Essays on Trade and China's Economy

Yang Pei

University of Houston

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My dissertation

1. Demographics, Trade, and Growth

2. The Decline in China's Trade Share of GDP: A Structural Accounting

Demographics, Trade, and Growth

Research Question

Motivation

- Nowadays, about one-third of global GDP is generated in countries with declining and aging populations
- Chief among them is China
  - As its population declines and ages, economic growth has also slowed down
- At the same time, the labor-intensive goods, that China used to specialize in, are now relocating their production
  - from China to other developing countries

Research Question: How much does demographic structure influence China's economic growth and trade patterns?

- Centering around two mechanisms
  - Age-dependent idea generation process that affects **productivity**
  - Age-dependent saving behavior that affects **capital accumulation**

What I do

- Conduct empirical analysis using Panel regression and Panel VARX model, I find
  - A strong positive association between countries' working age share, and
    - ★ Productivity growth; Investment or Saving share of GDP
  - **(Not today)** An inverse U-shaped response from a 1-percentage point young cohort share shock on
    - ★ Productivity growth; the growth rate of capital stock per person ▸ VARX

- Develop and Calibrate a OLG trade model features
  - Demographic-induced productivity change
  - Demographic-induced capital accumulation
  - Trade based on Ricardian and Heckscher-Ohlin comparative advantages (CA)

- By comparing baseline final steady state with two cases in which China's fertility and survival aligned to RoW:
  - Higher fertility boosts productivity, wage, and consumption, as more workers generate more ideas
  - Lower survival lowers productivity and wage but raises consumption by reducing desired savings

▸ Literature

Panel Regression

Effect of Demographic structure on TFP growth, and capital accumulation

$$Y_{it,t+4} = Constant + \alpha_1 Demographic_{it} + \alpha_2 Controls_{it} + f_i + f_t + \varepsilon_{it} \tag{1}$$

- Data sample: 74 countries. 10 non-overlapping 5 years from 1970 to 2019
- Dependent variables, $Y_{it,t+4}$:
  - Average yearly TFP growth rate; Average yearly Investment, or consumption share of GDP (during the period t to $t+4$)
- $Demographic_t$: Working age share [15-64/total]
- $Controls_{it}$: log real GDP per capita at t for country i; number of total population at t for country i
- f_i and f_t: country and year fixed effects

Panel regression

Main results

	Average value in the future 4 years	
VARIABLES	TFP growth rate	Cap.Formation(% GDP)
Work.Share (15-64)/ToT	11.43***	28.80**
	(3.33)	(2.17)
Control	YES	YES
Observations	732	724
R-squared	0.259	0.575

1 p.p. (or 1 s.d.) increase, in the working age share, is related to a 0.11 p.p. (or 0.81 s.d.) increase, in the average TFP growth rate over the following 4-year period.

1 p.p. (or 1 s.d.) increase, in the working age share, is related to a 0.29 p.p. (or 0.33 s.d.) increase, in the average capital formation share of GDP over the next four years.

Robustness checks: Detail

- Different age cohorts across total population: 3 cohorts: [0, 14], [15,64], [64,+); 4 cohorts: 0,24], [25,49], [50,74],[75, +); 5 cohorts: [0, 19], [20,39], [40,59], [60,79], [80,+)
- Other variable: new patent applications (per 1000 people); new industrial design applications (per 1000 people)

Model and intuition

The demographic process is governed by three exogenous variables:

- Initial population across ages, age- and time-varying fertility rates, and survival rates

▸ Demographic process

Producers produce tradable intermediate sectoral varieties given current productivity distribution

- The mean of the productivity distribution: **knowledge stock**

▸ Production

Heterogeneous households varying in age

- Differ in their ability to generate new ideas, which affects knowledge stock dynamics
  $\Rightarrow$ More people or more working age people $\rightarrow$ more new ideas generated $\rightarrow$larger increase in knowledge stock"

- Face a consumption-investment trade-off under perfect foresight
  $\Rightarrow$ Differing in saving behavior

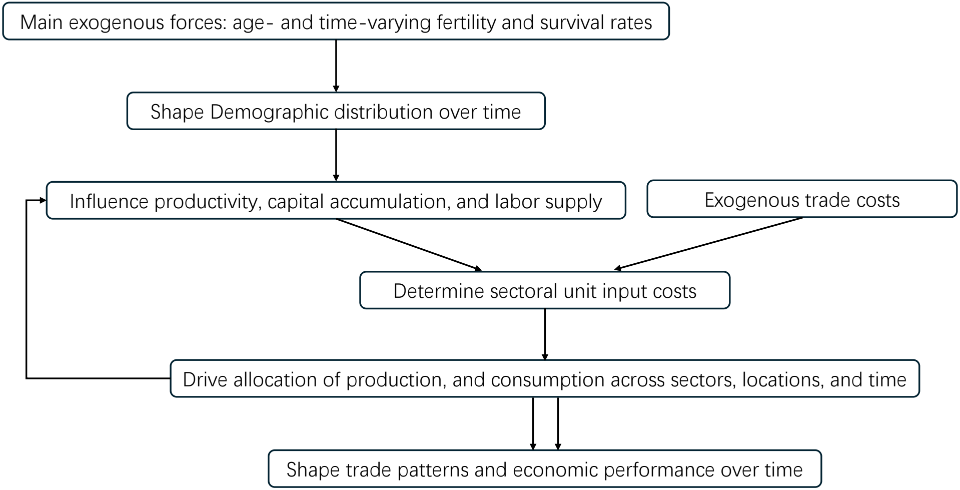
▸ Idea generation ▸ Capital accumulation

Comparative advantage regulates the allocation of production across locations and sectors

- Driven by differences in productivity, capital–labor ratios, and iceberg trade costs

▸ Trade

How model works



▸ Equilibrium

Calibration

Regions: CHN; Asian 5 (JPN, TWN, KOR, AUS, IND); USA and CAN; EUR; ROW

Sectors: Agr. ; {Labor-, Capital-intensive} $\otimes$ {Manu., Ser.}

Working age; Lifespan: 16 to 65; 85

Other time invariant parameters: From literature or impute from real data

Time varying shocks: Match real data

Time periods: 1970 to 2100

- Initial steady state: 1970; Final steady state: 2100

Data source:

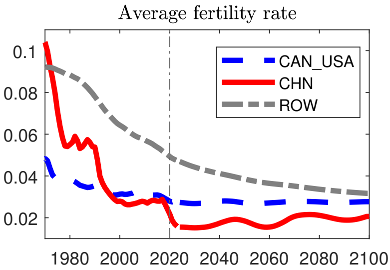
- 1971–2020: UN, PWT, WIOD Long IO Table
- 2021–2100: UN, Imputed

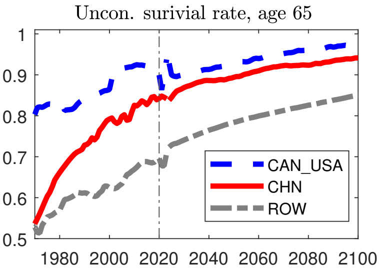
▸ Detail

Quantitative analysis

Compare final steady state

Goal: Assess long-run effects of China's demographic processes by comparing stationary equilibrium in 2100





Strategy: Compare baseline final steady state with two counterfactual scenarios:

- *Fertility = RoW:* Replace China's fertility with RoW trajectory (**higher** fertility rates)
- *Survival = RoW:* Replace China's survival with RoW trajectory (**lower** survival rates)

▸ Detail

Quantitative analysis

Compare final steady state

Table: Stationary balance growth equilibrium, China

Final Stationary balance growth equilibrium at 2100, China			
	(1) Baseline	**(2) Fert. = RoW**	**(3) Surv. = RoW**
i. Demographic variables			
Average fertility rate, 0/[21-49]	**0.02**	0.03	0.02
Survival rate, age 65	**0.94**	0.94	**0.85**
Working age pop. (billion.)	**0.30**	2.35	0.25
Implied pop. growth after 2100	**1.0%**	1.1%	1.0%
ii. Productivity in 2100			
Average productivity	**normalized as 1**	**1.65**	0.95
Implied average productivity growth	**0.3%**	0.4%	0.3%
iii. Other Outcomes in 2100			
Real wage rate	**normalized as 1**	1.38	0.94
Consumption rate = (1 - investment rate)	**49%**	**56%**	**52%**
Consumption per person	**normalized as 1**	1.49	1.08

Detail

Conclusions

Comparing the final balanced growth equilibrium reveals that both higher fertility and lower survival lead to increased consumption per person

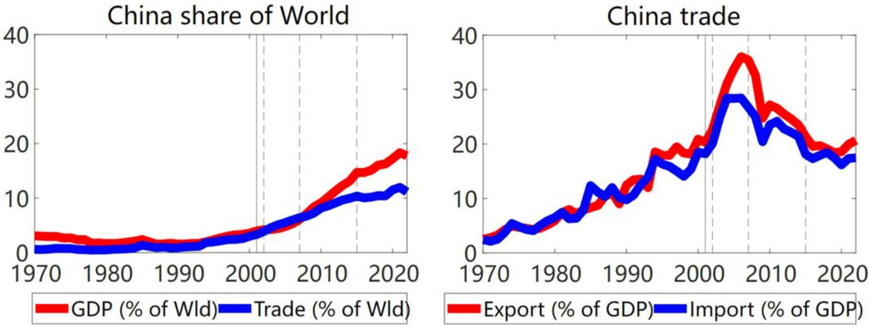
- Higher fertility increases wage and consumption:
  - More workers generate more ideas $\rightarrow$ higher productivity
  - A higher balanced-growth productivity rate reduces saving incentives

- Lower survival reduces wage but raises consumption
  - Fewer workers $\rightarrow$ lower productivity
  - Lower survival rate lowers desired savings

Overall, productivity is primarily determined by fertility, while capital per person is largely influenced by the survival rate, as it affects desired savings

The Decline in China's Trade Share of GDP: A Structural Accounting

Motivation



Source: WDI Database

Over the past 30 years, China's economy has grown enormously

- 1990-2019, Real GDP growth rate: 9.2% per year

A key feature of its growth is participation in the global economy

- 1990-2019, China's Real Trade growth rate: 10.6% per year

▸ Detail

Motivation

Despite China's increasing importance in global trade, its trade share of GDP has been declining since 2006

- At the sector level (During 2002 to 2007 and 2007 to 2015)
  - *Heavy industry* trade accounts for about 89% of trade share change

Detail

In parallel, China's internal economic integration also grows dramatically

- From 2002 to 2015, China's inner trade share of GDP almost doubled

- From 2000 to 2015, internal migrants almost doubled
  - Household registration system reform: labor moves to Coastal areas

Detail

Research Question:

- What forces have driven China's declining trade share?
  - What is the relative importance of each?

What I do

- Develop a multi-sector, multi-region Ricardian trade model (Caliendo and Parro, 2015):
  - International trade.
  - Inter-regional trade within China.
  - Labor mobility frictions across regions within China. (Tombe and Zhu, 2018)

- Calibrate (sector-region) exogenous shocks through gravity regression:
  - Total factor productivity (TFP) shocks
  - Asymmetric Trade cost shocks: **Intranational** trade and **International** trade
  - Labor mobility cost shocks

- Feed each shock separately into model to assess importance of each force

▸ Literature

Model

Overview

- Multi-region, multi-sector model with Eaton-Kortum Ricardian trade
  - N_0 China regions plus $N_1 = N - N_0$ other regions

Production

- Sectoral intermediate goods are produced using labor and sectoral composite intermediate goods
  - Under fréchet type productivity distribution
  - Sectoral intermediate goods are used for both consumption and as production inputs

Utility

- Aggregate consumption is a Cobb–Douglas aggregator of sectoral composite goods from each sector.
- Households derive utility from spending their income on aggregate consumption.

Labor Flow

- Labor moves across regions within China based on:
  - Destination wage rates
  - Fréchet-type migration costs capturing utility loss from leaving one's registered area

Trade

- Trade, determined by Ricardian comparative advantage affects sectoral reallocations

Production | Utility | Labor flow | Trade | Mechanism | Equalibrium

Calibration

Parameters and Shocks

Table: Calibration ▸ Detail

Model Structure Overview		
Regions	# of regions	11 total: 8 China regions; 3 foreign **Asian3**: Korea, Taiwan, Japan; **G6**: G7 w/o Japan; **ROW**
Periods	# of periods	2: 2002–2007; 2007–2015
Sectors	# of sectors	4: Agriculture, Light Industry, Heavy Industry, Services
Time Invariant Parameters		
$\theta = 4$	Trade elasticity	Simonovska and Waugh (2014)
$\kappa = 1.5$	Labor flow elasticity	Tombe and Zhu (2020)
$\sigma = 2$	Intermediate varieties elasticity	Broda and Weinstein (2006)
α_n^j	Expenditure share	Calculated from IO table
γ_n^j, $\gamma_n^{j,k}$	Production share	averaged across years
Time Varying Shocks		
λ_n^j	TFP	Match real data
κ_{ni}^j	Trade cost	Match real data
ν_n^j	Labor flow cost	Match real data
$\bar{L}^m$, M_{nm}	Labor supply and labor flow	Obtained from PWT and census

▸ Res ▸ Model fit ▸ IO

Counterfactual

Results: Single shocks

Table: Decompose Marginal effects

Marginal effects of different shocks	Trade Share of GDP (p.p. change)			
	2002-2007		*2007-2015*	
	External	*Internal*	*External*	*Internal*
All Forces (Baseline)	7.78	21.83	-10.28	5.16
TFP	**-12.55**	2.04	**-10.75**	-0.12
Demographic				
Migration firction	1.99	1.01	-1.84	0.14
Population growth	-0.36	0.08	-0.47	-0.07
Trade cost				
Intranational	-2.31	21.36	-0.24	-0.41
International	**9.86**	-1.65	-4.47	-1.42
Other forces	**6.08**	-1.42	0.37	2.25

Baseline : all shocks realized as actual

Counterfactual : hold specific shock at the base year level while all other shocks realized as actual

Marginal effects of specific shock $\equiv$ Trade share under **Baseline** - Trade share under **Counterfactual**

Counterfactual

Results: Single shocks at disaggregated level

Table: Decompose Marginal effects at disaggregated level

Decompose Marginal effects at the sector level	Trade Share of GDP (p.p. change)			
	2002-2007		*2007-2015*	
	External	*Internal*	*External*	*Internal*
All Forces	**7.78**	**21.83**	**-10.28**	**5.16**
Other forces	**6.08**	**-1.42**	**0.37**	**2.25**
Foregin TFP	**5.80**	-1.47	0.67	2.11
Foregin trade cost	-0.41	0.17	-0.68	0.25
Foregin labor	0.76	-0.14	0.56	-0.07
TFP	**-12.55**	**2.04**	**-10.75**	**-0.12**
Agriculture	-0.37	0.05	-4.70	-0.78
Light industry	-1.50	0.47	-0.90	0.03
Heavy industry	**-8.42**	5.41	**-8.63**	5.24
Service	**-8.70**	-4.12	**-13.96**	-4.31
International Trade cost	**9.86**	**-1.65**	**-4.47**	**-1.42**
Agriculture	-0.24	0.00	-1.83	-0.26
Light industry	0.63	-0.14	-0.39	0.08
Heavy industry	**6.74**	-0.23	-0.92	1.00
Service	0.56	-0.78	-4.85	-1.84

Conclusions

Build trade model to explain China's trade share change over time

- Key driving forces are China's TFP change and China's export trade cost change

Story for China's trade share of GDP Change

- Overall
  - From 2002 to 2007, China's trade share of GDP increase due to
    - ★ International trade cost decline, foreign regions TFP growth
  - From 2007 to 2015, China's trade share of GDP decline due to
    - ★ China's TFP growth
- At sector level
  - In both periods, changes in TFP within the heavy industry sector play a crucial role ▸ Detail
    - ★ Through input-output linkages, changes in TFP within the services sector hold the same level of importance

Thank You

APPENDIX 1: Demographics, Trade, and Growth

Related Literature

Demographic structure and productivity

- Empirical: Feyrer (2007); Maestas, Mullen, and Powell (2023); Jones (2010); Azoulay, Graff Zivin, and Wang (2010);
  - Replicate these results at the macro level using a larger set of countries and more recent years; further estimate the dynamic effects of demographic shocks
- Models: Becker, Murphy, and Tamura (1990); Lindh and Malmberg (1999); Aksoy, Basso, Smith, and Grasl (2019); Buera and Oberfeld (2020)
  - Model the relationship between demographics and productivity by assuming age-varying ability in generating new ideas

Multi-country trade models with capital accumulation

- Sposi (2022); Eaton, Kortum, Neiman, and Romalis (2016); Alvarez (2017); Ravikumar, Santacreu, and Sposi (2019); Anderson, Larch, and Yotov (2020); and Sposi, Yi, and Zhang (2021a)
  - Link capital accumulation to age-varying demographics and analyze its interaction with trade-induced relocation and economic growth

Changes in China's trade patterns and economic growth

- Liu and Ma (2018); Tombe and Zhu (2019); Fan (2019); Hao, Sun, Tombe, and Zhu (2020); Ma and Tang (2020), Alessandria, Khan, Khederlarian, Ruhl, and Steinberg (2021); Hanwei, Jiandong, and Yue (2024); Brandt, and Lim (2024)
  - Quantify trade pattern changes and economic growth from a demographic perspective

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Empirical

Data source

The United Nations Statistics Division (UNSD)

- Age cohorts share for every 5 years, Dependence ratio, Old dependence ratio, Young dependence ratio, Total population

Penn World Table (PWT 10.01)

- Average annual hours worked by persons engaged, Number of persons engaged, Mean years of schooling, Capital stock, Real GDP, Average depreciation rate of the capital stock
- TFP calculated by PWT based on above variables

CEPII

- Imports and Exports between two countries

World Development Indicators (WDI)

- Share of household consumption, capital formation, government consumption (% share of GDP), residents new patents application, residents new industrial design application

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Panel Regression

Effects of demographic structure and trade cost change on capital/labor ratio

$$GR.K/L_{it,t+4} = Constant + \beta_1 Demographic_{it} + \beta_2 TradeCost_{it} + \beta_3 Control_{it} + f_i + f_t + \varepsilon_{it} \quad (2)$$

- $GR.K/L_{it,t+4}$: Average capital per person (k) growth rate (%) for country i during the period t to $t+4$:

$$GR.K/L_{it,t+4} = [\frac{k_{i,s+4}}{k_{i,s}}]^{\frac{1}{4}} - 1$$

- $TradeCost_{it}$: The trade cost for country i at time t, which is constructed as the Head-Ries (HR) index (Head and Mayer, 2004):

$$TradeCost_{it} = (\frac{\pi_{i,row}}{\pi_{row,row}} \frac{\pi_{row,i}}{\pi_{ii}})^{-\frac{1}{2\theta}}$$

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Panel Regression Results

Under different cohort structure

	Average value in the future 4 years								
VARIABLES	TFP growth rate			Patent.Applications (per 1000 people)			Industrial.Design.Applications (per 1000 people)		
Different age intervals:	3 cohorts	4 cohorts	5 cohorts	3 cohorts	4 cohorts	5 cohorts	3 cohorts	4 cohorts	5 cohorts
3 cohorts:	21.48***	26.22***	25.36***	-1.60***	-1.56***	-1.11***	-0.89***	-0.55***	-0.53***
[0, 14], [15,64], [64,+)	(3.61)	(4.24)	(4.08)	(-4.60)	(-7.06)	(-4.09)	(-3.84)	(-3.87)	(-2.87)
	35.46***	34.48***	31.80***	0.58***	0.18	-1.72***	0.63***	0.71***	0.08
4 cohorts:	(5.19)	(4.28)	(4.35)	(2.73)	(0.46)	(-4.06)	(4.98)	(2.87)	(0.31)
[0,24], [25,49], [50,74],	38.25***	43.60***	34.74***	2.29**	4.90***	3.59***	-0.42	1.08***	1.75***
[75, +)	(3.42)	(4.41)	(3.46)	(2.50)	(7.40)	(6.47)	(-0.98)	(2.93)	(5.20)
		13.47	55.17***		-2.59	4.23***		-1.85**	-0.31
5 cohorts:		(0.90)	(5.35)		(-1.59)	(3.99)		(-1.99)	(-0.46)
[0, 19], [20,39], [40,59],			-21.89			-7.67***			-1.09
[60,79], [80,+)			(-1.08)			(-2.62)			(-0.57)
Initial.Log	-3.46***	-3.51***	-3.51***						
.Dependent	(-4.77)	(-4.49)	(-4.55)						
PoP.Growth									
Observations	732	732	732	395	395	395	215	215	215
R-squared	0.266	0.263	0.272	0.859	0.880	0.886	0.935	0.939	0.942
Time FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
Country FE	YES	YES	YES	YES	YES	YES	YES	YES	YES

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Panel Regression Results

Under different cohort structure

	Average value in the future 4 years								
VARIABLES	Cap.Formation(% GDP)			Gross.Consumption(% GDP)			K/L growth rate		
Different age intervals:	3 cohorts	4 cohorts	5 cohorts	3 cohorts	4 cohorts	5 cohorts	3 cohorts	4 cohorts	5 cohorts
3 cohorts:	9.34	16.69***	15.40**	98.55***	92.44***	92.98***	21.77***	24.08***	22.11***
[0, 14], [15,64], [64,+)	(0.98)	(2.64)	(2.32)	(9.21)	(14.84)	(12.62)	(3.69)	(4.50)	(4.02)
	34.10***	29.11***	26.71**	64.81***	60.55***	71.18***	32.98***	39.21***	36.72***
4 cohorts:	(6.74)	(4.14)	(2.52)	(9.15)	(5.58)	(5.39)	(5.32)	(5.36)	(5.30)
[0,24], [25,49], [50,74],	-31.87	37.83**	20.39	98.58***	59.95***	43.58*	8.34	19.18	27.00***
[75, +)	(-1.30)	(2.05)	(1.13)	(2.95)	(3.23)	(1.85)	(0.61)	(1.66)	(2.98)
		-124.60***	53.93**		150.74***	100.97**		4.22	21.25
5 cohorts:		(-2.77)	(2.37)		(3.21)	(2.47)		(0.24)	(1.41)
[0, 19], [20,39], [40,59],			-224.74***			126.47*			-9.87
[60,79], [80,+)			(-3.07)			(1.75)			(-0.33)
Trade Cost							-0.83**	-0.83**	-0.79**
							(-2.13)	(-2.11)	(-2.00)
Initial.Log							-1.99***	-1.98***	-1.93***
.Dependent							(-3.45)	(-3.21)	(-3.14)
PoP.Growth							-33.14*	-35.31**	-30.58
							(-1.84)	(-2.08)	(-1.64)
Observations	724	724	724	725	725	725	758	758	758
R-squared	0.971	0.972	0.972	0.996	0.996	0.996	0.785	0.787	0.787
Time FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
Country FE	YES	YES	YES	YES	YES	YES	YES	YES	YES

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Panel Regression Results

Regression Coefficients follows hump shape

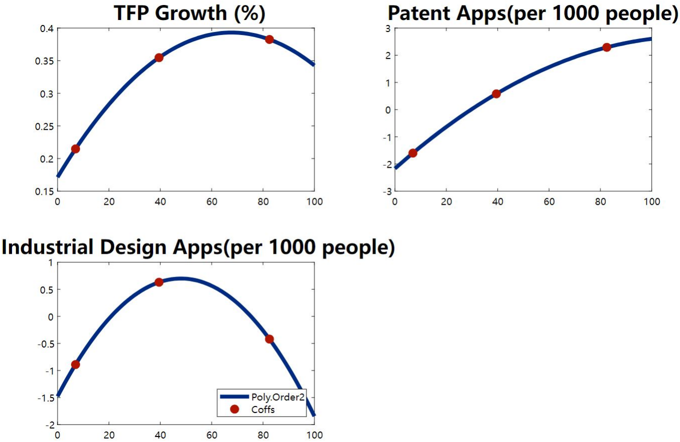

Figure: 3 cohorts: [0, 14], [15,64], [64,+)

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Panel Regression Results

Regression Coefficients follows hump shape

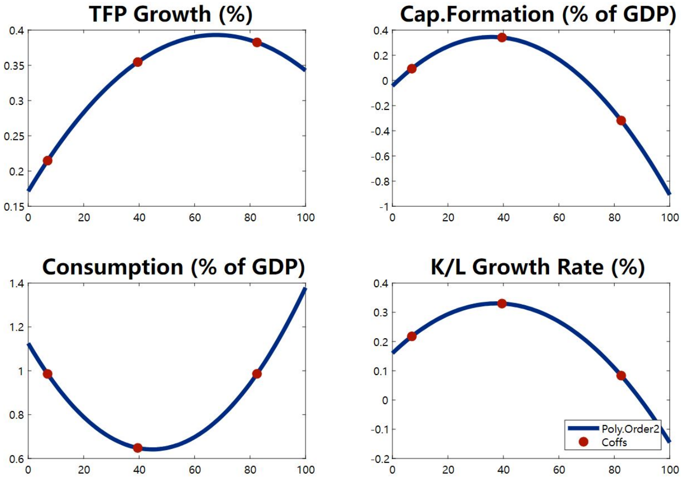

Figure: 3 cohorts: [0, 14], [15,64], [64,+)

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Panel Regression Results

Coefficients of different cohort

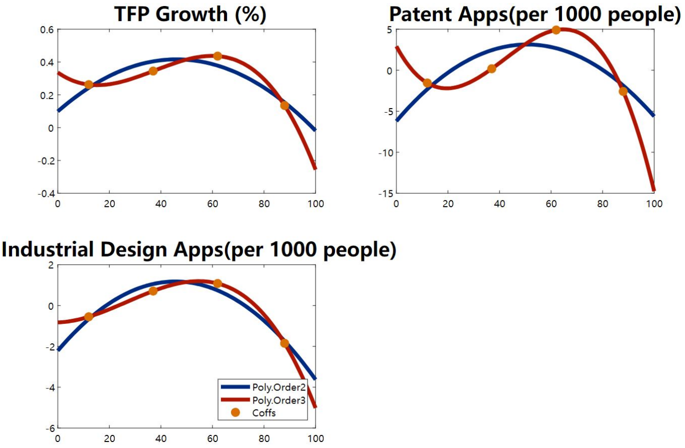

Figure: 4 cohorts

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Panel Regression Results

Coefficients of different cohort

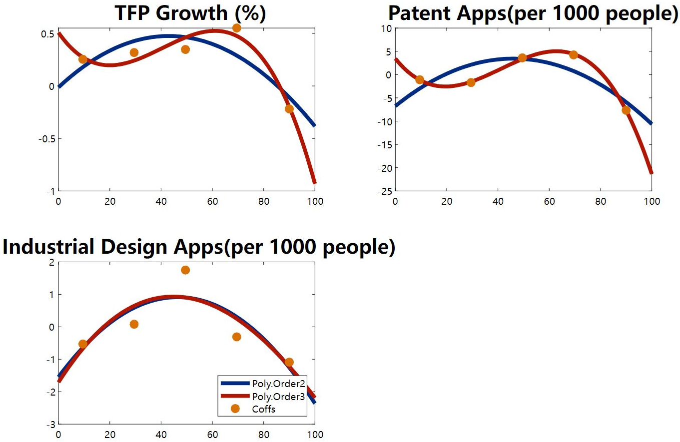

Figure: 5 cohorts

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Panel Regression Results

Coefficients of different cohort

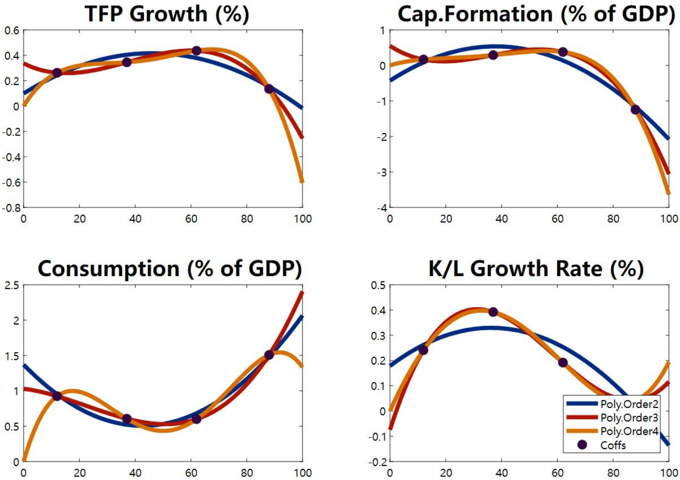

Figure: 4 cohorts

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Panel Regression Results

Coefficients of different cohort

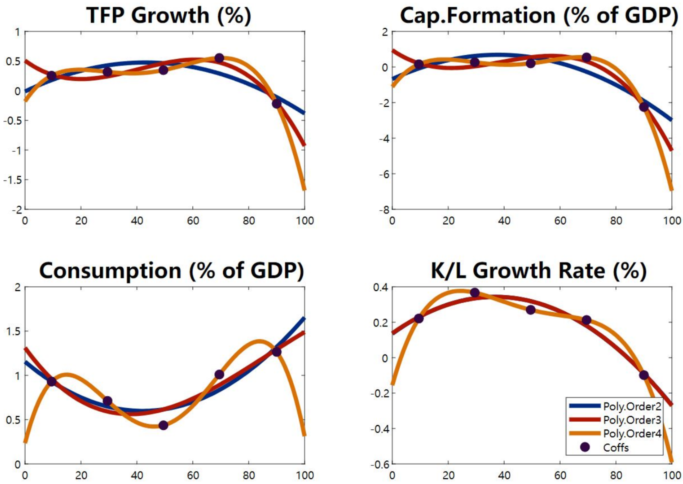

Figure: 5 cohorts

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Panel VARX model

Capital accumulation, TFP, and economic growth

VARX model:

$$Y_{n,t} = C + AY_{n,t-\mathbf{1}} + BX_{n,t-1} + \varepsilon_{n,t}$$

Endogenous variables:

$$Y_{nt} = \begin{bmatrix} the\ 5\ year\ growth\ rate\ of\ capital\ per\ person\ (\%) \\ the\ 5\ year\ growth\ rate\ of\ TFP\ (\%) \\ the\ 5\ year\ growth\ rate\ of\ the\ real\ GDP\ per\ capita\ (\%) \end{bmatrix}_{Country\ n, time\ t}$$

Exogenous variables:

$$X_{nt} = \begin{bmatrix} young\ people\ share\ (\%),\ (0-14) \\ old\ people\ share\ (\%),\ (65+) \\ trade\ cost\ change\ (\%) \\ the\ 5\ year\ growth\ rate\ of\ population (\%) \end{bmatrix}_{Country\ n, time\ t}$$

Time interval: 1 unit of time = 5 years. e.g. t = 1 means first 5 years

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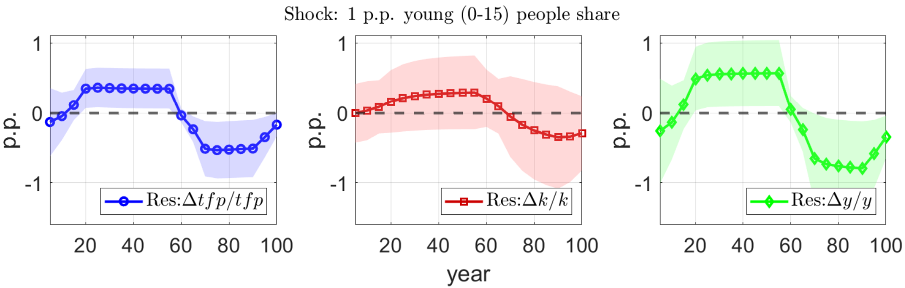
Panel VARX model main results

IRF of 1 p.p. young people share shock on
I.TFP growth; **II**. Growth rate of real capital stock per person **III**. Growth rate of real income stock per person



The IRF of +1 p.p. young people (0-15) share shock is hump shape

- Shock will pass down as people grow up

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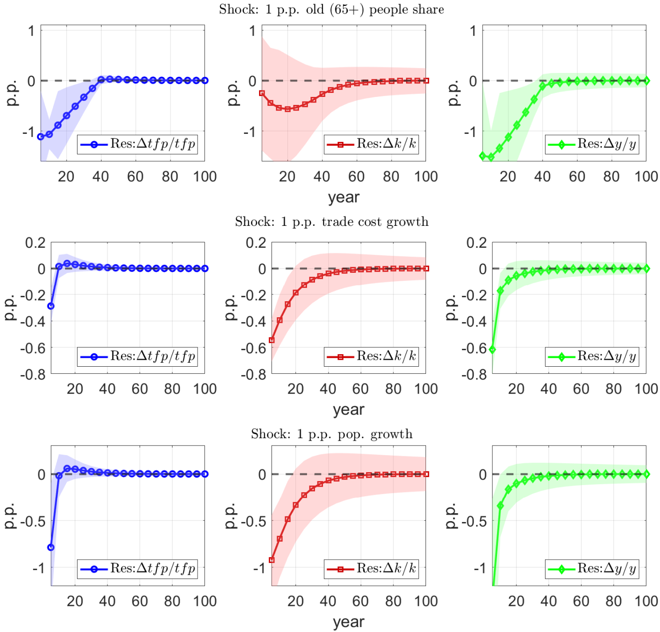
Panel VARX model



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Empirical findings

- Panel regression: higher working age share is related to higher
  - Productivity growth
    - New patent applications (per 1000 people)
  - Investment share of GDP

- Panel VARX model: the hump shape for IRF of 1 p.p. young people share shock on
  - Productivity growth
  - Growth rate of capital stock per person

Demographic structure

$N_{g,t}$: the number of households of age g alive at time t
$f_{g,t}$: the fertility rate of age g households at time t
$s_{g,t}$: the probability of surviving to age g at time t, given that they were alive at $g-1$
The implied unconditional probability of surviving g periods up to time t is given by:

$$S_{g,t} = \prod_{k=1}^{g} s_{k,t+k-g}$$

The demographic process can be describe as:

$$N_{1,t+1} = s_{1,t} \sum_{g=1}^{G} f_{g,t} N_{g,t}, s_{1,t} \equiv 1$$

$$N_{g+1,t+1} = s_{g+1,t+1} N_{g,t}.$$

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Demographic structure

$$\begin{bmatrix} N_{1,t+1} \\ \vdots \\ N_{g,t+1} \\ \vdots \\ N_{G,t+1} \end{bmatrix} = \begin{bmatrix} f_{1,t} & \cdots & f_{g,t} & \cdots & f_{G,t} \\ s_{2,t+1} & 0 & 0 & \cdots & 0 \\ 0 & s_{g+1,t+1} & 0 & \cdots & 0 \\ 0 & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & s_{G-1,t+1} & \cdots & 0 \\ 0 & 0 & 0 & s_{G,t+1} & 0 \end{bmatrix} \cdot \begin{bmatrix} N_{1,t} \\ \vdots \\ N_{g,t} \\ \vdots \\ N_{G,t} \end{bmatrix}.$$

or

$$N_{t+1} = \Omega_t N_t$$

At steady state

$$(1 + g_n)N_t = \Omega_t N_t$$

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Production

Overview

- A continuum of intermediate good $\omega \in [0,1]$ from country n sector j, $y^j_{n,t}(\omega)$: are produced by labor, capital, and sectoral composite intermediate good

$$y^j_{n,t}(\omega) \equiv q^j_{n,t}(\omega)\left[N^j_{n,t}(\omega)^{\beta^j_n} K^j_{n,t}(\omega)^{1-\beta^j_n}\right]^{\gamma^j_n} \prod_{k=1}^{J} m^{k,j}_{n,t}(\omega)^{\gamma^{k,j}_n} \tag{3}$$

- Intermediate goods are aggregated to build sectoral composite good

- Sectoral composite good is used for consumption, Investment, and intermediate goods production

- The productivity of each variety ω, $q^j_{n,t}(\omega)$, is a r.v., drawn from Fréchet distribution
  - The CDF of the distribution, $F^j_{n,t}(q) = exp(-\lambda^j_{n,t} q^{-\theta})$: **Knowledge frontier**
  - The mean of the distribution, $\lambda_{n,t}$: **Knowledge stock**

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Production

Knowledge stock dynamics (1/3)

(Omit the subscripts for sector j and country n for simplicity)

Between time t and $t+1$,

- The representative producer is characterized by its productivity level q, which is drawn from the current knowledge frontier
- Households generate some number of new ideas and share with producers
  - Both the number of new ideas and its productivity q_{new} are stochastic (Buera and Oberfield, Econometrica, 2019)
- Producers adopt the new idea if $q_{new} > q$

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Model

Production: Knowledge stock dynamics (2/3)

Ideas arrive following a Poisson Process with mean parameter α_t

$$\alpha_t \equiv (\sum_g \eta_g N_{g,t})^{\varphi} \tag{4}$$

- η_g: mean of ideas arrived per age g people per period
- $N_{g,t}$: number of age g people at time t
- α_t: mean of ideas arrived per unit of time
- $\varphi < 1$: reflect some crowding effects, or duplication of idea

The productivity of a new idea q_{new} is a r.v., where $q_{new} = zq\prime^{\rho}$

- z is the original component; draw from distribution $H(z)$ (Buera and Oberfield, Econometrica, 2019)
- $q\prime$ is an insight drawn from current knowledge frontier
- ρ captures the contribution of the quality of insights from the current knowledge frontier to the productivity of new ideas

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Model

Production: Knowledge stock dynamics (3/3)

- One can derive the **law of motion for stock of knowledge** (λ_t) :

$$\lambda_{t+1} - \lambda_t = \Gamma\,(1-\rho)\,\alpha_t\,(\lambda_t)^{\rho}\,; \qquad \alpha_t \equiv (\sum_g \eta_g N_{g,t})^{\varphi} \tag{5}$$

- An increase in the level of working-age population leads to higher knowledge stock
  - age-varing ability in generating ideas
- On the balanced growth path, higher population growth implies higher knowledge stock growth
  - more people generate more ideas, higher population growth rate implies higher idea growth

- w/o demographic: Chad Jones, 2022
- w/o demographic & insight drawn from external dist.: Oberfield and Buera, 2019

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Households

Overview

(Omit country subscripts for simplicity)

- Three exogenous variables governing the demographic process
  - The initial number of population across ages: N_{g,t_0}
  - $f_{g,t}$: number of the newborn from per age g cohort at time t
  - $s_{g,t}$: the probability of surviving to age g at time t, given that they were alive at $g-1$

- Households work at age 16, retired at age 65 and die at age $G = 85$

- The age g households that was born in period t choose lifetime consumption $\{c_{g,t+g-1}\}_{g=1}^{G}$ and savings $\{a_{g+1,t+g}\}_{g=1}^{G-1}$ to maximize expected lifetime utility

$$\sum_{g=1}^{G} \beta^{g-1} \psi_{t+g-1} S_{g,t+g-1} u\left(c_{g,t+g-1}\right), \text{ with } S_{g,t} \equiv \prod_{k=1}^{g} s_{k,t+k-g}$$

  - $u(c) = (c^{1-1/\sigma})/(1-1/\sigma)$
  - ψ_t: saving wedges, capture other forces (except demographics) impacting saving behavior

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Households

Budget constraint

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The budget constraint for households at age $g \in [1, G]$, time t is

$$P_{C,t} c_{g,t} + P_{I,t} a_{g+1,t+1} = P_{I,t} (1 + r_t) a_{g,t} + W_t \left(1 - \tau_t^L\right) E_t l_g + ts_t^D + ts_t^T$$
$$\forall\, t: \; a_{1,t} = a_{G+1,t} = 0$$

- $P_{C,t}$ and $P_{I,t}$: price level for consumption and investment
- W_t and R_t: wage and rental rate
- Household at age g own labor endowment $l_g = 1$, $\forall g \in [16, 65]$
- labor supply is adjusted for labor supply frictions τ_t^L and human capital index $E_{n,t}$
- Households save or borrow in the quantity of $a_{n,g+1,t+1}$ under interest rate Detail

$$r_{t+1} = \frac{R_{t+1}}{P_{I,t+1}} - \delta$$

- Transfers are equally distributed across the households
  - ts_t^D is the trade deficit induced transfer (Caliendo et.al, 2018) Detail
  - ts_t^T accidental death induced transfer: saving left by households who die before age G Detail

Trade

(I omit time t subscript to simplify notation)

- "Iceberg" trade costs: $\kappa_{ni}^{j} \geq 1$ for country n by sector j goods from country i
- Following Eaton and Kortum (2002), the fraction of country n's expenditures in sector j goods source from country i is:

$$\pi_{ni}^{j} = \frac{\lambda_i^j \left(c_i^j \kappa_{ni}^j\right)^{-\theta}}{\sum_{i=1}^{N} \lambda_i^j \left(c_i^j \kappa_{ni}^j\right)^{-\theta}} \tag{6}$$

  - c_n^j is the unit price of an input bundle in country n sector j

$$c_n^j \equiv \Upsilon_n^j \left[(W_n)^{\beta_n^j} (R_n)^{1-\beta_n^j} \right]^{\gamma_n^j} \prod_{k=1}^{J} {P_n^k}^{\gamma_n^{k,j}} \tag{7}$$

    - ★ P_n^j is the price of sectoral composite goods from country n sector j

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Aggregation

Capital

$$\sum_{j=1}^{J}\int_{0}^{1} k_{n,t}^{j}(\omega)d\omega = K_{n,t} = \sum_{g=E+1}^{E+G} \eta_{n,g-1,t-1}a_{n,g,t} \tag{8}$$

Labor

$$\sum_{j=1}^{J}\int_{0}^{1} l_{n,t}^{j}(\omega)d\omega = N_{n,t} = \sum_{g=E+1}^{E+G} \eta_{n,g,t}l_{g} \tag{9}$$

Consumption

$$C_{n,t} = \sum_{g=E+1}^{E+G} \eta_{n,g,t}c_{n,g,t} \tag{10}$$

Investment

$$I_{n,t} \equiv K_{n,t+1} - (1-\delta)K_{n,t} \tag{11}$$

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The financial market works with zero frictions

- Receive deposits of $P_{I,t} \sum a_{g,t} N_{g,t}$ from individuals
  - Repay those individuals an amount $(1 + r_t) \, P_{I,t} \sum a_{g,t} N_{g,t}$
- Loaned an amount $K_t = \sum a_{g,t} N_{g,t}$ to firms to use in production
  - Receives an amount $P_{I,t} \left(1 + \frac{R_t}{P_{I,t}} - \delta\right) K_t$ from firms
- Market clear implies

$$r_t = \frac{R_t}{P_{I,t}} - \delta \tag{12}$$

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Model

Trade deficit-induced transfers

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- A pre-determined share of GDP, $\phi_{n,t}$ is sent to a global portfolio, which in turn disperses a per-capita lump-sum transfer, T_t^P,to every country

- The net transfer, also recognized as trade deficit, are calculated as:

$$D_{n,t} = -\phi_{n,t}\left(R_{n,t}K_{n,t} + W_{n,t}E_{n,t}N_{n,t}\right) + \bar{L}_{n,t}T_t^P \tag{13}$$

- Dividing by the total economically relevant population $\bar{L}_{n,t}$ implies that total bequests are equally distributed across the population

$$D_{n,t} = -\phi_{n,t}\left(R_{n,t}K_{n,t} + W_{n,t}E_{n,t}N_{n,t}\right) + \frac{\bar{L}_{n,t}}{\sum_{n=1}^{N}\bar{L}_{n,t}}\sum_{n=1}^{N}\phi_{n,t}\left(R_{n,t}K_{n,t} + W_{n,t}E_{n,t}N_{n,t}\right) \tag{14}$$

Model

Demographics-induced transfers

- $TRSV_{n,t}$ is defined as demographic structure change-induced transfer which is due to the number of population changes between cohort $(s-1, t-1)$ and (s, t)

$$TRSV_{n,t} = P_{n,I,t}\left(1 + r_{n,t}\right) \sum_{g=E+2}^{E+S} \left(\eta_{n,g-1,t-1} - \eta_{n,g,t}\right) a_{n,g,t} \tag{15}$$

  - The number of population change can either counted as net death $(\eta_{n,g-1,t-1} - \eta_{n,g,t} > 0)$ or net immigrant $(\eta_{n,g-1,t-1} - \eta_{n,g,t} < 0)$
  - The asset change due to net death is treated as positive bequests
  - The net immigrant (g, t) enter country n with zero assets, and is treated as negative bequests

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Steady State

Definition 1: Stationary balanced growth equilibrium: A stationary balanced growth competitive equilibrium in the perfect foresight overlapping generations model with G period lived agents, and exogenous population dynamics, is defined as constant allocations of stationary consumption, capital and prices: $\left\{\{c_{n,g}\}_{g=1,\ n=1}^{G,\ N},\ \{b_{n,g+1}\}_{g=1,\ n=1}^{G-1,N},\ \{W_n,\ R_n\}_{n=1}^{N}\right\}$, such that:

i. The households taking prices transfer and deficit as given, optimize lifetime utility.

ii. Firms taking prices as given, minimize production cost.

iii. Each country purchases intermediate varieties from the least costly supplier/country subject to the trade cost.

iv. All markets are clear.

v. The population distribution reaches a stationary steady-state distribution before the economy reaches a steady state.

▸ Equations

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Model

Steady State (1/2)

Table: Steady-state conditions (1/2)

g_n	$N_{n,g,t+1} = (1+g_n)\, N_{n,g,t}$	$\forall n, t \in [T-1, \infty)$
g_{λ^j}	$\lambda^j_{n,t+1} = (1+g_{\lambda^j})\, \lambda^j_{n,t}$; $(1+g_{\lambda^j}) = (1+g_n)^{\frac{\varphi^j}{(1-\rho)}}$; $1+g_{A^j} \equiv (1+g_{\lambda^j})^{1/\theta}$	$\forall n, j, t \in [T, \infty)$
g_ω	$X \in [\frac{W_{n,t}}{P_{n,C,t}}, \frac{ts^T_{n,t}}{P_{C,n,t}}, \frac{ts^D_{n,t}}{P_{n,C,t}}, a_{n,g,t}, c_{n,g,t}]$; $X_{t+1} = (1+g_\omega)\, X_t$; $1+g_\omega = (1+g_{A^j})^{\frac{1}{\beta^j\gamma^j}} = (1+g_{\lambda^j})^{\frac{1}{\beta^j\gamma^j\theta}}$	$\forall n, t \in [T, \infty)$
$g_{rc^j_n}$	$X \in [\frac{c^j_{n,t}}{P^j_{n,t}}]$; $X_{t+1} = \left(1+g_{rc^j_n}\right) X_t$; $1+g_{rc^j_n} = (1+g_\omega)^{\beta^j\gamma^j} = (1+g_{\lambda^j})^{1/\theta}$	$\forall n, t \in [T, \infty)$
g_K	$X \in [C_{n,t}, C^j_{n,t}, I_{n,t}, I^j_{n,t}, K_{n,t}, Y^j_{n,t}, \frac{X^j_{n,t}}{P^j_{n,t}}, \frac{D_{n,t}}{P^j_{n,t}}, \frac{D_{n,t}}{P_{n,Ct}}, \frac{D_{n,t}}{P_{n,I,t}}]$; $X_{t+1} = (1+g_K)\, X_t$; $1+g_K = (1+g_\omega)(1+g_n)$	$\forall n, j, t \in [T, \infty)$
	$1+g_\omega = (1+g_n)^{\frac{\varphi^j}{\theta\beta^j\gamma^j(1-\rho)}}$; $\varphi^j/\varphi^k = \beta^j\gamma^j/\beta^k\gamma^k$; $\varphi^j = \theta(1-\rho)\,\beta^j\gamma^j\frac{\log(1+g_\omega)}{\log(1+g_n)}$;	$\forall n, j$
F0	$\lambda^j_{n,T+1} - \lambda^j_{n,T} = {N_{n,T}}^{\varphi^j}\left(\lambda^j_{n,T}\right)^\rho \left[\sum_g \eta^j_g \bar{N}_{n,g,T}\right]^{\varphi^j} \Gamma(1-\rho)$	$\forall(n)$
H1	$N_{n,T} \equiv \sum_{g=1}^G N_{n,g,T}$; $\bar{L}_{n,T} \equiv \sum_{g=G_0+1}^G N_{n,g,T}$; $L_{n,T} = \left(1-\tau^L_{n,T}\right)\sum_{g=G_0+1}^{G_1} N_{n,g,T}l_g$; $L^e_{n,T} = E_{n,T}L_{n,T}$	$\forall(n)$
H2	$P_{n,C,T}c_{n,g,T} + P_{n,I,T}(1+g_\omega)\,a_{n,g+1,T} = P_{n,I,T}(1+r_{n,T})\,a_{n,g,T} + W_{n,T}\left(1-\tau^L_{n,T}\right)E_{n,T}l_g + tr^D_{n,T} + tr^T_{n,T}$; $g \in [1, G]$	$\forall(n)$
H3	$a_{1,T} = a_{G+1,T} = 0$; $c_{n,g,T} > 0$, $\{c_{n,g,T}\}_{g=1}^G$; $\{a_{n,g+1,T}\}_{g=1}^{G-1}$	$\forall(n)$
H4	$tr^T_{n,T} \equiv \frac{D_{n,T}}{N_{n,T}}$; $tr^D_{n,T} = P_{n,I,T}(1+r_{n,T})\sum_{g=2}^G\left(\frac{\overline{N}_{n,g-1,T}}{1+g_n} - \overline{N}_{n,g,T}\right)a_{n,g,T}$	$\forall(n)$
H4'	$tr^D_{n,T} = tr^{D,1}_{n,T} + tr^{D,2}_{n,T} = P_{n,I,T}(1-\delta)\sum_{g=2}^G\left(\frac{\overline{N}_{n,g-1,T}}{1+g_n} - \overline{N}_{n,g,T}\right)a_{n,g,T} + P_{n,I,T}\left(\frac{R_{n,T}}{P_{n,I,T}}\right)\sum_{g=2}^G\left(\frac{\overline{N}_{n,g-1,T}}{1+g_n} - \overline{N}_{n,g,T}\right)a_{n,g,T}$	$\forall(n)$
H4"	$P_{n,C,T}c_{n,g,T} + P_{n,I,T}i_{n,g,T} = R_{n,T}a_{n,g,T} + W_{n,T}\left(1-\tau^L_{n,T}\right)E_{n,T}l_g + tr^{D,2}_{n,T} + tr^T_{n,T}$	$\forall(n)$
H4"'	$P_{n,I,T}i_{n,g,T} = P_{n,I,T}(1+g_\omega)\,a_{n,g+1,T} - \left[P_{n,I,T}(1-\delta)\,a_{n,g,T} + tr^{D,1}_{n,T}\right]$	$\forall(n)$
H5	$(1+g_\omega)\,c_{n,g+1,T} = \left[(\beta s_{n,g+1,T})\left(\frac{\psi_{n,g+1,T+1}}{\psi_{n,g,T}}\right)(1+r_{n,T})\right]^\sigma c_{n,g,T}$; $\forall\ g \in [1, G-1]$	$\forall(n)$
H6	$C_{n,T} \equiv \sum_{g=1}^G N_{n,g,T}c_{n,g,T}$; $K_{n,T} \equiv \sum_{g=2}^G \frac{N_{n,g-1,T}}{1+g_n}a_{n,g,T}$	$\forall(n)$

Model

Steady State (2/2)

Table: Steady-state conditions (2/2)

H7	$C_{n,T} \equiv \prod_{j=1}^{J} {C_{n,T}^{j}}^{\alpha_C^j}; I_{n,T} \equiv \prod_{j=1}^{J} {I_{n,T}^{j}}^{\alpha_I^j}; P_{n,I,T} = \prod_{j=1}^{J} \left[\frac{P_{n,T}^j}{\alpha_I^j}\right]^{\alpha_I^j}; P_{n,C,T} = \prod_{j=1}^{J} \left[\frac{P_{n,T}^j}{\alpha_C^j}\right]^{\alpha_C^j}$	$\forall(n)$
H8	$P_{n,T}^j I_{n,T}^j = \alpha_{I,n}^j P_{n,I,T} I_{n,T}; P_{n,T}^j C_{n,T}^j = \alpha_{C,n}^j P_{n,C,T} C_{n,T}$	$\forall(n,j)$
F1	$W_{n,T} L_{n,T}^e = \sum_{j=1}^{J} \beta^j \gamma^j \sum_{i=1}^{N} \pi_{in,T}^j X_{i,T}^j; R_{n,T} K_{n,T} = \sum_{j=1}^{J} \left(1-\beta^j\right) \gamma^j \sum_{i=1}^{N} \pi_{in,T}^j X_{i,T}^j$	$\forall(n)$
F2	$r_{n,T} = \frac{R_{n,T}}{P_{n,I,T}} - \delta$	$\forall(n)$
T1	$c_{n,T}^j \equiv \Upsilon^j \left[\left(W_{n,T}\right)^{\beta^j} \left(R_{n,T}\right)^{1-\beta^j}\right]^{\gamma^j} \prod_{k=1}^{J} {P_{n,T}^k}^{\gamma^{k,j}}; \Upsilon^j \equiv \gamma^j \beta^{j^{-\gamma^j \beta^j}} \gamma^j \left(1-\beta^j\right)^{-\gamma^j \left(1-\beta^j\right)} \prod_{k=1}^{J} \gamma^{k,j^{-\gamma^{k,j}}}$	$\forall(n,j)$
T2	$P_{n,T}^j = A \cdot \left[\sum_{i=1}^{N} \lambda_{i,T}^j \left(\kappa_{ni,T}^j c_{i,T}^j\right)^{-\theta}\right]^{-\frac{1}{\theta}}; A \equiv \Gamma\left(\frac{1+\theta-\sigma}{\theta}\right)^{\frac{1}{(1-\sigma)}}$	$\forall(n,j)$
T3	$\pi_{ni,T}^j \equiv \frac{X_{ni,T}^j}{\sum_{i=1}^{N} X_{ni,T}^j} = \frac{\lambda_{i,t}^j \left(c_{i,t}^j \kappa_{ni,T}^j\right)^{-\theta}}{\sum_{m=1}^{N} \lambda_{m,T}^j \left(c_{m,T}^j \kappa_{nm,T}^j\right)^{-\theta}} = \lambda_{i,T}^j \left(\frac{A c_{i,T}^j \kappa_{ni,T}^j}{P_{n,T}^j}\right)^{-\theta}$	$\forall(n,i,j)$
T4	$P_{C,n,T} C_{n,T} + P_{I,n,T} I_{n,T} = R_{n,T} K_{n,T} + W_{n,T} E_{n,T} L_{n,T} + D_{n,T} = R_{n,T} K_{n,T} + W_{n,T} L_{n,T}^e + D_{n,T} \equiv IN_{n,T}$	$\forall(n)$
T4’	$P_{n,C,T} C_{n,T} + P_{n,I,T} \left(1+g_K\right) K_{n,T} = \left(1 + \frac{R_{n,T}}{P_{n,I,T}} - \delta\right) P_{n,I,T} K_{n,T} + W_{n,T} L_{n,T}^e + D_{n,T}$	$\forall(n)$
T5	$\left(1+g_K\right) K_{n,T} = K_{n,T+1} = I_{n,T} + (1-\delta) K_{n,T}; \left(g_K + \delta\right) K_{n,T} = I_{n,T}$	$\forall(n)$
T6	$\sum_{j=1}^{J} \sum_{i=1}^{N} X_{in,T}^j - \sum_{j=1}^{J} \sum_{i=1}^{N} X_{ni,T}^j = NX_{n,T} = -D_{n,T}$	$\forall(n,j)$
T6’	$X_{n,T}^j = \alpha_C^j P_{C,n,T} C_{n,T} + \alpha_I^j P_{I,n,T} I_{n,T} + \sum_{k=1}^{J} \gamma^{j,k} \left(\sum_{i=1}^{N} X_{in,T}^k\right)$	$\forall(n,j)$
T7	$D_{n,T} = -\phi_{n,T} \left(R_{n,T} K_{n,T} + W_{n,T} L_{n,T}^e\right) + N_{n,T} T_T^P; T_T^P = \frac{\sum_{n=1}^{N} \phi_{n,T} \left(R_{n,T} K_{n,T} + W_{n,T} L_{n,T}^e\right)}{\sum_{n=1}^{N} N_{n,T}}$	$\forall(n)$
T7’	$D_{n,T} = -\phi_{n,T} \left(R_{n,T} K_{n,T} + W_{n,T} L_{n,T}^e\right) + \frac{N_{n,T}}{\sum_{n=1}^{N} N_{n,T}} \sum_{n=1}^{N} \phi_{n,T} \left(R_{n,T} K_{n,T} + W_{n,T} L_{n,T}^e\right)$	$\forall(n)$

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Transitional Dynamics

Definition 2: Dynamics equilibrium

Given a set of initial capital distributions and exogenous forces across countries and over time, the transitional dynamics equilibrium (equilibrium transition path) in the perfect foresight overlapping generations trade model with G-period lived agents is defined as allocations of consumption, capital and prices: $\left\{ \{c_{n,g}\}_{g=1,\ n=1}^{G,\ N},\ \{b_{n,g+1}\}_{g=1,\ n=1}^{G-1,N},\ \{W_n,\ R_n\}_{n=1}^{N} \right\}_{t=1,\cdots,T+1}$ satisfies the following conditions:

i. The households at different ages taking prices, transfer and deficit as given, optimize lifetime utility.

iii. Firms taking prices as given, minimize production cost.

iv. Each country purchases intermediate varieties from the least costly supplier/country subject to the trade cost.

v. All markets are clear.

▸ Equations

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Model

Transitional Dynamics (1/2)

Table: Dynamic equilibrium conditions (1/2)

I1	$\lambda^j_{n,t+1}-\lambda^j_{n,t}=\left(\lambda^j_{n,t}\right)^{\rho}\left(\sum_g \eta^j_g N_{n,g,t}\right)^{\varphi^j}\Gamma\left(1-\rho\right)=N_{n,t}{}^{\varphi^j}\left(\lambda^j_{n,t}\right)^{\rho}\left(\sum_g \eta^j_g \bar{N}_{n,g,t}\right)^{\varphi^j}\Gamma\left(1-\rho\right)$	$\forall(n,t)$
H1	$N_{n,t}\equiv\sum_{g=1}^{G}N_{n,g,t}$; $\bar{L}_{n,t}\equiv\sum_{g=G_0+1}^{G}N_{n,g,t}$; $L_{n,t}=\left(1-\tau^L_{n,t}\right)\sum_{g=G_0+1}^{G_1}N_{n,g,t}l_g=\left(1-\tau^L_{n,t}\right)\sum_{g=1}^{G}N_{n,g,t}l_g$; $L^e_{n,t}=E_{n,t}L_{n,t}$	$\forall(n,t)$
H2	$P_{n,C,t}c_{n,g,t}+P_{n,I,t}a_{n,g+1,t+1}=P_{n,I,t}\left(1+r_{n,t}\right)a_{n,g,t}+W_{n,t}\left(1-\tau^L_{n,t}\right)E_{n,t}l_g+tr^D_{n,t}+tr^T_{n,t}$; $g\in[1,G]$	$\forall(n,t)$
H3	$a_{1,t}=a_{G+1,t}=0$; $c_{n,g,t}>0$, $\{c_{n,g,t+g-1}\}_{g=1}^{G}$; $\{a_{n,g+1,t+g}\}_{g=1}^{G-1}$	$\forall(n,t)$
H4	$tr^T_{n,t}\equiv\frac{D_{n,t}}{N_{n,t}}$; $tr^D_{n,t}\equiv P_{n,I,t}\left(1+r_{n,t}\right)\frac{\sum_{g=2}^{G}\left(N_{n,g-1,t-1}-N_{n,g,t}\right)a_{n,g,t}}{N_{n,t}}$	$\forall(n,t)$
H4'	$tr^D_{n,t}=tr^{D,1}_{n,t}+tr^{D,2}_{n,t}=P_{n,I,t}\left(1-\delta\right)\sum_{g=2}^{G}\left(\frac{N_{n,g-1,t-1}-N_{n,g,t}}{N_{n,t}}\right)a_{n,g,t}+P_{n,I,t}\left(\frac{R_{n,t}}{P_{n,I,t}}\right)\sum_{g=2}^{G}\left(\frac{N_{n,g-1,t-1}-N_{n,g,t}}{N_{n,t}}\right)a_{n,g,t}$	$\forall(n)$
H4"	$P_{n,C,t}c_{n,g,t}+P_{n,I,t}i_{n,g,t}=R_{n,t}a_{n,g,t}+W_{n,t}\left(1-\tau^L_{n,t}\right)E_{n,t}l_g+tr^{D,2}_{n,t}+tr^T_{n,t}$	$\forall(n)$
H4"'	$P_{n,I,t}i_{n,g,t}=P_{n,I,t}a_{n,g+1,t+1}-\left[P_{n,I,t}\left(1-\delta\right)a_{n,g,t}+tr^{D,1}_{n,t}\right]$	$\forall(n)$
H5	$\frac{c_{n,g+1,t+1}}{c_{n,g,t}}=\left[\left(\beta s_{n,g+1,t+1}\right)\left(\frac{\psi_{n,t+1}}{\psi_{n,t}}\right)\frac{\frac{P_{n,I,t+1}}{P_{n,C,t+1}}}{\frac{P_{n,I,t}}{P_{n,C,t}}}\left(1+r_{n,t+1}\right)\right]^{\sigma}$; $\forall\ g\in[1,G-1]$	$\forall(n,t)$
H6	$C_{n,t}\equiv\sum_{g=1}^{G}N_{n,g,t}c_{n,g,t}$; $K_{n,t}\equiv\sum_{g=2}^{G}N_{n,g-1,t-1}a_{n,g,t}$	$\forall(n,t)$
H7	$C_{n,t}\equiv\prod_{j=1}^{J}C^j_{n,t}{}^{\alpha^j_{n,C,t}}$; $I_{n,t}\equiv\prod_{j=1}^{J}I^j_{n,t}{}^{\alpha^j_{n,I,t}}$; $P_{n,I,t}=\prod_{j=1}^{J}\left[\frac{P^j_{n,t}}{\alpha^j_{I,n}}\right]^{\alpha^j_{I,n}}$; $P_{n,C,t}=\prod_{j=1}^{J}\left[\frac{P^j_{n,t}}{\alpha^j_{C,n}}\right]^{\alpha^j_{C,n}}$	$\forall(n,t)$
H8	$P^j_{n,t}I^j_{n,t}=\alpha^j_{I,n}P_{n,I,t}I_{n,t}$; $P^j_{n,t}C^j_{n,t}=\alpha^j_{C,n}P_{n,C,t}C_{n,t}$	$\forall(n,j,t)$

Model

Transitional Dynamics (2/2)

Table: Dynamic equilibrium conditions (2/2)

F1	$W_{n,t}L^e_{n,t} = \sum_{j=1}^{J} \beta^j_n \gamma^j_n \sum_{i=1}^{N} \pi^j_{in,t} X^j_{i,t}$; $R_{n,t}K_{n,t} = \sum_{j=1}^{J} \left(1-\beta^j_n\right) \gamma^j_n \sum_{i=1}^{N} \pi^j_{in,t} X^j_{i,t}$	$\forall (n,t)$
F2	$r_{n,t} = \frac{R_{n,t}}{P_{n,I,t}} - \delta$	$\forall (n,t)$
T1	$c^j_{n,t} \equiv \Upsilon^j_n \left[(W_{n,t})^{\beta^j_n} (R_{n,t})^{1-\beta^j_n}\right]^{\gamma^j_n} \prod_{k=1}^{J} P^k_{n,t}{}^{\gamma^{k,j}_n}$ where $\Upsilon^j_n \equiv \gamma^j_n \beta^j_n{}^{-\gamma^j_n \beta^j_n} \gamma^j_n \left(1-\beta^j_n\right)^{-\gamma^j_n (1-\beta^j_n)} \prod_{k=1}^{J} \gamma^{k,j}_n{}^{-\gamma^{k,j}_n}$	$\forall (n,j,t)$
T2	$P^j_{n,t} = A^j \cdot \left[\sum_{i=1}^{N} \lambda^j_{i,t} \left(\kappa^j_{ni,t} c^j_{i,t}\right)^{-\theta}\right]^{-\frac{1}{\theta}}$ where $A^j \equiv \Gamma\left(\frac{1+\theta-\sigma}{\theta}\right)^{\frac{1}{(1-\sigma)}}$	$\forall (n,j,t)$
T3	$\pi^j_{ni,t} \equiv \frac{X^j_{ni,t}}{\sum_{i=1}^{N} X^j_{ni,t}} = \frac{\lambda^j_{i,t}\left(c^j_{i,t}\kappa^j_{ni,t}\right)^{-\theta}}{\sum_{m=1}^{N} \lambda^j_{m,t}\left(c^j_{m,t}\kappa^j_{nm,t}\right)^{-\theta}} = \lambda^j_{i,t}\left(\frac{A^j c^j_{i,t}\kappa^j_{ni,t}}{P^j_{n,t}}\right)^{-\theta}$	$\forall (n,i,j,t)$
T4	$P_{n,C,t}C_{n,t} + P_{n,I,t}I_{n,t} = R_{n,t}K_{n,t} + W_{n,t}E_{n,t}L_{n,t} + D_{n,t} = R_{n,t}K_{n,t} + W_{n,t}L^e_{n,t} + D_{n,t} \equiv IN_{n,t}$	$\forall (n,t)$
T4’	$P_{n,C,t}C_{n,t} + P_{n,I,t}K_{n,t+1} = \left(1 + \frac{R_{n,t}}{P_{n,I,t}} - \delta\right) P_{n,I,t}K_{n,t} + W_{n,t}L^e_{n,t} + D_{n,t}$	$\forall (n,t)$
T5	$K_{n,t+1} = I_{n,t} + (1-\delta) K_{n,t}$	$\forall (n,t)$
T6	$\sum_{j=1}^{J} \sum_{i=1}^{N} X^j_{in,t} - \sum_{j=1}^{J} \sum_{i=1}^{N} X^j_{ni,t} = NX_{n,t} = -D_{n,t}$	$\forall (n,j,t)$
T6’	$X^j_{n,t} = \alpha^j_{C,n} P_{C,n,t}C_{n,t} + \alpha^j_{I,n} P_{I,n,t}I_{n,t} + \sum_{k=1}^{J} \gamma^{j,k}_n \left(\sum_{i=1}^{N} X^k_{in,t}\right)$	$\forall (n,j,t)$
T7	$D_{n,t} = -\phi_{n,t}\left(R_{n,t}K_{n,t} + W_{n,t}L^e_{n,t}\right) + N_{n,t}T^P_t$; $T^P_t = \frac{\sum_{n=1}^{N} \phi_{n,t}\left(R_{n,t}K_{n,t} + W_{n,t}L^e_{n,t}\right)}{\sum_{n=1}^{N} N_{n,t}}$	$\forall (n,t)$
T7’	$D_{n,t} = -\phi_{n,t}\left(R_{n,t}K_{n,t} + W_{n,t}L^e_{n,t}\right) + \frac{N_{n,t}}{\sum_{n=1}^{N} N_{n,t}} \sum_{n=1}^{N} \phi_{n,t}\left(R_{n,t}K_{n,t} + W_{n,t}L^e_{n,t}\right)$	$\forall (n,t)$

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Initial and Final Steady States

Why 1970–2100?

- Households born in 2020 are forward-looking; model extends to 2100 to anchor expectations.

Initial Steady State (1970):

- Based on average demographics, wage, and population growth from 1965–1975.
- Assumes regions start in a steady state with stable growth.

Final Steady State (2100+):

- Fertility and survival rates fixed after 2100.
- Growth rates approach steady values but not yet reached.
  - Use average growth (2100–2185) to approximate balanced growth.
- Provides terminal conditions for solving the model.

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Country Groups

Table: Country Groups

couty	countrycode	country_nam	couty	countrycode	country_nam
1	AUS	Australia	14	IND	India
2	AUT	Austria	15	IRL	Ireland
3	BEL	Belgium	16	ITA	Italy
4	BRA	Brazil	17	JPN	Japan
5	CAN	Canada	18	KOR	Korea, Republic of
6	CHN	China	19	MEX	Mexico
7	DEU	Germany	20	NLD	Netherlands
8	DNK	Denmark	21	PRT	Portugal
9	ESP	Spain	22	SWE	Sweden
10	FIN	Finland	23	TWN	Taiwan
11	FRA	France	24	USA	United States of America
12	GBR	United Kingdom	25	ROW	Rest of the World
13	GRC	Greece			

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Sectors

Table: Sector classifications

#1.	5 Sector Classification	Index 1	Index 2	#2.	Sector Description
1	Agriculture, Mining and Quarrying	0.76	0.87	1	Agriculture, Hunting, Forestry and Fishing
1	Agriculture, Mining and Quarrying	0.40	0.34	2	Mining and Quarrying
2	Manufacture-labor intensive	0.59	0.72	3	Food, Beverages and Tobacco
2	Manufacture-labor intensive	0.64	0.72	4	Textiles, Textile, Leather and Footwear
2	Manufacture-labor intensive	0.63	0.78	5	Wood and Products of Wood and Cork
2	Manufacture-labor intensive	0.60	0.68	6	Pulp, Paper, Paper, Printing and Publishing
3	**Manufacture-capital intensive**	**0.47**	**0.44**	7	**Coke, Refined Petroleum and Nuclear Fuel**
3	**Manufacture-capital intensive**	**0.44**	**0.41**	8	**Chemicals and Chemical Products**
2	Manufacture-labor intensive	0.56	0.60	9	Rubber and Plastics
2	Manufacture-labor intensive	0.52	0.52	10	Other NonMetallic Mineral
2	Manufacture-labor intensive	0.51	0.51	11	Basic Metals and Fabricated Metal
2	Manufacture-labor intensive	0.57	0.62	12	Machinery, Nec
3	**Manufacture-capital intensive**	**0.49**	**0.44**	13	**Electrical and Optical Equipment**
2	Manufacture-labor intensive	0.55	0.56	14	Transport Equipment
2	Manufacture-labor intensive	0.66	0.81	15	Manufacturing, Nec; Recycling
3	**Manufacture-capital intensive**	**0.41**	**0.33**	16	**Electricity, Gas and Water Supply**
4	Services-labor intensive	0.72	0.93	17	Construction
4	Services-labor intensive	0.61	0.95	18	Wholesale and Retail Trade
4	Services-labor intensive	0.76	0.91	19	Hotels and Restaurants
4	Services-labor intensive	0.68	0.89	20	Transport and Storage
5	**Services-capital intensive**	**0.42**	**0.50**	21	**Post and Telecommunications**
5	**Services-capital intensive**	**0.50**	**0.51**	**22**	**Financial Intermediation**
5	**Services-capital intensive**	**0.44**	**0.40**	**23**	**Real Estate, Renting and Business Activities**
4	Services-labor intensive	0.75	0.86	24	Community Social and Personal Services

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Calibration

Time Invariant Parameters

Index	Description	Value or source
N	# of countries	5: CHN; Asian 5; USA and CAN; EUR; ROW Asian 5: JPN, TWN, KOR, AUS, IND
J	# of sectors	5: Agriculture; {Labor-, Capital-intensive} $\otimes$ {Manu., Services}
$G_0 + 1$	Age join labor market	16
$G_1 + 1$	Retried age	66
G	Lifespan for households	85
σ	Risk aversion	1
$\rho_{knowledge}$	Existing knowledge stock coefficient	0.7 (Burea and Oberfield, 2019)
φ^j	Idea duplication coefficient	$[0.67, 0.28, 0.19, 0.69, 0.41]$
β	Annual discount factor	0.96
δ	Capital depreciation rate	0.06
θ	Trade elasticity	4
ρ	Elasticity of substitution between varieties	2
$\gamma^{k,j}$	Sectoral composite goods shares in output	IO table (average across t)
γ^j	Value added shares in output	IO table (average across t)
β^j	Labor's share in value added	IO table (average across t)
α_C^j	Preference parameters	IO table (average across t)
α_I^j	Investment parameters	IO table (average across t)
$\eta_{n,t}^j$	Idea coefficient	Calculation

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Calibration

Time Varying Driving Forces

Index	Description	Value or source
Time Varing Shocks		
N_{n,t_0}	Initial labor supply	PWT 10.01
$\overline{N}_{n,g,t_0}$	Initial age distribution	United Nations
$s_{n,g,t}$	Conditional survival rate	United Nations
$f_{n,g,t}$	Fertility rate	United Nations
$\tau^L_{n,t}$	Labor supply wedges	PWT
$\phi_{n,t}$	Trade imbalance wedges	IO table
$\lambda^j_{n,t}$	Knowledge stock	Match real data
$\kappa^j_{ni,t}$	Trade cost	Match real data
$\psi_{n,t}$	Saving wedges	Match real data
$\psi_{n,g}$	Steady state saving wedges	Match real data
Time Varing Endogenous Variables		
$N_{n,t}$	Total labor supply	PWT 10.01
$\overline{N}_{n,g,t}$	Age distribution	United Nations

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Calibration

Key details

Several key time-varying shocks

$$\begin{pmatrix} \lambda^j_{n,t} \\ \kappa^j_{ni,t} \\ \psi_{n,t} \\ \phi_{n,t} \end{pmatrix} \equiv \begin{pmatrix} \text{knowledge stock} \\ \text{trade cost} \\ \text{saving wedges} \\ \text{trade imbalance wedges} \end{pmatrix} \leftrightarrow \begin{pmatrix} \text{sector prices} \\ \text{sector bilateral trade flows} \\ \text{aggregate saving rate} \\ \text{aggregate trade imbalance} \end{pmatrix}$$

Knowledge stock parameter, $\eta_{n,g}$ Details

- Assume that all working-age people have the same $\eta_g > 0, g \in [16, 65]$
- In 1970, the world economy is assumed to be on the balanced growth path, which implies

$$\eta_{n,g} = \frac{1 + g_{\lambda,1970}}{(\lambda_{n,1970})^{\rho-1} \left(N_{n,g\in[16,65],1970}\right)^{\varphi} \Gamma(1-\rho)}$$

- One can back out exogenous productivity shock, $\epsilon_{n,t}$, from

$$\lambda_{n,t+1} - \lambda_{n,t} = N_n{}^{\varphi} \left(\lambda_{n,t}\right)^{\rho} \left[\sum_g \eta_{n,g} \bar{N}_{n,g,t}\right]^{\varphi} \Gamma\left(1-\rho\right) + \epsilon_{n,t}$$

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Data sources

Table: Data sources

Variable description	Model counterpart	Data source (1971–2020)	Data source (2021–2100)
Age distribution	$\tilde{N}_{n,g,t}$	UN	UN, Imputed
Population	$N_{n,t}$	PWT	UN, Imputed
Employment	$L_{n,t}$	PWT	Imputed
Human capital index	$E_{n,t}$	PWT	Imputed
Value added	$W_{n,t}L_{n,t}E_{n,t} + R_{n,t}K_{n,t}$	WIOD & Long IO Table	Imputed
Gross output*	$P^{j}_{n,t}y_{n,t}$	WIOD & Long IO Table	Imputed
Gross expenditure*	$P^{j}_{n,t}Q^{j}_{n,t}$	WIOD & Long IO Table	Imputed
Trade flow*	$P^{j}_{n,t}Q^{j}_{n,t}T_{n,i,t}$	WIOD & Long IO Table	Imputed
Intermediate prices**	$P^{j}_{n,t}$	WIOD & Long IO Table	Imputed
Consumption***	$C_{n,t}$	WIOD & Long IO Table	Imputed
Investment***	$I_{n,t}$	WIOD & Long IO Table	Imputed
Initial capital stock***	$K_{n,t0}$	PWT	N/A

Notes: * Values are measured in current prices using market exchange rates. ** Prices are measured using PPP exchange rates. *** Quantities are measured as values deflated by prices.

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Constructing data from 2021-2200

Impute saving rate, then given total supply of labor and capital, along with the imputed productivity, solving the CP trade model under the fixed trade cost

$$\log\left(\frac{sr_{n,t}}{1-sr_{n,t}}\right)=\alpha_0+\alpha_1\log\left(\frac{sr_{n,t-1}}{1-sr_{n,t-1}}\right)+\alpha_2 Young_{n,t}+\alpha_3 Old_{n,t}+f_n+\epsilon_{n,t}$$

Table: Saving rate regression

	(1)	(2)	(3)
VARIABLES	SR	SR	SR
L1.SR		0.89***	
		(32.74)	
L5.SR	0.43***		
	(8.04)		
Young share	-1.06***	-0.19	-2.80***
	(-3.62)	(-1.34)	(-10.75)
Old share	-2.40***	-0.45*	-5.97***
	(-4.37)	(-1.66)	(-12.36)
Constant	-0.22**	-0.04	0.04
	(-2.24)	(-0.84)	(0.36)
Observations	255	275	280
R-squared	0.891	0.968	0.836
Region FE	YES	YES	YES

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Calibrate Knowledge stock process

On the balanced growth path (BLG), population and knowledge stock must grow at a constant rate, with the relation:

$$(1+g_\lambda)^{1-\rho} = (1+g_n)^{\varphi}$$

$1+g_n$ can be calculated from the population growth rate in 1970, and then averaged across regions.
$1+g_\lambda$ can be backed out from the real wage growth rate with the relation:

$$1+g_{\text{real wage}} = (1+g_\lambda)^{1/\theta\beta\gamma}$$

Thus,

$$\varphi = \frac{(1-\rho)\log(1+g_\lambda)}{\log(1+g_n)} = \frac{(1-\rho)\theta\beta\gamma\log(1+g_{\text{real wage}})}{\log(1+g_n)}$$

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Calibrate Knowledge stock process

To calibrate η_g, I assume that all working-age people have the same $\eta_g > 0$. In 1970, the world economy is assumed to be on the balanced growth path, which implies

$$1 + g_{\lambda,1970} = (\lambda_{n,1970})^{\rho-1} \left[\sum_{g \in [16,65]} \eta_g N_{n,g,1970} \right]^{\varphi} \Gamma(1-\rho)$$

Thus,

$$\eta_g = \frac{1 + g_{\lambda,1970}}{(\lambda_{n,1970})^{\rho-1} \left(N_{n,g\in[16,65],1970}\right)^{\varphi} \Gamma(1-\rho)}$$

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Calibration

Results ▸ Detail

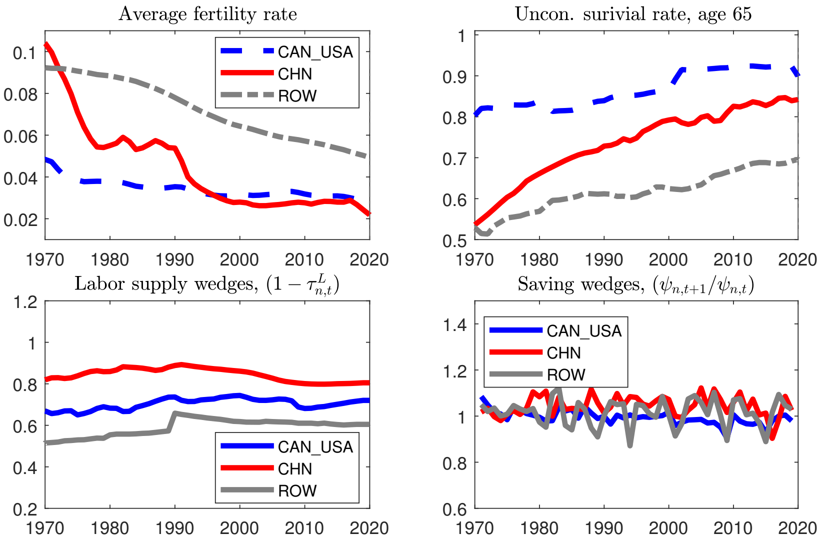

Figure: Demographic shocks and other wedges

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Calibration

Results ▸ Detail

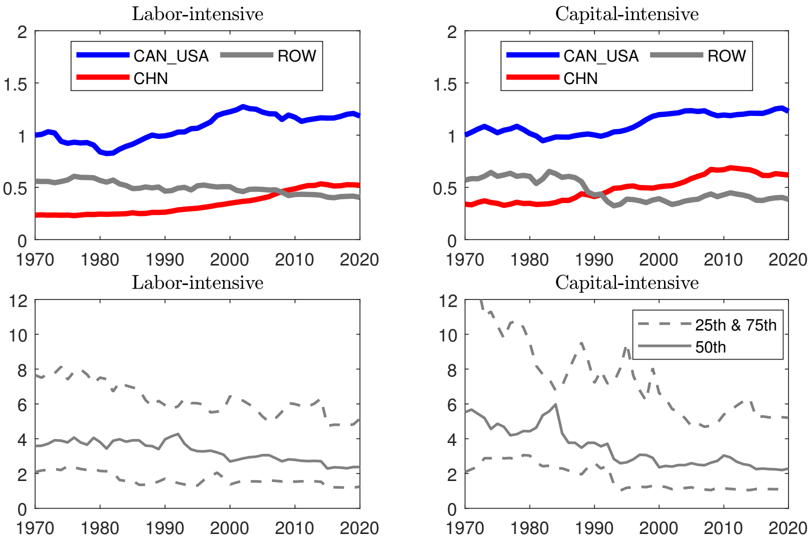

Figure: Knowledge stocks and trade costs

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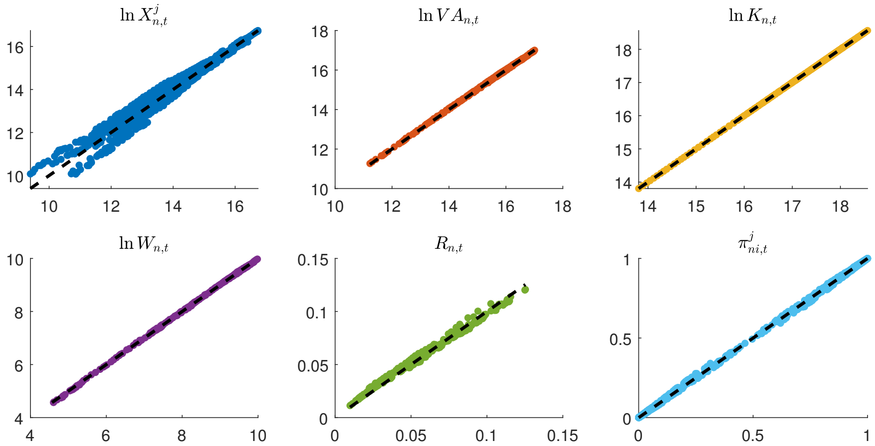
Calibration efficiency

Targeted Moments and other data



Note: vertical axis - model, horizontal axis - data.

Figure: Calibration Efficiency

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Calibration results

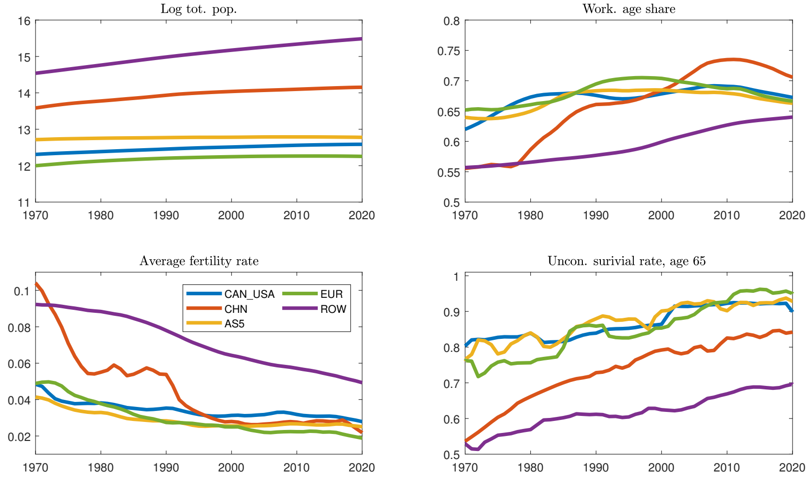

Figure: Demographics

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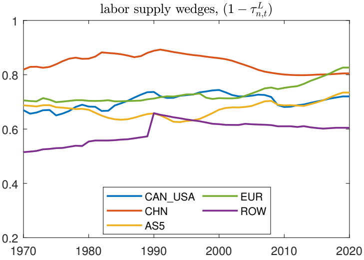
Calibration results



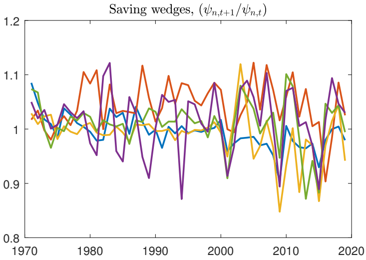


Figure: Demographics

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Calibration results

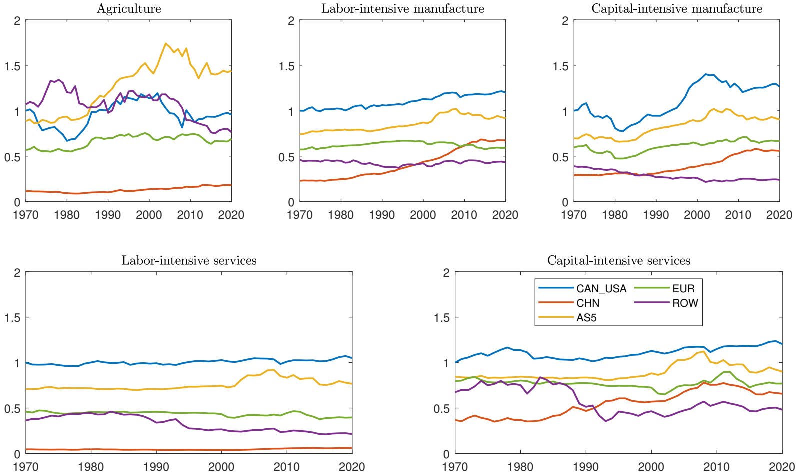

Figure: Demographics

Calibration results

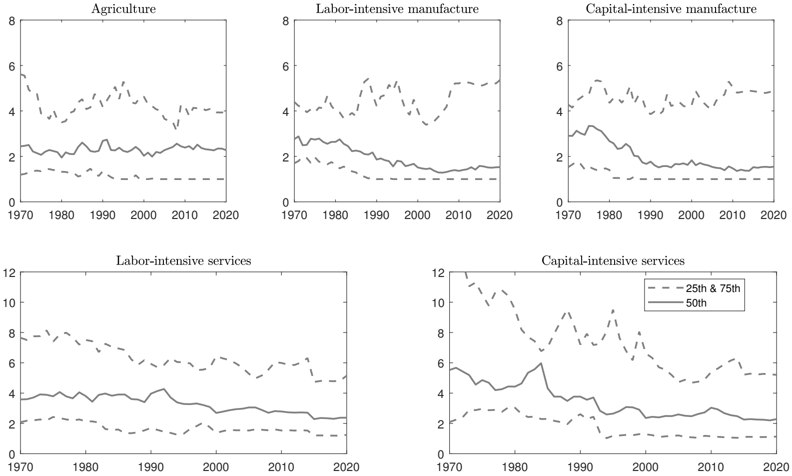

Figure: Demographics

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Table: Stationary balance growth equilibrium, China

Final Stationary balance growth equilibrium at 2100, China			
	(1) Baseline	**(2) Fert. = RoW**	**(3) Surv. = RoW**
i. Demographic variables			
Survival rate, age 65	**0.94**	0.94	0.85
Average fertility rate, 0/[21-49]	**0.02**	0.03	0.02
Expected lifespan	**82.3**	82.3	77.3
Share of working age	**0.56**	0.61	**0.60**
Total pop. (billion)	**0.5**	3.8	0.4
Implied pop. growth after 2100	**1.010**	1.011	1.010
ii. Balance growth path outcomes			
Average productivity	normalized as 1	1.65	0.95
Implied average productivity growth	**1.003**	1.004	1.003
iii. Outcomes in 2100			
Capital stock per person	**43.2**	48.6	42.0
Consumption per person	**2.9**	4.4	3.2
Investment per person	**3.04**	3.46	2.95
Income per person	**6.0**	7.8	**6.1**
Capital - efffcient labor ratio	**35.7**	36.5	32.0
Income per worker	**10.7**	12.8	**10.1**
Real wage rate	**2508**	3471	2347

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Counterfactual analysis

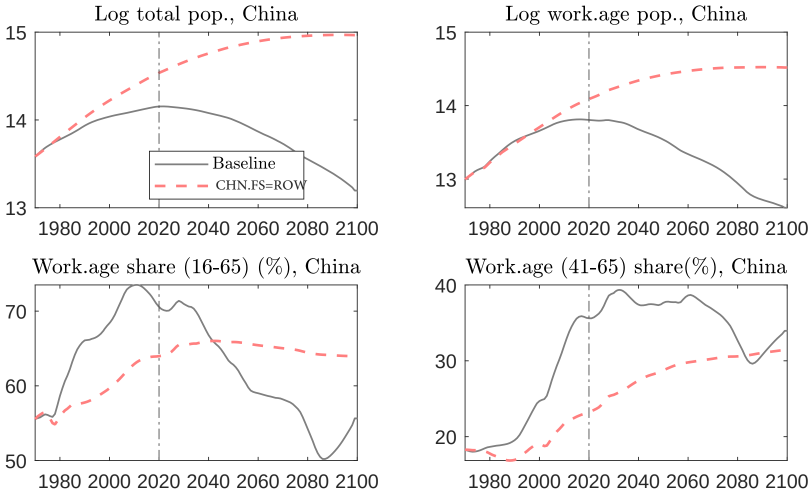
Design

Comparing baseline scenario with following three scenarios

- *China's fertility and survival* $=$ *ROW*, both channels work
  - Replace China's fertility and survival rates with those of the RoW
  - Open both channel: allow both productivity and saving change in response to demographic changes
- *China's fertility and survival* $=$ *ROW*, *only demographic-capital channel works*
  - Replace China's fertility and survival rates with those of the RoW
  - Open capital channel: allow saving change in response to demographic changes
  - Mute productivity channel: but retain the baseline productivity changes
- *China's fertility and survival* $=$ *ROW*, *only demographic-idea channel works*
  - Replace China's fertility and survival rates with those of the RoW
  - Open productivity channel: allow productivity to change as if China's demographic structure were replaced by that of RoW
  - Mute capital channel: maintain China's fertility and survival rates, and its implied demographic process

Counterfactual analysis

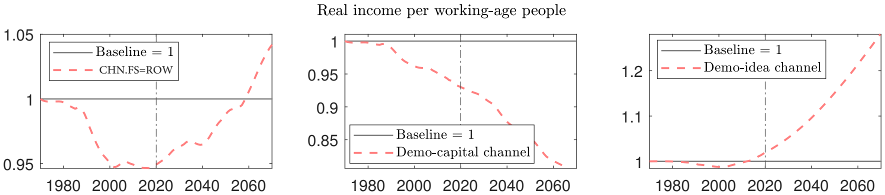
Demographic process



Turnpike Theorem

Counterfactual analysis

Implications for economic growth



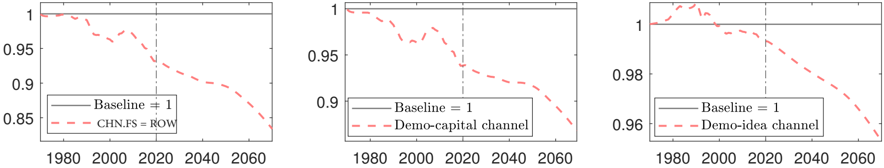
- China's low fertility and high survival rates compared to those of RoW, showing a short-run and long-run trade-off
  - Short run, a saving-favorable age structure leads to higher capital, and income per worker
    ▸ Capital process ▸ Saving-favorable age
  - Long run, after 2060, a lower path of knowledge stocks leads to a lower income per worker
    ▸ Knowledge process

▸ Details

Counterfactual analysis

Implications for trade pattern change

Revealed comparative advantage index, capital intensive sector



- Overall, China's low fertility and high survival rates compared to those of RoW, showing higher revealed CA on Capital-intensive production
  - Demo-capital channel: along the entire path, higher capital per worker—driven by a favorable age structure—enhances the comparative advantage in the capital-intensive sector
  - Demo-idea channel (Calibration showing that knowledge stock in the labor-intensive sector is more sensitive to the number of workers):
    - ★ Short run, more worker, leads to a greater increase in the knowledge stock for labor-intensive goods, thus showing lower RCA index for capital intensive sector
    - ★ Long run, less worker, leads to a greater slow down in the increase in the knowledge stock for labor-intensive goods, thus showing higher RCA index for capital intensive sector

Revealed comparative advantage (RCA) index (Balassa, 1965) | Details

How demographic structure affects China's growth and trade

Story from quantitative analysis

- China's low fertility and high survival rates compared to those of RoW, showing a short-run and long-run trade-off
  - Short run, a saving-favorable age structure leads to higher capital, and income per worker
    - along with a stronger comparative advantage in the capital-intensive sector
  - Long run, after 2060, a lower path of knowledge stocks leads to a lower income per worker
  - Trade liberalization encourages specialization and selection, extends short-run benefit period (numerical experiments)

Summary

How demographic forces shape China's economic growth and trade patterns?

- **Empirical Analysis**
  - A strong positive association between a country's working-age share and:
    - Productivity growth
    - Investment or saving share of GDP
  - An inverse U-shaped response of productivity growth and capital stock per person to a young cohort share shock.

- **Model and Counterfactual Analysis**
  - I build a OLG trade model feature aforementioned two mechanisms
  - I find a interesting trade-off in China's demographics compared to RoW's
    - **Short-run:** A saving-favorable age structure leads to higher capital, income per worker, and a stronger comparative advantage in capital-intensive sectors.
    - **Long-run (post-2060):** A lower knowledge stock trajectory results in lower productivity and income per worker.
    - Trade liberalization encourages specialization and selection, extending short-term benefits.

- **Future Work**
  - Simplify to 2 countries and 2 sectors
  - Exploring more direct ways to connect demographics and productivity:
    - Incorporating age-dependent productivity levels (i.e., the effectiveness of labor varies by age).
  - Designing a counterfactual to address:
    - To what extent demographic changes explain the recent slowdown in China's growth and the reallocation of labor-intensive production.

Compare Steady State ▸ Back

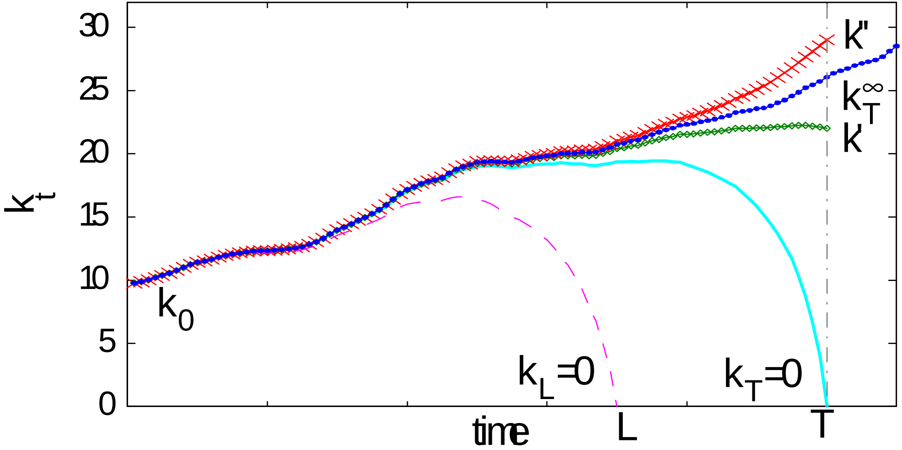
The role of demographics

	(1A)	(2A)	(3A)
Survival rate	low	**high**	high
Fertility rate	high	high	**low**
Trade cost	Autarky	Autarky	Autarky
Average lifespan	60.00	**71.00**	71.00
Population growth	0.05	0.05	**0.01**
Implied TFP growth	0.02	0.02	**0.01**
Working age share	0.43	0.44	0.63
Per efficient person			
Capital stock	0.0073	0.0086	0.0215
Output	0.0026	0.0029	0.0054
Consumption	0.0016	0.0017	0.0038
Investment	0.0010	0.0012	0.0016
capital - efficient labor ratio	0.0167	0.0195	0.0343
Price ratio			
Real wage rate	0.0030	0.0032	0.0043
Real rental rate	0.1788	0.1655	0.1250

- $(2A)$ v.s. $(1A)$: A higher average lifespan increases savings, which, acting as a supply of capital, leads to higher capital per efficient person
- $(3A)$ v.s. $(2A)$: With slower population and TFP growth, the number of effective persons grows more slowly. Less capital used to be spread across individuals, leads to higher capital per efficient person
- Capital-labor ratio implies a relative abundance of capital relative to labor

Illustration of turnpike theorem

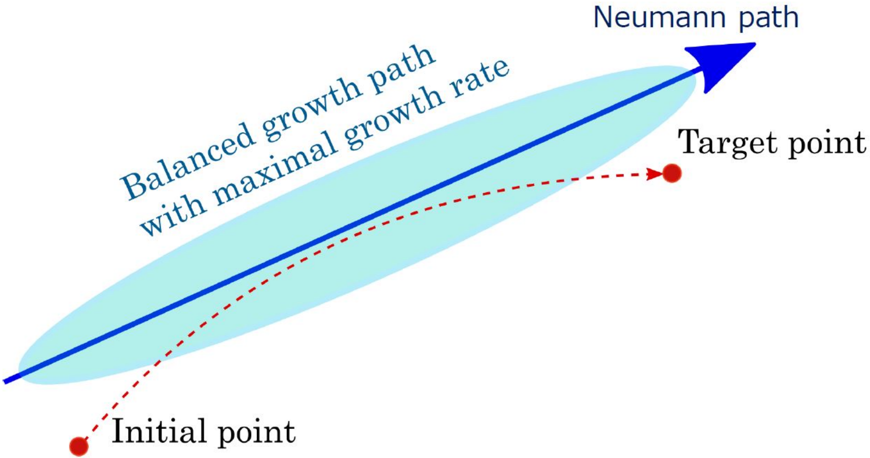
When you are young, you behave as if you will live forever...



Back *Sources*: Lilia Maliar and Serguei Maliar, 2017

Illustration of turnpike theorem

Put differently, terminal conditional has limited effects on the growth path



Dorfman, Samuelson, Solow 1958
McKenzie 1963

Back

Compare Steady State ▸ Back

The role of trade

	(3A)	(3B)
Survival rate	high	high
Fertility rate	low	low
Trade cost	Autarky	**Free trade**
Average lifespan	71.00	71.00
Population growth	0.01	0.01
Implied TFP growth	0.01	0.01
Working age share	0.63	0.63
Per efficient person		
Capital stock	0.022	0.061
Output	0.005	0.015
Consumption	0.004	0.011
Investment	0.002	0.005
capital - efficient labor ratio	0.034	0.097
Price ratio		
Real wage rate	0.004	0.012
Real rental rate	0.125	0.125

- $(3B)$ v.s. $(3A)$: Trade stimulate capital accumulation

Compare Steady State

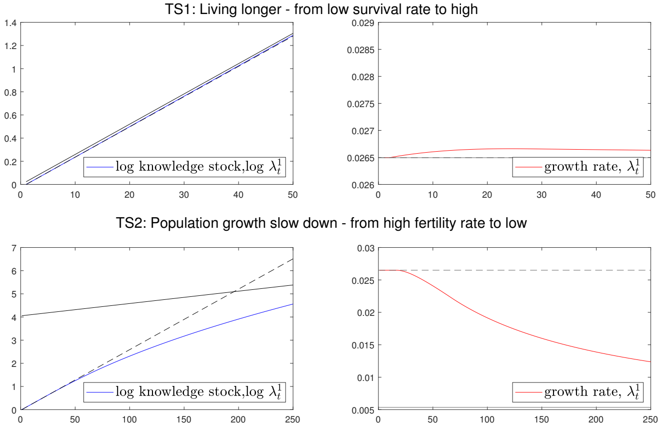
Back

	(1A)	(1B)	(2A)	(2B)	(3A)	(3B)
Survival rate	low		**high**		high	
Fertility rate	high		high		**low**	
Trade cost	100	1	100	1	100	1
Average lifespan	60.00	60.00	**71.00**	**71.00**	71.00	71.00
Population growth	0.05	0.05	0.05	0.05	**0.01**	**0.01**
Implied TFP growth	0.02	0.02	0.02	0.02	**0.01**	**0.01**
working age share	0.43	0.43	0.44	0.44	0.63	0.63
Per efffcient person						
Capital stock	0.0073	0.0205	0.0086	0.0244	0.0215	0.0609
Output	0.0026	0.0073	0.0029	0.0081	0.0054	0.0152
Consumption	0.0016	0.0046	0.0017	0.0048	0.0038	0.0107
Investment	0.0010	0.0028	0.0012	0.0033	0.0016	0.0046
capital - efffcient labor ratio	0.0167	0.0473	0.0195	0.0553	0.0343	0.0970
Price ratio						
Real wage rate	0.0030	0.0085	0.0032	0.0092	0.0043	0.0121
Real rental rate	0.1788	0.1788	0.1655	0.1655	0.1250	0.1250

Transitional dynamics: Knowledge stock changes over time ▸ detail

Before $t = 1$, economy is on the old balance growth path

Shock at $t = 1$: survival Rate (or fertility Rate) changed forever



$$\frac{\lambda_{t+1} - \lambda_t}{\lambda_t} = (\lambda_t)^{\rho - 1} (\sum_g \eta_g N_{g,t})^{\varphi} \Gamma (1 - \rho)$$

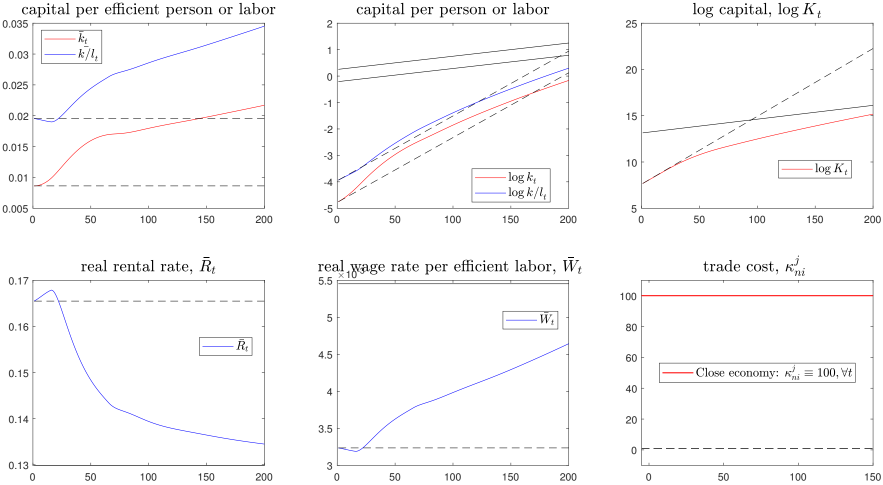
Simple application : assume only working-age people contribute to new idea generation

- $\eta_g = c > 0$ if $g \in (16, 65)$ and $\eta_g = 0$ if $g \notin (16, 65)$

◂ Back

Transitional dynamics - pop. growth slows down. Sym. Close economy

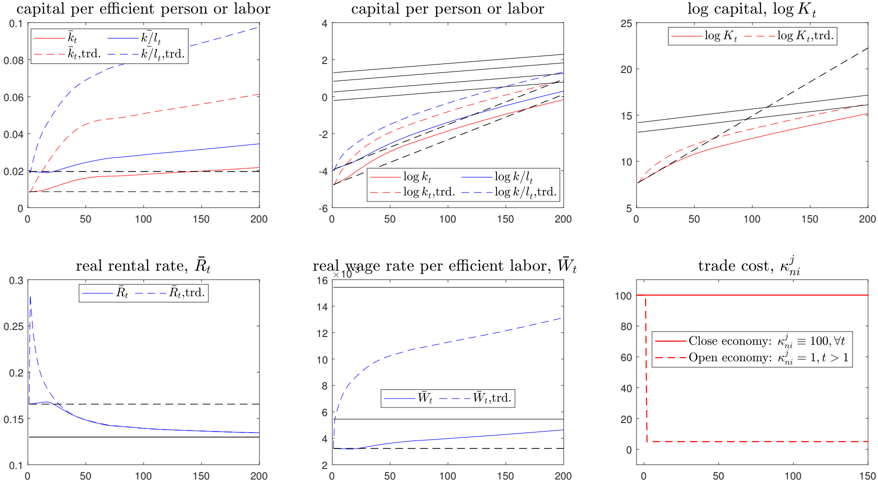
Open economy deatil
Living longer



Low fertility Rate: beneficial in the short run, but adverse in the long run.

- Short run, a lower population, raises capital per person above the old growth path
- Long run, productivity growth slows down, capital per person ultimately below old growth path

Transitional dynamics - pop. growth slows down. Close v.s. Open



Low fertility Rate Plus Trade liberalization

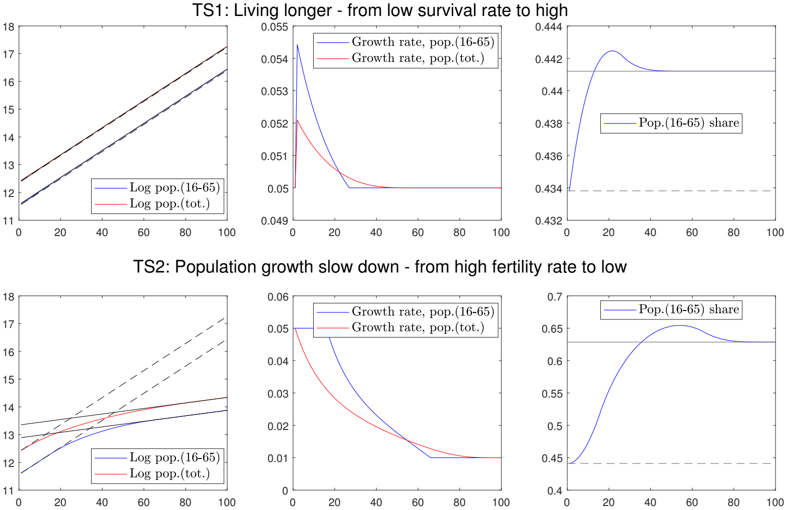
- Trade liberalization extends the beneficial period (during which capital per person remains above the old growth path).

Transitional dynamics: Population changes over time

Back

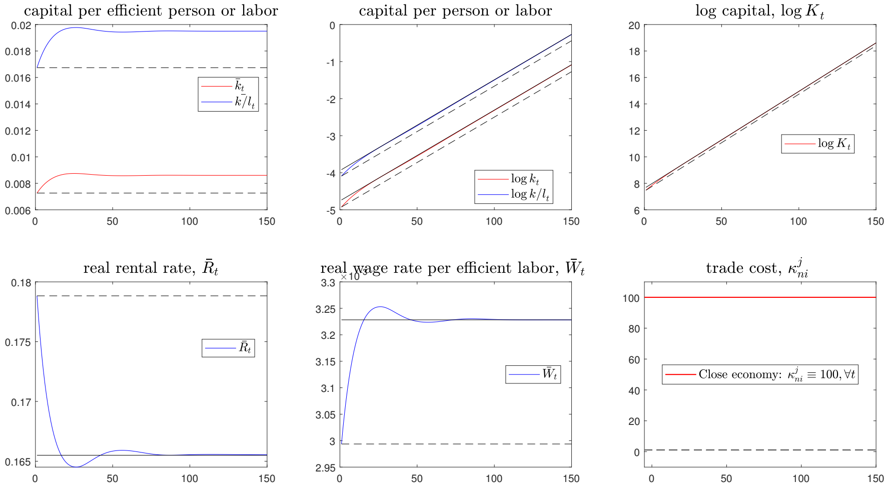
Before $t = 1$, economy is on the old balance growth path

Shock at $t = 1$: survival Rate (or fertility Rate) changed forever



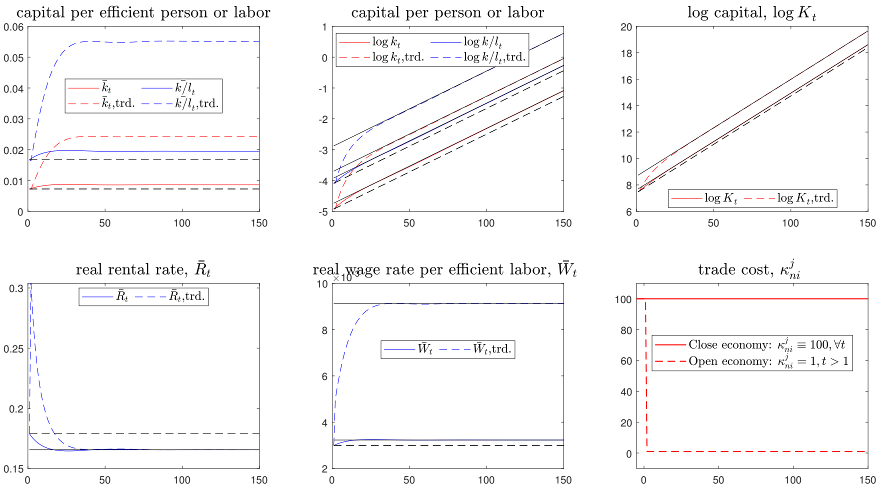
Transitional dynamics - living longer. Sym. Close economy

▸ Open economy ▸ Back



- A high survival rate stimulates capital accumulation and elevates the balanced growth path.

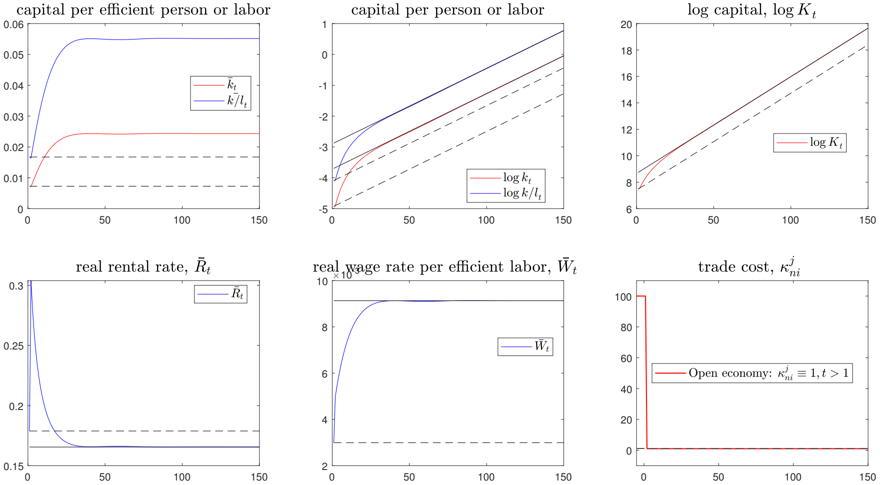
Transitional dynamics - living longer. Close v.s. Open
Back



- Trade also stimulates capital accumulation and elevates the balanced growth path.

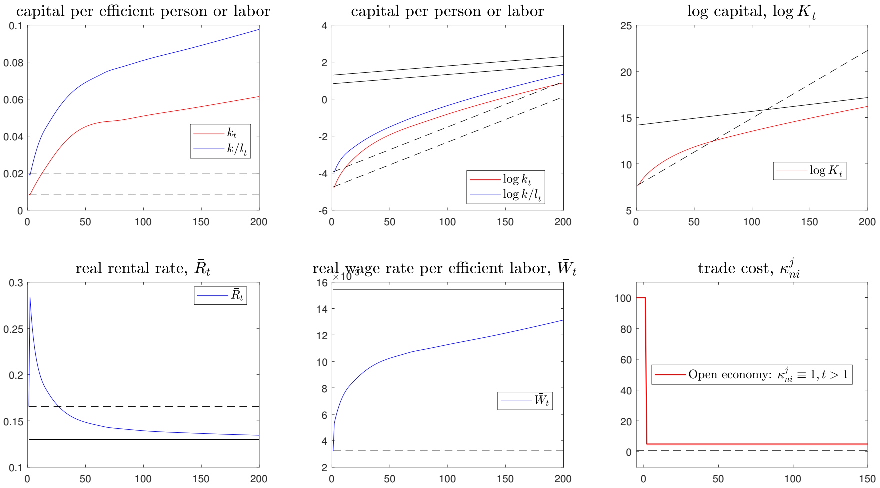
Transitional dynamics 1 - living longer. Sym. Open economy

back



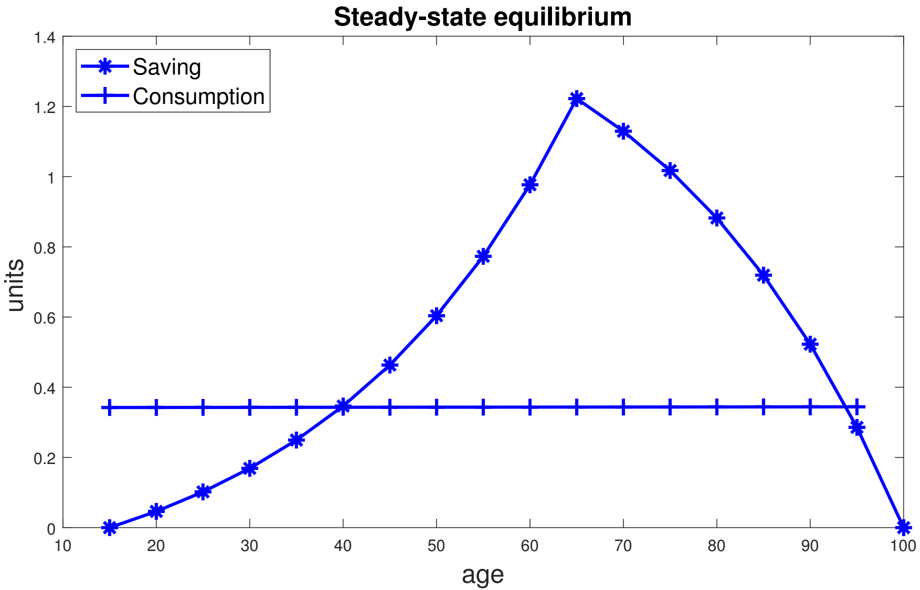
Transitional dynamics 2 - pop. growth slow down. Sym. Open economy

back



Counterfactual analysis

Age-varying savings stock



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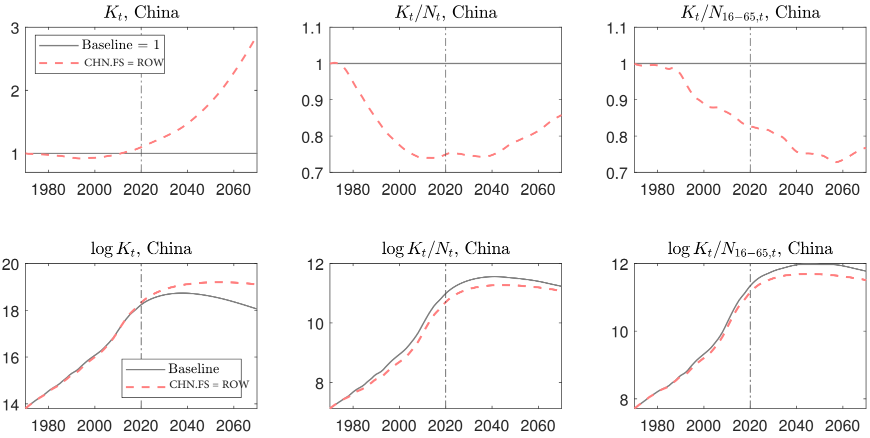
Counterfactual analysis

Capital process



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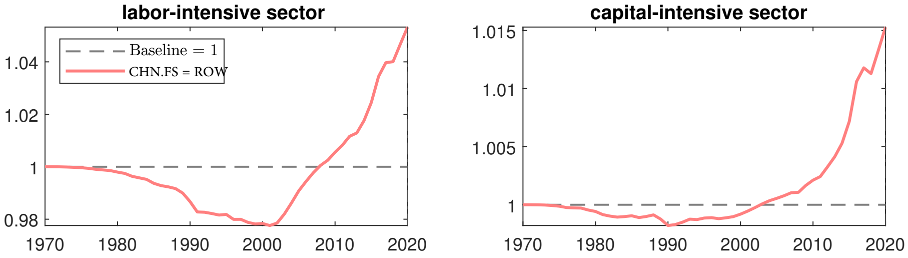
Counterfactual analysis

Knowledge stock process

Knowledge stock, China



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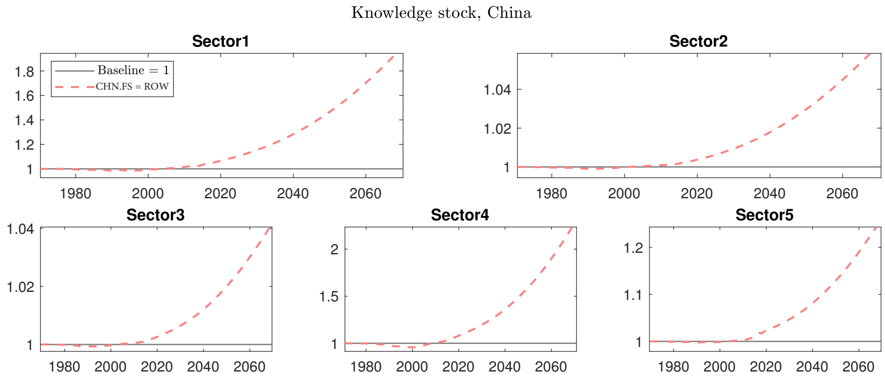
Counterfactual analysis

Knowledge stock process



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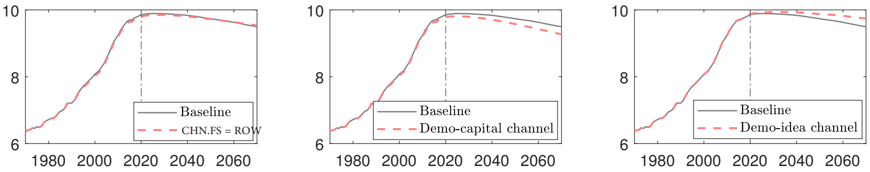
Counterfactual analysis

Income process

log real income per working-age people

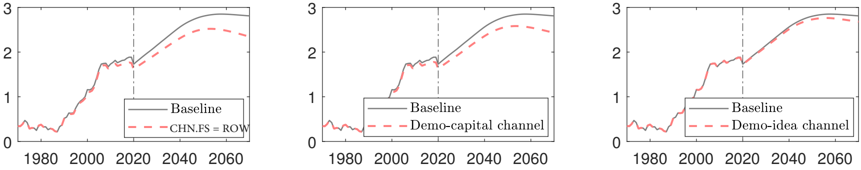


▸ Back

Counterfactual analysis

Trade patterns

Revealed comparative advantage index, capital intensive sector



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Balassa (1965) Revealed comparative advantage (RCA) index

$$RCA_{nj} = \frac{\frac{Export_{n,j}}{\sum_n Export_{n,j}}}{\frac{\sum_j Export_{n,j}}{\sum_{j,n} Export_{n,j}}} \tag{16}$$

where n means country, j means sector, $Export_{n,j}$ means the value of country n's sector j exports.

- The higher RCA_{nj}, the higher degree of specialization for country n in sector j products.

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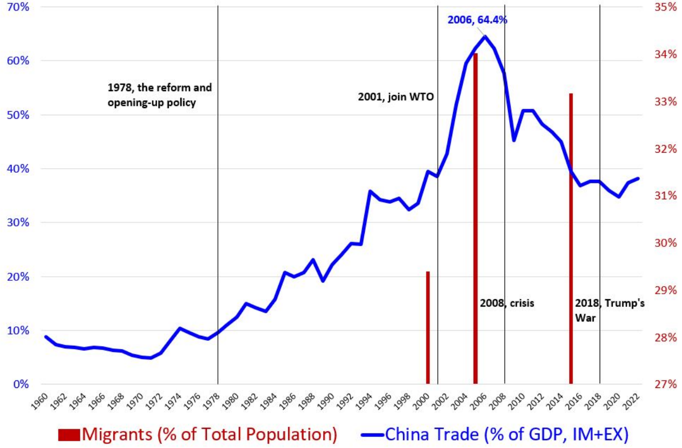
APPENDIX 2: The Decline in China's Trade Share of GDP: A Structural Accounting

China Trade and Migrants Data

Figure 1.B: China Trade and Migrants Data



Migrants: people living outside of their registration (*hukou*) province.

Source: WDI Database and China Statistical Yearly book

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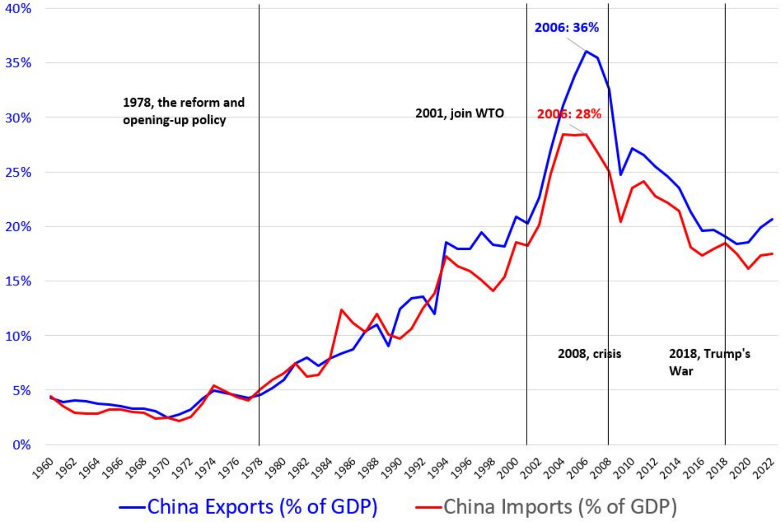
Detail Data



Source: WDI Database

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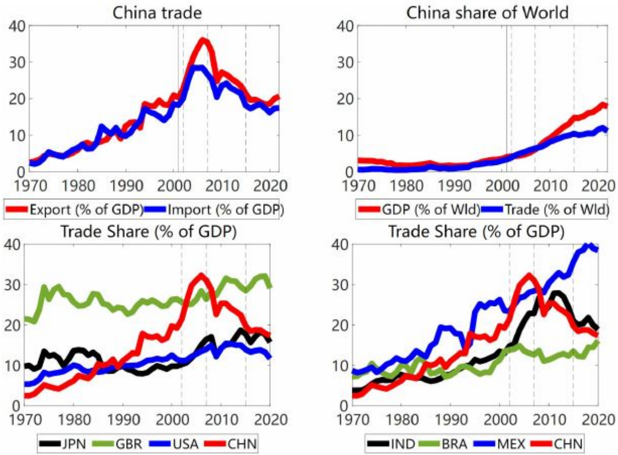
Detail Data



Note:The solid line represents the year 2001 when China joined the WTO. The three dotted vertical lines represent the years 2002, 2007, and 2015, respectively. These are the years for which I conducted the counterfactual analysis.

Source: WDI Database

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China trade share at sector level and migrants share

Table: China trade share at sector level and migrants share

	2002	2007	2015		2002	2007	2015
Import (% of GDP)	19.68%	25.78%	17.41%	***Export (% of GDP)***	23.46%	36.39%	20.03%
Agricultural Component	0.48%	0.80%	0.61%	*Agricultural Component*	0.37%	0.31%	0.14%
Light Industry Component	2.03%	1.36%	1.07%	*Light Industry Component*	5.21%	6.61%	3.17%
Heavy Industry Component	**15.16%**	**20.77%**	**10.08%**	***Heavy Industry Component***	**12.98%**	**24.22%**	**13.13%**
Services Component	2.01%	2.86%	5.65%	*Services Component*	4.91%	5.51%	3.59%
	2002	**2007**	**2015**		**2002**	**2007**	**2015**
Inner Trade (% of GDP)	26.95%	46.64%	50.53%	***China Trade (% of World)***	4.59%	6.72%	10.05%
Agricultural Component	1.37%	2.31%	2.23%	***China GDP (% of World)***	6.49%	9.24%	14.71%
Light Industry Component	4.51%	5.86%	6.11%				
Heavy Industry Component	**16.33%**	**27.85%**	**24.41%**		**2000**	**2005**	**2015**
Services Component	4.74%	10.61%	17.79%	***China Migrants (% of pop.)***	**29.40%**	**34.00%**	**33.20%**

- Heavy industry trade share change accounts for main change of China's Trade share change
- Migrants share changes more during period 2000-2005 than period 2005-2015

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China trade share at regional level

Table: China trade share at regional level

Trade (% of GDP)	***2002***	***2007***	***2015***		***2002***	***2007***	***2015***
Aggregate	21.57%	31.09%	18.72%	-	-	-	-
			Component classified by China regions				
NorthEast (NE)	1.16%	1.96%	0.72%	***SouthernCoastal (SC)***	**8.31%**	**7.55%**	**6.13%**
BeijingTianjin (BT)	1.72%	2.78%	1.58%	*Central (CE)*	0.80%	2.24%	1.02%
NorthernCoastal (NC)	1.58%	2.81%	1.83%	*NorthWest (NW)*	0.39%	1.60%	0.51%
EasternCoastal (EC)	**7.08%**	**10.83%**	**6.14%**	*SouthWest (SW)*	0.53%	1.31%	0.78%
			Component classified by foreign regions				
USA	2.86%	3.97%	3.22%	*AUS*	0.42%	0.73%	0.72%
JPN	2.83%	2.99%	1.52%	*GBR*	0.45%	0.61%	0.38%
KOR	1.33%	1.92%	1.38%	*FRA*	0.42%	0.66%	0.43%
TWN	1.22%	1.54%	0.76%	*IND*	0.21%	0.54%	0.55%
DEU	0.96%	1.68%	0.82%	*ITA*	0.30%	0.47%	0.26%
NLD	0.20%	0.32%	0.15%	*CAN*	0.33%	0.55%	0.42%
RUS	0.31%	0.64%	0.37%	*ROW1*	9.74%	14.47%	7.73%
G6	**5.32%**	**7.93%**	**5.54%**				
AS3	**5.37%**	**6.45%**	**3.66%**	*ROW2*	10.88%	16.70%	9.52%

- Eastern coastal and Southern coastal trade change accounts for main change of China's trade share change
- As main trade partner of China, G6 is as important as Asian3

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Literature Review

- **Ricardian trade model**
  Eaton and Kortum (2002), Caliendo and Parro (2015), Waugh (2010); Rodríguez,et.al(2020), **Tombe and Zhu (2020)**

- **Trade and geographical distribution of labor and economic activity**
  Allen and Arkolakis (2014), Caliendo, Parro, Rossi-Hansberg, and Sarte (2018), , Caliendo, Dvorkin, and Parro (2019), Rodriguez-Clare, Ulate, and Vasquez (2020)

- **Structural accounting decomposition**
  Swiecki (2014); Sposi, et.al(2018); Choi, et.al(2018);

- **Trade and Chinese economy**
  Brandt and Holz (2006), Brandt, Tombe, and Zhu (2013), Brandt and Lim (2020), Fan(2020), Alessandria, Khan, Khederlarian, Ruhl, and Steinberg (2021), Campante, Chor, and Li (2023)

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Model

Overview

- Multi-country, multi-sector model with Eaton-Kortum Ricardian trade
  - N_0 China regions plus $N_1 = N - N_0$ other regions

Production

$$q_n^j(\omega^j) = Z_n^j(\omega^j) l_n^j(\omega^j)^{\gamma_n^j} \prod_{k=1}^{J} m_n^{k,j}(\omega^j)^{\gamma_n^{k,j}}$$

- Intermediate goods, $q_n^j(\omega^j)$ are produced by labor, and sectoral composite intermediate good
- Variety-specific productivity $z_{n,t}^j(\omega)$ drawn from Fréchet $F_{n,t}^j(z) = exp(-\lambda_{n,t}^j z^{-\theta})$
- Sector composite good used in consumption, and intermediates

Trade

- Asymmetric iceberg costs
- Trade, determined by Ricardian comparative advantage, directly affects sectoral reallocations

$$\pi_{ni}^j = \frac{\lambda_i^j \left(\kappa_{ni}^j c_i^j\right)^{-\theta_j}}{\sum_{i=1}^{N} \lambda_i^j \left(\kappa_{ni}^j c_i^j\right)^{-\theta_j}} \quad ; \qquad c_n^j \propto w_n^{\gamma_n^j} \prod_{k=1}^{J} P_n^{k\,\gamma_n^{k,j}}$$

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Utility function

Each worker is endowed with 1 unit of labor. For each worker registered in region m, if this worker choosing working in region n, the Cobb-Douglas utility is:

$$U(\mathcal{C}_n) \equiv \mathcal{C}_n \equiv \prod_{k=1}^{J} \mathcal{C}_n^{k\,\alpha_n^k}, \sum_{k=1}^{J} \alpha_n^k = 1 \tag{17}$$

$$\sum_k P_n^k \mathcal{C}_n^k = P_n \mathcal{C}_n = \mathcal{I}_n \tag{18}$$

$$\mathcal{I}_n L_n = I_n \tag{19}$$

For each individual people choosing to work in region n

- his consumption on sector k composite intermediate good is $\mathcal{C}_n^k$
- his aggregate consumption or utility is defined as $\mathcal{C}_n$
- his wage rate is w_n
- Real income for each individual worker in region n is defined as $W_n \equiv \frac{w_n L_n + D_n}{P_n L_n}$

◂ Back 16

Model

Labor flow under migration costs

For each worker with registration place (a.k.a *hukou*) in region m moves to region n, the utility is:

$$U^{n,m} = \frac{z(\omega)}{\nu^{n,m}} U(\mathcal{C}_n)$$

- **Deterministic part I** : C_n, real consumption ▸ Detail
- **Deterministic part II**: $\nu^{n,m} \geq 1$, a proportional ratio captures utility loss when people choose to migrate out of registration place
- **Idiosyncratic part (Preference Shiftier for Moving)** : $z(\omega)$ drawn from Frechet Distribution with mean 1 and variance $(1/\kappa)$
  - The utility of people making the same migration chooses (e.g. $m \to n$) are still heterogeneous across individuals

The fraction of people migrate from m to n

$$\mathrm{m}^{n,m} = \frac{\left(\frac{W_n}{\nu^{n,m}}\right)^{\kappa}}{\sum_{n'}^{N0} \left(\frac{W_{n'}}{\upsilon^{n',m}}\right)^{\kappa}}$$

W_n: real income of representative worker migrates to region n ◂ Back 16

Trade cost, Price and Equilibrium Condition

- Trade cost follow the usual "iceberg" form: For country n, to receive 1 unit good from country i sector j, country i need transport $\kappa_{ni}^j \geq 1$ units good.
- c_n^j: The cost of a bundle of labor and sectoral composite intermediate good of country n sector j.
- $p_n^j(\omega^j)$: the price of intermediate good in country n.
- P_n^j: the price of sector composite intermediate good in country n.
- X_{ni}^j: The expenditure in country n of sector j goods from country i.
- X_n^j: The expenditure in country n of sector j goods.
- Trade cost follow the usual "iceberg" form: For country n, to receive 1 unit good from country i sector j, country i need transport $\kappa_{ni}^j \geq 1$ units good.

$$c_n^j = \Upsilon_n^j w_n^{\gamma_n^j} \prod_{k=1}^J P_n^{k\,\gamma_n^{j,k}},\ p_n^j(\omega^j) = \min_i \frac{c_i^j \kappa_{ni}^j}{z_n^j(\omega^j)},\ P_n^j \underset{a.e}{\to} A_j {\Phi_n^j}^{-\frac{1}{\theta_j}}, \Phi_n^j = \sum_{i=1}^N \lambda_i^j \left(\kappa_{ni}^j c_i^j\right)^{-\theta_j},$$

$$\pi_{ni}^j = \frac{X_{ni}^j}{\sum_{m=1}^N X_{nm}^j} = \frac{X_{ni}^j}{X_n^j}$$

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Model

Equilibrium

Given the model parameters $(\gamma_n^j, \gamma_n^{k,j}, \sigma^j, \alpha_n^k, \theta, \kappa)$, sectoral TFP and bilateral trade costs $(\lambda_n^j, \kappa_{ni})$, labor mobility frictions $(\nu^{n,m})$, and data on each region's trade deficit, initial total population $(D_n, L_n, \bar{L}_m)$, there exist unique values of labor migration share, expenditure share, and wage rate $\pi_{ni}^j, m^{n,m}, w_n$ that can solve the equations in following table.

(F1)	$c_n^j = \Upsilon_n^j {w_n}^{\gamma_n^j} \prod_{k=1}^J {P_n^k}^{\gamma_n^{k,j}}$; $\Upsilon_n^j \equiv \prod_{k=1}^J {\gamma_n^{k,j}}^{-\gamma_n^{k,j}} {\gamma_n^j}^{-\gamma_n^j}$	$\forall(n,j)$
(F2)	$P_n^j = A^j (\sum_{i=1}^N \lambda_i^j (\kappa_{ni}^j c_i^j)^{-\theta})^{-\frac{1}{\theta}}$; $A^j = \Gamma\left(\frac{1+\theta-\sigma^j}{\theta}\right)^{\frac{1}{(1-\sigma^j)}}$	$\forall(n,j)$
(F3)	$\pi_{ni}^j = \frac{\lambda_i^j (c_i^j \kappa_{ni}^j)^{-\theta}}{\sum_{m=1}^N \lambda_m^j (c_m^j \kappa_{nm}^j)^{-\theta}} = \lambda_i^j \left(A^j \frac{c_i^j \kappa_{ni}^j}{P_n^j}\right)^{-\theta}$	$\forall(n,j)$
(H1)	$P_n = \prod_{j=1}^J \left(\frac{P_n^j}{\alpha_n^j}\right)^{\alpha_n^j}$	$\forall(n)$
(H2)	$W_n \equiv \frac{I_n}{P_n L_n}$; $w_n L_n + D_n = I_n$	$\forall(n)$
(H3)	$m^{n,m} = \frac{\left(\frac{W_n}{\nu^{n,m}}\right)^\kappa}{\sum_{n'}^{N0} \left(\frac{W_{n'}}{\nu^{n',m}}\right)^\kappa}$	$\forall(n,m)$
(H4)	$L_n = \sum_m^{N0} m^{n,m} \bar{L}_m$	$\forall(n)$
(M1)	$X_n^j = \alpha_n^j I_n + \sum_{k=1}^J \gamma_n^{j,k} \left(\sum_{i=1}^N X_{in}^k\right)$	$\forall(n,j)$
(M2)	$\sum_{j=1}^J \sum_{i=1}^N X_{ni}^j - D_n = \sum_{j=1}^J \sum_{i=1}^N X_{in}^j$	$\forall(n,j)$
(M2′)	$w_n L_n = \sum_{j=1}^J \gamma_n^j \sum_{i=1}^N \pi_{in}^j X_i^j$	$\forall(n)$

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Mechanism

Analytical Solution

Under one-sector version of the model and friction-less trade

$$\text{TradeShareofGDP}_{\text{CHN}} = \frac{1}{\beta}\left(1 - \sum_{i \in \mathbb{N}_0} \pi_{ni}\right) = \frac{1}{\beta}\left(\sum_{i \in \mathbb{N}_1} \pi_{ni}\right) \tag{20}$$

$$\pi_{ni} = (Z_i)^{\frac{1}{1+\beta\theta}} \left[\sum_{i=1}^{N} (Z_i)^{\frac{1}{1+\beta\theta}}\right]^{-1} \tag{21}$$

- N_0 regions within China; $N_1 = N - N_0$ foreign regions
- $\mathbf{Z_n \equiv \lambda_n L_n}^{\theta\beta}$ is defied as **Productive Capacity** of the region n

Under friction-less migration

$$L_n = \frac{(\lambda_n)^{\frac{\kappa}{1+\kappa+\beta\theta}}}{\sum_{n'}^{N_0} (\lambda_{n'})^{\frac{\kappa}{1+\kappa+\beta\theta}}} \sum_{m}^{N_0} \bar{L}_m \tag{22}$$

- Higher TFP regions with higher labor supply

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Mechanism

Intuition

Intuition: Comparative Advantage (**CA**) and specialization

- TFP
  - As China's TFP increases, all else equal, because of **CA** forces, China produce more varieties, its share of total spending on domestic goods will increase; hence, the import share will decline.
- Trade cost
  - **International** trade cost increase: China specialize more varieties, trade share decrease
  - **Intranational** trade cost decrease: Foreign specialize relatively less varieties, trade share decrease
- Labor supply and Labor mobility cost
  - **Labor supply** decrease: Small country do not need to specialize in too many goods to be able to consume the goods it needs. The country will specialize on less varieties (right tail of the distribution), thus trade share increase.
  - **Labor mobility cost** decrease: ambiguous aggregate effects
    - ★ high TFP region: labor net inflow, specialize more varieties, trade share decrease
    - ★ low TFP region: labor net outflow, specialize less varieties, trade share increase

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Calibration
Overview

- **8 China regions plus 3 foreign regions; 2 periods**
  - **8 regions within China mainland**: NorthEast; BeijingTianjin; NorthernCoastal; EasternCoastal; SouthernCoastal; Central; NorthWest; SouthWest
  - **3 foreign regions**: "Asian3": Korean, Taiwan and Japan aggregate together; "G6": G7 country group without Japan; "ROW": aggregate of rest of the world
  - **2 periods**: 2002 to 2007, 2007 to 2015
- **Four broad sectors (ISIC v4)**
  - **Agriculture**: Agriculture, forestry and fishing (A)
  - **Light industry**: Manufacturing (C10-18);
  - **Heavy industry**: Mining and quarrying (B); Manufacturing (C19-33); Electricity, gas, steam and air conditioning supply (D); Water supply, sewerage, waste management and remediation activities (E)
  - **Services**: the remaining sectors from F to S
- **Data sources**
  - China IRIO table; WIOD table; OECD ICIO table; CEPII; Penn World Tables 10.0; The China's National Census Data

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Calibration

Time Varying Driving Forces

The structural gravity equation from the model:

$$\ln\left(\frac{X^j_{nit}}{X^j_{nnt}}\right) = \ln\left(\lambda^j_{it}\left(c^j_{it}\right)^{-\theta}\right) - \ln\left(\lambda^j_{nt}\left(c^j_{nt}\right)^{-\theta}\right) - \theta\ln\left(\kappa^j_{nit}\right) \tag{23}$$

I assume that unobserved trade cost terms κ^j_{ni} can be described by a symmetric component and an exporter-specific component, and the symmetric component is well proxied by population-weighted geographic distance:

$$\ln\left(\kappa^j_{ni}\right) = \mathrm{EX}^j_i + \beta^j \mathrm{lnDist}_{ni} + \epsilon^j_{ni} \tag{24}$$

Combine 24 and 23, I get the following structural equation:

$$\begin{aligned}\ln\left(\frac{X^j_{ni}}{X^j_{nn}}\right) &= \left\{\ln\left(\lambda^j_i\left(c^j_i\right)^{-\theta}\right) - \theta\mathrm{EX}^j_i\right\} + \left\{-\ln\left(\lambda^j_n\left(c^j_n\right)^{-\theta}\right)\right\} - \theta\beta^j\mathrm{lnDist}_{ni} - \theta\epsilon^j_{ni} \\ &= E^j_i + M^j_n + \Theta^j\mathrm{lnDist}_{ni} + \nu^j_{ni}\end{aligned} \tag{25}$$

where $E^j_i \equiv S^j_i - \theta\ \mathrm{EX}^j_i, M^j_n \equiv -S^j_n, \Theta^j \equiv -\theta\beta^j$, and $S^j_n \equiv \ln\left(\lambda^j_n\left(c^j_n\right)^{-\theta}\right)$

I run the regression 25 separately for each year and sector, then get estimated fixed effects $\tilde{E}^j_i$ and $\tilde{M}^j_n$.

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Calibration

Time Varying Driving Forces

Trade Cost

$$\tilde{\kappa}_{ni}^{j} = \{\left(\frac{X_{ni}^{j}}{X_{nn}^{j}}\right) exp(\tilde{S}_{n}^{j} - \tilde{S}_{i}^{j})\}^{-\frac{1}{\theta}} \tag{26}$$

TFP

$$\tilde{c}_{n}^{j} = \Upsilon_{n}^{j} \tilde{w}_{n}^{\gamma_{n}^{j}} \prod_{k=1}^{J} \tilde{P}_{n}^{k\,\gamma_{n}^{k,j}} \quad and \quad \Upsilon_{n}^{j} \equiv \prod_{k=1}^{J} \gamma_{n}^{k,j\,-\gamma_{n}^{k,j}} \gamma_{n}^{j\,-\gamma_{n}^{j}} \tag{27}$$

$$\tilde{P}_{n}^{j} = \; A^{j} \; \left[\left(\frac{exp(\tilde{S}_{n}^{j})}{\pi_{nn}^{j}}\right)\right]^{-\frac{1}{\theta}} \tag{28}$$

$$\tilde{\lambda}_{n}^{j} = \frac{exp\left(\tilde{S}_{n}^{j}\right)}{\left(\tilde{c}_{n}^{j}\right)^{-\theta}} \tag{29}$$

Migration cost

$$\tilde{\nu}^{n,m} = \left(\frac{\tilde{m}^{n,m}}{\tilde{m}^{m,m}}\right)^{-1/\kappa} \left(\frac{\tilde{W}_{n}}{\tilde{W}_{m}}\right) \quad where \quad \tilde{W}_{n} = \frac{\tilde{w}_{n} L_{n} + D_{n}}{\tilde{P}_{n} L_{n}} \tag{30}$$

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Regression Results

Table: Gravity Equation Results

Sector	Agriculture			Light industry			Heavy industry			Service		
Year	2002	2007	2015	2002	2007	2015	2002	2007	2015	2002	2007	2015
VARIABLES	ln(Xni/Xnn)											
logdist	-2.18***	-1.80***	-1.30***	-1.82***	-1.65***	-0.94***	-1.77***	-1.44***	-1.11***	-2.09***	-1.81***	-1.05***
	(-6.96)	(-6.18)	(-4.78)	(-7.82)	(-8.66)	(-3.86)	(-8.10)	(-8.66)	(-5.33)	(-7.84)	(-7.65)	(-3.73)
M_2	0.54	2.19***	2.63***	0.84**	0.98***	0.66	0.75**	0.25	0.24	0.63	0.65	0.02
	(1.01)	(4.43)	(5.73)	(2.13)	(3.05)	(1.59)	(2.02)	(0.90)	(0.67)	(1.39)	(1.61)	(0.04)
M_3	-1.26**	1.41***	0.32	-1.00**	-1.27***	-1.71***	-0.42	-0.83***	-1.54***	0.15	-0.04	-0.65
	(-2.35)	(2.84)	(0.70)	(-2.49)	(-3.92)	(-4.11)	(-1.12)	(-2.92)	(-4.33)	(0.33)	(-0.09)	(-1.35)
M_4	-0.15	1.86***	1.13**	-1.24***	-0.75**	-0.62	-0.36	-0.31	-0.02	-0.30	-0.78*	-0.15
	(-0.29)	(3.81)	(2.50)	(-3.16)	(-2.36)	(-1.53)	(-0.98)	(-1.10)	(-0.07)	(-0.67)	(-1.96)	(-0.31)
M_5	-0.31	1.46***	1.80***	0.14	0.22	-0.28	0.96***	0.70**	0.07	1.06**	0.23	0.35
	(-0.60)	(3.03)	(4.04)	(0.37)	(0.72)	(-0.70)	(2.67)	(2.55)	(0.20)	(2.40)	(0.58)	(0.75)
M_6	-1.37**	0.55	-0.28	-1.31***	-1.12***	-1.34***	-0.66*	-0.35	-0.68*	-0.67	0.22	-0.56
	(-2.60)	(1.13)	(-0.61)	(-3.32)	(-3.50)	(-3.27)	(-1.80)	(-1.23)	(-1.95)	(-1.49)	(0.56)	(-1.16)
M_7	0.04	1.42***	-0.12	0.72*	0.78**	-0.17	0.70*	0.40	-0.13	0.72	1.16***	-0.06
	(0.09)	(2.94)	(-0.28)	(1.87)	(2.48)	(-0.43)	(1.93)	(1.46)	(-0.39)	(1.62)	(2.94)	(-0.14)
M_8	-1.64***	0.35	-0.14	-0.83**	-0.07	-0.38	0.02	0.13	-0.07	1.05**	0.75*	-0.16
	(-3.18)	(0.72)	(-0.31)	(-2.15)	(-0.24)	(-0.94)	(0.06)	(0.46)	(-0.20)	(2.38)	(1.93)	(-0.35)
M_9	1.41*	2.05***	0.51	0.81	0.70	-0.51	1.04**	0.35	0.09	0.06	-0.61	-1.84***
	(1.91)	(3.01)	(0.81)	(1.48)	(1.58)	(-0.89)	(2.02)	(0.89)	(0.18)	(0.10)	(-1.10)	(-2.77)
M_10	0.13	1.27**	-0.48	-0.89**	-1.11***	-1.50***	-1.26***	-1.50***	-1.31***	-2.20***	-2.41***	-2.32***
	(0.25)	(2.62)	(-1.05)	(-2.29)	(-3.50)	(-3.70)	(-3.46)	(-5.39)	(-3.79)	(-4.96)	(-6.09)	(-4.91)
M_11	1.04	1.76***	-0.66	0.75	0.29	-1.02*	0.89*	0.13	-0.02	1.97***	0.98*	-1.34**
	(1.58)	(2.87)	(-1.15)	(1.52)	(0.71)	(-1.98)	(1.93)	(0.37)	(-0.04)	(3.50)	(1.95)	(-2.24)
Exporter FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Observations	110	110	110	110	110	110	110	110	110	110	110	110
R-squared	0.975	0.977	0.975	0.976	0.979	0.966	0.976	0.980	0.970	0.982	0.981	0.967

t-statistics in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

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Calibration

Results

TFP ▸ Detail

- **2002-2007**: China aggregate TFP increased 24% (weighted by average value-added share)
  - Heavy industry increased 14%
- **2007-2015**:China aggregate TFP increased 57%
  - Heavy industry increased 39%

Trade cost ▸ Detail

- **2002-2007**: For China,
  - In**tra**national trade cost decreased 17% (weighted by average trade share)
  - In**ter**national trade cost:
    - ★ Export cost decreased 27%
- **2007-2015**: For China,
  - In**tra**national trade cost decreased 4%
  - In**ter**national trade cost:
    - ★ Export cost decreased 23%

Migration cost ▸ Detail

- **2002-2007**: Migration cost decreased 25% (weighted by average labor flow share)
- **2007-2015**: Migration cost decreased 4%

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Calibration

Results: TFP change

Return

Table: TFP change across sectors and regions

Average TFP	*2002 to 2007*				***2007 to 2015***			
Change	*China*	*A7-JPN*	*AS3*	*ROW*	*China*	*A7-JPN*	*AS3*	*ROW*
Aggregate	**1.24**	1.18	1.00	1.46	**1.57**	1.24	1.00	1.42
Agricultural	1.36	1.15	1.00	1.52	1.34	0.87	1.00	1.13
Light Industry	1.14	0.97	1.00	1.16	1.28	1.10	1.00	1.03
Heavy Industry	1.14	1.15	1.00	1.29	1.39	1.02	1.00	0.98
Services	1.30	1.20	1.00	1.53	1.78	1.29	1.00	1.63

- TFP change of Asian3 normalized to 1.
- I aggregate the regional sectoral TFP using average value-added shares (average across year 2002, 2007, and 2015) as weights

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Calibration

Results: Labor migration Cost change

Return

Table: Labor migration cost change

Labor migration cost change									
2002 to 2007	***Source***								
Destination	*Ave.*	*NE*	*BT*	*NC*	*EC*	*SC*	*CE*	*NW*	*SW*
Aggregate (Ave)	**0.75**	0.54	2.09	0.89	1.02	0.66	0.63	0.98	0.75
NorthEast (NE)	1.21	1.00	1.81	1.01	1.52	0.77	0.72	1.04	0.83
BeijingTianjin (BT)	0.26	0.24	1.00	0.31	0.44	0.28	0.22	0.35	0.20
NorthernCoastal (NC)	0.77	0.85	1.92	1.00	1.34	0.91	0.76	1.20	0.72
EasternCoastal (EC)	0.63	0.52	1.36	0.53	1.00	0.55	0.46	0.73	0.38
SouthernCoastal (SC)	1.17	0.96	2.53	1.00	1.58	1.00	0.82	1.27	0.80
Central (CE)	1.21	1.25	3.00	1.53	1.76	1.16	1.00	2.11	1.07
NorthWest (NW)	0.77	1.06	1.90	0.85	1.17	0.59	0.57	1.00	0.63
SouthWest (SW)	1.04	1.47	2.65	1.35	1.83	1.32	1.00	2.05	1.00
2007 to 2015	***Source***								
Destination	*Ave.*	*NE*	*BT*	*NC*	*EC*	*SC*	*CE*	*NW*	*SW*
Aggregate (Ave)	**0.96**	0.66	0.23	1.05	1.41	0.57	1.49	0.64	1.26
NorthEast (NE)	1.36	1.00	0.31	2.21	1.57	0.94	2.21	1.17	1.35
BeijingTianjin (BT)	2.21	1.15	1.00	2.21	2.21	1.29	2.72	1.24	2.32
NorthernCoastal (NC)	0.91	0.64	0.30	1.00	0.82	0.39	1.04	0.58	1.06
EasternCoastal (EC)	0.63	0.46	0.26	0.89	1.00	0.56	1.31	0.44	1.14
SouthernCoastal (SC)	1.56	0.80	0.49	1.96	1.59	1.00	2.50	1.19	1.87
Central (CE)	0.46	0.30	0.11	0.64	0.43	0.26	1.00	0.43	0.71
NorthWest (NW)	1.51	0.72	0.30	1.44	1.45	0.69	2.09	1.00	2.14
SouthWest (SW)	0.62	0.34	0.29	0.71	0.63	0.37	1.19	0.45	1.00

- **2002-2007**: average migration cost change is 0.75 (weighted by average labor flow across 3 years)
- **2007-2015**: average migration cost change is 0.96

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Calibration

Results: Trade Cost change

Return

Table: Average Trade Cost Change across sectors and regions

Average Trade Cost Change	***China and China***		***Foreign and Foreign***	
	2002 to 2007	*2007 to 2015*	*2002 to 2007*	*2007 to 2015*
Aggregate	**0.83**	0.96	0.96	0.93
Agricultural	0.84	0.92	0.98	1.10
Light Industry	0.85	1.01	1.03	1.05
Heavy Industry	0.82	1.04	0.98	1.00
Services	0.83	0.83	0.93	0.83
	China to Foreign (Ex)		***Foreign to China (Im)***	
	2002 to 2007	*2007 to 2015*	*2002 to 2007*	*2007 to 2015*
Aggregate	**0.73**	**0.77**	**1.00**	**1.16**
Agricultural	0.74	0.64	1.04	1.56
Light Industry	0.74	0.74	1.14	1.34
Heavy Industry	0.70	0.89	0.98	1.12
Services	0.77	0.58	0.99	1.18

- **2002-2007**: For China, both Intranational trade cost and international trade cost decrease
- **2007-2015**: Trade cost not change to much except the international trade cost.

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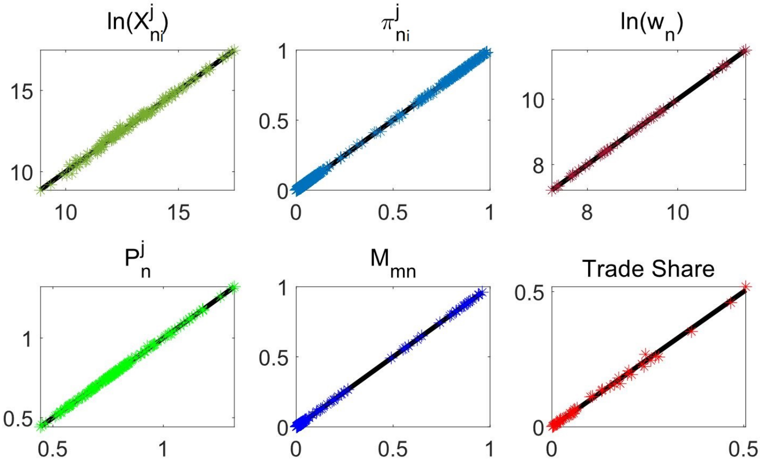
Calibration

Calibration Efficiency



Note: The scatter plots have actual data on the x axis and model-generated value on the y axis with the 45 degree line on the diagonal.

Figure: Calibration Efficiency

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Calibration

Baseline Model and Data

Table: Model fit

China Trade Share of GDP		*Data*	*Model: Balanced trade*	*Model: Exogenous trade deficits*
			Baseline 1	*Baseline 2*
Import (% of GDP)	*2002*	19.68%	**22.09%**	**19.43%**
	2007	25.78%	**29.86%**	**24.58%**
	2015	17.41%	**19.59%**	**18.08%**
Export (% GDP)	*2002*	23.46%	-	**23.19%**
	2007	36.39%	-	**35.25%**
	2015	20.03%	-	**20.69%**
Internal trade (% of GDP)	*2002*	26.95%	23.96%	26.05%
	2007	46.64%	45.79%	45.88%
	2015	50.53%	50.96%	51.79%

- The model reproduces trade share of GDP relatively well
- In the main text, I use ***Baseline 1*** as baseline and do counterfactual under balanced trade
- In the robustness checks, I use ***Baseline 2*** as baseline a do counterfactual with exogenous trade deficit to GDP ratio

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IO linkages

Input-Output linkages	*Source sector*							
	Agricultural	*Light*	*Heavy*	*Services*	*Agricultural*	*Light*	*Heavy*	*Services*
Destination sector	*Average cross China regions*				-			
Agricultural	0.16	0.09	0.11	0.07	-	-	-	-
Light	0.20	0.30	0.10	0.11	-	-	-	-
Heavy	**0.01**	**0.03**	**0.51**	**0.12**	-	-	-	-
Services	0.02	0.05	0.22	0.21	-	-	-	-
Destination sector	*NorthEast*				*BeijingTianjin*			
Agricultural	0.18	0.28	0.01	0.01	0.21	0.13	0.00	0.01
Light	0.14	0.26	0.01	0.05	0.10	0.36	0.01	0.04
Heavy	**0.12**	**0.11**	**0.56**	**0.25**	**0.18**	**0.14**	**0.62**	**0.22**
Services	0.06	0.09	0.12	0.21	0.10	0.12	0.14	0.29
	NorthernCoastal				*EasternCoastal*			
Agricultural	0.18	0.23	0.01	0.01	0.14	0.12	0.01	0.01
Light	0.11	0.35	0.04	0.05	0.13	0.39	0.03	0.04
Heavy	**0.14**	**0.11**	**0.59**	**0.24**	**0.13**	**0.16**	**0.63**	**0.24**
Services	0.04	0.08	0.11	0.20	0.07	0.10	0.11	0.25
	SouthernCoastal				*Central*			
Agricultural	0.15	0.13	0.01	0.01	0.20	0.26	0.01	0.01
Light	0.12	0.38	0.03	0.05	0.10	0.31	0.03	0.05
Heavy	**0.10**	**0.14**	**0.62**	**0.19**	**0.10**	**0.09**	**0.53**	**0.23**
Services	0.07	0.10	0.13	0.24	0.05	0.09	0.14	0.22
	NorthWest				*SouthWest*			
Agricultural	0.19	0.31	0.01	0.01	0.20	0.25	0.01	0.01
Light	0.08	0.22	0.01	0.04	0.09	0.20	0.02	0.05
Heavy	**0.12**	**0.08**	**0.49**	**0.25**	**0.09**	**0.11**	**0.54**	**0.26**
Services	0.07	0.09	0.13	0.21	0.04	0.10	0.15	0.22

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