Consumption-led Growth

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Introduction
Motivation I

- Gourinchas and Jeanne (2013): the capital allocation puzzle

Figure 1

Average productivity growth and capital inflows between 1980 and 2000 for 68 non-OECD countries.

2. Net capital inflows are measured as the ratio of a country's current account deficit over its GDP, averaged over the period 1980–2000. The construction of the data is explained in more detail in Section 3.

3. The regression line on Figure 1 has a slope $-0.72$ (p-value of 0.1%).

As we show in this article, the pattern observed in Figure 1 is just one illustration of a range of results that point in the same direction. Capital flows from rich to poor countries are not only low (as argued by Lucas (1990)), but their allocation across developing countries is negatively correlated or uncorrelated with the predictions of the standard textbook model. This is the “allocation puzzle.”
Motivation I

- Gourinchas and Jeanne (2013): **the capital allocation puzzle**

![Graph showing productivity growth and capital inflows for 68 non-OECD countries between 1980 and 2000.](image)

Average productivity growth and capital inflows between 1980 and 2000 for 68 non-OECD countries.

- In this paper, we swap the axes of this plot: **can international capital flows alter productivity growth trajectories?**
1. What is the relationship between openness and growth?
   - trade openness
   - financial openness
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2. Is it possible to borrow like Argentina or Spain and grow like China?
   (i) What is wrong with Spanish-style (consumption-led) growth?
   (ii) What is special about Chinese-style (export-led) growth?
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• A model of endogenous convergence growth
  - to open the blackbox of productivity evolution under different openness regimes
  - a “neoclassical” (DRS) environment with endogenous innovation decisions by entrepreneurs
  - emphasis on the feedback from international borrowing into the pace and composition (T vs NT) of convergence
Figure 1: CA imbalances in the Euro Zone
Figure 1: Sectoral reallocation in the Euro Zone (Piton, 2017)
Main Insights

• Openness has two effects (on incentives for innovation):
  (i) change in relative market size
  (ii) increase in foreign competition and domestic cost of production, a price effect
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- Trade deficits (a) unambiguously favor non-tradable sector and (b) tend to reduce pace of innovation
  - reduced-form relationship between \( NX \) and sectoral growth
  - furthermore, \( NX / Y \) is a sufficient statistic
  - trade surpluses promote GDP growth
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- Laissez-faire productivity growth is in general suboptimal
  - capital controls may improve upon market allocation
• Neoclassical investment theory: Barro, Mankiw & Sala-i-Martin (1995)

• Learning-by-doing and Dutch disease

• Trade and growth

• Financial flows and growth:

• Trade and growth with Frechet distributions and beyond
Model Setup
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- Real small open economy in continuous time
  - exogenous world interest rate $r^*$ in terms of world good

- Two sector economy:
  - $\gamma$ tradable (exportable) and
  - $1 - \gamma$ non-tradable (non-exportable)

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- Rest of the world (ROW) in steady state:
  \[ W^* = A_T^* = A_N^* = A^* \quad \text{and} \quad P_F^* = P_N^* = P^* = 1 \]

- We study convergence growth trajectories:
  \[ A_T(0), A_N(0) < \bar{A} \leq A^* \]

- Growth results from new product creation by profit-maximizing entrepreneurs
Households

- Representative household:

\[
\max_{\{C(t), L(t)\}} \int_0^\infty e^{-\vartheta t} U(t) dt, \quad U = \frac{1}{1-\sigma} C^{1-\sigma} - \frac{1}{1+\varphi} L^{1+\varphi}
\]

s.t. \[
\dot{B} = r^* B + WL + \Pi - PC \overset{=GDP}{=} Y
\]
Households

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\]

s.t. \(\dot{B} = r^* B + WL + \Pi - PC\) \(= GDP\) \(= Y\)

- Static market clearing (goods and labor):

\[
WL = Y + NX, \quad C^\sigma L^{\varphi} = W/P
\]
Demand

- Two sectors:

\[ Y = PC = \gamma P_T C_T + (1 - \gamma) P_N C_N \]

where

\[ C = C_T^\gamma C_N^{1-\gamma} \quad \text{and} \quad C_T = \left[ \kappa \frac{1}{\rho} C_F^\rho + (1 - \kappa) \frac{1}{\rho} C_H^\rho \right] \frac{\rho}{\rho - 1}, \quad \rho > 1 \]

- Aggregators of individual varieties:

\[ C_H = \left[ \frac{1}{\gamma} \int_0^{\Lambda_T} C_H(i) \frac{\rho - 1}{\rho} \, di \right] \frac{\rho}{\rho - 1} \quad \text{and} \quad C_N = \left[ \frac{1}{1 - \gamma} \int_0^{\Lambda_N} C_N(i) \frac{\rho - 1}{\rho} \, di \right] \frac{\rho}{\rho - 1} \]
Exports and Imports

- Tradable expenditure:
  \[ \gamma P_T C_T = \int_0^{\Lambda_T} P_H(i) C_H(i) \, di + \gamma P_F C_F \]

- Aggregate imports:
  \[ X^* = \gamma P_F C_F = \gamma \kappa \left( \frac{P_F}{P_T} \right)^{1-\rho} Y, \quad P_F = \tau P_F^* = \tau \]

- Aggregate exports:
  \[ X = \gamma P_H^* C_H^* = \gamma \kappa (\tau P_H)^{1-\rho} Y^* \]

- Net exports:
  \[ NX = X - X^* = \gamma \kappa \tau^{1-\rho} \left[ P_H^{1-\rho} Y^* - P_T^{\rho-1} Y \right] \]
Technology and Revenues

- Technology of product $i \in [0, \Lambda_J]$ in sector $J \in \{T, N\}$:
  \[ Y_J(i) = A_J(i)L_J(i) \]
Technology and Revenues

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• Marginal cost pricing if technology is non-excludable:

$$P_H = \frac{W}{A_T} \quad \text{where} \quad A_T = \left[ \frac{1}{\gamma} \int_0^{\Lambda_T} A_T(i)^{\rho-1} \, di \right]^{\frac{1}{\rho-1}}$$
Technology and Revenues

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- Revenues:
  \[ R_N(i) = P_N(i)C_N(i) = \left( \frac{P_N(i)}{P_N} \right)^{1-\rho} R_N, \]
  \[ R_T(i) = P_H(i)C_H(i) + P_H^*(i)C_H^*(i) = \left( \frac{P_H(i)}{P_H} \right)^{1-\rho} R_T \]

  where $R_N = Y$ and
  \[ R_T = (1 - \kappa) \left( \frac{P_H}{P_T} \right)^{1-\rho} Y + \kappa(\tau P_H)^{1-\rho} Y^* = Y \left[ 1 + \frac{NX}{\gamma Y} \right] \]
Technology Draws

- An entrepreneur has $n \gg 1$ possible ideas (projects):

$$Z_{J(\ell)}(\ell) \overset{iid}{\sim} \text{Frechet}(z, \theta), \quad \ell = 1..n, \quad \theta > \rho - 1$$

- A fraction $\gamma$ of ideas are tradable, $J(\ell) = T$
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- The technology is privately owned for one period
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- Period profits:
  \[
  \Pi_T(\ell) = \frac{1}{\rho} \left( \frac{\rho}{\rho - 1} \frac{W}{Z_T(\ell)} \frac{1}{P_H} \right)^{1-\rho} R_T \\
  \Pi_N(\ell) = \frac{1}{\rho} \left( \frac{\rho}{\rho - 1} \frac{W}{Z_N(\ell)} \frac{1}{P_N} \right)^{1-\rho} R_N
  \]
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  $$\Pi_T(\ell) = \frac{1}{\rho} \left( \frac{\rho}{\rho - 1} \frac{W}{Z_T(\ell)P_H} \right)^{1-\rho} R_T = q \frac{R_T}{A_T^{\rho-1}} Z_T(\ell)^{\rho-1}$$
  
  $$\Pi_N(\ell) = \frac{1}{\rho} \left( \frac{\rho}{\rho - 1} \frac{W}{Z_N(\ell)P_N} \right)^{1-\rho} R_N = q \frac{R_N}{A_N^{\rho-1}} Z_N(\ell)^{\rho-1}$$
Technology Adoption

- Project choice:

\[
\hat{\ell} = \arg \max_{\ell=1..n} \prod_{J(\ell)}(\ell)
\]

and we define \((\hat{Z}_T, \hat{Z}_N, \hat{Z})\) and \((\hat{\Pi}_T, \hat{\Pi}_N, \hat{\Pi})\)
Project choice:
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\hat{\ell} = \arg \max_{\ell=1..n} \Pi_{J(\ell)}(\ell)
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**Lemma 1**  (i) *The probability to adopt a tradable project:*

\[
\pi_T \equiv \mathbb{P}\{\hat{\Pi}_T \geq \hat{\Pi}_N\} = \frac{\gamma \cdot \chi^{\rho-1}_\theta}{\gamma \cdot \chi^{\rho-1} + 1 - \gamma}, \quad \chi \equiv \left(\frac{P_H}{P_N}\right)^{\rho-1} \frac{R_T}{R_N}.
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- **Lemma 1** (i) The probability to adopt a tradable project:
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  \]
  (ii) The productivity conditional on adoption:
  \[
  \mathbb{E}\left\{\hat{Z}_T^{\rho - 1} \mid \hat{\Pi}_T \geq \hat{\Pi}_N\right\} = \left(\frac{\pi_T}{\gamma}\right)^{\nu - 1} A^{\rho - 1},
  \]
  where \(A^* \equiv \mathbb{E}\hat{Z} = (nz)^{1/\theta} \Gamma(\nu)^{1/\rho} \) and \(\nu \equiv 1 - \frac{\rho - 1}{\theta} \in (0, 1)\).
Productivity Dynamics

- \( \lambda \) is the innovation rate and \( \delta \) is the rate at which technologies become obsolete:

\[
\dot{\Lambda}_T = \lambda \pi_T - \delta \Lambda_T
\]

- Assume \( \lambda \) is country-specific and \( \lambda \leq \delta \)
Productivity Dynamics

- $\lambda$ is the innovation rate and $\delta$ is the rate at which technologies become obsolete:

$$\dot{\Lambda}_T = \lambda \pi_T - \delta \Lambda_T$$

- Assume $\lambda$ is country-specific and $\lambda \leq \delta$

- **Lemma 2** The sectoral productivity dynamics is given by:

$$\frac{\dot{A}_T}{A_T} = \frac{\delta}{\rho - 1} \left[ \left( \frac{\bar{A}}{A_T} \right)^{\rho - 1} \left( \frac{\pi_T}{\gamma} \right)^\nu - 1 \right]$$

where $\bar{A} \equiv A^* \left( \frac{\lambda}{\delta} \right)^{\frac{1}{\rho - 1}}$. 
\[ \frac{\dot{A}_T(t)}{A_T(t)} = \frac{1}{\rho - 1} \left[ \lambda \left( \frac{A^*}{A_T(t)} \right)^{\rho-1} \left( \frac{\pi_T(t)}{\gamma} \right)^{\nu} - \delta \right], \]

\[ \frac{\pi_T(t)}{1 - \pi_T(t)} = \frac{\gamma}{1 - \gamma} \chi(t)^{\frac{\theta}{\rho - 1}}, \]

\[ \chi = \left( \frac{P_H}{P_N} \right)^{\rho-1} \frac{R_T}{R_N} = \left( \frac{A_N}{A_T} \right)^{\rho-1} \left[ 1 + \frac{NX}{\gamma Y} \right], \]

\[ B(0) + \int_0^\infty e^{-rt} NX(t) = 0. \]
Closed Economy
Closed Economy, $\kappa \equiv 0$

- In closed economy $R_T = R_N = Y$, and therefore:
  \[
  \chi = \left( \frac{P_H}{P_N} \right)^{\rho - 1} = \left( \frac{A_N}{A_T} \right)^{\rho - 1}
  \]

- The project choice is, thus:
  \[
  \frac{\pi_T(t)}{1 - \pi_T(t)} = \frac{\gamma}{1 - \gamma} \left( \frac{A_N(t)}{A_T(t)} \right)^{\theta}
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- **Proposition 1** (i) *Starting from $A_T(0) = A_N(0)$, equilibrium project choice in the closed economy is $\pi_T(t) \equiv \gamma$,

  $$A_T(t) = \left[ e^{-\delta t} A_T(0)^{\rho^{-1}} + (1 - e^{-\delta t}) \bar{A}^{\rho^{-1}} \right]^{\frac{1}{\rho^{-1}}} \text{ and } \bar{A}_T = \gamma \frac{\lambda}{\delta}.$$  

(ii) *Equilibrium allocation $C = w^{\frac{1+\varphi}{\sigma+\varphi}}$, $L = w^{\frac{1-\sigma}{\sigma+\varphi}}$, $w = A$.

(iii) *Efficiency:* \[\ldots\]*
Balanced Trade
Balanced Trade

- Consider open economy with $\kappa > 0$ and $\tau \geq 1$

- **Lemma 3**  
  (i) The relative revenue shifter is given by:

  \[
  \frac{R_T}{R_N} = (1 - \kappa) \left( \frac{P_H}{P_T} \right)^{1-\rho} + \kappa (\tau P_H)^{1-\rho} \frac{Y^*}{Y} = 1 + \frac{NX}{\gamma Y}.
  \]

  (ii) Under balanced trade, $\chi = (A_N/A_T)^{\rho-1}$, and hence $\pi_T(t)$ and $(A_T(t), A_N(t))$ follow the same path as in autarky.
Balanced Trade

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- Equilibrium allocation is nonetheless different from autarkic:

$$w = C = A \cdot \left( \frac{1}{\tau^{2\rho-1}} \frac{A^*}{A_T} \right)^{\frac{\kappa \gamma}{1+(2-\kappa)(\rho-1)}}$$
Balanced Trade

• Consider open economy with $\kappa > 0$ and $\tau \geq 1$

• **Lemma 3** (i) The relative revenue shifter is given by:

$$\frac{R_T}{R_N} = (1 - \kappa) \left( \frac{P_H}{P_T} \right)^{1-\rho} + \kappa \left( \rho P_H \right)^{1-\rho} \frac{Y^*}{Y} = 1 + \frac{NX}{\gamma Y}.$$

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• Laisser-faire productivity dynamics is suboptimal. The planner would choose $\pi_T(t) < \gamma$ for all $t \geq 0$. 
Open Economy
Financial Openness

- With open current account:

\[ \frac{\pi_T}{1 - \pi_T} = \frac{\gamma}{1 - \gamma} \left( \frac{A_N}{A_T} \right)^\theta \left[ 1 + \frac{NX}{\gamma Y} \right]^{\frac{\theta}{\rho-1}} \]
Financial Openness

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\]

• **Lemma 4** \( NX(t) < 0 \) and \( A_T(t) \geq A_N(t) \) \( \Rightarrow \) \( \dot{A}_T(t) < \dot{A}_N(t) \).

• **Proposition 5** In st.st. with \( \overline{NX} = -r^* \bar{B} > 0 \): \( \bar{A}_T > \bar{A} > \bar{A}_N \).

• **Proposition 6** Starting from \( A_T(0) = A_N(0) < \bar{A} \), there exist two cutoffs \( 0 < t_1 < t_2 < \infty \):

  - \( NX(t) < 0 \) for \( t \in [0, t_1) \) and \( NX(t) > 0 \) for \( t > t_1 \), and
  - \( A_T(t) < A_N(t) \) for \( t \in (0, t_2) \) and \( A_T(t) > A_N(t) \) for \( t > t_2 \). At \( t = t_2 \), \( A_T(t) = A_N(t) = A(t) < A^a(t) \).
Figure 2: Productivity convergence in closed and open economies
Impact of Openness

- Two effects of openness:
  1. Relative size of the market: \( Y/Y^* \)
  2. Competition: \( P_T/P_H < 1 \)

\[
1 + \frac{NX}{\gamma Y} = \left( \frac{P_H}{P_T} \right)^{1-\rho} \cdot \left[ (1 - \kappa) + \kappa \left( \frac{\tau}{P_H} \right)^{1-\rho} \frac{X^*}{P_T^{\rho-1} Y} \right]
\]
Endogenous Innovation
Endogenous Innovation Rate

- Entrepreneurship decision as in Lucas (1978) if $\hat{\Pi} \geq \phi W$:

  $$\lambda = \Phi \left( \frac{\hat{\Pi}}{W} \right) \quad \text{and} \quad \frac{\hat{\Pi}}{W} = \frac{\rho R_N/W}{A_\rho^{-1}} \max \left\{ \chi \hat{Z}_T^{\rho-1}, \hat{Z}_N^{\rho-1} \right\}$$

- Lemma 5

  $$\frac{\hat{\Pi}}{W} = \rho \cdot \left( \frac{A^*}{A} \cdot \frac{A}{\hat{A}_\theta} \right)^{\rho-1} \cdot \psi \left( 1 + \frac{NX}{Y} \right)$$

- Proposition 8

  (i) $\lambda$ is increasing in $A^*/A$ and in $A/\hat{A}_\theta \geq 1$.

  (ii) $\lambda$ increases with trade openness $\sigma < 1$ and $\phi < \infty$.

  (iii) When $\sigma = 1$, $\Psi \approx 1 + \left[ \left( A_N/A_T \right)^{1-\gamma} - \phi \right]^{1+\phi} \cdot NX/Y$, and $\lambda$ increases with $NX$ when $A_N \geq A_T$. 

- Endogenous non-tradable tilt reinforces the negative effect of trade deficits on innovation rate.

- Induced $NX > 0$ with policy if the goal is max growth rate.
Endogenous Innovation Rate

- Entrepreneurship decision as in Lucas (1978) if \( \hat{\Pi} \geq \phi W \):
  \[
  \lambda = \Phi \left( \frac{\hat{\Pi}}{W} \right) \quad \text{and} \quad \frac{\hat{\Pi}}{W} = \frac{\phi R_N/W}{A^{\rho-1}_N} \max \left\{ \chi \hat{Z}_T^{\rho-1}, \hat{Z}_N^{\rho-1} \right\}
  \]

- **Lemma 5**
  \[
  \frac{\hat{\Pi}}{W} = \varrho \cdot \left( \frac{A^*}{A} \cdot \frac{A}{\hat{A}_\theta} \right)^{\rho-1} \cdot \psi \left( 1 + \frac{NX}{Y} \right)
  \]

- **Proposition 8**
  (i) \( \lambda \) is increasing in \( A^*/A \) and in \( A/\hat{A}_\theta \geq 1 \).
  (ii) \( \lambda \) increases with trade openness iff \( \sigma < 1 \) and \( \varphi < \infty \).
  (iii) When \( \sigma = 1 \), \( \Psi \approx 1 + \left[ \left( \frac{A_N}{A_T} \right)^{1-\gamma} - \frac{\varphi}{1+\varphi} \right] \frac{NX}{Y} \), and \( \lambda \) increases with \( NX \) when \( A_N \geq A_T \).
Endogenous Innovation Rate

- Entrepreneurship decision as in Lucas (1978) if $\hat{E}\hat{\Pi} \geq \phi W$:
  \[ \lambda = \Phi \left( \frac{\hat{E}\hat{\Pi}}{W} \right) \quad \text{and} \quad \frac{\hat{E}\hat{\Pi}}{W} = \frac{\varrho R_N/W}{A^p_N} \max \left\{ \chi \hat{Z}_T^{-1}, \hat{Z}_N^{-1} \right\} \]

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- **Proposition 8** (i) $\lambda$ is increasing in $A^*/A$ and in $A/\hat{A}_\theta \geq 1$.
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  (iii) When $\sigma = 1$, $\psi \approx 1 + \left[ \left( \frac{A_N}{A_T} \right)^{1-\gamma} - \frac{\varphi}{1+\varphi} \right] \frac{NX}{Y}$, and $\lambda$ increases with $NX$ when $A_N \geq A_T$.

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- Induced $NX > 0$ with policy if the goal is max growth rate
Empirical Implications
Empirical Implications

- Reduced-form relationship between $NX$ and sectoral growth:

$$\frac{\dot{A}_T(t)}{A_T(t)} - \frac{\dot{A}_N(t)}{A_N(t)} = g_0 \left[ -(\rho - 1)(1 + \mu) \log \frac{A_T(t)}{A_N(t)} + \frac{\mu}{\gamma} \frac{NX(t)}{Y(0)} \right],$$

with $g_0 \equiv \frac{\delta}{\rho - 1} \left( \frac{\lambda}{\delta} \frac{A^n}{A_0} \right)^{\rho - 1}$, which is also the base growth rate

- holds whether $NX \neq 0$ are market outcomes or policy-induced
- i.e., applies equally for $NX < 0$ in Spain and $NX > 0$ in China

- $NX/Y$ is a sufficient statistic for the feedback effect from equilibrium allocation to sectoral productivity growth
Preliminary empirical results

- KLEMS panel of sector-country productivity growth
  (17 OECD countries, 33 ∼3-digit sectors, 2001–2007 change)

- Empirical specification:
  \[ \Delta \log A_{ks} = d_k + d_s + b \cdot \log A^0_{ks} + c \cdot \Lambda_s \cdot n x_k + \varepsilon_{ks} \]
  - \( \Delta \log A_{ks} \) is productivity growth in sector \( s \), country \( k \)
  - \( \Lambda_s \) is median sector-level home share across countries
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  \]

<table>
<thead>
<tr>
<th>Dep. var: ( \Delta \log A_{ks} )</th>
<th>VA/L ( (1) )</th>
<th>RVA/L ( (2) )</th>
<th>KLEMS ( (3) )</th>
<th>VA/L ( (4) )</th>
<th>RVA/L ( (5) )</th>
</tr>
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<tbody>
<tr>
<td>( \Lambda_s \cdot n x_k )</td>
<td>(-0.36^{***})</td>
<td>(-0.41^{**})</td>
<td>0.07</td>
<td>(-0.20)</td>
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<td>(0.10)</td>
<td>(0.15)</td>
<td>(0.20)</td>
<td>(0.14)</td>
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<td>( \log A^0_{ks} )</td>
<td>(-4.75^{**})</td>
<td>(-4.43^{***})</td>
<td>(-0.74)</td>
<td>(-2.17^{**})</td>
<td>(-3.40^{***})</td>
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<td>(1.76)</td>
<td>(0.98)</td>
<td>(0.72)</td>
<td>(0.73)</td>
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<td>( R^2 )</td>
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<td>0.57</td>
<td>0.33</td>
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<td>0.59</td>
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<td>Observations</td>
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</tbody>
</table>

--- 6% trade deficit reduces relative sectoral productivity growth by 1% across tradability quartiles (25th–75th)
Unit Labor Costs

- Two ULC measures: $\frac{w}{A}$ and $\frac{W}{A_T}$
  - move together holding $\tau$ constant

- Autarky (assume $\sigma = 1$):
  $$w^a(t) = C^a(t) = A(t)$$

- Balanced trade:
  $$w^b(t) = C^b(t) = A(t) \left( \frac{A^*}{A_T(t)} \right)^{\frac{\kappa \gamma}{1+(2-\kappa)(\rho-1)}} > A(t)$$

- Open financial account:
  $$w^b(0) < w(0) < C(0)$$

- ULC increase on impact and gradually fall along the convergence path
Applications
1. Physical capital and financial frictions

2. Misallocation and growth policy

3. Rollover crisis
   - Sudden stop in capital flows during transition triggers a reversal in trade deficits and a recession in non-tradable sector
   - Rapid take off in tradable productivity growth, provided labor market can flexibly adjust by a sharp decline in wages
Rollover Crisis
Conclusion
Conclusion

- Standard endogenous growth forces have a robust implication for the relationship between trade deficits and:
  1. non-tradable tilt of innovation
  2. overall lower speed of convergence growth

- Countries that borrow along the convergence growth trajectory are likely to experience asymmetric and slower convergence
  - lagging tradable productivity
  - high unit labor costs and depressed innovation rate
  - particularly vulnerable to rollover crisis along such trajectories

- Countries that are concerned with GDP growth rather than welfare might find it optimal to subsidize exports
Appendix
Price Indexes

- Average sectoral prices:
  \[ P_H = \left[ \frac{1}{\gamma} \int_0^{\Lambda_T} P_H(i)^{1 - \rho} \, di \right]^{\frac{1}{1 - \rho}} \quad \text{and} \quad P_N = \left[ \frac{1}{1 - \gamma} \int_0^{\Lambda_N} P_N(i)^{1 - \rho} \, di \right]^{\frac{1}{1 - \rho}} \]

- Aggregate price indexes:
  \[ P = P_T^{\gamma} P_N^{1 - \gamma} \text{ where } P_T = \left[ \kappa P_F^{1 - \rho} + (1 - \kappa) P_H^{1 - \rho} \right]^{\frac{1}{1 - \rho}} \]

- Equilibrium sectoral prices:
  \[ P_H = \frac{W}{A_T}, \quad P_N = \frac{W}{A_N} \quad \text{and} \quad P_F = \tau \]

- Real wage rate:
  \[ w = \frac{W}{P} = A \left[ 1 - \kappa + \kappa \left( \frac{W}{\tau A_T} \right)^{\rho - 1} \right]^{\frac{\gamma}{\rho - 1}}, \quad A \equiv A_T^{\gamma} A_N^{1 - \gamma} \]
Solution for NX

- Equilibrium system:

\[ C = w^{\frac{1 + \varphi}{\sigma + \varphi}} \left[ 1 + \frac{NX}{Y} \right]^{-\frac{\varphi}{\sigma + \varphi}} \quad \text{where} \quad w = A \left( \frac{W}{\tau A_T} \right)^{\kappa \gamma} \]

and

\[ \frac{NX}{Y} = \frac{\gamma \kappa}{\left( \frac{W}{\tau A_T} \right)^{\rho - \kappa \gamma}} \left[ \tau^{1 - 2\rho} \frac{A^*^{\frac{1 + \varphi}{\sigma + \varphi}}}{C} \frac{A}{A_T} - \left( \frac{W}{\tau A_T} \right)^{(1 - \kappa \gamma) + (2 - \kappa)(\rho - 1)} \right] \]
Efficiency in Closed Economy

- **Proposition** (i) If $A_T(0) = A_N(0)$, then $\pi_T^*(t) = \gamma$ and $A_T(t) = A_N(t)$ for all $t$ maximizes $A(t)$ for all $t$.  (ii) If $A_N(t) > A_T(t)$ at some $t$, then $\pi_T^*(t) \in (\gamma, \pi_T(t))$, and laissez-faire dynamics with $\pi_T(t)$ is suboptimal.

- Optimal policy satisfies (for $J \in \{T, N\}$):

\[
\left(\frac{\pi_T^*}{1 - \pi_T^*}\right)^{1-\nu} = \frac{\xi_T}{\xi_N} \left(\frac{A_N}{A_T}\right)^{\rho-1},
\]

where $b_J(t)\xi_T(t) - \dot{\xi}_J(t) = a_J(t)$,

and $a_J(t) \equiv \left(\frac{A_J(t)}{A(t)}\right)^{\eta-1} A(t)^{\zeta}$, $b_J(t) \equiv \vartheta + \delta \left(\frac{\bar{A}}{A_J(t)}\right)^{\rho-1} \left(\frac{\pi_J(t)}{\gamma_J}\right)^{\nu}$

- $b_J(t)$ plays the role of discount rate and $a_J(t)$ is the flow benefit

- $\xi_T/\xi_N = R_T/R_N$ in the limit of $\vartheta \to \infty$ (perfect impatience)
  Otherwise, $\xi_T/\xi_T \in (1, R_T/R_N)$

- Patents with finite time-varying duration can decentralize $\pi_T^*(t)$
Comparison with Learning-by-Doing

- General learning-by-doing formulation:

\[ Y_T(t) = F(A_T(t), L_T(t)), \]
\[ \dot{A}_T(t) = G(A_T(t), A_N(t), L_T(t), L_N(t)) \]
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- Mapping of the baseline model into learning-by-doing:

\[ F(A_T, L_T) = AL, \]
\[ G(A_T, A_N, L_T, L_N) = \tilde{G}(A_T, \pi_T(A_T, A_N, L_T, L_N)), \]
\[ \tilde{G}(A_T, \pi_T) = \frac{\delta}{\rho - 1} \left[ \left( \frac{A}{A_T} \right)^{\rho - 1} \left( \frac{\pi_T}{\gamma} \right)^{\nu} - 1 \right], \]
\[ \frac{\pi_T}{1 - \pi_T} \frac{1 - \gamma}{\gamma} = \left( \frac{A_N}{A_T} \right)^{\theta} \left( \frac{R_T}{R_N} \right)^{\frac{\rho}{\rho - 1}} \quad \text{and} \quad \frac{R_T}{R_N} = \frac{L_T}{L_N} \]