Feeding China's Rise: The Growth Effects of Trading with China, 1993-2011

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Motivation

Straight from the headlines:

"*China is the one country that might be able to jump-start the global economic recovery; and yet its own economic growth is based on a foundation that is increasingly showing signs of strain*"

Arvind Subramainian, Project Syndicate, 14/4/2016

Motivation

Straight from the headlines:

"*The [Reserve Bank of Australia] said the global economy appeared to be growing at a slightly lower pace than had been expected, while key trading partner China's growth rate was continuing to moderate.*"

"Australia's central bank holds interest rates at record low", ChannelNewsAsia 5/4/2016

Motivation

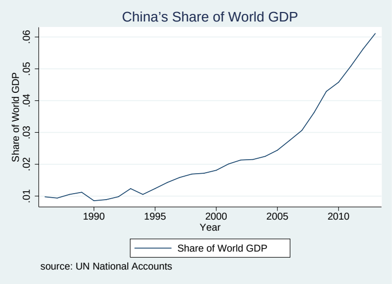
Straight from the headlines:

"*The new normal for China is sub-8% growth, a level seen for most of the past decade as the government's bottom line.*

China will cast a long shadow from the ore mines of Brazil to the car factories of Germany. As the largest source of future economic growth globally, the world is relying on the Chinese "

Kate Allen & Simon Rabinovitch, "The China slowdown, in numbers", FT, 15/7/2013

China's rise in world GDP and trade, in pictures



To me, these sobering forecasts raise two questions:

1. Hasn't China done enough?
2. Just how much has increased trade with China contributed to the growth and welfare of its trading partners over the past twenty years?

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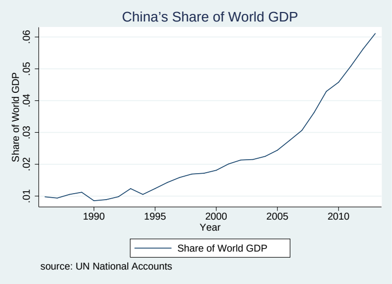

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   (**broad question explored in this paper**)

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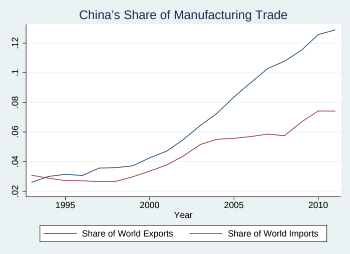

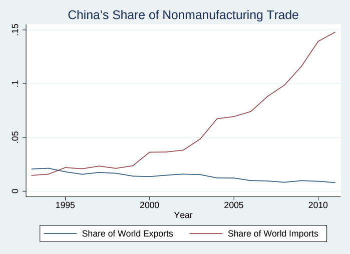

Importantly, China's trade has not grown evenly across all sectors...

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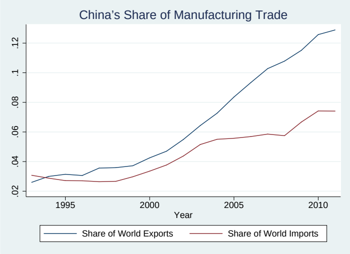

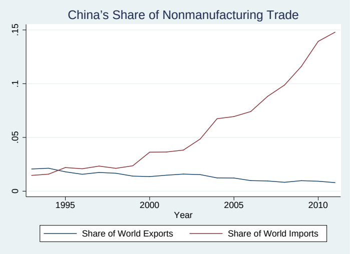

(at least) 2 potentially conflicting effects to to highlight here:

1. A dramatic shift from non-manufactured exports towards manufacturing.
   - Plausibly may have made other manufacturing-exporters **worse off** by eroding their terms of trade.

     (Hicks, 1953; Samuelson, 2004)

Motivation

China's rise in world GDP and trade, in pictures

Importantly, China's trade has not grown evenly across all sectors...

(at least) 2 potentially conflicting effects to highlight here:

1. A dramatic shift from non-manufactured exports towards manufacturing.
2. Within manufacturing, a pronounced shift towards increased trade in capital goods (e.g., machinery, equipment) in particular.
   - Presents viable mechanism for trade-induced capital accumulation

     (Eaton and Kortum, 2001; Mutreja, Ravikumar, & Sposi, 2016)

Proposed Framework

To deliver answers, I will construct and quantify a dynamic, many-country trade model with the following features:

- Trade in (and use in production of) Non-manufactured products (e.g. Agriculture, Mining)
  - upstream, capital-intensive, and important for developing countries
- China becomes a major producer and exporter of traded capital goods during the period - lowers the cost of investment in trading partners
- Input-output linkages between intermediate goods produced in China and more downstream goods produced abroad (and vice versa)
- A role for factor intensity differences: *Ceteris parabus*, China's comparative advantage in labor-intensive production should drive up the reward to capital investment in other countries when China opens to trade.

linkages

Proposed Framework

Quantification

- The model will be fitted to match trade, output, and capital accumulation for 72 developed and developing countries for the years 1993-2011.
- To quantify the model, I take inspiration from the "dynamic trade accounting" methods of Eaton, Kortum, Neiman, & Romalis (2015) ("EKNR")

  (previously: Chari, Kehoe, & McGrattan 2007; Kehoe, Ruhl, & Steinberg 2013)

▸ more

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- However, the analysis performed in this paper adopts an overall larger-scale perspective than that of EKNR (72 countries, 6 sectors)

  This necessitates, in some key places, introducing novel techniques:

  - A straightforward, scalable algorithm for solving dynamic trade models with complex sectoral production linkages
  - A fast, flexible "dummy variables only" method for estimating sectoral-level prices
  - a natural mapping between sectoral prices and the aggregate prices of consumption and investment

    (main modeling innovation)

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Today's Agenda

1. Describe a dynamic, many-country trade model with multiple sectors

Key messages:

- Changes in *sectoral-level* trade can have very different implications in a "static" setting (with fixed capital) vs. a fully dynamic setting.
- Intuition: changes in trade that lower the cost of production and/or consumption do not necessarily lower the price of investment or raise the return to capital.

How much did China's transformation contribute to world growth?

Today's Agenda

1. Describe a dynamic, many-country trade model with multiple sectors

2. Recover changes in sectoral-level technology levels and trade frictions to match world trade, output for the years 1993-2011

Key messages:

- China enjoys much higher rates of sectoral productivity growth and "globalization" than the rest of the world at large between 1993 and 2011.
- China's relative productivity growth is heavily biased to towards manufacturing sectors
- An especially dramatic reduction in trade frictions for China's capital goods sector

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1. Describe a dynamic, many-country trade model with multiple sectors
2. Recover changes in sectoral-level technology levels and trade frictions to match world trade, output for the years 1993-2011
3. Present how China's "exceptional" productivity growth and trade liberalization has contributed to growth in other countries
   - All told, these factors were responsible for (only) **1.2%** of the combined real GDP growth in China's trading partners between 1993 and 2007
   - Significantly larger contribution between 2008 and 2011 (**8.8%**) (helped bolster global economy during recession/recovery)
   - Capital accumulates slowly in response to change in sectoral prices; majority of capital accumulation effects actually yet to be felt

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But what is more interesting is how we get there...

- ◇ **Key idea**: China's change in comparative advantage from Non-Manufacturing to Manufacturing hurts (some) trading partners' terms of trade in the short run, but promotes growth in the long run.
- ◇ Capital accumulation contributes about 40% of China's contribution to growth as of 2007
- ◇ 2/3rds of this capital accumation in turn is due to dynamic sectoral linkages identified by the model

How much did China's transformation contribute to world growth?

Before turning to the model, there are some **important limitations** left on the table that should be acknowledged:

1. I take from the H-O model the canonical assumptions of *constant returns to scale* and *perfect factor mobility* across industries
   - Latter assumption in particular is not innocuous in the case of China
2. Can't in good conscience treat 1993-2011 as a continuous perfect foresight equilibrium transition path; I break up the period into 1993-2007 and 2008-2011.
3. All trade imbalances treated as exogenous. These could be endogenized (Reyes-Heroles, 2015)
4. No multinational activity or FDI.

Related Literature I

Quantifying the "China" Impact:

Samuelson (2004); Hsieh & Ossa (2011); Autor, Dorn, & Hanson (2013); Di Giovanni, Levchenko, & Zhang (2014)

Trade and Growth with Dynamics:

Anderson, Larch, & Yotov (2015); Eaton, Kortum, Neiman, & Romalis (2015); Ravikumar, Santacreu, & Sposi (2016)

Quantifying comparative advantage:

Shikher (2011, 2012); Costinot, Donaldson, & Komunjer (2012); Levchenko & Zhang (2016); Hanson, Lind, & Muendler (2015); Di Giovanni, Levchenko, & Zhang (2014)

Other related frameworks:

Caliendo & Parro (2015)

Related Literature II

Neoclassical trade meets Neoclassical growth:

Chen (1992), Ventura (1997), Atkeson & Kehoe (2000), Bajona & Kehoe (2010), Caliendo (2010)

Evidence for the responsiveness of capital accumulation to trade:

Wacziarg (2001), Baldwin & Seghezza (2008), Wacziarg & Welch (2008), Anderson, Larch, & Yotov (2015)

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   - Intuition: changes in trade that lower the cost of production and/or consumption do not necessarily lower the price of investment or raise the return to capital.

2. Describe a dynamic, many-country trade model with multiple sectors

3. Recover changes in sectoral-level technology levels and trade frictions to match world trade data for the years 1993-2011

Model: Overview

- **Trade**: CES "Armington" ("love-of-varieties") assumption: creates scope for *intra*-industry trade
  - Relative unit cost differences across industries will also give rise to comparative advantage & *inter*-industry trade.
- **Consumption & Utility**: Cobb-Douglas across industries and concave (log) across time
- **Investment**: Also Cobb-Douglas across industries, but with different share requirements than the utility function
- **Production**: All goods are produced with a combination of labor, capital, and intermediate inputs produced by other industries.
  - Both factor intensities and intermediate input requirements differ by industries.
  - These requirements are taken directly from input-output tables.

full model

Model: Overview

An equilibrium in this model will be a (rational expectations) **Perfect Foresight Equilibrium**, where:

- Capital and investment satisfy an Euler condition in every period and satisfy a TVC as $t \to \infty$
- Trade, production, and prices within each period satisfy the competitive equilibrium conditions implied by the trade model.

▸ full model

Model: 4 Key Ideas

4 key ideas from the model:

- The investment choice ($I_{i,t}$)
- Factor rewards ($w_{i,t}$, $r_{i,t}$)
- Consumption and investment prices ($P_{i,C,t}$, $P_{i,IV,t}$)
- Sectoral linkages

Model: 4 Key Ideas

1. The investment choice ($I_{i,t}$)

Real investment made by households in each period ($I_{i,t}$) obeys the following Euler equation:

$$\frac{E_{i,C,t+1}}{E_{i,C,t}}\left(\frac{I_t}{K_t}\right)^{1\text{-}\kappa} = \rho\frac{\phi_{i,t+1}\chi_{i,t}}{P_{i,IV,t}}\left\{\kappa r_{i,t+1} + (1-\kappa)\frac{E_{i,IV,t+1}}{K_{i,t+1}} + (1-\delta)\frac{P_{i,IV,t+1}}{\chi_{i,t+1}}\left(\frac{I_{i,t+1}}{K_{i,t+1}}\right)^{1\text{-}\kappa}\right\}$$

where:

- $r_{i,t+1}$: future return to capital
- $P_{i,IV,t}$: current price of investment
- δ: depreciation rate
- $E_{i,C,t}$, $E_{i,IV,t}$: Consumption and investment expenditure

"Bells and whistles"
κ: governs "capital adjustment costs"; $\phi_{i,t}$ and $\chi_{i,t}$: "structural residuals" needed to exactly match the data (more on these later).

Model: 4 Key Ideas

2. Factor rewards $(w_{i,t}, r_{i,t})$

Factor rewards in the model come from factor market clearing, respond to changes in sectoral output:

$$w_{i,t}L_{i,t} = \sum_k \beta^w_{i,k} \cdot Y_{i,k,t}; \qquad r_{i,t}K_{i,t} = \sum_k \beta^r_{i,k} \cdot Y_{i,k,t}$$

- $\beta^w_{i,k}$: share of labor in production of sector k
- $\beta^w_{i,k}$: share of capital in production of sector k

Trade raises the relative price of output in capital-intensive sectors ⇒ raises the relative return to capital

- creates link between neoclassical trade and neoclassical growth

Model: 4 Key Ideas

3. Consumption and investment prices ($P_{i,C,t}$, $P_{i,IV,t}$)

Final goods prices *also* depend on the makeup of sectoral prices

$$P_{i,C,t} = \prod_k P_{i,k,t}^{\gamma^k_{i,C,t}} \qquad P_{i,IV,t} = \prod_k P_{i,k,t}^{\gamma^k_{i,IV,t}}$$

- $\gamma^k_{i,C,t}$: *usage share* of sector k in consumption
- $\gamma^k_{i,IV,t}$: *usage share* of sector k in investment

Lower relative prices in sectors used more intensively in investment ⇒lower relative price of investment

- creates a second link between sectoral-level trade and capital accumulation

Model: Key Idea #4: *Sectoral Linkages*

Steady state consumption in the model can be written in the form of an "ACR"-type formula:

$$\widehat{G}_i^{SS} \approx \underbrace{\prod_k \widehat{\pi}_{ii,k}^{-\frac{\gamma_{i,C}^k}{\beta_{i,k}^W \theta}}}_{\text{unadjusted gains}} \times \underbrace{\prod_k \prod_l \left[\frac{\widehat{P}_{i,l}}{\widehat{P}_{i,k}}\right]^{-\frac{\beta_{i,k}^l \gamma_{i,C}^k}{\beta_{i,k}^W}}}_{\text{input-output linkages}} \times \underbrace{\prod_k \prod_l \left[\frac{\widehat{P}_{i,l}}{\widehat{P}_{i,k}}\right]^{-\gamma_{i,IV}^l \frac{\beta_{i,k}^r \gamma_{i,C}^k}{\beta_{i,k}^W}}}_{\text{dynamic sectoral linkages}}$$

- $\widehat{\pi}_{ii}$: change in i's internal trade share for sector k
- θ: trade elasticity parameter ("$1-\sigma$") governing intra-industry trade
- each sector must be weighted by its share in consumption, $\gamma_{i,C}^k$

(Arkolakis, Costinot, & Rodríguez-Clare, 2012)

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Model: Key Idea #4: *Sectoral Linkages*

The role of input-output linkages is as in Caliendo & Parro (2015)

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Intuition: real wage gains are higher if trade lowers the relative price of sectors that are used intensively as inputs to other sectors (high $\beta_{i,k}^l$)

- $\beta_{i,k}^l$: share requirement for use of l needed for production of k (from I-O table)

more

Model: Key Idea #4: *Sectoral Linkages*

In the **full model**, sectoral linkages contribute a second, strictly dynamic component:

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When a given $\widehat{P}_{i,l}$ falls, there are additional dynamic benefits if its usage in investment $\gamma_{i,IV}^l$ is high and/or its use of capital in production $\beta_{i,k}^r$ is low.

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Upshot:
The same change in sectoral-level trade can have very different effects for "static" vs. "dynamic" gains from trade.

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1. Describe a dynamic, many-country trade model with multiple sectors
2. Recover changes in sectoral-level technology levels and trade frictions to match world trade, output for the years 1993-2011

   Key messages:

   - China enjoys much higher rates of sectoral productivity growth and "globalization" than the rest of the world at large between 1993 and 2011.
   - China's relative productivity growth is heavily biased to towards manufacturing sectors
   - An especially dramatic reduction in trade frictions for China's capital goods sector
3. Present how China's "exceptional" productivity growth and trade liberalization has contributed to growth in other countries

Accounting procedure

The full vector of "structural residuals" I need for the model to exactly match the data at time t is

$$\Psi_t = \{A_{i,k,t}, d_{ij,k,t}, \gamma^k_{i,C,t}, \gamma^k_{i,IV,t}, \beta^v_{i,k,t}, D_{i,t}, L_{i,t}, \chi_{i,t}, \widehat{\phi}_{i,t+1}\}.$$

- Ψ_t is allowed to vary in order to *exactly match* all observed data (e.g., from 1993-2007).
- It then remains unchanged thereafter (on the path to steady state).
- Counterfactuals will thus isolate the contribution of "China" to what actually occurred in other countries during this period

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Identification of Unkown Time-varying Parameters

Parameter	*Variable*	*Identified by*
$A_{i,k,t}$	Sectoral technology levels	*Estimated* using "dummies only" gravity with *time-varying*, *symmetric* pair fixed effects†
$d_{ij,k,t}$	Bilateral trade frictions	
$\chi_{i,t}$	Investment efficiency	Realization of next period capital K_{t+1} given current period I_t, K_t
$\widehat{\phi}_{i,t+1}$	Inter-temporal preference	How much investment (I_t) is chosen at period t, given perfect foresight about the future.

†Combines Lechenko & Zhang (2016) with Egger & Nigai (2015)

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Time-invariant Parameters

Industry	Value
Trade elasticity (θ)	4.00
Investment adjustment (κ)	0.55
Depreciation (δ)	0.05
Time preference (ρ)	0.95

Data Sources & Construction I

Countries/Regions included (**72**)

- OECD (32) plus 39 non-OECD countries plus 1 "Rest of World" aggregate ▸ list
- "Rest of World" based on available data for excluded countries, absorbs residual trade imbalances and contributes residual world GDP (roughly ~7% of world GDP).

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Industry groupings (**6**):

1. "Non-Manufucturing": Agriculture, Fishing, Forestry, & Mining
2. "Capital-intensive Manufacturing": Food & Beverages, Refined Fuels, Chemicals, Metal Products
3. "Labor-intensive Manufacturing": Textiles & Clothing, Wood Products, Paper Products, Mineral Products
4. "Capital goods": Electrical Machinery, Office computing equipment, Medical/Optical Equipment, Telecommunications Equipment, Motor vehicles, Machinery & Equipment n.e.c., Manufacturing n.e.c.
5. "Construction"
6. "Other Services": all other services besides construction.

(based on ISIC rev 3 industry codes)

Data Sources & Construction II

Bilateral Trade

UN COMTRADE

Production

OECD STAN, UNIDO INDSTAT, and UN National Accounts

Production Technologies

OECD Input-Output Tables (incl. data for 23 non-OECD countries)

GDP, Investment, & Trade Balances

OECD STAN and UN National Accounts

Investment and Consumption Prices, Factor Endowments

Penn World Tables v8.1

All prices are deflated to **1993 USD equivalents**, which serves as a numeraire

Production Linkages

	Input Output Table (*Median Coefficients*)							
	Using industry						*Final Use*	
	NM	MK	ML	K	F	O	C	IV
Input industry								
Non-Manufacturing (NM)	0.096	0.263	0.072	0.006	0.018	0.016	0.038	0.018
Capital-Intensive Manufacturing (MK)	0.074	0.167	0.099	0.084	0.086	0.031	0.121	0.010
Labor-Intensive Manufacturing (ML)	0.012	0.034	0.185	0.091	0.162	0.022	0.042	0.020
Capital Goods (K)	0.012	0.008	0.016	0.255	0.050	0.244	0.042	0.283
Construction (F)	0.007	0.003	0.003	0.002	0.003	0.017	0.000	0.446
Other Services (O)	0.132	0.200	0.255	0.226	0.196	0.277	0.672	0.177
Value Added								
Value added share (β^v)	0.623	0.286	0.305	0.286	0.358	0.596		
Labor share (α^w)	0.260	0.440	0.570	0.570	0.560	0.520		
Capital share (α^r)	0.740	0.560	0.430	0.430	0.440	0.480		

Shocks

China's productivity growth and globalization vs. the Rest of the World, 1993-2007 *(annualized)*

Industry	$\widehat{A}^{1/\theta}_{nonCHN}$	$\widehat{A}^{1/\theta}_{CHN}$	$\widehat{A}^{1/\theta}_{CHN+}$	$\widehat{d}_{nonCHN}$	$\widehat{d}_{CHN}$	$\widehat{d}_{CHN+}$
Non-Manufacturing	-.008	-.003	**.004**	-.007	-.012	**-.005**
Capital-intensive Manuf.	-.008	.023	**.032**	-.006	-.011	**-.005**
Labor-intensive Manuf.	.008	.029	**.021**	-.002	-.004	**-.002**
Capital Goods	.012	.042	**.030**	-.005	-.026	**-.022**
Construction	-.008	-.01	-.001	.	.	.
Other services	.005	-.002	-.007	-.001	-.049	-.048
Manufacturing	.002	.032	.030	-.004	-.016	-.012
Total	.002	.024	.022	-.003	-.015	-.013

Notes: Annualized percentage changes over time (1993-2007). Shocks highlighted in bold are those are used in the counterfactuals.

Table shows how much faster China's estimated technology levels has grown vs. the rest of the world for each sector ($\widehat{A}^{1/\theta}_{CHN+}$) and how much faster its trade barriers have fallen ($\widehat{d}_{CHN+}$)

▸ pictures ▸ 2008-2011

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- Capital accumulation contributes about 40% of China's contribution to growth as of 2007
- Two-thirds of this capital accumation in turn is due to dynamic sectoral linkages identified by the model

Model Results (1993-2007)

Using shocks to *both* technologies and trade frictions

	Model Outcomes for Selected Countries					
	Static Model (2007 values)			*Dynamic Model (2007 values)*		
	Real GDP	$\widehat{r}/\widehat{w}$	$\widehat{P}_{IV}/\widehat{P}_C$	Real GDP	$\widehat{K}$	$\hat{x}$
(selected countries)						
Australia	0.0043	0.0088	-0.0045	0.0073	0.0063	0.0142
China	0.6386	0.0442	-0.2005	0.7800	0.2049	0.1079
Ethiopia	0.0066	0.0009	-0.0074	0.0083	0.0029	0.0086
Germany	0.0001	0.0061	-0.0051	0.0013	0.0025	0.0069
Italy	-0.0004	0.0031	-0.0026	0.0004	0.0012	0.0032
Japan	0.0009	0.0026	-0.0062	0.0019	0.0015	0.0048
Malaysia	0.0127	0.0020	-0.0248	0.0170	0.0057	0.0099
Peru	0.0052	0.0083	-0.0080	0.0075	0.0044	0.0131
USA	0.0018	0.0013	-0.0051	0.0024	0.0012	0.0038
Vietnam	0.0242	-0.0117	-0.0100	0.0264	0.0034	-0.0006
World	0.0272	0.0097	-0.0118	0.0675	0.0266	0.0071
Non-China	0.0028	0.0029	-0.0058	0.0048	0.0025	0.0048

Left: How much do China's changing sectoral productivities and trade liberalization contribute to 2007 real GDP in a "static" (*fixed capital*) setting?

Right: Results from the full dynamic model with capital accumulation factored in.

Model Results (1993-2007)

Using shocks to *both* technologies and trade frictions

	Model Outcomes for Selected Countries					
	Static Model (2007 values)			*Dynamic Model (2007 values)*		
	Real GDP	$\widehat{r}/\widehat{w}$	$\widehat{P}_{IV}/\widehat{P}_C$	Real GDP	$\widehat{K}$	$\hat{x}$
(selected countries)						
Australia	0.0043	0.0088	-0.0045	0.0073	0.0063	0.0142
China	0.6386	0.0442	-0.2005	0.7800	0.2049	0.1079
Ethiopia	0.0066	0.0009	-0.0074	0.0083	0.0029	0.0086
Germany	0.0001	0.0061	-0.0051	0.0013	0.0025	0.0069
Italy	-0.0004	0.0031	-0.0026	0.0004	0.0012	0.0032
Japan	0.0009	0.0026	-0.0062	0.0019	0.0015	0.0048
Malaysia	0.0127	0.0020	-0.0248	0.0170	0.0057	0.0099
Peru	0.0052	0.0083	-0.0080	0.0075	0.0044	0.0131
USA	0.0018	0.0013	-0.0051	0.0024	0.0012	0.0038
Vietnam	0.0242	-0.0117	-0.0100	0.0264	0.0034	-0.0006
World	0.0272	0.0097	-0.0118	0.0675	0.0266	0.0071
Non-China	0.0028	0.0029	-0.0058	0.0048	0.0025	0.0048

Broad takeaways: developing, resource-oriented, and Asian economies tend to gain more across the board

About 40% of the rest of the world's real GDP gains as of 2007 are due to capital accumulation

(much larger effects in the long-run, however)

▸ big ▸ 2008-2011

Model Results (1993-2007)

***Decomposition*: using changes in China's productivity changes only**

Model Outcomes for Selected Countries

	Static Model (2007 values)			*Dynamic Model (2007 values)*		
	Real GDP	$\widehat{r}/\widehat{w}$	$\widehat{P}_{IV}/\widehat{P}_{C}$	Real GDP	$\widehat{K}$	$\hat{x}$
(selected countries)						
Australia	0.0034	0.0077	-0.0036	0.0060	0.0054	0.0126
China	0.5527	0.0446	-0.1626	0.6710	0.1791	0.0906
Ethiopia	0.0049	0.0007	-0.0055	0.0063	0.0022	0.0069
Germany	-0.0004	0.0055	-0.0039	0.0007	0.0020	0.0060
Italy	-0.0005	0.0026	-0.0020	0.0001	0.0009	0.0027
Japan	-0.0001	0.0022	-0.0046	0.0007	0.0011	0.0036
Malaysia	0.0077	0.0020	-0.0185	0.0109	0.0037	0.0074
Peru	0.0042	0.0073	-0.0063	0.0062	0.0037	0.0116
USA	0.0013	0.0010	-0.0033	0.0017	0.0008	0.0025
Vietnam	0.0196	-0.0113	-0.0071	0.0209	0.0011	-0.0018
World	0.0240	0.0092	-0.0063	0.0603	0.0233	0.0058
Non-China	0.0017	0.0025	-0.0045	0.0033	0.0018	0.0038

When we only consider productivity changes, a handful of countries suffer negative consequences in the static setting.

When capital is endogenous, however, everyone realizes higher real GDP.

big trade frictions only

Model Results (1993-2007)

Appraising dynamic sectoral linkages

	Model Outcomes for Selected Countries								
	Static Model (2007 values)			*Dynamic Model (2007 values)*			*Dynamic Model (Steady State)*		
	Real GDP	$\widehat{r}/\widehat{w}$	$\widehat{P}_{IV}/\widehat{P}_C$	Real GDP	$\widehat{K}$	$\hat{x}$	Real GDP	$\widehat{K}$	$\widehat{\mathbf{U}}$
A. No factor intensity differences or final usage differences ($\alpha^r_{i,k} = \alpha^r_{i,k}$; $\gamma^k_{i,C} = \gamma^k_{i,IV} = \gamma^k_i$)									
DEU	0.0002	0.0000	0.0000	0.0003	0.0000	-0.0001	0.0021	0.0021	0.0007
KOR	0.0037	0.0000	0.0000	0.0044	0.0008	0.0010	0.0150	0.0150	0.0061
PER	0.0051	0.0000	0.0000	0.0051	-0.0001	0.0008	0.0132	0.0132	0.0066
USA	0.0018	0.0000	0.0000	0.0020	0.0003	0.0009	0.0055	0.0055	0.0020
VNM	0.0242	0.0000	0.0000	0.0278	0.0081	0.0061	0.0534	0.0535	0.0287
All Non-China	0.0028	0.0000	0.0000	0.0038	0.0007	0.0013	0.0083	0.0080	0.0053

When factor intensity differences and final usage differences are removed, the effect on 2007 capital falls by more than 2/3rds

The effect on steady state capital falls by almost 90% (from 7.62%)

big

Closing Remarks

Rich framework for teasing out the effects of changes in the sectoral composition of trade:

- static vs. dynamic dichotomies, H-O forces, I-O linkages, trade in capital goods all play a role
- Evidence for Samuelson (2004) result in the short-run, reverses in the long-run due to capital accumulation.

Highlights the role of "dynamic sectoral linkages" in shaping the gains from trade

- Explain three-fourth's of China's effects on capital accumulation in other countries
- These can take a long time to truly manifest, however.

Main result:

China's "exceptional" trade liberalization and productivity growth between 1993-2007 in tradeables added about half a point each to the rest of the world's 2007 real GDP. I also find a similar result for the (much shorter) period 2008-2011.

Closing Remarks

Future lines of attack:

- How do results differ with an endogenous trade balance?
- More sectors → closer to Caliendo and Parro
- More stark experiments: e.g., shutting off capital goods trade with China entirely.

Other Results

I also experimented with "neutralizing" (rather than removing) China's productivity growth, in two different ways:

- Removing productivity growth differences *across* NonManufacturing vs. the Manufacturing sectors (higher static gains for South Korea, Germany, among others)
- Doing the same *within* the Manufacturing categories only (larger dynamic gains for $nonCHN$ countries).

table

Dynamic gains from trade in this setting less sensitive to changes in "θ" than static gains from trade.

table

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Model Results (1993-2007)

Using shocks to both technologies and trade frictions

	Model Outcomes for Selected Countries								
	Static Model (1993 values)			*Dynamic Model (2007 values)*			*Dynamic Model (Steady State)*		
	Real GDP	$\widehat{r}/\widehat{w}$	$\widehat{P}_{IV}/\widehat{P}_C$	Real GDP	$\widehat{K}$	$\hat{x}$	Real GDP	$\widehat{K}$	$\widehat{\mathbf{U}}$
(selected countries)									
Australia	0.0043	0.0088	-0.0045	0.0073	0.0063	0.0142	0.0799	0.1306	0.0093
Brazil	0.0012	0.0035	-0.0033	0.0023	0.0022	0.0059	0.0303	0.0487	0.0028
Canada	0.0017	0.0017	-0.0041	0.0025	0.0016	0.0035	0.0256	0.0411	0.0033
China	0.6386	0.0442	-0.2005	0.7800	0.2049	0.1079	2.2631	3.0027	1.0583
Ethiopia	0.0066	0.0009	-0.0074	0.0083	0.0029	0.0086	0.0711	0.0932	0.0098
France	0.0004	0.0020	-0.0022	0.0009	0.0009	0.0026	0.0114	0.0205	0.0008
Germany	0.0001	0.0061	-0.0051	0.0013	0.0025	0.0069	0.0208	0.0438	0.0008
Italy	-0.0004	0.0031	-0.0026	0.0004	0.0012	0.0032	0.0135	0.0226	0.0001
Japan	0.0009	0.0026	-0.0062	0.0019	0.0015	0.0048	0.0227	0.0422	0.0010
Malaysia	0.0127	0.0020	-0.0248	0.0170	0.0057	0.0099	0.2133	0.2720	0.0457
Peru	0.0052	0.0083	-0.0080	0.0075	0.0044	0.0131	0.1099	0.1643	0.0161
South Africa	0.0035	0.0030	-0.0062	0.0048	0.0024	0.0071	0.0442	0.0694	0.0064
South Korea	0.0037	0.0009	-0.0080	0.0054	0.0024	0.0036	0.0313	0.0494	0.0058
USA	0.0018	0.0013	-0.0051	0.0024	0.0012	0.0038	0.0202	0.0354	0.0022
Vietnam	0.0242	-0.0117	-0.0100	0.0264	0.0034	-0.0006	0.0712	0.0789	0.0302
World	0.0272	0.0097	-0.0118	0.0675	0.0266	0.0071	0.2099	0.3282	0.1308
Non-China	0.0028	0.0029	-0.0058	0.0048	0.0025	0.0048	0.0530	0.0762	0.0075

"Static" columns show effects (as of 2007) of China's changing sectoral productivities and trade liberalization

The remaining columns add 2007 results with capital accumulation factored in, followed by long-run (steady state) outcomes.

Using shocks to both technologies and trade frictions

	Model Outcomes for Selected Countries								
	Static Model (1993 values)			*Dynamic Model (2007 values)*			*Dynamic Model (Steady State)*		
	Real GDP	$\widehat{r}/\widehat{w}$	$\widehat{P}_{IV}/\widehat{P}_{C}$	Real GDP	$\widehat{K}$	$\hat{x}$	Real GDP	$\widehat{K}$	$\widehat{\mathbf{U}}$
(selected countries)									
Australia	0.0043	0.0088	-0.0045	0.0073	0.0063	0.0142	0.0799	0.1306	0.0093
Brazil	0.0012	0.0035	-0.0033	0.0023	0.0022	0.0059	0.0303	0.0487	0.0028
Canada	0.0017	0.0017	-0.0041	0.0025	0.0016	0.0035	0.0256	0.0411	0.0033
China	0.6386	0.0442	-0.2005	0.7800	0.2049	0.1079	2.2631	3.0027	1.0583
Ethiopia	0.0066	0.0009	-0.0074	0.0083	0.0029	0.0086	0.0711	0.0932	0.0098
France	0.0004	0.0020	-0.0022	0.0009	0.0009	0.0026	0.0114	0.0205	0.0008
Germany	0.0001	0.0061	-0.0051	0.0013	0.0025	0.0069	0.0208	0.0438	0.0008
Italy	-0.0004	0.0031	-0.0026	0.0004	0.0012	0.0032	0.0135	0.0226	0.0001
Japan	0.0009	0.0026	-0.0062	0.0019	0.0015	0.0048	0.0227	0.0422	0.0010
Malaysia	0.0127	0.0020	-0.0248	0.0170	0.0057	0.0099	0.2133	0.2720	0.0457
Peru	0.0052	0.0083	-0.0080	0.0075	0.0044	0.0131	0.1099	0.1643	0.0161
South Africa	0.0035	0.0030	-0.0062	0.0048	0.0024	0.0071	0.0442	0.0694	0.0064
South Korea	0.0037	0.0009	-0.0080	0.0054	0.0024	0.0036	0.0313	0.0494	0.0058
USA	0.0018	0.0013	-0.0051	0.0024	0.0012	0.0038	0.0202	0.0354	0.0022
Vietnam	0.0242	-0.0117	-0.0100	0.0264	0.0034	-0.0006	0.0712	0.0789	0.0302
World	0.0272	0.0097	-0.0118	0.0675	0.0266	0.0071	0.2099	0.3282	0.1308
Non-China	0.0028	0.0029	-0.0058	0.0048	0.0025	0.0048	0.0530	0.0762	0.0075

Broad takeaways: developing, resource-oriented, and Asian economies tend to gain more across the board

About 40% of the rest of the world's GDP gains as of 2007 are due to capital accumulation; much larger effects in the long-run, however.

Model Results (2008-2011)

Using shocks to both technologies and trade frictions

	Model Outcomes for Selected Countries (2008-2011)								
	Static Model (2011 values)			*Dynamic Model (2011 values)*			*Dynamic Model (Steady State)*		
	Real GDP	$\widehat{r}/\widehat{w}$	$\widehat{P}_{IV}/\widehat{P}_{C}$	Real GDP	$\widehat{K}$	$\hat{x}$	Real GDP	$\widehat{K}$	$\widehat{\mathbf{U}}$
(selected countries)									
Australia	0.0041	0.0104	-0.0032	0.0113	0.0050	0.0303	0.1676	0.2702	0.0270
Brazil	0.0014	0.0030	-0.0022	0.0038	0.0018	0.0121	0.0616	0.0977	0.0092
Canada	0.0013	0.0016	-0.0023	0.0033	0.0013	0.0069	0.0436	0.0717	0.0067
China	0.3051	0.0116	-0.0696	1.7342	0.1557	0.3024	7.1785	9.6281	2.7962
Ethiopia	0.0029	0.0012	-0.0021	0.0082	0.0032	0.0107	0.0756	0.0977	0.0141
France	0.0005	0.0015	-0.0019	0.0008	0.0007	0.0057	0.0228	0.0435	0.0010
Germany	-0.0001	0.0037	-0.0027	0.0004	0.0014	0.0118	0.0318	0.0675	0.0003
Italy	-0.0002	0.0019	-0.0019	-0.0003	0.0007	0.0064	0.0273	0.0470	-0.0004
Japan	-0.0003	0.0026	-0.0031	0.0009	0.0009	0.0081	0.0291	0.0574	0.0005
Malaysia	0.0050	0.0038	-0.0103	0.0182	0.0053	0.0159	0.2882	0.3724	0.0674
Peru	0.0037	0.0056	-0.0054	0.0110	0.0045	0.0180	0.1651	0.2490	0.0348
South Africa	0.0030	0.0044	-0.0050	0.0078	0.0031	0.0173	0.0924	0.1503	0.0182
South Korea	-0.0010	0.0017	-0.0040	0.0035	0.0010	0.0051	0.0431	0.0764	0.0032
USA	0.0013	0.0012	-0.0035	0.0036	0.0009	0.0086	0.0399	0.0711	0.0051
Vietnam	0.0106	-0.0057	-0.0105	0.0365	0.0034	0.0043	0.1448	0.1833	0.0559
World	0.0259	0.0081	-0.0036	0.1114	0.0278	0.0156	0.3223	0.6285	0.2182
Non-China	0.0017	0.0029	-0.0033	0.0059	0.0017	0.0089	0.0844	0.1244	0.0124

The noteworthy result here is that China's percentage contribution to non-China world GDP over this 4 year period (0.59%) is actually larger than it was for the entire 14 year period 1993-2007.

back

Model Results (1993-2007)

Using shocks to trade frictions only

	Model Outcomes for Selected Countries								
	Static Model (1993 values)			*Dynamic Model (2007 values)*			*Dynamic Model (Steady State)*		
	Real GDP	$\widehat{r}/\widehat{w}$	$\widehat{P}_{IV}/\widehat{P}_C$	Real GDP	$\widehat{K}$	$\hat{x}$	Real GDP	$\widehat{K}$	$\widehat{U}$
(selected countries)									
Australia	0.0027	0.0047	-0.0027	0.0040	0.0029	0.0064	0.0286	0.0448	0.0046
Brazil	0.0008	0.0022	-0.0020	0.0014	0.0012	0.0034	0.0148	0.0239	0.0015
Canada	0.0012	0.0017	-0.0021	0.0017	0.0010	0.0022	0.0120	0.0186	0.0020
China	0.0361	0.0135	-0.0235	0.0490	0.0248	0.0139	0.1141	0.1352	0.0594
Ethiopia	0.0043	0.0008	-0.0048	0.0052	0.0016	0.0051	0.0337	0.0433	0.0057
France	0.0006	0.0011	-0.0012	0.0009	0.0005	0.0015	0.0064	0.0108	0.0008
Germany	0.0009	0.0024	-0.0031	0.0014	0.0013	0.0036	0.0123	0.0243	0.0011
Italy	0.0001	0.0015	-0.0015	0.0005	0.0006	0.0018	0.0075	0.0123	0.0003
Japan	0.0014	0.0015	-0.0042	0.0019	0.0010	0.0032	0.0137	0.0241	0.0014
Malaysia	0.0106	0.0028	-0.0170	0.0131	0.0038	0.0070	0.1127	0.1415	0.0308
Peru	0.0029	0.0041	-0.0051	0.0040	0.0020	0.0060	0.0386	0.0574	0.0073
South Africa	0.0022	0.0021	-0.0037	0.0029	0.0014	0.0039	0.0191	0.0298	0.0033
South Korea	0.0047	0.0012	-0.0054	0.0060	0.0022	0.0034	0.0216	0.0318	0.0059
USA	0.0013	0.0010	-0.0033	0.0017	0.0008	0.0025	0.0110	0.0193	0.0014
Vietnam	0.0107	-0.0043	-0.0088	0.0121	0.0029	0.0013	0.0327	0.0433	0.0122
World	0.0042	0.0031	-0.0034	0.0092	0.0046	0.0032	0.0418	0.0609	0.0158
Non-China	0.0022	0.0018	-0.0035	0.0033	0.0014	0.0030	0.0261	0.0371	0.0045

All countries benefit from trade liberalization, however. Thus, trade liberalization contributes a relatively larger share of the "static" gains from trade here.

back

Model Results (1993-2007)

Using shocks to tradeable productivities only

	Model Outcomes for Selected Countries								
	Static Model (1993 values)			*Dynamic Model (2007 values)*			*Dynamic Model (Steady State)*		
	Real GDP	$\widehat{r}/\widehat{w}$	$\widehat{P}_{IV}/\widehat{P}_C$	Real GDP	$\widehat{K}$	$\hat{x}$	Real GDP	$\widehat{K}$	$\widehat{\mathbf{U}}$
(selected countries)									
Australia	0.0034	0.0077	-0.0036	0.0060	0.0054	0.0126	0.0722	0.1179	0.0080
Brazil	0.0009	0.0028	-0.0026	0.0018	0.0017	0.0050	0.0272	0.0437	0.0024
Canada	0.0012	0.0011	-0.0032	0.0018	0.0011	0.0027	0.0222	0.0358	0.0026
China	0.5527	0.0446	-0.1626	0.6710	0.1791	0.0906	1.8694	2.3972	0.9229
Ethiopia	0.0049	0.0007	-0.0055	0.0063	0.0022	0.0069	0.0617	0.0807	0.0080
France	0.0001	0.0016	-0.0017	0.0005	0.0007	0.0022	0.0097	0.0177	0.0004
Germany	-0.0004	0.0055	-0.0039	0.0007	0.0020	0.0060	0.0175	0.0379	0.0002
Italy	-0.0005	0.0026	-0.0020	0.0001	0.0009	0.0027	0.0116	0.0197	-0.0001
Japan	-0.0001	0.0022	-0.0046	0.0007	0.0011	0.0036	0.0173	0.0340	0.0000
Malaysia	0.0077	0.0020	-0.0185	0.0109	0.0037	0.0074	0.1768	0.2253	0.0345
Peru	0.0042	0.0073	-0.0063	0.0062	0.0037	0.0116	0.0992	0.1477	0.0142
South Africa	0.0027	0.0023	-0.0048	0.0037	0.0018	0.0058	0.0390	0.0612	0.0053
South Korea	0.0005	0.0007	-0.0057	0.0017	0.0011	0.0019	0.0218	0.0366	0.0022
USA	0.0013	0.0010	-0.0033	0.0017	0.0008	0.0025	0.0110	0.0193	0.0014
Vietnam	0.0196	-0.0113	-0.0071	0.0209	0.0011	-0.0018	0.0616	0.0664	0.0257
World	0.0240	0.0092	-0.0063	0.0603	0.0233	0.0058	0.1909	0.2974	0.1199
Non-China	0.0017	0.0025	-0.0045	0.0033	0.0018	0.0038	0.0460	0.0664	0.0058

When we only consider productivity changes, a handful of countries suffer negative consequences in the static setting.

When capital is endogenous, however, everyone realizes higher real GDP.

back

Model Results (1993-2007)

Appraising "dynamic sectoral linkages"

Model Outcomes for Selected Countries

	Static Model (2007 values)			*Dynamic Model (2007 values)*			*Dynamic Model (Steady State)*		
	Real GDP	$\widehat{r}/\widehat{w}$	$\widehat{P}_{IV}/\widehat{P}_{C}$	Real GDP	$\widehat{K}$	$\hat{x}$	Real GDP	$\widehat{K}$	$\widehat{\mathbf{U}}$
A. No factor intensity differences or final usage differences ($\alpha^r_{i,k} = \alpha^r_{i,k}$; $\gamma^k_{i,C} = \gamma^k_{i,IV} = \gamma^k_i$)									
DEU	0.0002	0.0000	0.0000	0.0003	0.0000	-0.0001	0.0021	0.0021	0.0007
KOR	0.0037	0.0000	0.0000	0.0044	0.0008	0.0010	0.0150	0.0150	0.0061
PER	0.0051	0.0000	0.0000	0.0051	-0.0001	0.0008	0.0132	0.0132	0.0066
USA	0.0018	0.0000	0.0000	0.0020	0.0003	0.0009	0.0055	0.0055	0.0020
VNM	0.0242	0.0000	0.0000	0.0278	0.0081	0.0061	0.0534	0.0535	0.0287
All Non-China	0.0028	0.0000	0.0000	0.0038	0.0007	0.0013	0.0083	0.0080	0.0053
B. Remove factor intensity differences only ($\alpha^r_{i,k} = \alpha^r_{i,k}$)									
DEU	0.0002	0.0000	-0.0048	0.0005	0.0005	0.0014	0.0065	0.0128	0.0007
KOR	0.0037	0.0000	-0.0080	0.0052	0.0019	0.0028	0.0223	0.0317	0.0059
PER	0.0051	0.0000	-0.0080	0.0055	0.0007	0.0030	0.0209	0.0284	0.0075
USA	0.0018	0.0000	-0.0051	0.0022	0.0008	0.0026	0.0101	0.0168	0.0019
VNM	0.0242	0.0000	-0.0098	0.0288	0.0101	0.0073	0.0609	0.0719	0.0285
All Non-China	0.0028	0.0000	-0.0057	0.0043	0.0015	0.0031	0.0161	0.0209	0.0054
C. Remove differences in final demand shares only ($\gamma^k_{i,C} = \gamma^k_{i,IV} = \gamma^k_i$)									
DEU	0.0001	0.0061	0.0000	0.0011	0.0022	0.0058	0.0104	0.0211	0.0007
KOR	0.0037	0.0009	0.0000	0.0047	0.0015	0.0021	0.0161	0.0181	0.0057
PER	0.0052	0.0083	0.0000	0.0071	0.0036	0.0107	0.0833	0.1087	0.0150
USA	0.0018	0.0013	0.0000	0.0023	0.0009	0.0025	0.0106	0.0133	0.0023
VNM	0.0242	-0.0117	0.0000	0.0253	0.0014	-0.0018	0.0501	0.0367	0.0303
All Non-China	0.0028	0.0029	0.0000	0.0043	0.0017	0.0032	0.0294	0.0347	0.0073

back

China's productivity growth and globalization vs. the Rest of the World, 2008-2011

Industry	$\widehat{A}^{1/\theta}_{nonCHN}$	$\widehat{A}^{1/\theta}_{CHN}$	$\widehat{A}^{1/\theta}_{CHN+}$	$\widehat{d}_{nonCHN}$	$\widehat{d}_{CHN}$	$\widehat{d}_{CHN+}$
Non-Manufacturing	.031	.076	**.046**	.006	-.01	**-.016**
Capital-intensive Manuf.	-.029	.014	**.044**	-.006	.01	**.016**
Labor-intensive Manuf.	-.008	.053	**.061**	-.001	-.008	**-.006**
Capital Goods	.007	.067	**.060**	-.002	.004	**.006**
Construction	-.018	-.029	-.011	.	.	.
Other services	.002	.003	.001	-.002	-.051	-.049
Manufacturing	-.016	.039	.055	-.004	.001	.005
Total	.000	.038	.038	.000	-.002	-.002

Notes: Annualized percentage changes over time. Shocks highlighted in bold are those are used in the counterfactuals.

back

Recovering shocks: Trade, Prices, and Technology

Consider the equation for trade flows:

$$X_{ij,k,t} = \frac{A_{i,k,t}\left(c_{i,k,t}d_{ij,k,t}\right)^{-\theta}}{P_{j,k,t}^{-\theta}} E_{j,k,t}$$

Note that it has distinct *exporter*, *importer*, and *pair* components:

- $A_{i,k,t}c_{i,k,t}^{-\theta}$: "absolute advantage" of the exporting country
- $E_{j,k,t}/P_{j,k,t}^{-\theta}$: market size and price level of the importing country
- $d_{ij,k,t}^{-\theta}$: bilateral (*pair*-specific) trade frictions

Recovering shocks: Trade, Prices, and Technology

The trade equation then takes the following (estimable) form:

$$X_{ij,k,t} = \exp\left[\underbrace{\ln\left(A_{i,k,t}c_{i,k,t}^{-\theta}\right)}_{\ln\Gamma_{ikt}} + \underbrace{\ln\left(\frac{E_{j,k,t}}{P_{j,k,t}^{-\theta}}\right)}_{\ln\Phi_{jkt}} + \underbrace{\ln d_{ij,k,t}^{-\theta}}_{\ln\eta_{ijkt}}\right] + \varepsilon_{ijkt}.$$

$\ln\Gamma_{ikt}$, $\ln\Phi_{jkt}$, $\ln\eta_{ijkt}$: *fixed effects* which are computed using **Poisson PML** estimation

(the pair fixed effect, $\ln\eta_{ijkt}$, is symmetric)

Recovering shocks: Trade, Prices, and Technology

The trade equation then takes the following (estimable) form:

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This specification is both highly flexible as well as very efficient

- only restrictions needed for identification are (i) η_{ijkt} is symmetric in both directions, (ii) all $\eta_{ii,k,t} = 1$
- prefer PPML for its nice aggregation properties (Fally, 2015)
- iterative methods can be used to quickly solve for any number of fixed effects

Recovering shocks: Trade, Prices, and Technology

$$X_{ij,k,t} = \exp\left[\underbrace{\ln\left(A_{i,k,t}c_{i,k,t}^{-\theta}\right)}_{\ln \Gamma_{ikt}} + \underbrace{\ln\left(\frac{E_{j,k,t}}{P_{j,k,t}^{-\theta}}\right)}_{\ln \Phi_{jkt}} + \underbrace{\ln d_{ij,k,t}^{-\theta}}_{\ln \eta_{ijkt}}\right] + \varepsilon_{ijkt}.$$

Prices, $\{P_{j,k,t}\}$, then follow directly from Φ_{jkt}, data on $E_{j,kt}$.

Recovering shocks: Trade, Prices, and Technology

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Prices, $\{P_{j,k,t}\}$, then follow directly from Φ_{jkt}, data on $E_{j,kt}$

$c_{i,k,t} = c(w, r, P)$ can be computed using $\{P_{j,k,t}\}$, data on $\{w\}$, $\{r\}$

Recovering shocks: Trade, Prices, and Technology

$$X_{ij,k,t} = \exp\left[\underbrace{\ln\left(A_{i,k,t}c_{i,k,t}^{-\theta}\right)}_{\ln \Gamma_{ikt}} + \underbrace{\ln\left(\frac{E_{j,k,t}}{P_{j,k,t}^{-\theta}}\right)}_{\ln \Phi_{jkt}} + \underbrace{\ln d_{ij,k,t}^{-\theta}}_{\ln \eta_{ijkt}}\right] + \varepsilon_{ijkt}.$$

Prices, $\{P_{j,k,t}\}$, then follow directly from Φ_{jkt}, data on $E_{j,kt}$

$c_{i,k,t} = c(w, r, P)$ can be computed using $\{P_{j,k,t}\}$, data on $\{w\}$, $\{r\}$

Technologies $\{A_{i,k,t}\}$ then follow from the estimated Γ's.

back

Construction and Services Sectors

Finally, how to model sectors for which bilateral trade flows are not available?

Construction and Services Sectors

Finally, how to model sectors for which bilateral trade flows are not available?

The price levels for these sectors can be backed out from data on investment and consumption price levels.

$$P_{i,F}^{\gamma_{i,IV}^{F}} = \frac{P_{i,IV}}{\prod_{k \neq F} P_{i,k}^{\gamma_{i,IV}^{k}}} \qquad P_{i,O}^{\gamma_{i,IV}^{O}} = \frac{P_{i,C}}{\prod_{k \neq O} P_{i,k}^{\gamma_{i,C}^{k}}}$$

Fitting the Model to Data

Construction and Services Sectors

Finally, how to model sectors for which bilateral trade flows are not available?

The price levels for these sectors can be backed out from data on investment and consumption price levels.

$$P_{i,F}^{\gamma_{i,IV}^{F}} = \frac{P_{i,IV}}{\prod_{k \neq F} P_{i,k}^{\gamma_{i,IV}^{k}}} \qquad P_{i,O}^{\gamma_{i,IV}^{O}} = \frac{P_{i,C}}{\prod_{k \neq O} P_{i,k}^{\gamma_{i,C}^{k}}}$$

Construction is non-traded $\Longrightarrow A_{i,F} = P_{i,F}^{-\theta} / c_{i,F}^{-\theta}$

For Other Services, $A_{i,O}$ follows from $\pi_{ii,O} = A_{i,O} c_{i,O}^{-\theta} / P_{i,O,t}^{-\theta}$.

Construction and Services Sectors

To exactly match services trade, I can also compute (aggregated) "export-side" and "import-side" trade costs for services, using only data on a country's total services exports and imports

(from UN National Accounts)

These can be solved for from the following system:

$$d_{m,O,t}^{ex-\theta} = \frac{EX_{m,O,t}}{A_{m,O,t} c_{m,O,t}^{-\theta} \sum_{j \neq m} \frac{E_{j,O,t}}{P_{j,O,t}^{-\theta}} d_{j,O,t}^{im-\theta}}; \qquad d_{m,O,t}^{im-\theta} = \frac{IM_{m,O,t}}{\frac{E_{m,O,t}}{P_{m,O,t}^{-\theta}} \sum_{j \neq m} A_{j,O,t} c_{j,O,t}^{-\theta} d_{j,O,t}^{ex-\theta}}.$$

This will exactly match services trade balances in the data and allow services to be endogenously traded in counterfactuals.

back

Dynamic Gains from Trade

The complete formula for the steady state real consumption change is:

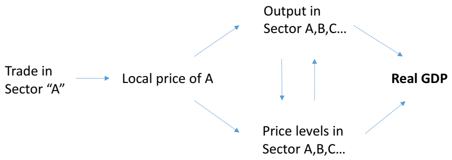
$$\widehat{G}_i^{SS} = \underbrace{\frac{\widehat{\left(1 - x_i\right)}}{\widehat{\vartheta}_w}}_{\substack{\text{standard}\\ \text{intertemporal}\\ \text{tradeoff}}} \times \underbrace{\prod_k \left\{ \widehat{\pi}_{ii,k}^{-\frac{\gamma_{i,C}^k}{\beta_{i,k}^w \theta}} \times \prod_l \left[\frac{\widehat{P}_{i,l}}{\widehat{P}_{i,k}} \right]^{-\frac{\beta_{i,k}^l \gamma_{i,C}^k}{\beta_{i,k}^w}} \right\}}_{\text{static real wage gains}} \times \underbrace{\prod_k \prod_l \left[\frac{\widehat{P}_{i,l}}{\widehat{P}_{i,k}} \right]^{-\gamma_{i,IV}^l \frac{\beta_{i,k}^r \gamma_{i,C}^k}{\beta_{i,k}^w}}}_{\substack{\text{dynamic sectoral}\\ \text{linkages}}}$$

back

Proposed Framework

Key concept: Sectoral Linkages

Within each period, the model embeds the "static" gains from trade of, e.g., Caliendo & Parro (2015),

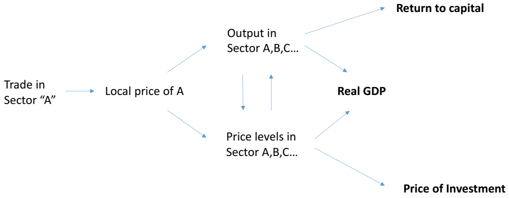


"Static" gains from trade with input-output linkages

whereby imported inputs in each sector stimulate output in other sectors via I-O linkages.

Key concept: Sectoral Linkages

In my setting, however, sectors are differentiated not only by their input-usage patterns, but also by how they shape incentives for capital accumulation.



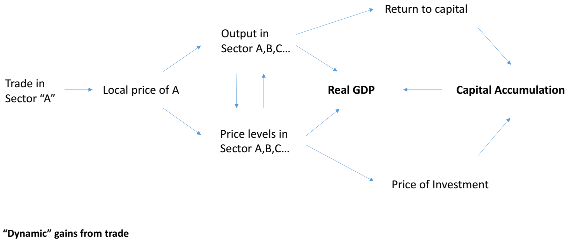
Linking "static" outcomes with "dynamic" outcomes

2 main ways:

1. Increased output in capital-intensive sectors → **higher return to capital**
2. Lower prices of goods used intensively in investment → **lower price of investment**

Key concept: Sectoral Linkages

In my setting, however, sectors are differentiated not only by their input-usage patterns, but also by how they shape incentives for capital accumulation.



Upshot:

These *dynamic* sectoral linkages provide a richer set of possibilities for the gains from trade and, ultimately, larger real GDP gains in the rest of the world from China's trade expansion.

back

EKNR in more detail

- Huge contribution bridging trade and macro, establishing "dynamic trade accounting" methodology
- Influences several modeling choices to be presented here
- My setting differs from EKNR's in the following key respects:
  - More active sectors (necessitates different accounting techniques)
  - My model matches (in levels) national statistics on capital stocks, investment spending, and investment prices
  - Aside from construction, all non-manufacturing activity in ENKR is "hidden"

back

Differences from EKNR *(cont'd)*

- Focus here is more on quantifying and decomposing gains from trade and globalization. In particular:

  "How do changes in the sectoral *structure* of international trade lead to dynamic vs. static gains from trade?"

  (old question, but has proven difficult to answer)

- These additions come via the following innovations and data sources
  - A straightforward, scalable algorithm for solving dynamic trade models with complex sectoral production linkages
  - A fast, flexible "dummy variables only" method for estimating changes in technology levels over time
  - A method for mapping sectoral price changes to changes in the national "investment price"

back

Related Literature

Differences from EKNR *(cont'd)*

- Only one capital series per country: invested by households, used by firms.
- Annual perspective, rather than monthly.
- Trade frictions are assumed to be symmetric, recovered via estimation
- Economic activity in all sectors is endogenously determined
  - Only construction is non-traded
  - "Services" are traded subject to trade frictions recovered from the data.
  - (but trade balances are taken as exogenous)

back

Model: Households

Household Consumption, Investment, and Utility

The (aggregated) inter-temporal problem is to maximize

$$\mathbf{U}_i = \sum_{t=0}^{\infty} \rho^t \cdot \phi_{i,t} \cdot \log C_{i,t} \tag{1}$$

such that

$$w_{i,t}L_{i,t} + r_{i,t}K_{i,t} + D_{i,t} = P_{i,C,t} \cdot C_{i,t} + P_{i,IV,t} \cdot I_{i,t} \tag{2}$$

$$K_{i,t+1} = K\left(K_t, I_t, \chi_{i,t}\right) \tag{3}$$

$$P_{i,C,t} = \prod_k P_{i,k,t}^{\gamma_{i,C}^k} \qquad P_{i,IV,t} = \prod_k P_{i,k,t}^{\gamma_{i,IV}^k}$$

$\phi_{i,t}$: "time preference" shock. $\chi_{i,t}$: "investment efficiency" shock.

$\gamma_{i,C}^k$ and $\gamma_{i,IV}^k$: (Cobb-Douglas) consumption and investment share parameters.

$D_{i,t}$: trade deficit (treated as exogenous)

more

Household Consumption, Investment, and Utility

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$$K_{i,t+1} = K\left(K_t, I_t, \chi_{i,t}\right) \tag{3}$$

Eq (1)-(3) describe a standard inter-temporal problem:

Households trade-off some consumption today in the form of investment, which enhances future income via capital accumulation.

Model: Households

Household Consumption, Investment, and Utility

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such that

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$$K_{i,t+1} = \chi_{i,t} K_{i,t}^{1-\kappa} I_{i,t}^{\kappa} + (1-\delta) K_{i,t} \tag{3}$$

The specific law of motion for K follows EKNR and Lucas and Prescott (1971):

- δ: depreciation of last-period capital
- κ: governs “adjustment costs” for investments made on top of a small existing level of capital
- $\chi_{i,t}$: efficiency/yield of investment

Model: Households

Household Consumption, Investment, and Utility

The (aggregated) inter-temporal problem is to maximize

$$\mathbf{U}_i = \sum_{t=0}^{\infty} \rho^t \cdot \phi_{i,t} \cdot \log C_{i,t} \tag{1}$$

such that

$$w_{i,t} L_{i,t} + r_{i,t} K_{i,t} + D_{i,t} = P_{i,C,t} \cdot C_{i,t} + P_{i,IV,t} \cdot I_{i,t} \tag{2}$$

$$K_{i,t+1} = \chi_{i,t} K_{i,t}^{1-\kappa} I_{i,t}^{\kappa} + (1-\delta) K_{i,t} \tag{3}$$

The Euler equation associated with this problem is:

$$\frac{P_{IV,t}}{E_{C,t}} \left(\frac{I_t}{K_t} \right)^{1-\kappa} = \rho \frac{\widehat{\phi}_{i,t+1} \chi_{i,t}}{E_{C,t+1}} \left\{ \kappa r_{t+1} + (1-\kappa) \frac{E_{IV,t+1}}{K_{t+1}} + (1-\delta) \frac{P_{IV,t+1}}{\chi_{t+1}} \left(\frac{I_{t+1}}{K_{t+1}} \right)^{1-\kappa} \right\}$$

(i subscript is suppressed)

Trade, Production, and Prices

Trade between i and j in each sector k takes the following standard “gravity” form:

$$X_{ij,k} = \frac{A_{i,k}\left(c_{i,k} d_{ij,k}\right)^{1\text{-}\sigma}}{P_{j,k}^{1\text{-}\sigma}} E_{j,k} \tag{4}$$

where $d_{ij,k}$ is an iceberg trade cost, $A_{i,k}$ is i’s “technology”-level, $c_{i,k}$ is the production cost and

$$P_{j,k}^{1\text{-}\sigma} = \sum_i A_{i,k}\left(c_{i,k} d_{ij,k}\right)^{1\text{-}\sigma}$$

captures the aggregate price index for industry k in market j, by the structure of the CES Armington trade model

(as well as other such models)

Trade, Production, and Prices

$$X_{ij,k} = \frac{A_{i,k}\left(c_{i,k}d_{ij,k}\right)^{1\text{-}\sigma}}{P_{j,k}^{1\text{-}\sigma}} E_{j,k} \tag{4}$$

The combined "trade elasticity" parameter $\sigma - 1$ can be treated as a single parameter, "θ"

- Emphasizes generality
- Illustrates connection with original Eaton & Kortum (2002) model (and, by extension, that of EKNR)

Trade, Production, and Prices

$$X_{ij,k} = \frac{A_{i,k}\left(c_{i,k}d_{ij,k}\right)^{-\theta}}{P_{j,k}^{-\theta}}E_{j,k} \tag{4}$$

The combined "trade elasticity" parameter $\sigma - 1$ can be treated as a single parameter, "θ"

- Emphasizes generality
- Illustrates connection with original Eaton & Kortum (2002) model (and, by extension, that of EKNR)

Trade, Production, and Prices

$$X_{ij,k} = \frac{A_{i,k}\left(c_{i,k} d_{ij,k}\right)^{-\theta}}{P_{j,k}^{-\theta}} E_{j,k} \tag{4}$$

The production technology for producing good k can be described via the "input bundle cost" $c_{i,k}$:

$$c_{i,k} = \left(w_i^{\alpha_k^w} \cdot r_i^{\alpha_k^r}\right)^{\beta_{i,k}^v} \cdot \prod_l P_{i,l}^{\beta_{i,k}^l} \tag{5}$$

- α_k^w, α_k^r: factor intensities
- $\beta_{i,k}^v$: value-added share
- $\beta_{i,k}^l$: capture "Input-Output linkages" from input industry l to the using industry k

Key Assumption: Inputs to consumption, investment, and production all use the same aggregates from each industry

$\Rightarrow$ "P" in (4) is the same as in (5)

Closing the Model

Goods market clearing

$$\sum_j X_{ij,k,t} = Y_{i,k,t} \quad \Longrightarrow \quad Y_{i,k,t} = A_{i,k,t} c_{i,k,t}^{-\theta} \cdot \sum_j \frac{d_{ij,k,t}^{-\theta}}{P_{j,k,t}^{-\theta}} E_{j,k,t}$$

Factor market clearing

$$w_{i,t} L_{i,t} = \sum_k \alpha_k^w \cdot \beta_{i,k}^v \cdot Y_{i,k,t}; \qquad r_{i,t} K_{i,t} = \sum_k \alpha_k^w \cdot \beta_{i,k}^v \cdot Y_{i,k,t}$$

Transversality condition

$$\lim_{t \to \infty} K_{i,t} = K_{i,SS} < \infty$$

▸ back

Static Trade Equilibrium

$$c_{i,k} = \left(w_i^{\alpha_k^w} \cdot r_i^{\alpha_k^r}\right)^{\beta_{i,k}^v} \cdot \prod_l P_{i,l}^{\beta_{i,k}^l} \tag{6}$$

$$P_{j,k}^{-\theta} = \sum_i A_{i,k} \cdot \left(c_{i,k} d_{ij,k}\right)^{-\theta} \tag{7}$$

$$Y_{i,k} = \sum_j \frac{A_{i,k} \cdot \left(c_{i,k} d_{ij,k}\right)^{-\theta}}{P_{j,k}^{-\theta}} E_{j,k} \tag{8}$$

$$GDP_i = \sum_k \beta_{i,k}^v \cdot Y_{i,k} \tag{9}$$

$$E_{i,k} = \gamma_i^k \cdot (GDP_i + D_i) + \sum_l \beta_{i,l}^k Y_{i,l} \tag{10}$$

$$w_i = \frac{\sum_k \alpha_k^w \cdot \beta_{i,k}^v \cdot Y_{i,k}}{L_i}; \tag{11a}$$

$$r_i = \frac{\sum_k \alpha_k^r \cdot \beta_{i,k}^v \cdot Y_{i,k}}{K_i} \tag{11b}$$

These 6 equations describe a general equilibrium given endowments, technologies, and trade frictions.

Static Trade Equilibrium

$$c_{i,k} = \left(w_i^{\alpha_k^w} \cdot r_i^{\alpha_k^r}\right)^{\beta_{i,k}^v} \cdot \prod_l P_{i,l}^{\beta_{i,k}^l} \quad (1)$$

$$P_{j,k}^{-\theta} = \sum_i A_{i,k} \cdot \left(c_{i,k} d_{ij,k}\right)^{-\theta} \quad (2)$$

$$Y_{i,k} = \sum_j \frac{A_{i,k} \cdot \left(c_{i,k} d_{ij,k}\right)^{-\theta}}{P_{j,k}^{-\theta}} E_{j,k} \quad (3)$$

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$$w_i = \frac{\sum_k \alpha_k^w \cdot \beta_{i,k}^v \cdot Y_{i,k}}{L_i}; \quad (6a)$$

$$r_i = \frac{\sum_k \alpha_k^r \cdot \beta_{i,k}^v \cdot Y_{i,k}}{K_i} \quad (6b)$$

Note: the absorption share $\gamma_i^k \equiv x_i \cdot \gamma_{i,IV}^k + (1 - x_i) \cdot \gamma_{i,C}^k$ and capital stock K_i come from the dynamic component of the model.

Static Trade Equilibrium

$$c_{i,k} = \left(w_i^{\alpha_k^w} \cdot r_i^{\alpha_k^r}\right)^{\beta_{i,k}^v} \cdot \prod_l P_{i,l}^{\beta_{i,k}^l} \quad (1)$$

$$P_{j,k}^{-\theta} = \sum_i A_{i,k} \cdot \left(c_{i,k} d_{ij,k}\right)^{-\theta} \quad (2)$$

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$$GDP_i = \sum_k \beta_{i,k}^v \cdot Y_{i,k} \quad (4)$$

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$$w_i = \frac{\sum_k \alpha_k^w \cdot \beta_{i,k}^v \cdot Y_{i,k}}{L_i}; \quad (6a)$$

$$r_i = \frac{\sum_k \alpha_k^r \cdot \beta_{i,k}^v \cdot Y_{i,k}}{K_i} \quad (6b)$$

The linkages between trade, factor rewards, and output/expenditure are best illustrated by examining the static *equilibrium in changes*

(e.g., as in Dekle, Eaton, & Kortum, 2007)

Equilibrium: Solving the Static Model

Static Trade Equilibrium (*in changes*)

$$c_{i,k} = \left(w_i^{\alpha_k^w} \cdot r_i^{\alpha_k^r}\right)^{\beta_{i,k}^v} \cdot \prod_l P_{i,l}^{\beta_{i,k}^l} \quad (1)$$

$$P_{j,k}^{-\theta} = \sum_i A_{i,k} \cdot \left(c_{i,k} d_{ij,k}\right)^{-\theta} \quad (2)$$

$$Y_{i,k} = \sum_j \frac{A_{i,k} \cdot \left(c_{i,k} d_{ij,k}\right)^{-\theta}}{P_{j,k}^{-\theta}} E_{j,k} \quad (3)$$

$$GDP_i = \sum_k \beta_{i,k}^v \cdot Y_{i,k} \quad (4)$$

$$E_{i,k} = \gamma_i^k \cdot (GDP_i + D_i) + \sum_l \beta_{i,l}^k Y_{i,l} \quad (5)$$

$$w_i = \frac{\sum_k \alpha_k^w \cdot \beta_{i,k}^v \cdot Y_{i,k}}{L_i}; \quad (6a)$$

$$r_i = \frac{\sum_k \alpha_k^r \cdot \beta_{i,k}^v \cdot Y_{i,k}}{K_i} \quad (6b)$$

Let's consider:

A set of trade cost shocks $\widehat{d}_{ij,k} = d'_{ij,k}/d_{ij,k}$ and/or "technology" shocks $\widehat{A}_{i,k} = A'_{i,k}/A_{i,k}$

These will enter directly only through eq. (7') and (8')

Equilibrium: Solving the Static Model

Static Trade Equilibrium (*in changes*)

$$\widehat{c}_{i,k} = \left(\widehat{w}_i^{\alpha_k^w} \cdot \widehat{r}_i^{\alpha_k^r}\right)^{\beta_{i,k}^v} \cdot \prod_k \widehat{P}_{i,l}^{\beta_{i,k}^l} \qquad (1')$$

$$\widehat{P}_{j,k}^{-\theta} = \sum_i \pi_{ij,k} \cdot \widehat{A}_{i,k} \left(\widehat{c}_{i,k}\widehat{d}_{ij,k}\right)^{-\theta} \qquad (2')$$

$$Y_{i,k}' = \sum_j \pi_{ij,k} \cdot \frac{\widehat{A}_{i,k}\left(\widehat{c}_{i,k}\widehat{d}_{ij,k}\right)^{-\theta}}{\widehat{P}_{j,k}^{-\theta}} E_{j,k}' \qquad (3')$$

$$GDP_i' = \sum_k \beta_{i,k}^v \cdot Y_{i,k}' \qquad (4')$$

$$E_{i,k}' = \gamma_i^k \cdot \left(GDP_i' + D_i\right) + \sum_l \beta_{i,l}^k Y_{i,l}' \qquad (5')$$

$$\widehat{w}_i = \frac{L_i}{L_i'} \frac{\sum_k \alpha_k^w \cdot \beta_{i,k}^v \cdot Y_{i,k}'}{\sum_k \alpha_k^w \cdot \beta_{i,k}^v \cdot Y_{i,k}}; \qquad (6'a)$$

$$\widehat{r}_i = \frac{K_i}{K_i'} \frac{\sum_k \alpha_k^r \cdot \beta_{i,k}^v \cdot Y_{i,k}'}{\sum_k \alpha_k^r \cdot \beta_{i,k}^v \cdot Y_{i,k}} \qquad (6'b)$$

Let's consider:

A set of trade cost shocks $\widehat{d}_{ij,k} = d_{ij,k}'/d_{ij,k}$ and/or "technology" shocks $\widehat{A}_{i,k} = A_{i,k}'/A_{i,k}$

These will enter directly only through eq. (7') and (8')

Equilibrium: Solving the Static Model

Static Trade Equilibrium (*in changes*)

$$\widehat{c}_{i,k} = \left(\widehat{w}_i^{\alpha_k^w} \cdot \widehat{r}_i^{\alpha_k^r}\right)^{\beta_{i,k}^v} \cdot \prod_k \widehat{P}_{i,l}^{\beta_{i,k}^l} \qquad (1')$$

$$\widehat{P}_{j,k}^{-\theta} = \sum_i \pi_{ij,k} \cdot \widehat{A}_{i,k} \left(\widehat{c}_{i,k} \widehat{d}_{ij,k}\right)^{-\theta} \qquad (2')$$

$$Y'_{i,k} = \sum_j \pi_{ij,k} \cdot \frac{\widehat{A}_{i,k} \left(\widehat{c}_{i,k} \widehat{d}_{ij,k}\right)^{-\theta}}{\widehat{P}_{j,k}^{-\theta}} E'_{j,k} \qquad (3')$$

$$GDP'_i = \sum_k \beta_{i,k}^v \cdot Y'_{i,k} \qquad (4')$$

$$E'_{i,k} = \gamma_i^k \cdot \left(GDP'_i + D_i\right) + \sum_l \beta_{i,l}^k Y'_{i,l} \qquad (5')$$

$$\widehat{w}_i = \frac{L_i}{L'_i} \frac{\sum_k \alpha_k^w \cdot \beta_{i,k}^v \cdot Y'_{i,k}}{\sum_k \alpha_k^w \cdot \beta_{i,k}^v \cdot Y_{i,k}}; \qquad (6'a)$$

$$\widehat{r}_i = \frac{K_i}{K'_i} \frac{\sum_k \alpha_k^r \cdot \beta_{i,k}^v \cdot Y'_{i,k}}{\sum_k \alpha_k^r \cdot \beta_{i,k}^v \cdot Y_{i,k}} \qquad (6'b)$$

Intuitively, shocks in/with other countries are transmitted via the "trade share", $\pi_{ij,k}$

By consistently aggregating these shocks to the country level, (7') and (8') dramatically reduce the dimensionality of the problem.

Equilibrium: Solving the Static Model

Static Trade Equilibrium (*in changes*)

$$\widehat{c}_{i,k} = \left(\widehat{w}_i^{\alpha_k^w} \cdot \widehat{r}_i^{\alpha_k^r}\right)^{\beta_{i,k}^v} \cdot \prod_k \widehat{P}_{i,l}^{\beta_{i,k}^l} \qquad (1')$$

$$\widehat{P}_{j,k}^{-\theta} = \sum_i \pi_{ij,k} \cdot \widehat{A}_{i,k} \left(\widehat{c}_{i,k} \widehat{d}_{ij,k}\right)^{-\theta} \qquad (2')$$

$$Y'_{i,k} = \sum_j \pi_{ij,k} \cdot \frac{\widehat{A}_{i,k} \left(\widehat{c}_{i,k} \widehat{d}_{ij,k}\right)^{-\theta}}{\widehat{P}_{j,k}^{-\theta}} E'_{j,k} \qquad (3')$$

$$GDP'_i = \sum_k \beta_{i,k}^v \cdot Y'_{i,k} \qquad (4')$$

$$E'_{i,k} = \gamma_i^k \cdot \left(GDP'_i + D_i\right) + \sum_l \beta_{i,l}^k Y'_{i,l} \qquad (5')$$

$$\widehat{w}_i = \frac{L_i}{L'_i} \frac{\sum_k \alpha_k^w \cdot \beta_{i,k}^v \cdot Y'_{i,k}}{\sum_k \alpha_k^w \cdot \beta_{i,k}^v \cdot Y_{i,k}}; \qquad (6'a)$$

$$\widehat{r}_i = \frac{K_i}{K'_i} \frac{\sum_k \alpha_k^r \cdot \beta_{i,k}^v \cdot Y'_{i,k}}{\sum_k \alpha_k^r \cdot \beta_{i,k}^v \cdot Y_{i,k}} \qquad (6'b)$$

Step I

Note first that, given $\{\widehat{w}, \widehat{r}, E'\}$ one can solve for output, producer costs, and intermediate prices using (6')-(8')

Static Trade Equilibrium (*in changes*)

$$\widehat{c}_{i,k} = \left(\widehat{w}_i^{\alpha_k^w} \cdot \widehat{r}_i^{\alpha_k^r}\right)^{\beta_{i,k}^v} \cdot \prod_k \widehat{P}_{i,l}^{\beta_{i,k}^l} \qquad (1')$$

$$\widehat{P}_{j,k}^{-\theta} = \sum_i \pi_{ij,k} \cdot \widehat{A}_{i,k} \left(\widehat{c}_{i,k}\widehat{d}_{ij,k}\right)^{-\theta} \qquad (2')$$

$$Y'_{i,k} = \sum_j \pi_{ij,k} \cdot \frac{\widehat{A}_{i,k}\left(\widehat{c}_{i,k}\widehat{d}_{ij,k}\right)^{-\theta}}{\widehat{P}_{j,k}^{-\theta}} E'_{j,k} \qquad (3')$$

$$GDP'_i = \sum_k \beta_{i,k}^v \cdot Y'_{i,k} \qquad (4')$$

$$E'_{i,k} = \gamma_i^k \cdot \left(GDP'_i + D_i\right) + \sum_l \beta_{i,l}^k Y'_{i,l} \qquad (5')$$

$$\widehat{w}_i = \frac{L_i}{L'_i} \frac{\sum_k \alpha_k^w \cdot \beta_{i,k}^v \cdot Y'_{i,k}}{\sum_k \alpha_k^w \cdot \beta_{i,k}^v \cdot Y_{i,k}}; \qquad (6'a)$$

$$\widehat{r}_i = \frac{K_i}{K'_i} \frac{\sum_k \alpha_k^r \cdot \beta_{i,k}^v \cdot Y'_{i,k}}{\sum_k \alpha_k^r \cdot \beta_{i,k}^v \cdot Y_{i,k}} \qquad (6'b)$$

Step II

Changes in factor rewards, GDP, and expenditure follow immediately after obtaining $\{Y_i^k\}$

Equilibrium: Solving the Static Model

Static Trade Equilibrium (*in changes*)

$$\widehat{c}_{i,k} = \left(\widehat{w}_i^{\alpha_k^w} \cdot \widehat{r}_i^{\alpha_k^r}\right)^{\beta_{i,k}^v} \cdot \prod_k \widehat{P}_{i,l}^{\beta_{i,k}^l} \qquad (1')$$

$$\widehat{P}_{j,k}^{-\theta} = \sum_i \pi_{ij,k} \cdot \widehat{A}_{i,k} \left(\widehat{c}_{i,k}\widehat{d}_{ij,k}\right)^{-\theta} \qquad (2')$$

$$Y_{i,k}' = \sum_j \pi_{ij,k} \cdot \frac{\widehat{A}_{i,k} \left(\widehat{c}_{i,k}\widehat{d}_{ij,k}\right)^{-\theta}}{\widehat{P}_{j,k}^{-\theta}} E_{j,k}' \qquad (3')$$

$$GDP_i' = \sum_k \beta_{i,k}^v \cdot Y_{i,k}' \qquad (4')$$

$$E_{i,k}' = \gamma_i^k \cdot \left(GDP_i' + D_i\right) + \sum_l \beta_{i,l}^k Y_{i,l}' \qquad (5')$$

$$\widehat{w}_i = \frac{L_{i,k}}{L_{i,k}'} \frac{\sum_k \alpha_k^w \cdot \beta_{i,k}^v \cdot Y_{i,k}'}{\sum_k \alpha_k^w \cdot \beta_{i,k}^v \cdot Y_{i,k}}; \qquad (6'a)$$

$$\widehat{r}_i = \frac{K_{i,k}}{K_{i,k}'} \frac{\sum_k \alpha_k^r \cdot \beta_{i,k}^v \cdot Y_{i,k}'}{\sum_k \alpha_k^r \cdot \beta_{i,k}^v \cdot Y_{i,k}} \qquad (6'b)$$

Steps III, IV, V...

Plugging $\{\widehat{w}, \widehat{r}, E'\}$ back into (6')-(8'), and continuously iterating, converges very quickly to a set of Y_i^k's that solves the above system.

To account for dynamic linkages (via capital accumulation) what needs to be added to the above iteration system is:

Equilibrium: Solving the dynamic model

To account for dynamic linkages (via capital accumulation) what needs to be added to the above iteration system is:

1. **Update investment at time t** (*via the Euler equation*):

$$\frac{x'_{i,t}}{1-x'_{i,t}} = \rho \frac{\widehat{\phi}_{i,t+1}\chi_{i,t}}{E'_{i,C,t+1}} \cdot \frac{\kappa \cdot r_{i,t+1}\widehat{r}_{i,t+1} + (1-\kappa)\frac{E'_{i,IV,t+1}}{K_{i,t+1}} + (1-\delta)\frac{\widehat{P}^{\kappa}_{i,IV,t+1}}{\chi_{i,t+1}}\frac{E'^{1-\kappa}_{i,IV,t}}{K^{1-\kappa}_{i,t}}}{\widehat{P}^{\kappa}_{i,IV,t} \cdot \frac{E'^{-\kappa}_{i,IV,t}}{K^{1-\kappa}_{i,t}}},$$

where:

- $x' = \frac{E'_{i,IV}}{GDP'+D}$ is the updated investment rate
- $\widehat{P}_{IV} = \prod_k \widehat{P}_{IV}^{k\gamma^k_{i,IV}}$ is the change in the price of investment
- E'_C and E'_{IV} are updated consumption and investment spending
- initial equilibrium r_{t+1} can be computed from data.

Equilibrium: Solving the dynamic model

To account for dynamic linkages (via capital accumulation) what needs to be added to the above iteration system is:

1. **Update investment at time t** (*via the Euler equation*):

$$\frac{x'_{i,t}}{1-x'_{i,t}} = \rho \frac{\widehat{\phi}_{i,t+1}\chi_{i,t}}{E'_{i,C,t+1}} \cdot \frac{\kappa \cdot r_{i,t+1}\widehat{r}_{i,t+1} + (1-\kappa)\frac{E'_{i,IV,t+1}}{K_{i,t+1}} + (1-\delta)\frac{\widehat{P}^{\kappa}_{i,IV,t+1}}{\chi_{i,t+1}}\frac{E'^{1-\kappa}_{i,IV,t}}{K^{1-\kappa}_{i,t}}}{\widehat{P}^{\kappa}_{i,IV,t}\cdot\frac{E'^{-\kappa}_{i,IV,t}}{K^{1-\kappa}_{i,t}}},$$

2. **Update capital at time $t+1$** (*via the Law of Motion*):

$$K'_{i,t+1} = \chi_{i,t}K^{1-\kappa}_{i,t}\left[\frac{x'_{it}\cdot\left(GDP'_{i,t}+D_{i,t}\right)}{\widehat{P}_{i,IV,t}}\right]^{\kappa} + (1-\delta)\,K_{i,t}$$

Equilibrium: Solving the dynamic model

To account for dynamic linkages (via capital accumulation) what needs to be added to the above iteration system is:

1. **Update investment at time t** (*via the Euler equation*):

$$\frac{x'_{i,t}}{1-x'_{i,t}} = \rho \frac{\widehat{\phi}_{i,t+1}\chi_{i,t}}{E'_{i,C,t+1}} \cdot \frac{\kappa \cdot r_{i,t+1}\widehat{r}_{i,t+1} + (1-\kappa)\,\frac{E'_{i,IV,t+1}}{K_{i,t+1}} + (1-\delta)\,\frac{\widehat{P}^{\kappa}_{i,IV,t+1}}{\chi_{i,t+1}}\,\frac{E'^{1-\kappa}_{i,IV,t}}{K^{1-\kappa}_{i,t}}}{\widehat{P}^{\kappa}_{i,IV,t} \cdot \frac{E'^{-\kappa}_{i,IV,t}}{K^{1-\kappa}_{i,t}}},$$

2. **Update capital at time $t+1$** (*via the Law of Motion*):

$$K'_{i,t+1} = \chi_{i,t} K^{1-\kappa}_{i,t} \left[\frac{x'_{it} \cdot \left(GDP'_{i,t} + D_{i,t} \right)}{\widehat{P}_{i,IV,t}} \right]^{\kappa} + (1-\delta)\, K_{i,t}$$

3. **Update new** $\left\{ \widehat{r}, \widehat{P}_{IV}, E'_C, E'_{IV} \right\}$ **from the static model at time** $t+1$

Equilibrium: Solving the dynamic model

To account for dynamic linkages (via capital accumulation) what needs to be added to the above iteration system is:

1. **Update investment at time t** (*via the Euler equation*):

$$\frac{x'_{i,t}}{1-x'_{i,t}} = \rho \frac{\widehat{\phi}_{i,t+1}\chi_{i,t}}{E'_{i,C,t+1}} \cdot \frac{\kappa \cdot r_{i,t+1}\widehat{r}_{i,t+1} + (1-\kappa)\frac{E'_{i,IV,t+1}}{K_{i,t+1}} + (1-\delta)\frac{\widehat{P}^{\kappa}_{i,IV,t+1}}{\chi_{i,t+1}}\frac{E'^{1-\kappa}_{i,IV,t}}{K^{1-\kappa}_{i,t}}}{\widehat{P}^{\kappa}_{i,IV,t} \cdot \frac{E'^{-\kappa}_{i,IV,t}}{K^{1-\kappa}_{i,t}}},$$

2. **Update capital at time $t+1$** (*via the Law of Motion*):

$$K'_{i,t+1} = \chi_{i,t} K^{1-\kappa}_{i,t} \left[\frac{x'_{it} \cdot \left(GDP'_{i,t} + D_{i,t} \right)}{\widehat{P}_{i,IV,t}} \right]^{\kappa} + (1-\delta) K_{i,t}$$

3. **Update new $\left\{\widehat{r}, \widehat{P}_{IV}, E'_C, E'_{IV}\right\}$ from the static model at time $t+1$**

4. **Iterate repeatedly on $\{K_{i,t}\}_1^{T_{SS}}$ from $\{K_{,i,1}\}$ to $\{K_{i,T_{SS}}\}$ until capital paths converge for all countries.**
    - Competitive equilibrium conditions necessarily satisfied in every period
    - Need to iterate *twice,* first time for initial capital path

Included countries

Table: Included Countries

OECD *(32 countries/regions)*: Australia, Austria, Belgium-Luxembourg, Canada, Switzerland, Chile, Czech Republic, Germany, Denmark, Spain, Finland, France, United Kingdom, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, South Korea, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic Slovenia, Sweden, Turkey, United States

Non-OECD *(40 countries/regions)*: Argentina, Bangladesh, Bulgaria, Bolivia, Brazil, China, Colombia, Costa Rica, Ecuador, Egypt, Ethiopia, Fiji, Ghana, Guatemala, Honduras, Hungary, Indonesia, India, Iran, Jordan, Kenya, Sri Lanka, Mauritius, Nigeria, Nepal, New Zealand, Panama, Pakistan, Peru, Russia, Senegal, Thailand, Trinidad & Tobago, Tanzania,Ukraine, Uruguay, Venezuela, Vietnam, South Africa, "Rest of World"

back

Constructing Final Demand and Value Added Shares

γ's and β^v's are constructed using the following minimization problem:

$$\min_{\{\gamma\}\{\beta^v\}} \sum_k \left\{ Y_k(\Gamma, \mathbf{B}) - Y_k^{data} \right\}^2 + \omega_\gamma \left\{ \gamma_k^C - \gamma_k^{C,data} \right\}^2 + \omega_\gamma \left\{ \gamma_k^{IV} - \gamma_k^{IV,data} \right\}^2$$
$$+ \omega_\beta \left\{ \beta_k^v - \beta_k^{v,data} \right\}^2$$

such that

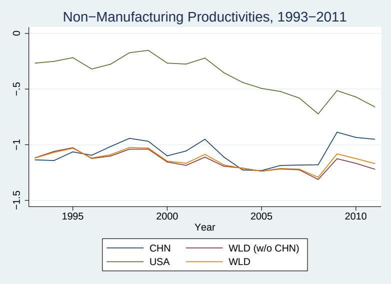
$$\sum_k \gamma_k^C = 1; \quad \sum_k \gamma_k^{IV} = 1; \quad \sum_k \beta_k^v Y_k = GDP.$$

When $\omega_\gamma = \omega_\beta = 0$, usually many different $\{\gamma, \beta^v\}$ combinations solve $Y = Y^{data}$.

Adding non-zero weights $\omega_\gamma > 0$, $\omega_\beta > 0$ then enables you to select parameter combinations that closely resemble shares from the data and are relatively stable over time.

back

Non-manufacturing



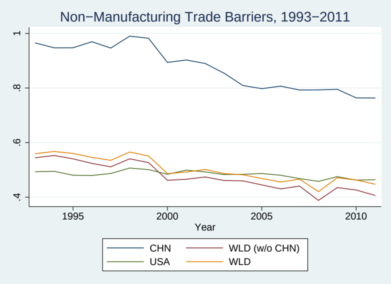
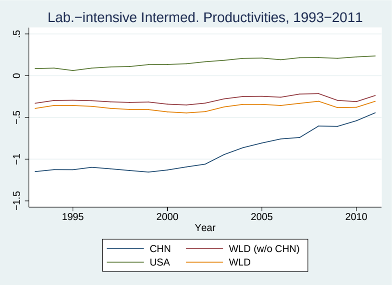


Figure: (Log) changes in sectoral productivity and trade barriers

services back

China vs. the World

Labor-Intensive Intermediates



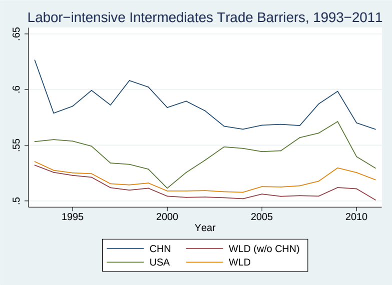
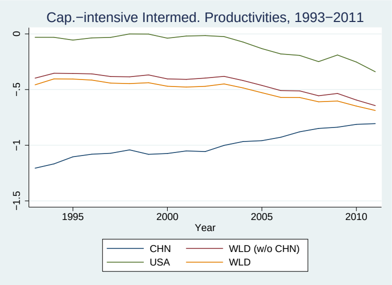


Figure: (Log) changes in sectoral productivity and trade barriers

services back

Capital-Intensive Intermediates



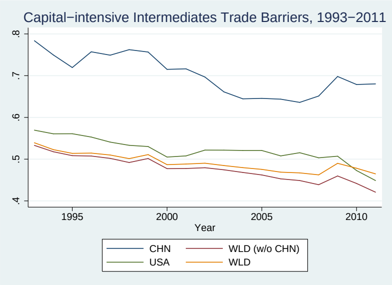
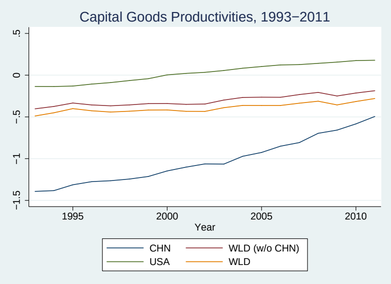


Figure: (Log) changes in sectoral productivity and trade barriers

▸ services ▸ back

Capital Goods



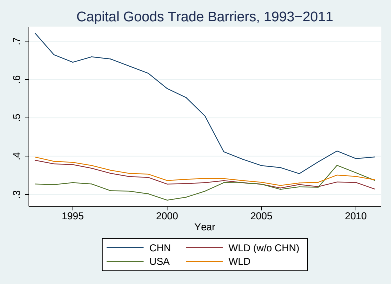


Figure: (Log) changes in sectoral productivity and trade barriers

services back

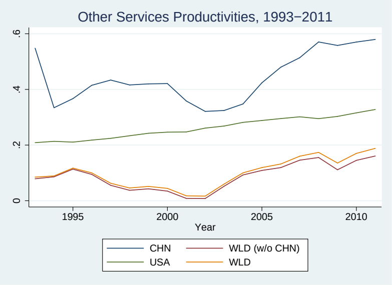
China's productivity growth and globalization vs. the Rest of the World, 2008-2011

Industry	$\widehat{A}^{1/\theta}_{nonCHN}$	$\widehat{A}^{1/\theta}_{CHN}$	$\widehat{A}^{1/\theta}_{CHN+}$	$\widehat{d}_{nonCHN}$	$\widehat{d}_{CHN}$	$\widehat{d}_{CHN+}$
Non-Manufacturing	.031	.076	**.046**	.006	-.01	**-.016**
Capital-intensive Manuf.	-.029	.014	**.044**	-.006	.01	**.016**
Labor-intensive Manuf.	-.008	.053	**.061**	-.001	-.008	**-.006**
Capital Goods	.007	.067	**.060**	-.002	.004	**.006**
Construction	-.018	-.029	-.011	.	.	.
Other services	.002	.003	.001	-.002	-.051	-.049
Manufacturing	-.016	.039	.055	-.004	.001	.005
Total	.000	.038	.038	.000	-.002	-.002

Notes: Annualized percentage changes over time. Shocks highlighted in bold are those are used in the counterfactuals.

back

Services



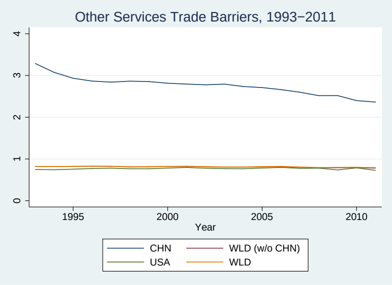


Figure: (Log) changes in sectoral productivity and trade barriers

back

A model with endogenous trade balances

To endogenize the trade balance, replace the household budget constraint with:

$$w_{i,t}L_{i,t} + r_{i,t}K_{i,t} + \underbrace{B_{i,t} - \varphi_{i,t}R_t B_{i,t-1}}_{D_{i,t}} = P_{i,C,t} \cdot C_{i,t} + P_{i,IV,t} \cdot I_{i,t},$$

which elaborates on each country's trade balance as the difference between new borrowing, $B_{i,t}$, and interest payments on the previous period's borrowing, $\varphi_{i,t}R_t B_{i,t-1}$.

$\varphi_{i,t}$ is a "borrowing friction" which would now be needed to match each country's trade balance.

back

Recovering shocks: Trade, Prices, and Technology

To aggregate sectoral productivity shocks:

$$A_{nonCHN,k,t}^{1/\theta} \equiv \left\{ \sum_{i \in nonCHN} A_{i,k,t}^{-1/\theta} \times Y_{i,k,t} \right\}^{-1} \times \sum_{i \in nonCHN} Y_{i,k,t}. \tag{7}$$

For trade barriers:

$$d_{nonCHN} \equiv \left\{ \sum_{i \in nonCHN} d_{i,k,t}^{-2\theta} \times X_{ii,k,t} \right\}^{-\frac{1}{2\theta}} \times \left\{ \sum_{i \in nonCHN} X_{ii,k,t} \right\}^{\frac{1}{2\theta}}. \tag{8}$$

back

Definitions

"Real GDP" in each period

Expenditure-side ("welfare relevant") measure:

$$realGDP = \frac{\sum_k \beta_k, Y_k}{P_C^{1-x} \cdot P_{IV}^{1-x}}$$

"Welfare":

Discounted future (log) real consumption:

$$\mathbf{U} = \sum_{t=0}^{\infty} \rho^t \cdot \phi_t \cdot \log \frac{E_{C,t}}{P_{C,t}}$$

Model Results (2008-2011)

Using shocks to both technologies and trade frictions

Model Outcomes for Selected Countries (2008-2011)									
	Static Model (2011 values)			*Dynamic Model (2011 values)*			*Dynamic Model (Steady State)*		
	Real GDP	$\widehat{r}/\widehat{w}$	$\widehat{P}_{IV}/\widehat{P}_C$	Real GDP	$\widehat{K}$	$\hat{x}$	Real GDP	$\widehat{K}$	$\widehat{\mathbf{U}}$
(selected countries)									
Australia	0.0041	0.0104	-0.0032	0.0113	0.0050	0.0303	0.1676	0.2702	0.0270
Brazil	0.0014	0.0030	-0.0022	0.0038	0.0018	0.0121	0.0616	0.0977	0.0092
Canada	0.0013	0.0016	-0.0023	0.0033	0.0013	0.0069	0.0436	0.0717	0.0067
China	0.3051	0.0116	-0.0696	1.7342	0.1557	0.3024	7.1785	9.6281	2.7962
Ethiopia	0.0029	0.0012	-0.0021	0.0082	0.0032	0.0107	0.0756	0.0977	0.0141
France	0.0005	0.0015	-0.0019	0.0008	0.0007	0.0057	0.0228	0.0435	0.0010
Germany	-0.0001	0.0037	-0.0027	0.0004	0.0014	0.0118	0.0318	0.0675	0.0003
Italy	-0.0002	0.0019	-0.0019	-0.0003	0.0007	0.0064	0.0273	0.0470	-0.0004
Japan	-0.0003	0.0026	-0.0031	0.0009	0.0009	0.0081	0.0291	0.0574	0.0005
Malaysia	0.0050	0.0038	-0.0103	0.0182	0.0053	0.0159	0.2882	0.3724	0.0674
Peru	0.0037	0.0056	-0.0054	0.0110	0.0045	0.0180	0.1651	0.2490	0.0348
South Africa	0.0030	0.0044	-0.0050	0.0078	0.0031	0.0173	0.0924	0.1503	0.0182
South Korea	-0.0010	0.0017	-0.0040	0.0035	0.0010	0.0051	0.0431	0.0764	0.0032
USA	0.0013	0.0012	-0.0035	0.0036	0.0009	0.0086	0.0399	0.0711	0.0051
Vietnam	0.0106	-0.0057	-0.0105	0.0365	0.0034	0.0043	0.1448	0.1833	0.0559
World	0.0259	0.0081	-0.0036	0.1114	0.0278	0.0156	0.3223	0.6285	0.2182
Non-China	0.0017	0.0029	-0.0033	0.0059	0.0017	0.0089	0.0844	0.1244	0.0124

The noteworthy result here is that China's percentage contribution to non-China world GDP over this 4 year period (0.59%) is actually larger than it was for the entire 14 year period 1993-2007.

Other Results

	Model Outcomes for Selected Countries								
	Static Model (2007 values)			*Dynamic Model (2007 values)*			*Dynamic Model (Steady State)*		
	Real GDP	$\widehat{r}/\widehat{w}$	$\widehat{P}_{IV}/\widehat{P}_C$	Real GDP	$\widehat{K}$	$\hat{x}$	Real GDP	$\widehat{K}$	$\widehat{\mathbf{U}}$
A. Effect of China's relative TFP change across Manufacturing vs. Non-manufacturing									
CHN	0.0000	0.0384	-0.0551	0.0120	0.0256	0.0223	0.1548	0.2430	0.0196
DEU	-0.0003	0.0020	-0.0012	0.0001	0.0007	0.0022	0.0076	0.0156	-0.0001
KOR	-0.0026	0.0037	-0.0019	-0.0020	0.0008	0.0011	0.0073	0.0138	-0.0013
PER	0.0030	0.0079	-0.0033	0.0045	0.0029	0.0091	0.0513	0.0748	0.0093
USA	0.0004	0.0011	-0.0014	0.0006	0.0005	0.0016	0.0076	0.0133	0.0006
VNM	0.0063	-0.0116	-0.0057	0.0058	-0.0021	-0.0038	0.0225	0.0233	0.0083
All Non-China	0.0007	0.0030	-0.0016	0.0016	0.0012	0.0025	0.0226	0.0325	0.0030
B. Effect of China's reflative TFP changes within Manufacturing only									
CHN	0.0000	0.0019	0.0094	0.0011	0.0024	-0.0006	-0.0006	-0.0057	0.0017
DEU	-0.0002	0.0004	0.0001	-0.0001	0.0002	0.0002	-0.0004	0.0000	-0.0003
KOR	-0.0004	-0.0018	0.0008	-0.0007	-0.0007	-0.0013	-0.0044	-0.0065	-0.0009
PER	-0.0004	-0.0015	0.0000	-0.0006	-0.0003	-0.0012	-0.0027	-0.0032	-0.0008
USA	-0.0002	-0.0004	0.0000	-0.0002	-0.0001	-0.0004	-0.0010	-0.0013	-0.0002
VNM	0.0010	0.0020	0.0015	0.0015	0.0014	0.0010	0.0065	0.0077	0.0020
All Non-China	-0.0003	-0.0006	0.0002	-0.0004	-0.0001	-0.0006	-0.0012	-0.0013	-0.0006

Notes: Table examines how much *relative* changes in China's sectoral TFPs during the period 1993-2007 contributed to actual outcomes. Panel A isolates the effect of China's growing comparative advantage in manufactured versus non-manufactured goods. Panel B leaves China's relative sectoral productivity growth in Non-Manufacturing versus Manufacturing as-is and instead focuses on China's change in comparative advantage *within* the three manufacturing sectors. Both exercises are constructed to preserve China's overall level of real GDP growth.

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Other Results

Model Outcomes for Selected Countries

	Static Model (2007 values)			*Dynamic Model (2007 values)*			*Dynamic Model (Steady State)*		
	Real GDP	$\widehat{r}/\widehat{w}$	$\widehat{P}_{IV}/\widehat{P}_C$	Real GDP	$\widehat{K}$	$\hat{x}$	Real GDP	$\widehat{K}$	$\widehat{\mathbf{U}}$
A. Lower trade elasticity ($\theta = 2.00$; $\kappa = 0.55$)									
CHN	0.9235	0.0500	-0.2982	1.1268	0.2755	0.1355	3.2431	4.6286	1.5008
DEU	0.0020	0.0048	-0.0093	0.0035	0.0025	0.0072	0.0286	0.0502	0.0037
KOR	0.0096	0.0026	-0.0159	0.0132	0.0052	0.0073	0.0620	0.0875	0.0155
PER	0.0109	0.0095	-0.0152	0.0134	0.0046	0.0140	0.1010	0.1463	0.0214
USA	0.0042	0.0015	-0.0098	0.0052	0.0020	0.0064	0.0304	0.0499	0.0048
VNM	0.0468	-0.0138	-0.0203	0.0538	0.0140	0.0063	0.1459	0.1640	0.0582
All Non-China	0.0066	0.0039	-0.0110	0.0100	0.0039	0.0076	0.0634	0.0885	0.0132
B. Higher trade elasticity ($\theta = 6.00$; $\kappa = 0.55$)									
CHN	0.5440	0.0375	-0.1613	0.6642	0.1791	0.0973	1.9319	2.4403	0.9145
DEU	-0.0005	0.0074	-0.0038	0.0009	0.0029	0.0081	0.0212	0.0492	-0.0001
KOR	0.0017	-0.0012	-0.0054	0.0028	0.0013	0.0018	0.0185	0.0334	0.0021
PER	0.0030	0.0063	-0.0055	0.0054	0.0045	0.0136	0.1093	0.1660	0.0144
USA	0.0011	0.0010	-0.0036	0.0016	0.0010	0.0030	0.0162	0.0297	0.0014
VNM	0.0165	-0.0094	-0.0064	0.0170	0.0000	-0.0027	0.0396	0.0465	0.0195
All Non-China	0.0014	0.0020	-0.0042	0.0029	0.0020	0.0039	0.0507	0.0745	0.0054

Notes: Table shows how much changes in China's sectoral TFPs and trade barriers during the period 1993-2007 contributed to actual outcomes for a small selection of countries, versus a counterfactual where China's sectoral TFP changes and trade barrier reductions matched those of its trade partners. Each panel experiments with varying a key parameter from the model.

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Other Results

	Model Outcomes for Selected Countries								
	Static Model (2007 values)			*Dynamic Model (2007 values)*			*Dynamic Model (Steady State)*		
	Real GDP	$\widehat{r}/\widehat{w}$	$\widehat{P}_{IV}/\widehat{P}_C$	Real GDP	$\widehat{K}$	$\hat{x}$	Real GDP	$\widehat{K}$	$\widehat{\mathbf{U}}$
C. Lower capital adjustment costs ($\theta = 4.00$; $\kappa = 0.75$)									
CHN	0.6386	0.0442	-0.2005	0.8105	0.2590	0.1692	2.2012	2.8814	1.0596
DEU	0.0001	0.0061	-0.0051	0.0017	0.0032	0.0082	0.0150	0.0309	0.0011
KOR	0.0037	0.0009	-0.0080	0.0059	0.0031	0.0049	0.0261	0.0393	0.0061
PER	0.0052	0.0083	-0.0080	0.0083	0.0060	0.0175	0.0818	0.1212	0.0147
USA	0.0018	0.0013	-0.0051	0.0026	0.0015	0.0053	0.0147	0.0254	0.0021
VNM	0.0242	-0.0117	-0.0100	0.0271	0.0048	0.0010	0.0612	0.0653	0.0280
All Non-China	0.0028	0.0029	-0.0058	0.0052	0.0033	0.0065	0.0393	0.0573	0.0071
D. Higher capital adjustment costs ($\theta = 4.00$; $\kappa = 0.35$)									
CHN	0.6386	0.0442	-0.2005	0.7397	0.1414	0.0621	2.4603	3.2415	1.0207
DEU	0.0001	0.0061	-0.0051	0.0009	0.0017	0.0061	0.0460	0.0977	0.0004
KOR	0.0037	0.0009	-0.0080	0.0049	0.0017	0.0025	0.0521	0.0868	0.0050
PER	0.0052	0.0083	-0.0080	0.0068	0.0030	0.0103	0.1899	0.2881	0.0181
USA	0.0018	0.0013	-0.0051	0.0023	0.0009	0.0028	0.0411	0.0726	0.0024
VNM	0.0242	-0.0117	-0.0100	0.0256	0.0020	-0.0023	0.0971	0.1171	0.0330
All Non-China	0.0028	0.0029	-0.0058	0.0043	0.0017	0.0035	0.0891	0.1208	0.0081

Notes: Table shows how much changes in China's sectoral TFPs and trade barriers during the period 1993-2007 contributed to actual outcomes for a small selection of countries, versus a counterfactual where China's sectoral TFP changes and trade barrier reductions matched those of its trade partners. Each panel experiments with varying a key parameter from the model.

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