International Trade and Innovation Dynamics with Endogenous Markups*

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* The views expressed herein are the authors’ and may not represent those of Banco de España or the Eurosystem.
Motivation

- **Globalization stimulates innovation** through:
  - Market size effects (exports).
  - Escape-competition effects (imports).

- **But...** Trade-induced innovation may **affect concentration and markups**:
  - Successful innovators pull away from competitors ⇒ *Concentration* ↑
  - “Innovation feedback” ⇒ Consequences for *misallocation, growth and welfare*.

- **This paper:**
  - Macro model to study *innovation-markups feedback* and its interaction with trade.
  - Trade induces **higher growth, lower markups in short-run and higher markups in long-run**.
What We Do

1. Model:

- 2-country GE model with: (i) leader & fringe firms; (ii) R&D; (iii) oligopolistic competition.

- **Key features:**
  1. Bertrand game b/w domestic and foreign leaders ⇒ **Endogenous markups.** [Atkeson-Burstein (‘08)]
  2. R&D by leaders ⇒ **Distribution of technology gaps.**

- **Key interaction** → Leaders strategically use R&D to increase market share and markups.

2. Quantification:

- Calibration to present-day U.S. manufacturing sector.

- Study fall in trade costs consistent with change in trade openness from 1970s to today.
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Main Results

- **Lower trade costs** $\rightarrow$ **TFP growth** $\uparrow$ by 0.12 ppt (8.1%) and **agg. markup** $\uparrow$ by 1.70 ppt (7.2%).

  1. **Direct effects:** ("classical" static pro-competitive effect)
     - Import competition lowers aggregate markup through market share reallocation.

  2. **Innovation feedback effects:** ("new" dynamic anti-competitive effect)
     - Innovation increases most where firms are technologically close.
       - In these industries, distancing from competitors pays off the most.
     - Distribution becomes more polarized: more industries with one very dominant firm.
       - Pushes aggregate markup upward through composition effect.

- We conduct **transition dynamics** exercise to disentangle both effects.

- **Welfare:**
  - Lower trade costs $\Rightarrow$ **9.2% $\uparrow$** in welfare.
  - Two-thirds of gains due to innovation feedback channel.
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Related Literature

1 Trade and Innovation:
Grossman and Helpman (‘91), Rivera-Batiz and Romer (‘91), Acemoglu (‘02), Baldwin and Robert-Nicoud (‘08), Lileeva and Trefler (‘10), Atkeson and Burstein (‘10), Aw, Roberts, Xu (‘11), Bustos (‘11), Bloom, Draca, Van Reenen (‘16), Sampson (‘16), Chen and Steinwender (‘19), Hsieh, Klenow, Nath (‘19), Autor, Dorn, Hanson, Pisano, Shu (‘20), Akcigit, Ates, Impullitti (‘21), Perla, Tonetti, Waugh (‘21).

2 Trade and Markups:
Krugman (‘79), Atkeson and Burstein (‘08), Melitz and Ottaviano (‘08), De Loecker and Warzynski (‘12), Edmond, Midrigan, Xu (‘15), De Loecker, Goldberg, Khandelwal, Pavcnik (‘16), Arkolakis, Costinot, Donaldson, Rodriguez-Clare (‘18).

3 Both:
Impullitti and Licandro (‘18), Lim, Trefler, Yu (‘18), Aghion, Bergeaud, Lequien, Melitz (‘19), Impullitti, Licandro, Rendahl (‘21).
Model
Model Environment

- Continuous time. Two symmetric countries ($H$ and $F$). (focus on $H$ throughout wlog)
- Preferences:

\[
\max \int_{0}^{+\infty} e^{-\rho t} \ln C_{t}^{H} dt \quad \text{s.t.} \quad \dot{A}_{t}^{H} \leq r_{t}^{H} A_{t}^{H} + w_{t}^{H} - P_{t}^{H} C_{t}^{H}
\]

- Final good: (non-tradable)

\[
\ln Y_{t}^{H} = \int_{0}^{1} \ln (Y_{jt}^{H}) \, dj
\]

- Industry $j$: (tradable)

\[
Y_{jt}^{H} = \left( \left( \omega_{H} \right)^{1/n} (Y_{jtH}^{H})^{\frac{n-1}{n}} + \left( \omega_{F} \right)^{1/n} (Y_{jtF}^{H})^{\frac{n-1}{n}} + \left( \omega_{C} \right)^{1/n} (Y_{jtC}^{H})^{\frac{n-1}{n}} \right)^{\frac{n}{n-1}}
\]

  - Domestic leader
  - Foreign leader
  - Competitive fringe

- Pricing → Bertrand competition between leaders; fringe price at marginal cost.
- Technology → $y_{jt}^{H} = q_{jt}^{H} e_{jt}^{H}$.
- Exporting → Leaders only. Iceberg cost $\tau > 1$. 

Trade, Innovation and Markups
Model Environment

- Continuous time. Two symmetric countries \((H\) and \(F)\). (focus on \(H\) throughout wlog)

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\max \int_0^{+\infty} e^{-\rho t} \ln C_t^H dt \quad \text{s.t.} \quad \dot{A}_t^H \leq r_t^H A_t^H + w_t^H - P_t^H C_t^H
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\[
\ln Y_t^H = \int_0^1 \ln (Y_{jt}^H) \, dj
\]

- Industry \(j\): (tradable)

\[
Y_{jt}^H = \left[ (\omega_H)^{\frac{1}{\eta}} (Y_{jH,t}^H)^{\frac{n-1}{\eta}} + (\omega_F)^{\frac{1}{\eta}} (Y_{jF,t}^H)^{\frac{n-1}{\eta}} + (\omega_C)^{\frac{1}{\eta}} (Y_{jC,t}^H)^{\frac{n-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}
\]

- Pricing \quad \Rightarrow \quad Bertrand competition between leaders; fringe price at marginal cost.

- Technology \quad \Rightarrow \quad y_{jt}^H = q_{jt} v_{jt}^H.

- Exporting \quad \Rightarrow \quad Leaders only. Iceberg cost \(\tau > 1\).
Innovation

1  R&D by leaders:
   ■ Poisson innovation rate $z$ has cost $\chi_i z^{\psi_i} Y^H \rightarrow$ Advance from $q$ to $q(1 + \lambda)$, with $\lambda > 0$.
   ■ Technology gaps: (fringe has the same technology in both countries)

\[
\frac{q_H}{q_F} = (1 + \lambda)^n, \quad \text{with } n \in \{\ldots, -2, -1, 0, 1, 2, \ldots\} \\
\begin{array}{c}
\text{Behind} \\
\text{Neck to neck} \\
\text{Ahead}
\end{array}
\]

\[
\frac{q_H}{q_C} = (1 + \lambda)^{n_C}, \quad \text{with } n_C \in \{0, 1, 2, \ldots\} \\
\begin{array}{c}
\text{Neck to neck} \\
\text{Ahead}
\end{array}
\]

2  Catch-up:
   ■ If behind, leaders innovate at rate $z + \xi$, where $\xi > 0$.
   ■ Fringe catches up at rate $\zeta > 0$, but can never overtake leader.

3  Entrants: (country $\times$ industry-specific)
   ■ Pay $\chi_e x^{\psi_e} Y^H \rightarrow$ Enter at rate $x$, displace domestic leader, improve $q$ by $(1 + \lambda)$.
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Model Solution (sketched)

1 Static part: Prices and markups.

- Firm prices:
  - Domestic leader: \( p_{jH}^H = \mu_{jH}^H \cdot \frac{w^H}{q_{jH}} \)
  - Foreign leader: \( p_{jF}^H = \mu_{jF}^H \cdot \tau \cdot \frac{w^H}{q_{jF}} \)
  - Fringe: \( p_{jC_H}^H = \frac{w^H}{q_{jC_H}} \)

- Markups \( \mu_{jf}^H \) are increasing function of market share: \( \sigma_{jf}^H \equiv \frac{Sales_{jf}^H}{\sum_f Sales_{jf}^H} \).

- Static conditions are functions of relative qualities → Industry state: \( n = (n, n_C) \).

2 Dynamic part (BGP): Innovation decisions for industry \( n = (n, n_C) \).

- Innovation policies \( z_H(n) \) (incumbents) and \( x_H(n) \) (entrants) solve HJB Equations.

- Technology gap distribution: \( \{ \varphi(n) \}_{n \in \mathbb{Z} \times \mathbb{Z}_+} \), solves a set of KF Equations.
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1 Static part: Prices and markups.

- Firm prices:
  \[ \begin{align*}
  p_{jH}^H &= \mu_{jH}^H \cdot \frac{w^H}{q_{jH}} , \\
  p_{jF}^H &= \mu_{jF}^H \cdot \tau \cdot \frac{w^H}{q_{jF}} , \\
  p_{jC}^H &= \frac{w^H}{q_{jC}} 
  \end{align*} \]

  - Domestic leader
  - Foreign leader
  - Fringe

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- Technology gap distribution:
  \( \{ \varphi(n) \}_{n \in \mathbb{Z} \times \mathbb{Z}_+} \), solves a set of KF Equations.
Key Objects of Interest

1  Growth rate:

\[ g = \ln(1 + \lambda) \left( \sum_{n=\infty}^{+\infty} \sum_{n_c=0}^{+\infty} \varphi(n) i_H(n) \right) \]

where \( i_H(n) \equiv x_H(n) + z_H(n) + \xi [n<0] \) is the innovation rate in industry \( n \).

2  Aggregate markup:

\[ \mu = \left( \sum_{n=\infty}^{+\infty} \sum_{n_c=0}^{+\infty} \varphi(n) \left( \mu(n) \right)^{-1} \right)^{-1} = \left( \frac{wL}{Y} \right)^{-1} \]

where \( \mu(n) = \left( \sum_f \sigma_f^H(n) \left( \mu_f^H(n) \right)^{-1} \right)^{-1} \) is the aggregate markup in industry \( n \).
Qualitative Features

**Takeaways:**

1. **Profits** are S-shaped, thus...

2. **Innovation incentives** highest around neck-to-neck states.

3. **Industry markups** highest in high-\(n\) states.

*Legend: \(n = \text{Distance domestic leader to foreign leader};\ n_C = \text{Distance domestic leader to fringe.}\)*
Calibration
Calibration

- Set 3 parameters externally, calibrate 8 parameters internally \( \rightarrow (\eta, \lambda, \chi_i, \chi_e, \tau, \omega, \xi, \zeta) \).
- Match 9 moments reflecting present-day U.S. manufacturing sector.

### Parameter Values

#### Solution Algorithm

<table>
<thead>
<tr>
<th>Moment</th>
<th>Model</th>
<th>Data</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. From aggregate data</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Productivity growth</td>
<td>1.61%</td>
<td>1.58%</td>
<td>EU KLEMS, 2019 Release</td>
</tr>
<tr>
<td>R&amp;D share of value added</td>
<td>8.3%</td>
<td>9.8%</td>
<td>OECD</td>
</tr>
<tr>
<td>Import share of value added</td>
<td>24.0%</td>
<td>23.5%</td>
<td>U.S. Census Bureau, NBER-CES</td>
</tr>
<tr>
<td>SD import shares across industries</td>
<td>18.1%</td>
<td>21.3%</td>
<td>U.S. Census Bureau, NBER-CES</td>
</tr>
<tr>
<td><strong>B. From firm-level data</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average markup</td>
<td>33.0%</td>
<td>35.4%</td>
<td>Compustat</td>
</tr>
<tr>
<td>Standard deviation of markups</td>
<td>49.5%</td>
<td>48.1%</td>
<td>Compustat</td>
</tr>
<tr>
<td>Entry rate</td>
<td>5.2%</td>
<td>6.5%</td>
<td>U.S. Census Bureau</td>
</tr>
<tr>
<td>Contribution of entrants to growth</td>
<td>27.0%</td>
<td>25.7%</td>
<td>Akcigit and Kerr (2018)</td>
</tr>
<tr>
<td>Employment share of the fringe</td>
<td>17.5%</td>
<td>18.2%</td>
<td>U.S. Census Bureau, NSF</td>
</tr>
</tbody>
</table>
The Quantitative Effects of Trade Shocks
Effects of Globalization $\Rightarrow \tau \downarrow$ from Import Share $\approx 12\%$, consistent with 1970s

1. **Comparing BGPs:** Effects on growth and aggregate markup.

2. **Transition dynamics:** Impact (via reallocation) vs. transition (via innovation feedback).
Effects of Globalization $\Rightarrow \tau \downarrow$ from Import Share $\approx 12\%$, consistent with 1970s

1. **Comparing BGPs:** Effects on growth and aggregate markup.

2. **Transition dynamics:** Impact (via reallocation) vs. transition (via innovation feedback).

3. **Static profits:** Differences in % from high-$\tau$ BGP to low-$\tau$ BGP.

   $n = \text{Distance domestic leader to foreign leader}; \quad n_c = \text{Distance domestic leader to fringe}.$

3 Key Effects:

1. Reallocation of market shares away from domestic firms $\rightarrow$ Profit S-shape is accentuated.

2. 

3. 

Trade, Innovation and Markups
Effects of Globalization ⇒ $\tau \downarrow$ from Import Share $\approx 12\%$, consistent with 1970s

### Comparing BGPs:
Effects on growth and aggregate markup.

### Transition dynamics:
Impact (via reallocation) vs. transition (via innovation feedback).

#### Innovation:
Differences in % from high-$\tau$ BGP to low-$\tau$ BGP.

$n = \text{Distance domestic leader to foreign leader};\; n_C = \text{Distance domestic leader to fringe}.$

### 3 Key Effects:

1. Reallocation of market shares away from domestic firms.
2. More innovation around neck-to-neck states $\Rightarrow$ Because profits decrease most for those firms.
3. 

Trade, Innovation and Markups
Effects of Globalization $\Rightarrow \tau \downarrow$ from Import Share $\approx 12\%$, consistent with 1970s


**Distribution:** Technology gap distributions in high-$\tau$ BGP (red) and low-$\tau$ BGP (white).

$n = \text{Distance domestic leader to foreign leader}; \quad n_C = \text{Distance domestic leader to fringe}.$

3 Key Effects:

1. Reallocation of market shares away from domestic firms.
3. Distributions shift toward extremes states (polarization) $\Rightarrow$ Because higher innovation in the middle.
Effects of Globalization $\Rightarrow \tau \downarrow$ from Import Share $\approx 12\%$, consistent with 1970s


2. **Figure**: BGP solutions across different values of $\tau$.

- **Overall**:
  - Higher economic growth, but also higher aggregate markup and concentration.
  - What’s the contribution of innovation feedback? $\Rightarrow$ Look at transition dynamics.
Effects of Globalization ⇒ τ ↓ from Import Share ≈ 12%, consistent with 1970s


2. Transition dynamics: Impact (via reallocation) vs. transition (via innovation feedback).

<table>
<thead>
<tr>
<th></th>
<th>Initial</th>
<th>Final</th>
<th>Δ (p.p.)</th>
<th>Impact (p.p.)</th>
<th>Transition (p.p.)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Panel 1. High to low τ</strong></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Productivity growth</td>
<td>1.49%</td>
<td>1.61%</td>
<td>+0.12</td>
<td>+0.08</td>
<td>+0.04</td>
</tr>
<tr>
<td>Aggregate markup</td>
<td>23.55%</td>
<td>25.25%</td>
<td>+1.70</td>
<td>−1.14</td>
<td>+2.84</td>
</tr>
<tr>
<td><strong>Panel 2. Autarky to low τ</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Productivity growth</td>
<td>1.32%</td>
<td>1.61%</td>
<td>+0.29</td>
<td>+0.25</td>
<td>+0.04</td>
</tr>
<tr>
<td>Aggregate markup</td>
<td>23.33%</td>
<td>25.25%</td>
<td>+1.92</td>
<td>−2.47</td>
<td>+4.39</td>
</tr>
<tr>
<td><strong>Panel 3. Autarky to free trade (τ = 1)</strong></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Productivity growth</td>
<td>1.32%</td>
<td>1.73%</td>
<td>+0.41</td>
<td>+0.33</td>
<td>+0.08</td>
</tr>
<tr>
<td>Aggregate markup</td>
<td>23.33%</td>
<td>29.16%</td>
<td>+5.86</td>
<td>−3.35</td>
<td>+9.21</td>
</tr>
</tbody>
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Table: Transition dynamics results from one-time permanent reduction in τ.

Robustness: Lower μ target, Exogenous η, Fixed export costs
Welfare

- **CE welfare definition:**

\[
\int_0^{+\infty} e^{-\rho t} \ln \left( C^A_t (1 + \gamma) \right) dt = \int_0^{+\infty} e^{-\rho t} \ln \left( C^B_t \right) dt
\]

Economy transitioning from high-\(\tau\) BGP to low-\(\tau\) BGP

Counterfactual economy on high-\(\tau\) BGP throughout

- Moving from 1970s BGP to present-day BGP:
  - 9.2% gain → Due to (i) less labor misallocation; (ii) higher growth.
  - Keeping innovation/distribution fixed → CE gains are only one-third as high.
  - Gains are unequally shared (corporate profits increase more than wages).

- **Autarky to present-day:** 19.1%. **Autarky to free-trade:** 36.7%.

- **Social Planner:**
  - 6.8% CE gains (< decentralized allocation).
  - CE gains are large because large inefficiencies reduced.
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Conclusion

- We study the **effects of globalization on economic growth and markups**:

  1. Increase in **long-run growth** through higher innovation.

  2. Aggregate markup falls on impact but increases in the long-run.
     - Reversal entirely due to **shift in distribution** from innovation response.

  3. Welfare:
     - 9.2% gain in CE terms → From (i) lower static resource misallocation; (ii) higher growth.
     - Most of the gains (**two-thirds**) accounted for by higher growth.

Thank you!
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Thank you!
Appendix
Appendix: Static Solution

Firm’s problem:

$$\max_{\{y_{jH}^H, y_{jH}^F\}} \left\{ \left( p_H^H(y_{jH}^H, \hat{y}_{jF}^H) - \frac{w_H^H}{q_{jH}^H} \right) y_{jH}^H + \left( p_F^H(y_{jH}^F, \hat{y}_{jF}^F) - \tau \frac{w_H^H}{q_{jH}^H} \right) y_{jH}^F \right\}$$

- Domestic profits, $\pi_{jH}^H$
- Foreign profits, $\pi_{jH}^F$

BGP: industry $j$ identified by step sizes $n = (n, n_C)$. Demand functions:

$$\left( \frac{y_{jF}^H(n)}{y_{jH}^H(n)} \right)^{-\frac{1}{\eta}} = (1 + \lambda)^n \cdot \tau \cdot \left( \frac{\omega_H}{\omega_F} \right) \cdot \left( \frac{1 - \sigma_H^H(n)}{1 - \sigma_F^H(n)} \cdot \frac{\frac{n}{n-1} - \sigma_F^H(n)}{n - 1} - \sigma_H^H(n) \right)$$

$$\left( \frac{y_{jC}^H(n)}{y_{jH}^H(n)} \right)^{-\frac{1}{\eta}} = (1 + \lambda)^{n_C} \cdot \left( \frac{\omega_H}{\omega_C} \right) \cdot \left( \frac{1 - \sigma_H^H(n)}{1 - \sigma_H^H(n)} \cdot \frac{\frac{n}{n-1} - \sigma_H^H(n)}{n - 1} - \sigma_H^H(n) \right)$$

- A system of 2 equations and 2 unknowns: $\frac{y_{jF}^H}{y_{jH}^H}$ and $\frac{y_{jC}^H}{y_{jH}^H}$.

- Static profits $\Rightarrow \pi_{jH}^H(n) = \left( \frac{n}{\sigma_H^H(n)} - (\eta - 1) \right)^{-1} Y^H$
Appendix: Value Functions (BGP)

- Relevant state: $n = (n, n_C)$.

- Leader:

$$\begin{align*}
rV_H(n) &= \max_{z_H(n)} \left\{ \pi_H(n) - \chi_i(z_H(n))^{\psi_i} - x_H(n)V_H(n) \\
&\quad + \left( z_H(n) + \xi_{[n<0]} \right) \left( V_H(n+1, n_C+1) - V_H(n) \right) \\
&\quad + (x_F(n) + z_F(n) + \xi_{[n>0]}) \left( V_H(n-1, n_C) - V_H(n) \right) \\
&\quad + \xi_{[n_C>0]} \left( V_H(n, n_C-1) - V_H(n) \right) \right\} + \dot{V}_H(n, n_C)
\end{align*}$$

- Entrant:

$$\max_{x_H(n)} \left\{ x_H(n)V_H(n+1, n_C+1) - \chi_e(x_H(n))^{\psi_e} \right\}$$
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\[
rv_H(n) = \max_{z_H(n)} \left\{ \begin{array}{c}
\pi_H(n) - \chi_i(z_H(n))^\psi_i - x_H(n)V_H(n) \\
\text{Domestic and foreign profits} \\
\text{R&D cost} \\
\text{Loss from entry in } H \\
+ \left( z_H(n) + \xi_{[n<0]} \right) \left( V_H(n + 1, n_C + 1) - V_H(n) \right) \\
+ \left( x_F(n) + z_F(n) + \xi_{[n>0]} \right) \left( V_H(n - 1, n_C) - V_H(n) \right) \\
+ \zeta_{[n_C>0]} \left( V_H(n, n_C - 1) - V_H(n) \right) \right\} + \dot{V}_H(n, n_C)
\]

- Entrant:

\[
\max_{x_H(n)} \left\{ x_H(n) V_H(n + 1, n_C + 1) - \chi_e(x_H(n))^\psi_e \right\}
\]
Appendix: Value Functions (BGP)

- Relevant state: $n = (n, n_C)$.

- Leader:

$$rV_H(n) = \max_{z_H(n)} \left\{ \pi_H(n) - \chi_i(z_H(n))^{\psi_i} - x_H(n)V_H(n) + \left( z_H(n) + \xi_{[n<0]} \right) \left( V_H(n+1, n_C + 1) - V_H(n) \right) \right. $$

$$\left. + \left( x_F(n) + z_F(n) + \xi_{[n>0]} \right) \left( V_H(n-1, n_C) - V_H(n) \right) + \xi_{[n_C>0]} \left( V_H(n, n_C - 1) - V_H(n) \right) \right\} + \dot{V}_H(n, n_C)$$

- Entrant:

$$\max_{x_H(n)} \left\{ x_H(n) V_H(n+1, n_C + 1) - \chi_e(x_H(n))^{\psi_e} \right\}$$
Appendix: Value Functions (BGP)

- **Relevant state:** \( n = (n, n_C) \).

- **Leader:**

\[
rV_H(n) = \max_{z_H(n)} \left\{ \pi_H(n) - \chi_i(z_H(n))^\psi_i - x_H(n)V_H(n) \right. \\
\left. + \left( z_H(n) + \xi_{[n<0]} \right) \left( V_H(n+1, n_C+1) - V_H(n) \right) \right. \\
\left. + \left( x_F(n) + z_F(n) + \xi_{[n>0]} \right) \left( V_H(n-1, n_C) - V_H(n) \right) \right. \\
\left. + \zeta_{[n_C>0]} \left( V_H(n, n_C-1) - V_H(n) \right) \right\} + \dot{V}_H(n, n_C)
\]

- **Entrant:**

\[
\max_{x_H(n)} \left\{ x_H(n)V_H(n+1, n_C+1) - \chi_e(x_H(n))^\psi_e \right\}
\]
Appendix: Value Functions (BGP)

- Relevant state: \( n = (n, n_C) \).

- Leader:

\[
\begin{align*}
\text{r}V_H(n) &= \max_{z_H(n)} \left\{ \pi_H(n) - \chi_i(z_H(n))^{\psi_i} - x_H(n)V_H(n) \\
&\quad + \left( z_H(n) + \xi [n < 0] \right) \left( V_H(n + 1, n_C + 1) - V_H(n) \right) \\
&\quad + \left( x_F(n) + z_F(n) + \xi [n > 0] \right) \left( V_H(n - 1, n_C) - V_H(n) \right) \\
&\quad + \xi [n_C > 0] \left( V_H(n, n_C - 1) - V_H(n) \right) \right\} + \dot{V}_H(n, n_C)
\end{align*}
\]

\( \text{Fringe catching up} \)
\( \text{Economic growth} \)

- Entrant:

\[
\max_{x_H(n)} \left\{ x_H(n)V_H(n + 1, n_C + 1) - \chi_e(x_H(n))^{\psi_e} \right\}
\]
Appendix: Value Functions (BGP)

■ Relevant state: \( n = (n, n_C) \).

■ Leader:

\[
\begin{align*}
    rV_H(n) &= \max_{z_H(n)} \left\{ \pi_H(n) - \chi_i(z_H(n))^\psi_i - x_H(n) V_H(n) \right. \\
    & \quad + \left( z_H(n) + \xi \mathbb{I}_{n<0} \right) \left( V_H(n+1, n_C+1) - V_H(n) \right) \\
    & \quad + \left( x_F(n) + z_F(n) + \xi \mathbb{I}_{n>0} \right) \left( V_H(n-1, n_C) - V_H(n) \right) \\
    & \quad + \left. \zeta \mathbb{I}_{n_C>0} \left( V_H(n, n_C-1) - V_H(n) \right) \right\} + \dot{V}_H(n, n_C)
\end{align*}
\]

■ Entrant:

\[
\begin{align*}
    \max_{x_H(n)} \left\{ x_H(n) V_H(n+1, n_C+1) - \chi_e(x_H(n))^\psi_e \right\}
\end{align*}
\]
Appendix: Flow Equations

- Denote $n_C$ the distance to the “worst” leader, and $i_H = z_H + x_H + \xi \mathbb{I}_{[n<0]}$.
- Flow equations:

$$
\dot{\phi}(n, 0) = \zeta \phi(n, 1) + \phi(n, 0) - \phi(n, 0) \left( i_H(n, 0) + i_F(n, 0) \right)
$$

∀$n_C \geq 1$ :  $\dot{\phi}(n, n_C) = \zeta \phi(n, n_C + 1) + \phi(n, n_C) - \phi(n, n_C) \left( i_H(n, n_C) + i_F(n, n_C) + \zeta \right)$

where:

$$
\phi(n, 0) \equiv \begin{cases} 
\varphi(n + 1, 0)i_F(n + 1, 0) & \text{if } n < 0 \\
0 & \text{if } n = 0 \\
\varphi(n - 1, 0)i_H(n - 1, 0) & \text{if } n > 0 
\end{cases}
$$

∀$n_C > 0$ :  $\phi(n, n_C) \equiv \begin{cases} 
\varphi(n - 1, n_C - 1)i_H(n - 1, n_C - 1) + \varphi(n + 1, n_C)i_F(n + 1, n_C) & \text{if } n < 0 \\
\varphi(n - 1, n_C - 1)i_H(n - 1, n_C - 1) + \varphi(n + 1, n_C - 1)i_F(n + 1, n_C - 1) & \text{if } n = 0 \\
\varphi(n - 1, n_C)i_H(n - 1, n_C) + \varphi(n + 1, n_C - 1)i_F(n + 1, n_C - 1) & \text{if } n > 0 
\end{cases}$
Appendix: Dynamic Solution

Step 1. Solve for \( \{ \pi_H(n), \sigma_H(n) \} \) on a grid \( n \in \mathcal{N} = \{-\bar{n}, \ldots, \bar{n}\} \times \{0, \ldots, \bar{n}\} \).

Step 2. Value function & step-size distribution:

Step 2.1 Use VFI to solve value function, \( \{ v_H(n) \}_{n \in \mathcal{N}} \).

Step 2.2 Compute optimal innovation policies \( \{ (z_H(n), x_H(n)) \}_{n \in \mathcal{N}} \) using:

\[
\begin{align*}
  z_H(n) &= \left( \frac{v_H(n+1, n_C + 1) - v_H(n)}{\chi_i \psi_i} \right)^{\frac{1}{\psi_i - 1}}, \\
  x_H(n) &= \left( \frac{v_H(n+1, n_C + 1)}{\chi_e \psi_e} \right)^{\frac{1}{\psi_e - 1}}
\end{align*}
\]

Step 2.3 Using flow equations, compute invariant distribution, \( \{ \varphi(n) \}_{n \in \mathcal{N}} \).

Step 3. Compute the wage \( w \) using labor market clearing:

\[
\frac{wL}{Y} = \sum_{n=-\bar{n}}^{\bar{n}} \sum_{n_C=0}^{\bar{n}} \varphi(n) \left( \sigma_{cH}(n) + \left( \frac{\eta - 1}{\eta} \right) \left[ \frac{\sigma_H(n)(1 - \sigma_H(n))}{\eta(1 - \sigma_H(n)) + \sigma_H(n)} + \frac{\sigma_F(n)(1 - \sigma_F(n))}{\eta(1 - \sigma_F(n)) + \sigma_H(n)} \right] \right)
\]
### Appendix: Parameter Values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\rho$</td>
<td>0.02</td>
<td>Discount rate</td>
</tr>
<tr>
<td>$\psi_i$</td>
<td>2</td>
<td>R&amp;D cost elasticity (incumbents)</td>
</tr>
<tr>
<td>$\psi_e$</td>
<td>2</td>
<td>R&amp;D cost elasticity (entrants)</td>
</tr>
<tr>
<td>$\lambda$</td>
<td>0.087</td>
<td>Innovation step</td>
</tr>
<tr>
<td>$\chi_i$</td>
<td>1.370</td>
<td>R&amp;D cost scale (incumbents)</td>
</tr>
<tr>
<td>$\chi_e$</td>
<td>23.179</td>
<td>R&amp;D cost scale (entrants)</td>
</tr>
<tr>
<td>$\eta$</td>
<td>11.161</td>
<td>Elasticity of substitution</td>
</tr>
<tr>
<td>$\tau$</td>
<td>1.275</td>
<td>Iceberg trade cost</td>
</tr>
<tr>
<td>$\omega_H$</td>
<td>0.493</td>
<td>Taste shifters</td>
</tr>
<tr>
<td>$\xi$</td>
<td>0.235</td>
<td>Catch-up rate of lagging leader</td>
</tr>
<tr>
<td>$\zeta$</td>
<td>5.446</td>
<td>Catch-up rate of the fringe</td>
</tr>
</tbody>
</table>

*Set externally*

*Calibrated internally*

**Table:** Baseline calibration: parameter values.
Appendix: Robustness 1: Lower markup target

Check: Re-calibrate with halved targets for average and standard deviation of markups.

Transition dynamics results:

<table>
<thead>
<tr>
<th></th>
<th>Initial</th>
<th>Final</th>
<th>Δ (p.p.)</th>
<th>Impact (p.p.)</th>
<th>Transition (p.p.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Productivity growth</td>
<td>1.50%</td>
<td>1.59%</td>
<td>+0.09</td>
<td>+0.06</td>
<td>+0.03</td>
</tr>
<tr>
<td>Aggregate markup</td>
<td>16.18%</td>
<td>17.15%</td>
<td>+0.97</td>
<td>−0.82</td>
<td>+1.79</td>
</tr>
<tr>
<td>Trade share</td>
<td>11.64%</td>
<td>23.36%</td>
<td>+11.72</td>
<td>+10.43</td>
<td>+1.29</td>
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<tr>
<td>Emp. share of the fringe</td>
<td>25.59%</td>
<td>17.58%</td>
<td>−8.01</td>
<td>−7.27</td>
<td>−0.74</td>
</tr>
<tr>
<td>Trade cost (τ)</td>
<td>1.3026</td>
<td>1.1874</td>
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<td>.</td>
</tr>
</tbody>
</table>
Appendix: Robustness 2: Exogenous $\eta$

- **Check**: Re-calibrate setting $\eta \in \{7, 16\}$ exogenously.

- **Transition dynamics results**:

<table>
<thead>
<tr>
<th></th>
<th>Initial</th>
<th>Final</th>
<th>$\Delta$ (p.p.)</th>
<th>Impact (p.p.)</th>
<th>Transition (p.p.)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Panel A. Fixing $\eta = 7$</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Productivity growth</td>
<td>1.48%</td>
<td>1.61%</td>
<td>+0.13</td>
<td>+0.09</td>
<td>+0.04</td>
</tr>
<tr>
<td>Aggregate markup</td>
<td>30.70%</td>
<td>32.20%</td>
<td>+1.5</td>
<td>−1.08</td>
<td>+2.58</td>
</tr>
<tr>
<td>Trade share</td>
<td>13.50%</td>
<td>27.05%</td>
<td>+13.55</td>
<td>+12.58</td>
<td>+0.97</td>
</tr>
<tr>
<td>Emp. share of the fringe</td>
<td>30.31%</td>
<td>20.51%</td>
<td>−9.80</td>
<td>−9.17</td>
<td>−0.63</td>
</tr>
<tr>
<td>Trade cost ($\tau$)</td>
<td>1.6404</td>
<td>1.3240</td>
<td>.</td>
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<td>.</td>
</tr>
<tr>
<td><strong>Panel B. Fixing $\eta = 16$</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Productivity growth</td>
<td>1.49%</td>
<td>1.61%</td>
<td>+0.12</td>
<td>+0.08</td>
<td>+0.04</td>
</tr>
<tr>
<td>Aggregate markup</td>
<td>20.02%</td>
<td>22.21%</td>
<td>+2.19</td>
<td>−0.87</td>
<td>+3.06</td>
</tr>
<tr>
<td>Trade share</td>
<td>10.73%</td>
<td>21.48%</td>
<td>+10.75</td>
<td>+8.84</td>
<td>+1.91</td>
</tr>
<tr>
<td>Emp. share of the fringe</td>
<td>23.51%</td>
<td>16.23%</td>
<td>−7.28</td>
<td>−6.50</td>
<td>−0.78</td>
</tr>
<tr>
<td>Trade cost ($\tau$)</td>
<td>1.3637</td>
<td>1.2420</td>
<td>.</td>
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</tr>
</tbody>
</table>
Appendix: Robustness 3: Fixed cost of exporting

- **Check:** Re-calibrate with fixed cost of exporting ($\kappa$). Target share of firms that export.

- **Extended model:** Export threshold on market share $\rightarrow$ Firm exports iff $\sigma^F_H > \hat{\sigma}$ where

$$\hat{\sigma} \equiv \frac{\kappa \eta}{1 + \kappa (\eta - 1)}$$

- **Transition dynamics results:**

<table>
<thead>
<tr>
<th></th>
<th>Initial</th>
<th>Final</th>
<th>$\Delta$ (p.p.)</th>
<th>Impact (p.p.)</th>
<th>Transition (p.p.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Productivity growth</td>
<td>1.45%</td>
<td>1.59%</td>
<td>+0.15</td>
<td>+0.04</td>
<td>+0.11</td>
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<tr>
<td>Aggregate markup</td>
<td>33.02%</td>
<td>33.98%</td>
<td>+0.96</td>
<td>−2.00</td>
<td>+2.96</td>
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<tr>
<td>Trade share</td>
<td>11.62%</td>
<td>23.26%</td>
<td>+11.64</td>
<td>+11.04</td>
<td>+0.60</td>
</tr>
<tr>
<td>Emp. share of the fringe</td>
<td>26.69%</td>
<td>17.79%</td>
<td>−8.90</td>
<td>−8.65</td>
<td>−0.25</td>
</tr>
<tr>
<td>Trade cost ($\tau$)</td>
<td>1.3492</td>
<td>1.2752</td>
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</table>
### A. Aggregate data

<table>
<thead>
<tr>
<th>Moment</th>
<th>Baseline</th>
<th>Lower $\mu$</th>
<th>$\eta = 7$</th>
<th>$\eta = 16$</th>
<th>$\kappa$</th>
<th>cost</th>
<th>Data</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Productivity growth</td>
<td>1.61%</td>
<td>1.59%</td>
<td>1.61%</td>
<td>1.61%</td>
<td>1.59%</td>
<td>1.58%</td>
<td>EU KLEMS</td>
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<tr>
<td>R&amp;D share of VA</td>
<td>8.3%</td>
<td>6.3%</td>
<td>9.7%</td>
<td>7.6%</td>
<td>10.8%</td>
<td>9.8%</td>
<td>OECD</td>
<td></td>
</tr>
<tr>
<td>Import share</td>
<td>24.0%</td>
<td>23.4%</td>
<td>27.0%</td>
<td>21.5%</td>
<td>23.3%</td>
<td>23.5%</td>
<td>Census, NBER</td>
<td></td>
</tr>
<tr>
<td>St. dev. import shares</td>
<td>18.1%</td>
<td>17.2%</td>
<td>14.6%</td>
<td>21.2%</td>
<td>21.2%</td>
<td>21.3%</td>
<td>Census, NBER</td>
<td></td>
</tr>
<tr>
<td>Share of exporting firms</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>63.4%</td>
<td>49.0%</td>
<td>Bernard et al. (‘18)</td>
<td></td>
</tr>
</tbody>
</table>

### B. Firm-level data

<table>
<thead>
<tr>
<th>Moment</th>
<th>Baseline</th>
<th>Lower $\mu$</th>
<th>$\eta = 7$</th>
<th>$\eta = 16$</th>
<th>$\kappa$</th>
<th>cost</th>
<th>Data</th>
<th>Data Source</th>
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</thead>
<tbody>
<tr>
<td>Average markup</td>
<td>33.0%</td>
<td>20.4%</td>
<td>39.7%</td>
<td>30.5%</td>
<td>36.6%</td>
<td>35.4%</td>
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</tr>
<tr>
<td>St. dev. of markups</td>
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<td>26.7%</td>
<td>47.0%</td>
<td>51.3%</td>
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<td>Entry rate</td>
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<td>6.4%</td>
<td>5.2%</td>
<td>5.2%</td>
<td>5.9%</td>
<td>6.5%</td>
<td>Census</td>
<td></td>
</tr>
<tr>
<td>Contr. entrants growth</td>
<td>27.0%</td>
<td>24.2%</td>
<td>28.0%</td>
<td>26.0%</td>
<td>26.6%</td>
<td>25.7%</td>
<td>Akcigit-Kerr (‘18)</td>
<td></td>
</tr>
<tr>
<td>Emp. share of fringe</td>
<td>17.5%</td>
<td>17.6%</td>
<td>20.5%</td>
<td>16.2%</td>
<td>17.8%</td>
<td>18.2%</td>
<td>Census, NSF</td>
<td></td>
</tr>
</tbody>
</table>

**Table:** Calibration results for the different robustness exercises.

* = Targets for these moments are halved in the robustness exercise labeled “Lower $\mu$. “
Appendix: Social Planner (1/2)

1 Static inefficiencies → Details → Labor misallocation, within and across industries.

- **Within** → SP wants zero markup dispersion within industries.
- **Across** → SP allocates equal labor to all industries.

Figure: Left: TFP losses wrt 1st best. Right: Labor allocation wrt 1st best.

2 Dynamic inefficiencies → Details → Business stealing (−) and knowledge (+) externalities.

- Planner wants higher R&D share of GDP and higher growth rate.
Insights from Social Planner solution:

1. Moving from 1970s BGP to present-day (BGP comparison):
   - 9.2% CE gains for the Decentralized Equilibrium.
   - 6.8% CE gains for the Social Planner.

2. Reduction in trade costs closes the gap between DE allocation and Pareto frontier.
   - 16% reduction in misallocation ($1 − Y_0^{DE} / Y_0^{SP}$) between autarky and baseline.
   - SP growth rate is almost invariant to $\tau$ (↑ 0.3%).
Appendix: Social Planner (Static Part)

- Labor allocation in the DE (differences with SP in olive):

\[ \ell_H(n) = \sigma_H(n) \cdot \left( \frac{\mu_H(n)}{\mu} \right)^{-1} \]

where \( \sigma_H(n) = \left( 1 + \frac{\omega_C}{\omega_H} (1 + \lambda)^{-n_c(\eta-1)} \left( \frac{\mu_H(n)}{\mu_C H(n)} \right)^{\eta-1} + \frac{\omega_F}{\omega_H} \left( \frac{(1 + \lambda)^{-n}}{\tau} \right)^{\eta-1} \left( \frac{\mu_H(n)}{\mu_F(n)} \right)^{\eta-1} \right)^{-1} \)

- The SP’s labor allocation corresponds to \( \mu_H = \mu^*_H = \mu_C H = \mu = 1 \).

- Markup dispersion yields TFP losses:

\[ TFP(n) = \left( \frac{\omega_H}{\sigma_H(n)} \right)^{-\frac{1}{\eta-1}} \left( \sigma_H(n) + \sigma_C H(n) \frac{\mu_H(n)}{\mu_C H(n)} + \sigma_F(n) \frac{\mu_H(n)}{\mu_F(n)} \right)^{-1} \]

\[ TFP^*(n) = \left( \frac{\omega_H}{\sigma_H^*(n)} \right)^{-\frac{1}{\eta-1}} \]
Appendix: Social Planner (Dynamic Part)

- SP chooses R&D rates (incumbents):

\[
\frac{\chi_i \psi_i \left[ z_i^* (n, n_C) \right]^{\psi_i - 1}}{1 - \text{R&D Share}^{H*}} = \frac{\ln(1 + \lambda)}{\rho} + \nu(n + 1, n_C + 1) - \nu(n, n_C)
\]

- Marginal social cost of innovation

- Permanent increase in productivity

- Change in shadow value of innovation

- Marginal social return of innovation

Differences between social and private costs/returns:

1. Firms do not internalize that their innovations will benefit future innovators (positive externality).

2. Firms do not internalize that part of their (private) gains from innovation comes from decrease in value of other firms through business stealing (negative externality).