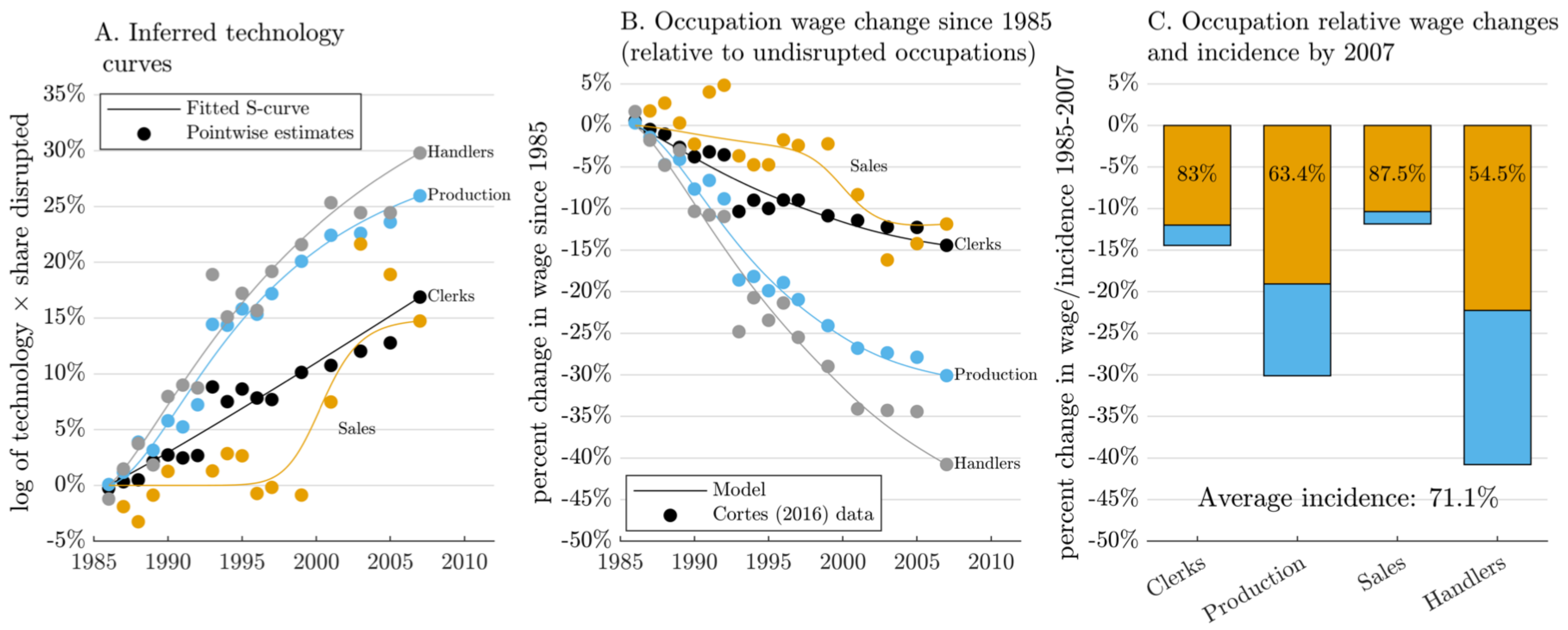


THE AUTOMATION OF ROUTINE JOBS

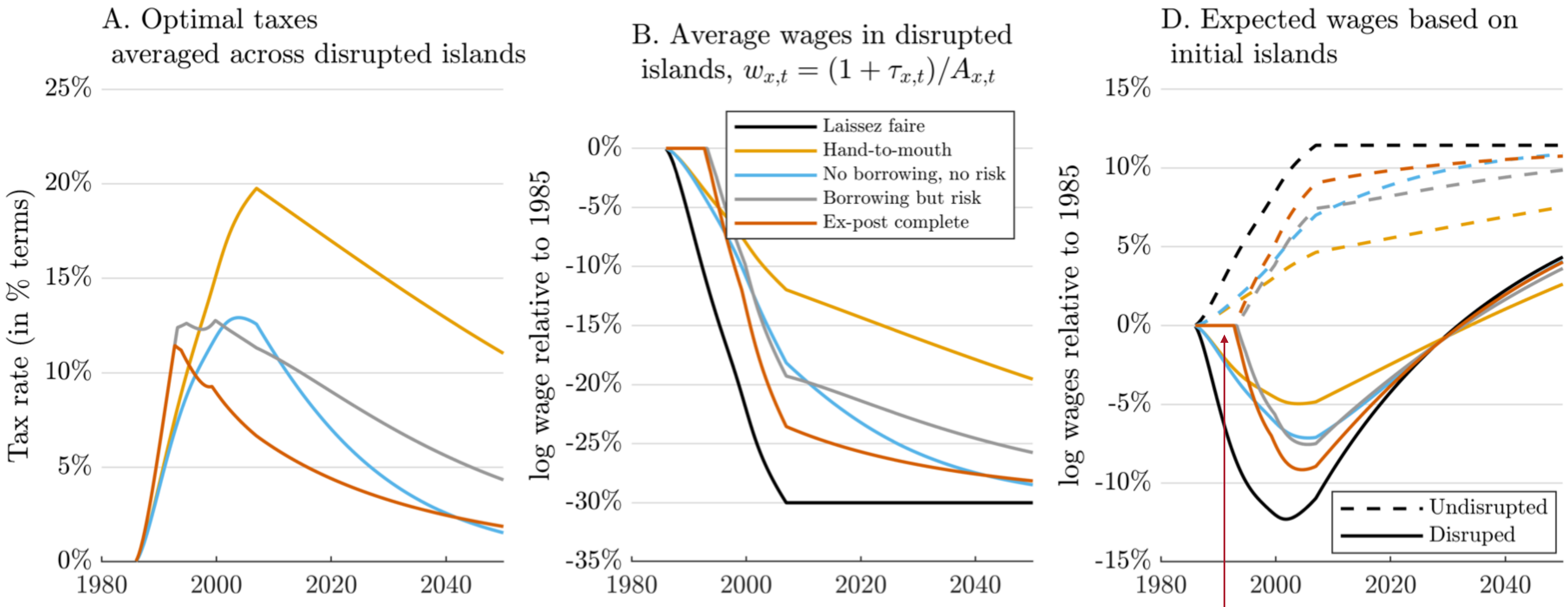
- Output is CES of islands with elasticity of substitution $\sigma = 0.85$ (Goos et al. 2014)
- 4 disrupted islands. Island $x \in \mathscr{D}$ represents the share $s_{o(x)}$ of jobs in occupation $o(x)$ (sales, clerks, production, material handling) being replaced.
- One undisrupted island accounting for all other jobs.
- $s_{o(x)}, A_{x,t}, \alpha$ jointly calibrated to match:
  1. estimates of cost-saving gains of 30% (Acemoglu-Restrepo, 2020) $\Rightarrow A_{x,2007}$
  2. path for occupational wages in Cortes (2016) $\Rightarrow A_{x,t}, s_{o(x)}$
  3. average incidence of 71% across routine jobs from Cortes (2016) $\Rightarrow \alpha = 2.5\,\%$
- Remaining parameters: $r = \rho = 5\,\%$; inverse IES of 2.

THE AUTOMATION OF ROUTINE JOBS

- To reduce noise, we fit an S-curve for technology $A_{x,t}$
- Model reproduces all the key moments in Cortes (2016)

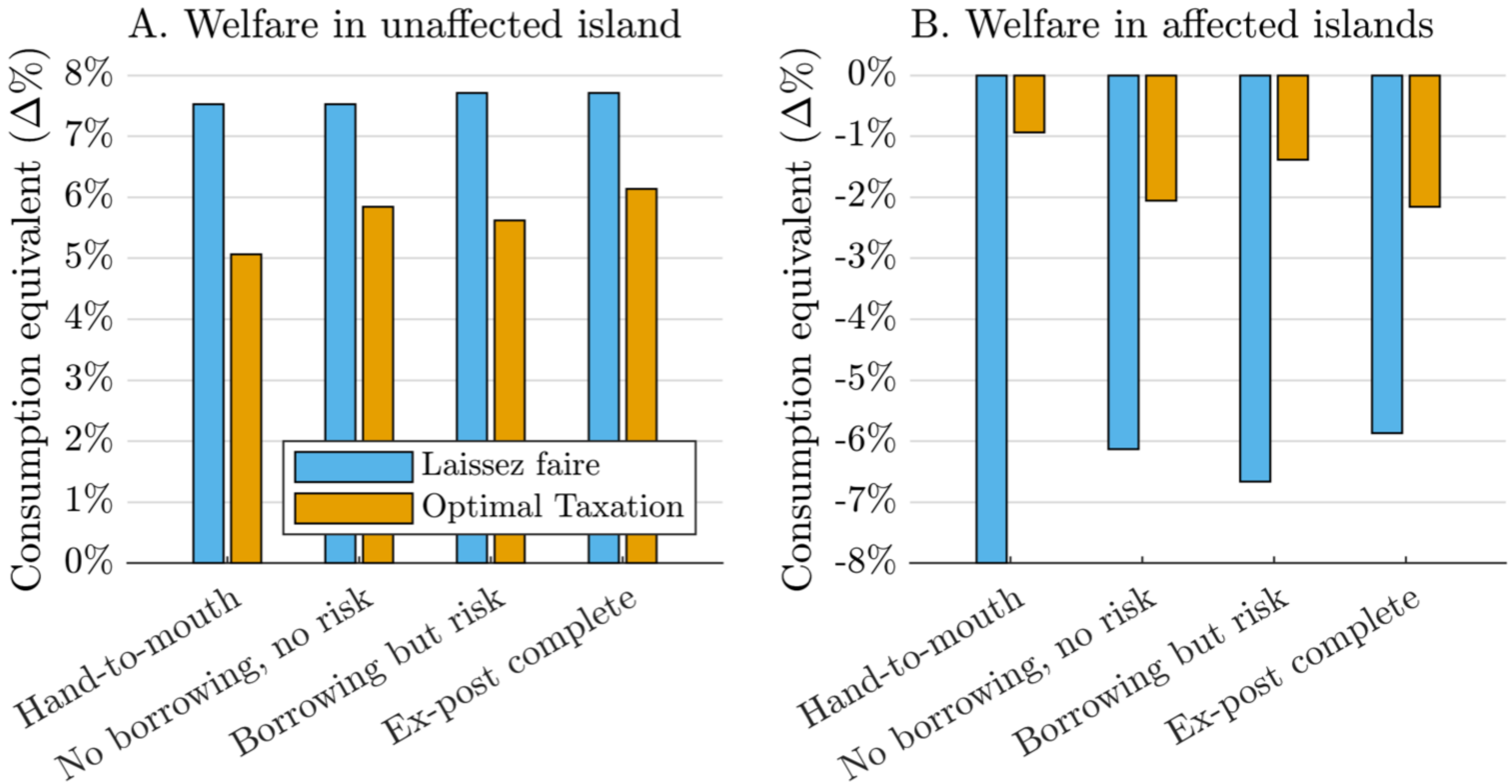


THE AUTOMATION OF ROUTINE JOBS

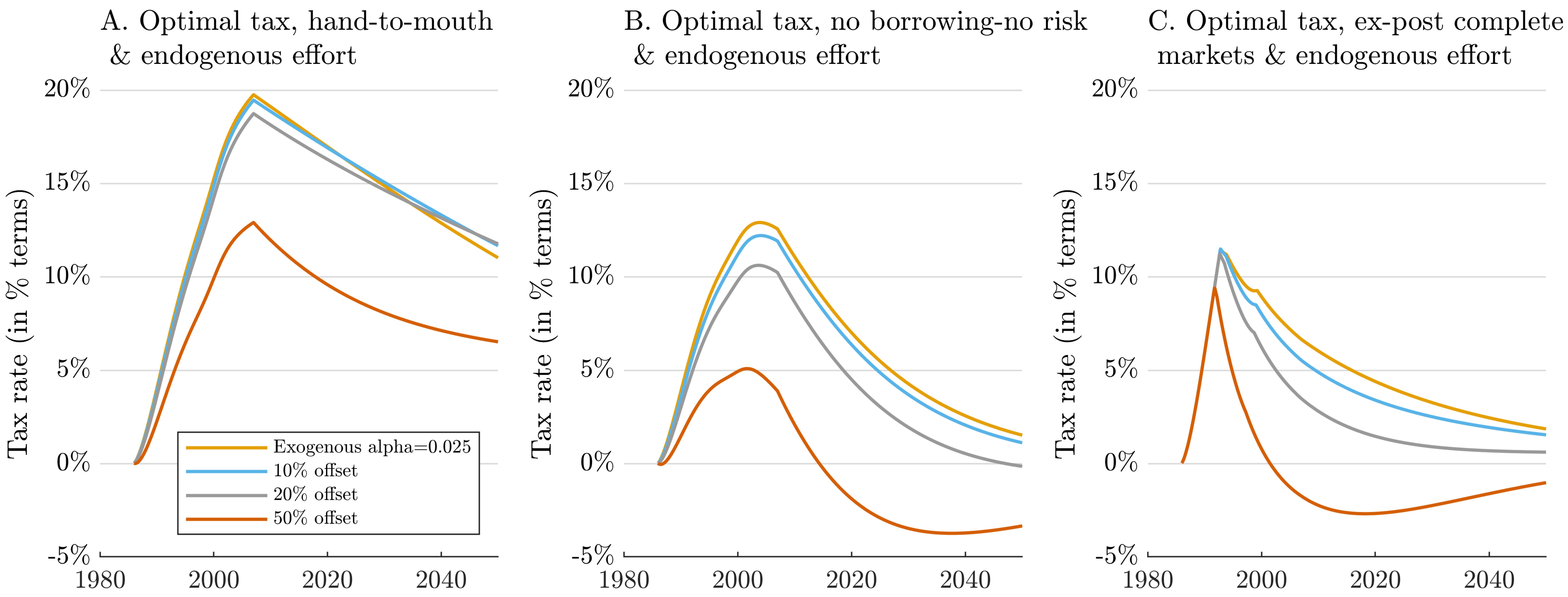


Full delay similar to announcement

THE AUTOMATION OF ROUTINE JOBS



THE AUTOMATION OF ROUTINE JOBS

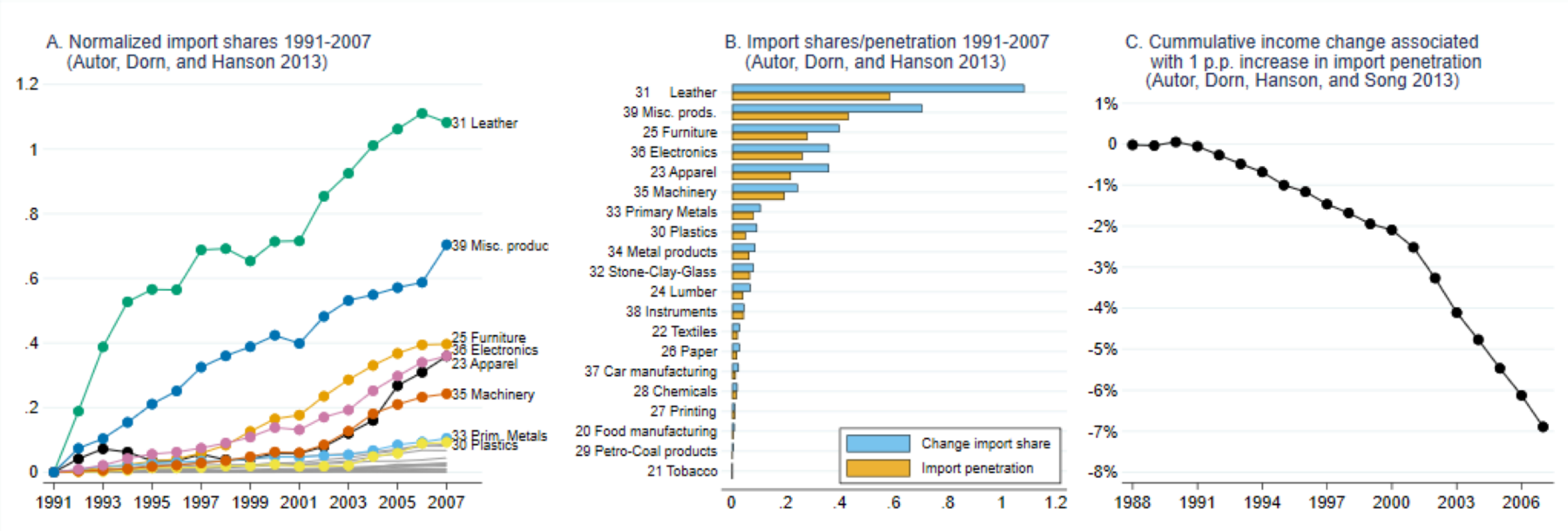


- **Offset:** percent reduction in α of moving to optimal policy for exogenous effort

THE CHINA SHOCK

- **Autor et al. (2013):** rapid increase in Chinese import penetration since 1991.

- Using SSA data, **Autor et al. (2014)** document large decline income for workers who held these jobs by 1990. Average exposure leads to income loss equal to 50% of baseline income during 1991-2007.

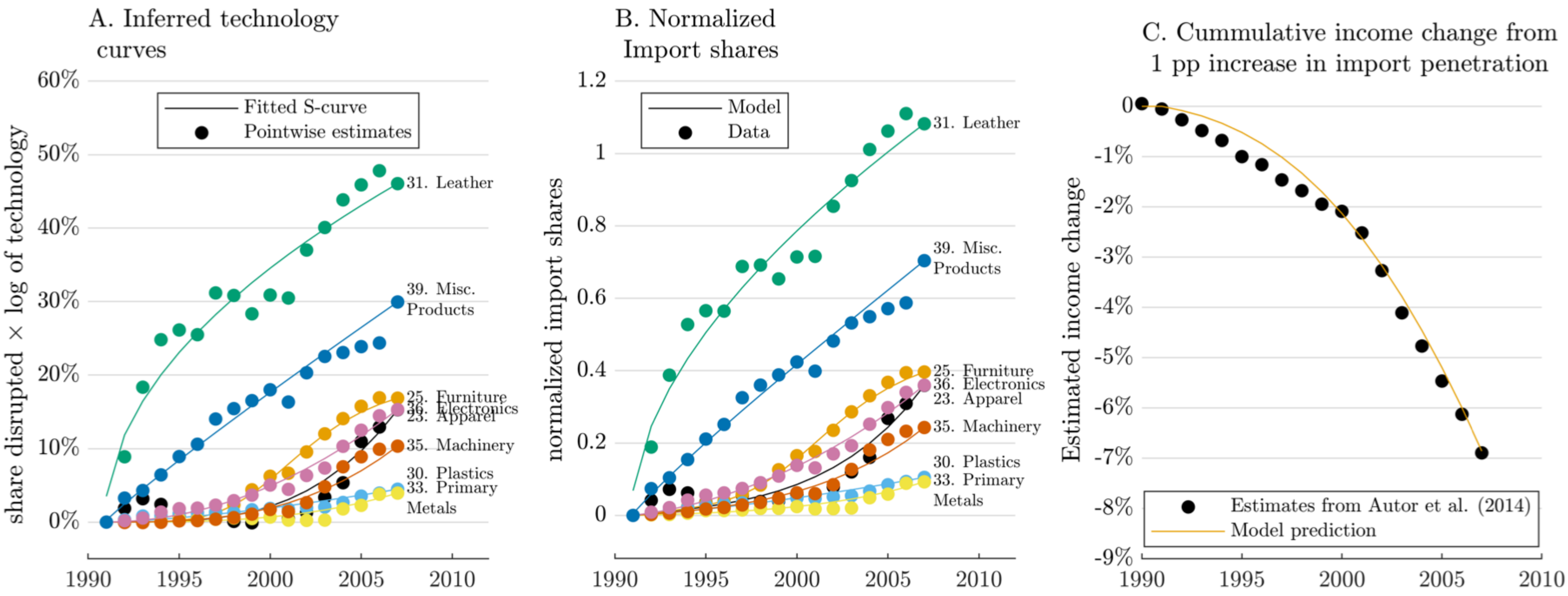


THE CHINA SHOCK

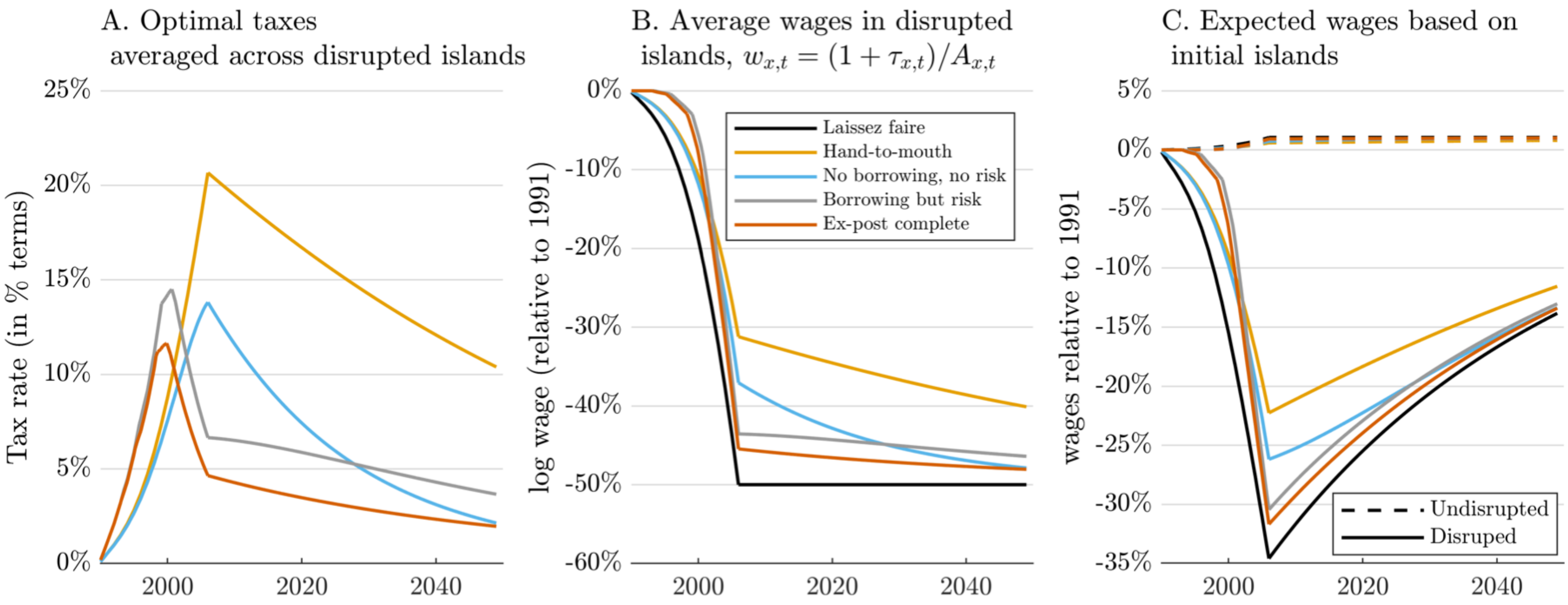
- Output is CES of islands with $\sigma = 2$ (Broda and Weinstein et al. 2006)
- 20 disrupted islands. Island $x \in \mathscr{D}$ represents the share $s_{i(x)}$ of varieties in 2-digit industry $i(x)$ being outcompeted by China.
- One undisrupted island accounting for all other jobs.
- $s_{i(x)}, A_{x,t}, \alpha$ jointly calibrated to match:
  1. price declines associated with China Shock (Bai and Stumpner, 2019) $\Rightarrow A_{x,2007}$
  2. path for imports by 2-digit industry in Autor et al. (2013) $\Rightarrow A_{x,t}, s_{o(x)}$
  3. income decline for exposed workers in Autor et al. (2014) $\Rightarrow \alpha = 1.8\,\%$
- Remaining parameters: $r = \rho = 5\,\%$; inverse IES of 2.

THE CHINA SHOCK

- To reduce noise, we fit an S-curve for technology $A_{x,t}$
- Model reproduces all the key evidence for the China Shock



THE CHINA SHOCK



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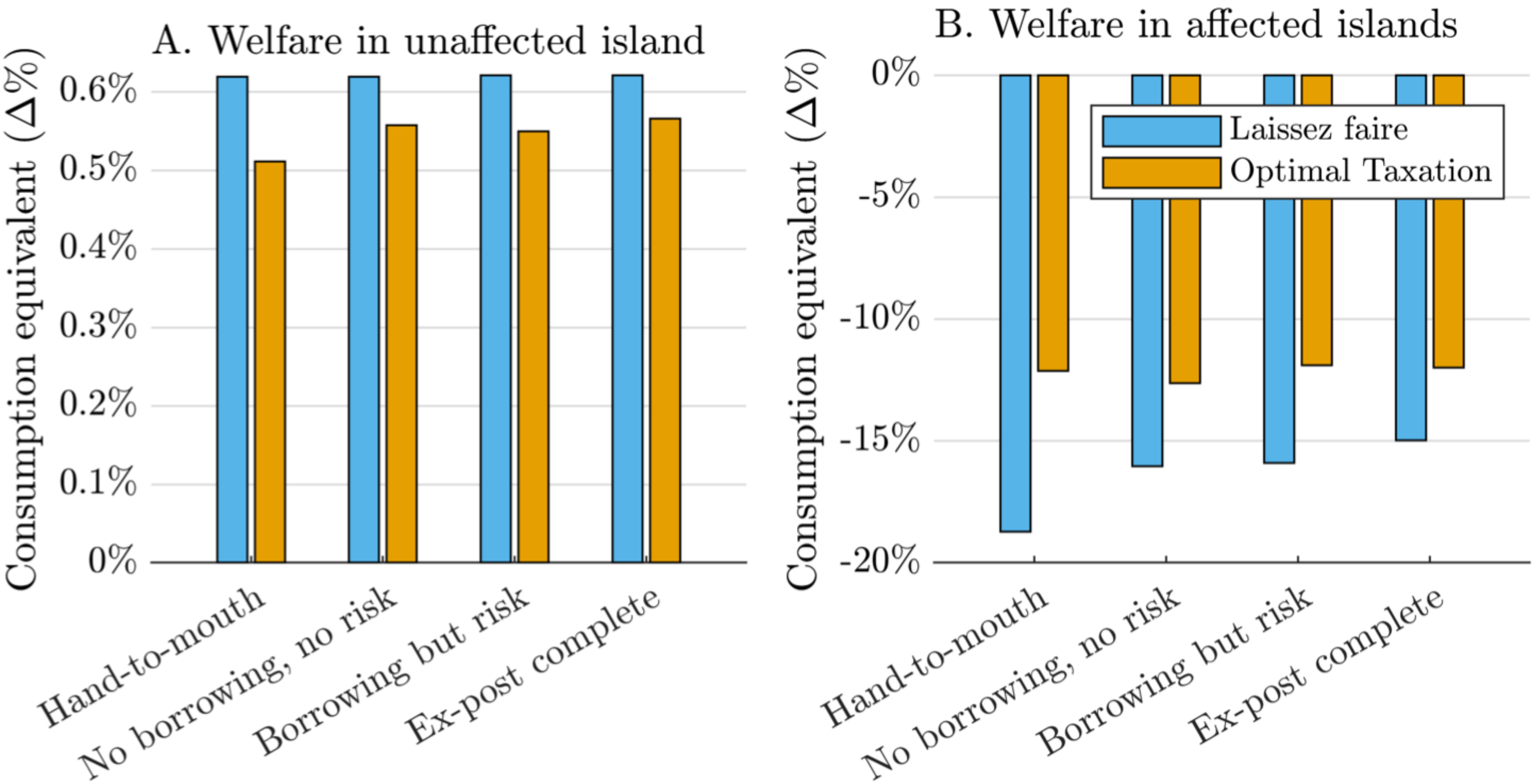

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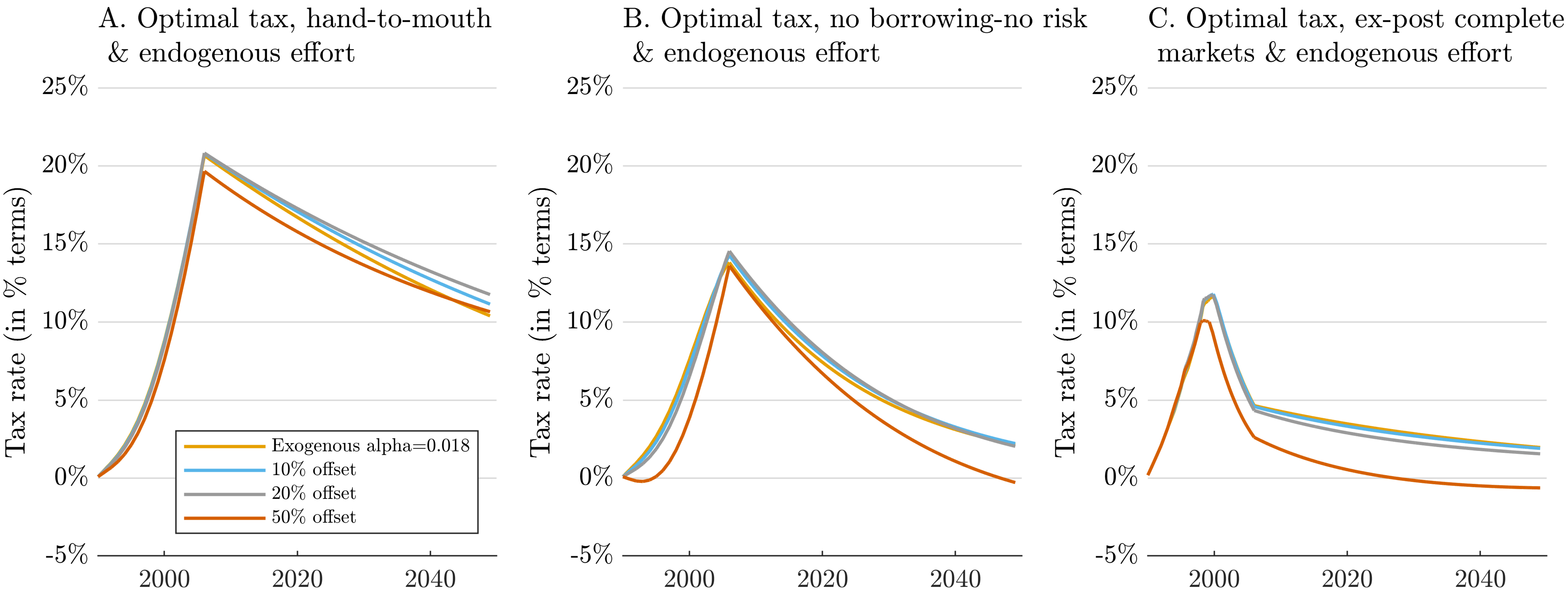


- **Offset:** percent reduction in α of moving to optimal policy for exogenous effort

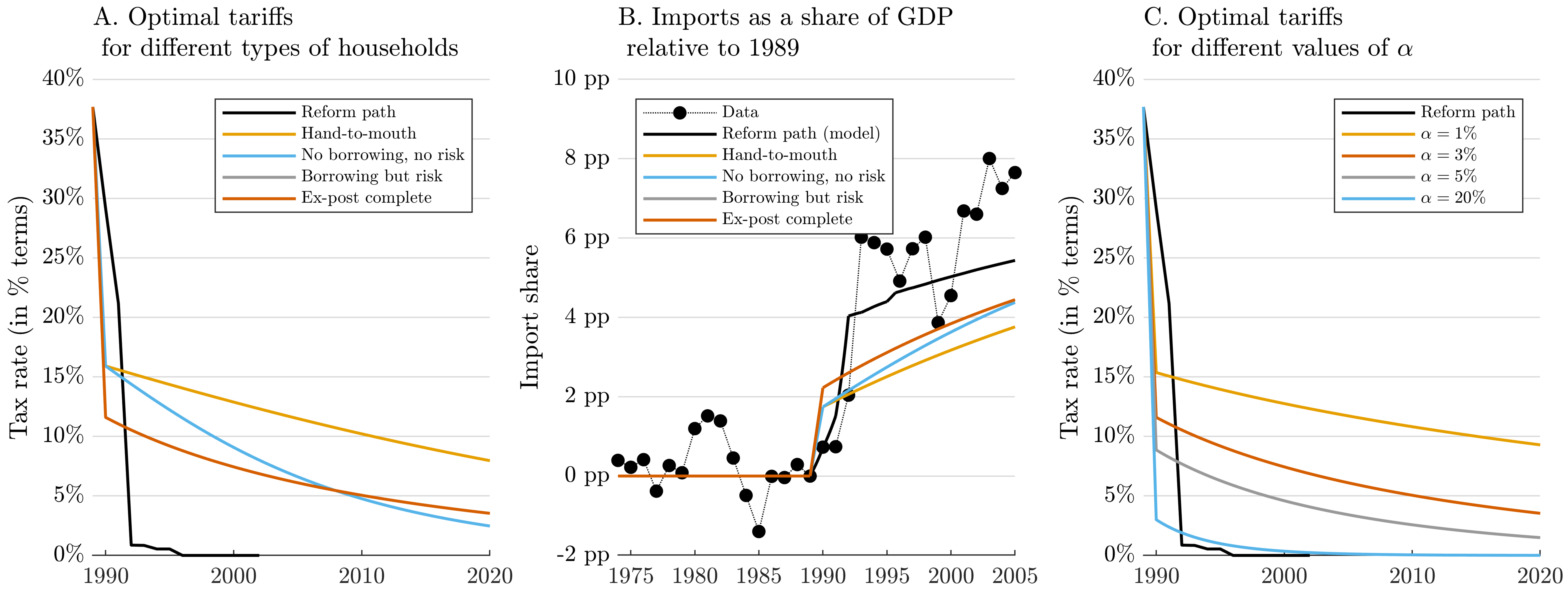
COLOMBIA'S TRADE LIBERALIZATION

- In 1990, Colombia embarked in ambitious reform program, dropping effective tariffs from 75% to 25% in only 2 years.
- Goldberg-Pavcnik (2005): estimate that a 10 pp drop in tariffs leads to a 1% decline in wages of workers in that industry.

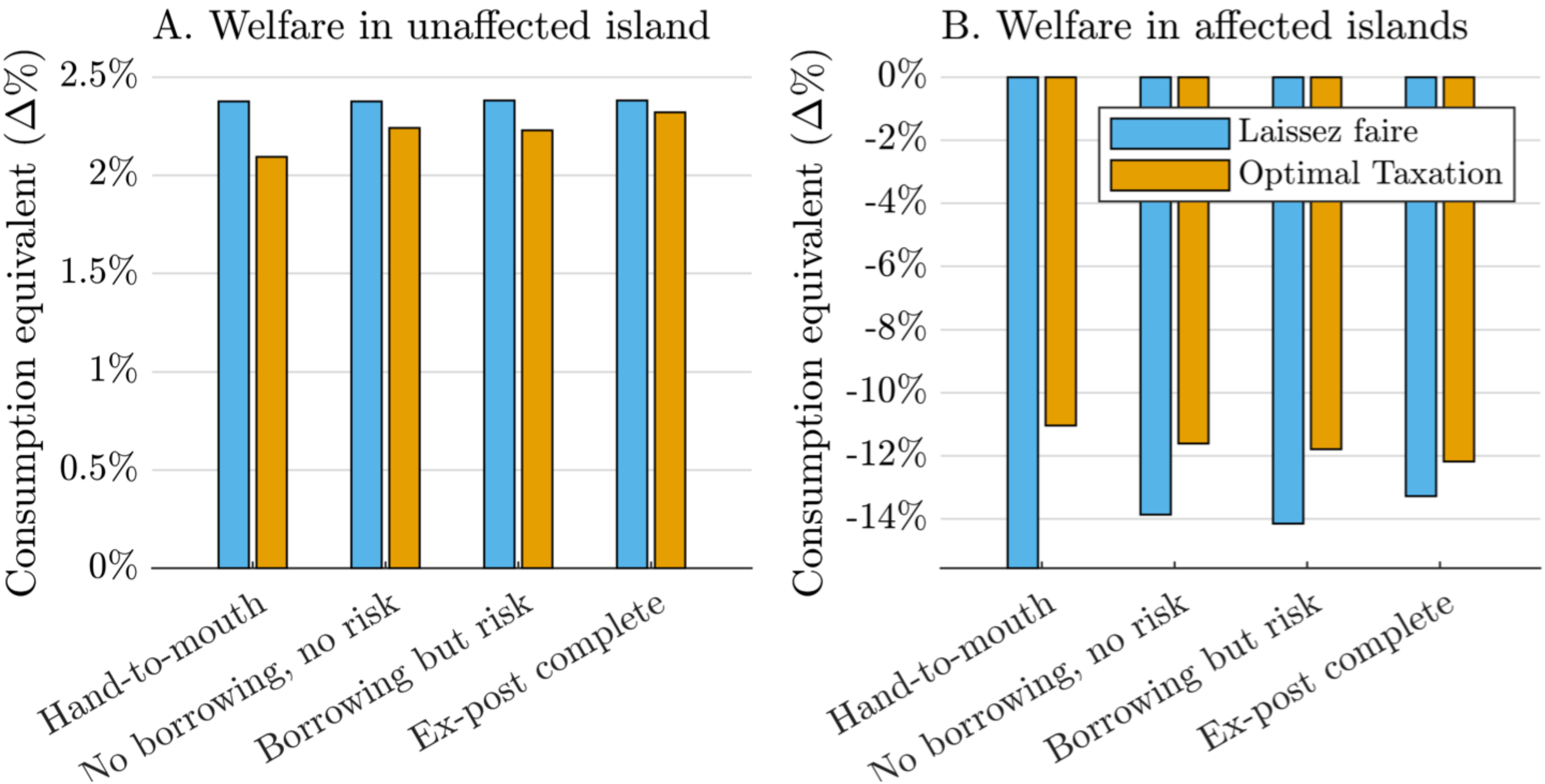
COLOMBIA'S TRADE LIBERALIZATION

- Output is CES of islands with $\sigma = 2$ (Broda and Weinstein et al. 2006)
- 25 disrupted islands. Island $x \in \mathcal{D}$ represents the share $s_{i(x)}$ of varieties in 2-digit industry $i(x)$ being outcompeted by imports after the liberalization.
- We assume that for these islands, $(1 + \tau_{x,0})/A_x = \bar{w}$ before reform
- One undisrupted island accounting for all other jobs.
- $s_{i(x)}, \alpha$ jointly calibrated to match:
  1. Rise in imports by 2-digit industry $\Rightarrow s_{i(x)}$
  2. income decline associated with drop in protection $\Rightarrow \alpha = 3\,\%$
- Remaining parameters: $r = \rho = 5\,\%$; inverse IES of 2.

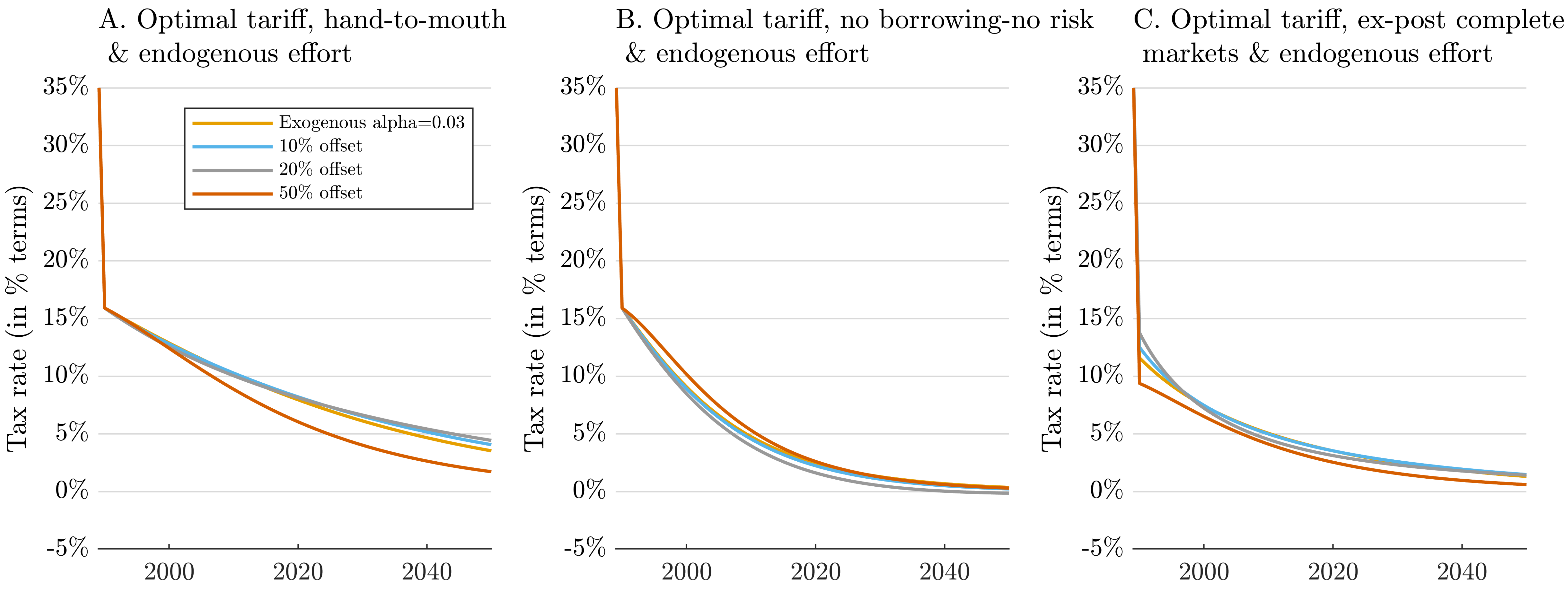
COLOMBIA'S TRADE LIBERALIZATION



COLOMBIA'S TRADE LIBERALIZATION



COLOMBIA'S TRADE LIBERALIZATION



- **Offset:** percent reduction in α of moving to optimal policy for exogenous effort

NEXT STEPS

- Working on quantitative results with government choice of $\tau_{x,t}$ and $\mathscr{R}_t^*$… All that is needed are estimates of ε_ℓ

- This version provided scenarios for endogenous effort, but can we calibrate relevant elasticity?