Trade, Technology, and the Skill Premium: The Case of Mexico

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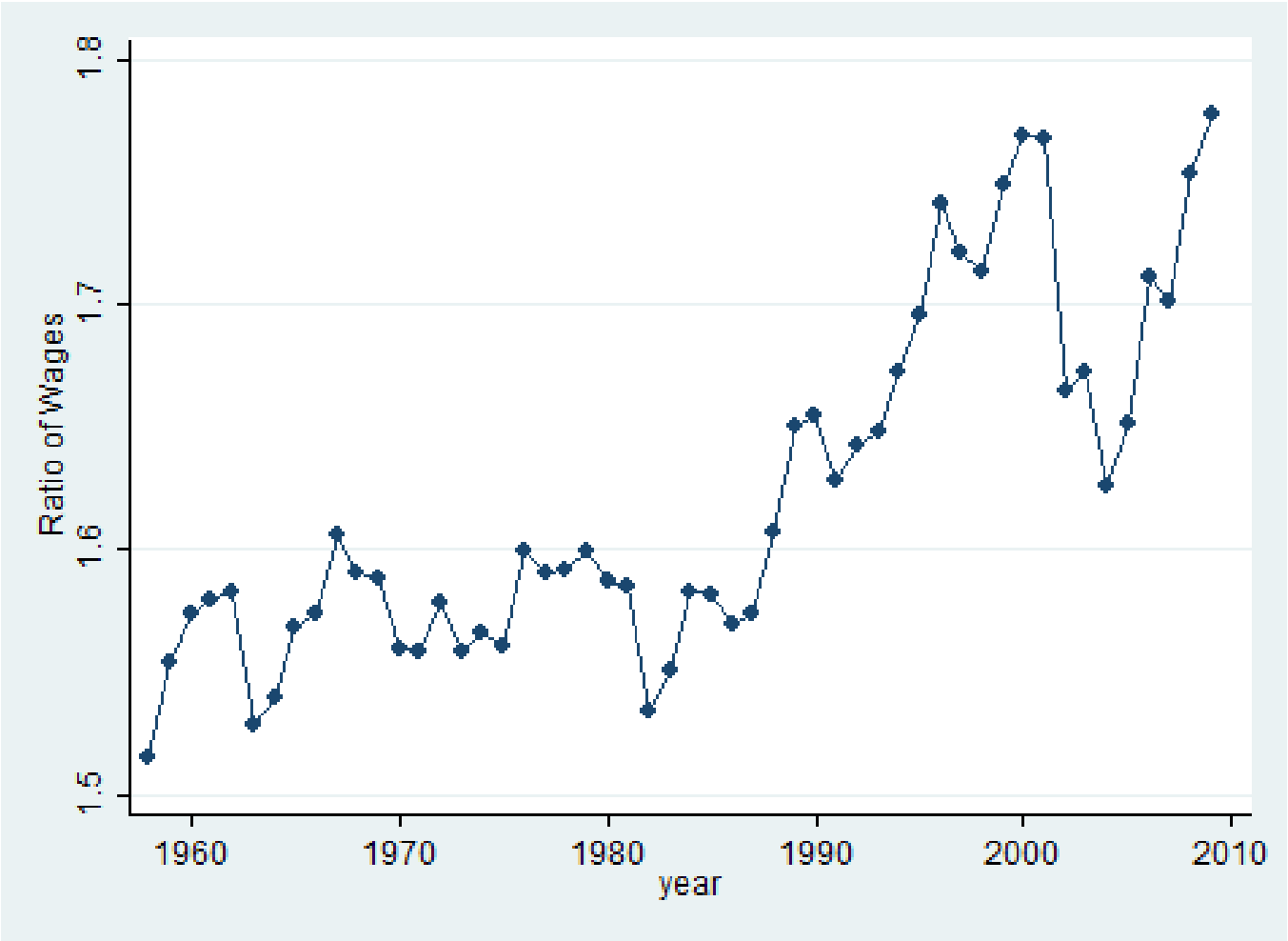
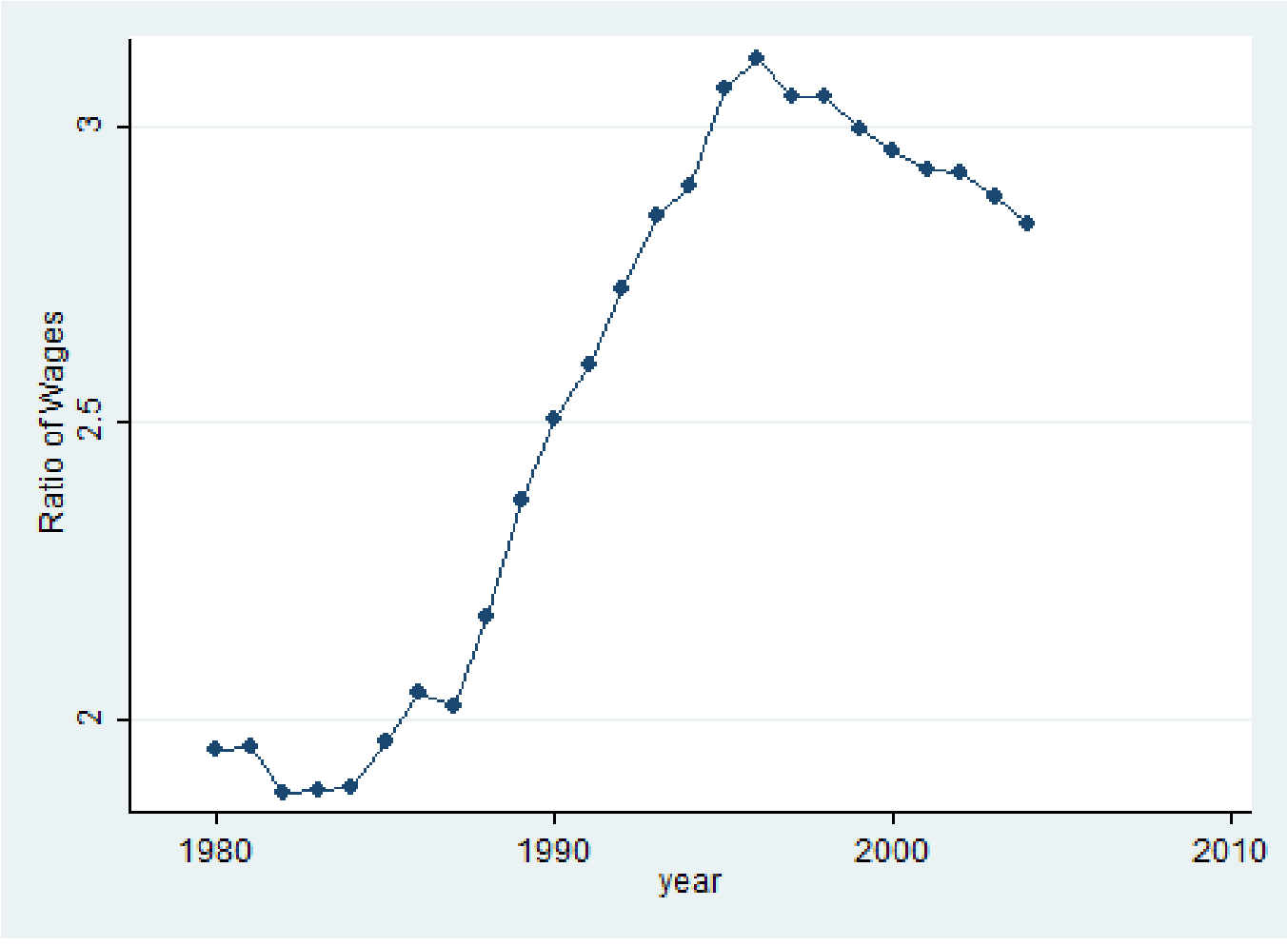
Motivation

- In the 1980's the manufacturing skill premium began to rise in the US and Mexico

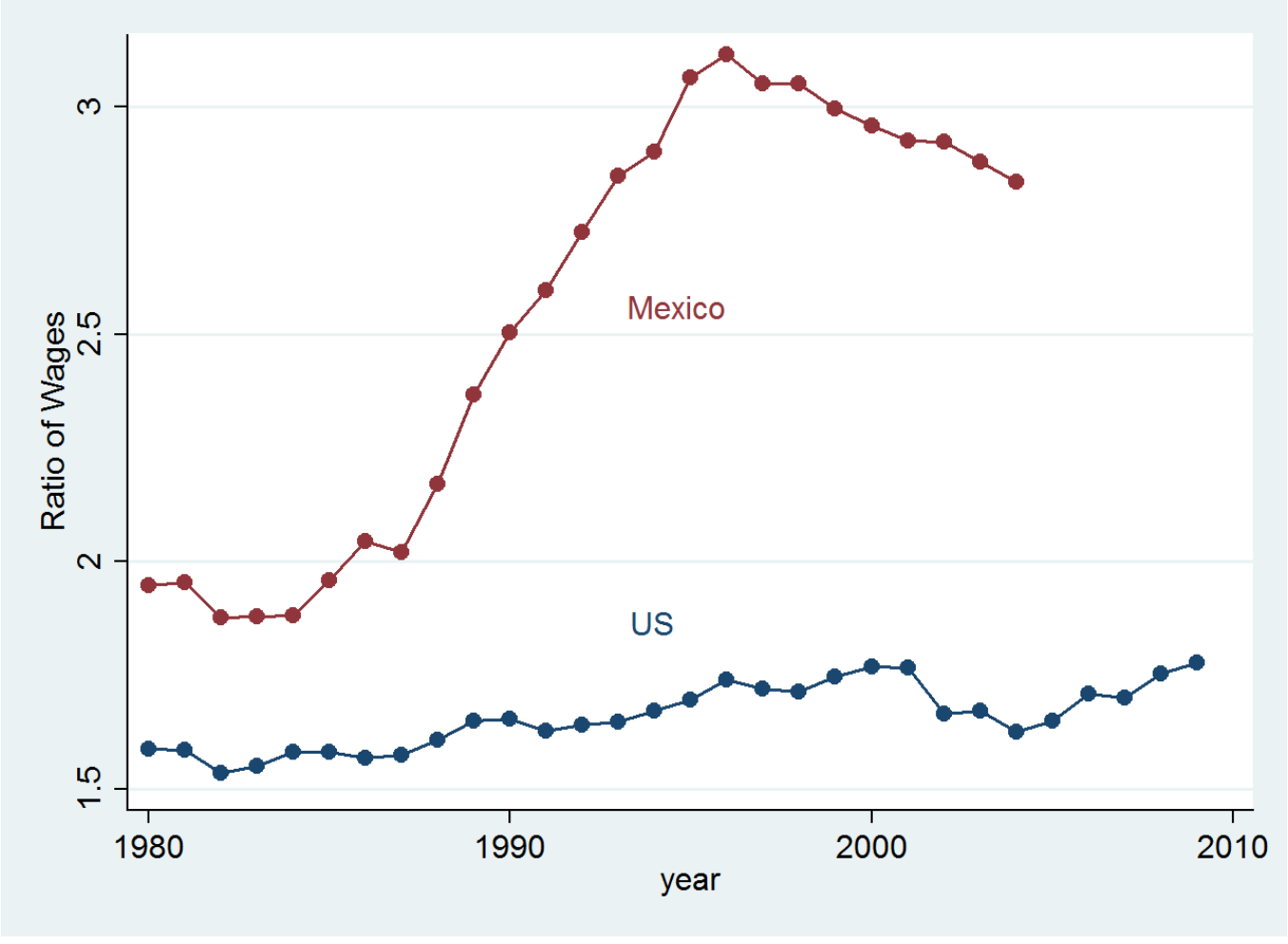
US Manufacturing Skill Premium



Mexico Manufacturing Skill Premium



Increase in Skill Premia



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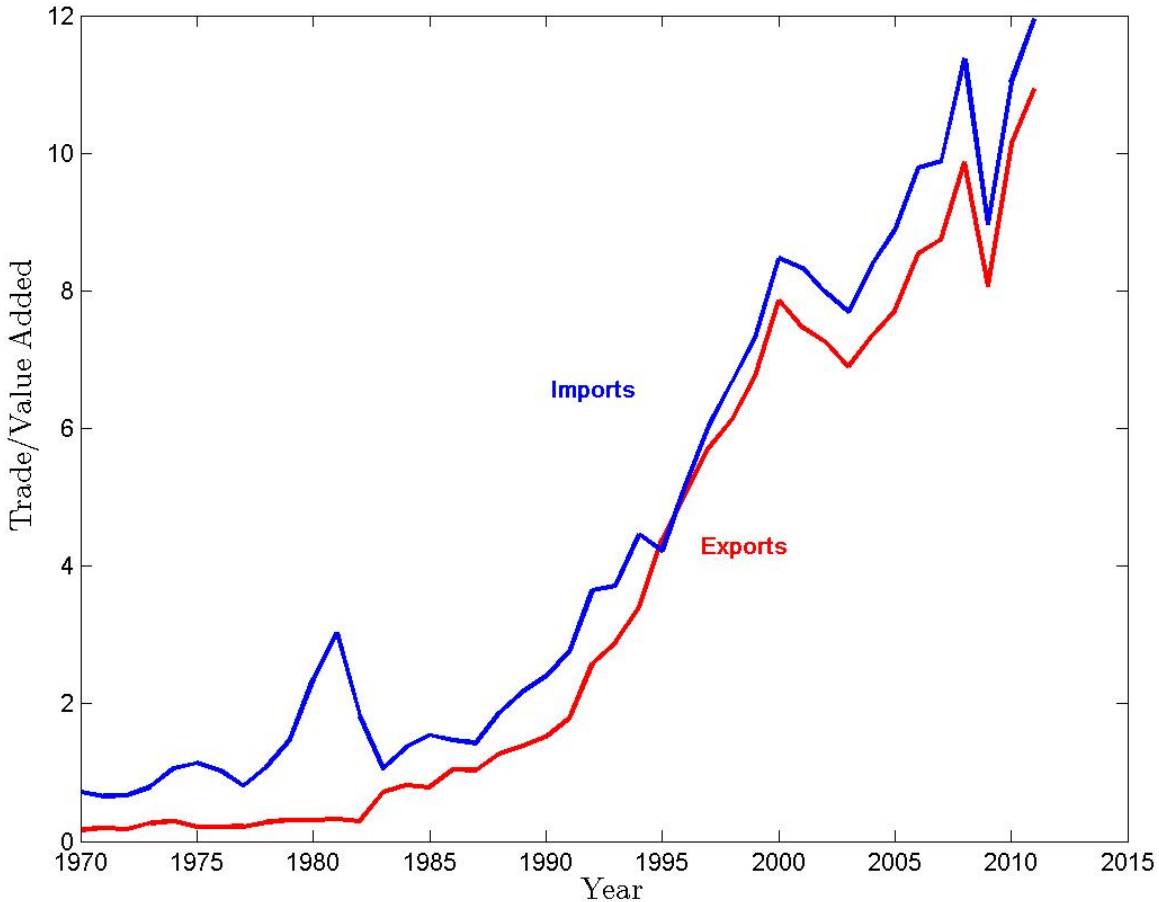
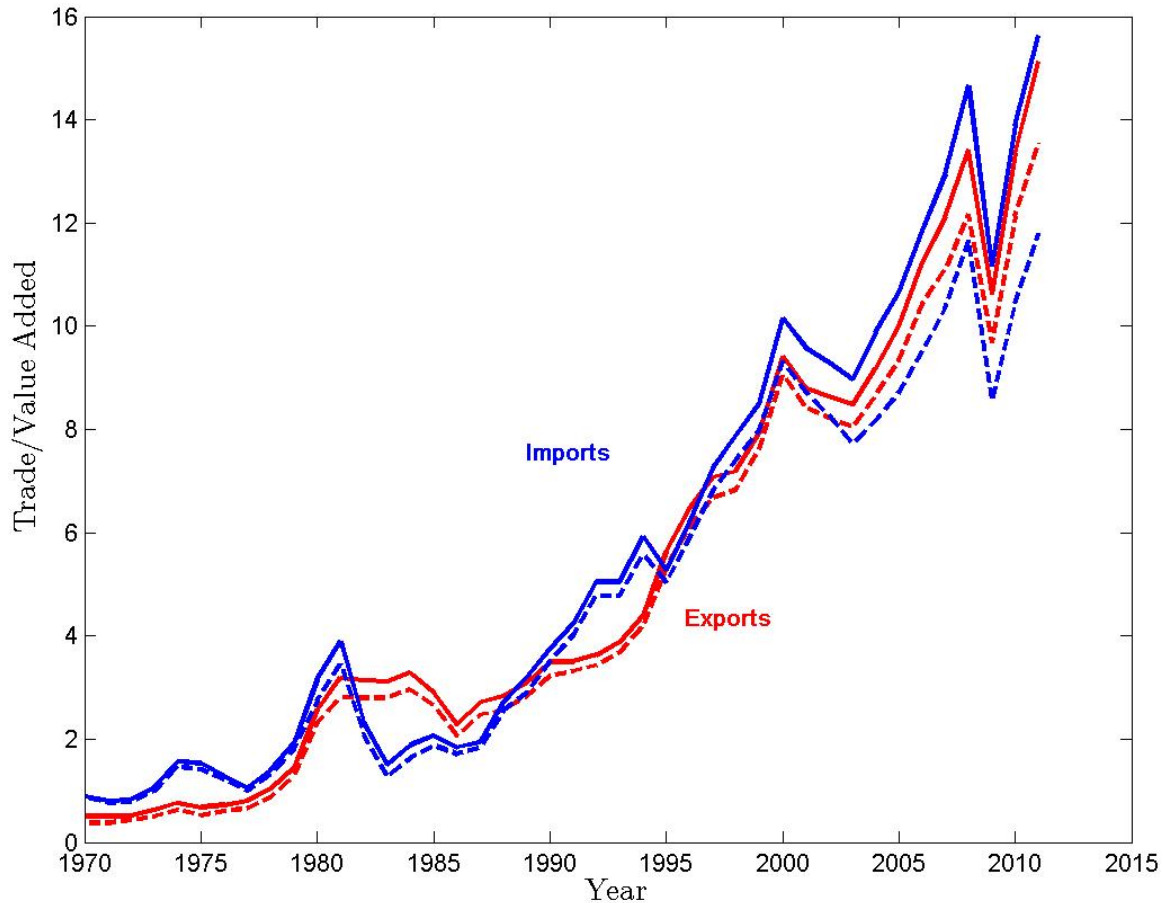
Mexican Manufacturing Trade



Manufacturing Trade/GDP

Mexican Merchandise Trade



Merchandise Trade/GDP | US Imports from Mexico

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- Literature has had difficulty in establishing a large role of increase in trade flows on skill premium
  - Skill premium moves counter to theoretical predictions in Mexico (increases)

Question

Why did the skill premium go up by so much in Mexico?

This Project

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  - U.S. through an "investment channel"

For Today

Evidence from Mexico

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- Rising skill premia in both countries, larger in Mexico
- 12% of the rise in the skill premium in Mexico and 10% of the rise in the U.S.

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Evidence from Mexico

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Adding trade in technology reverses standard H-O predictions

Evidence of the Mechanism

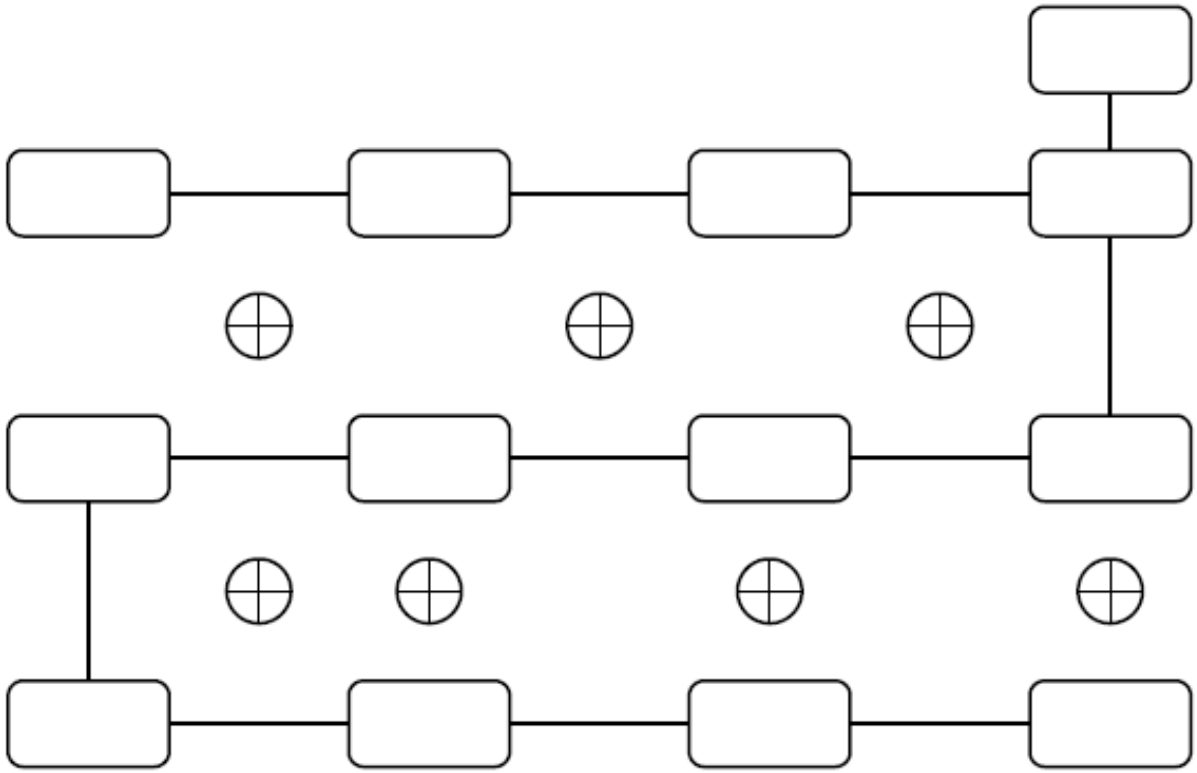
Case Study: The Auto Industry

In the 1980's US auto makers partnered with Mexican parts manufacturers to produce

- Crankshafts
- Intake Manifold
- Cylinder Head
- Cylinder Block

using the "latest state-of-the art." Interviewed managers said there was "no difference in the technology used in Detroit and Mexico."

Production Line: Standard Set Up



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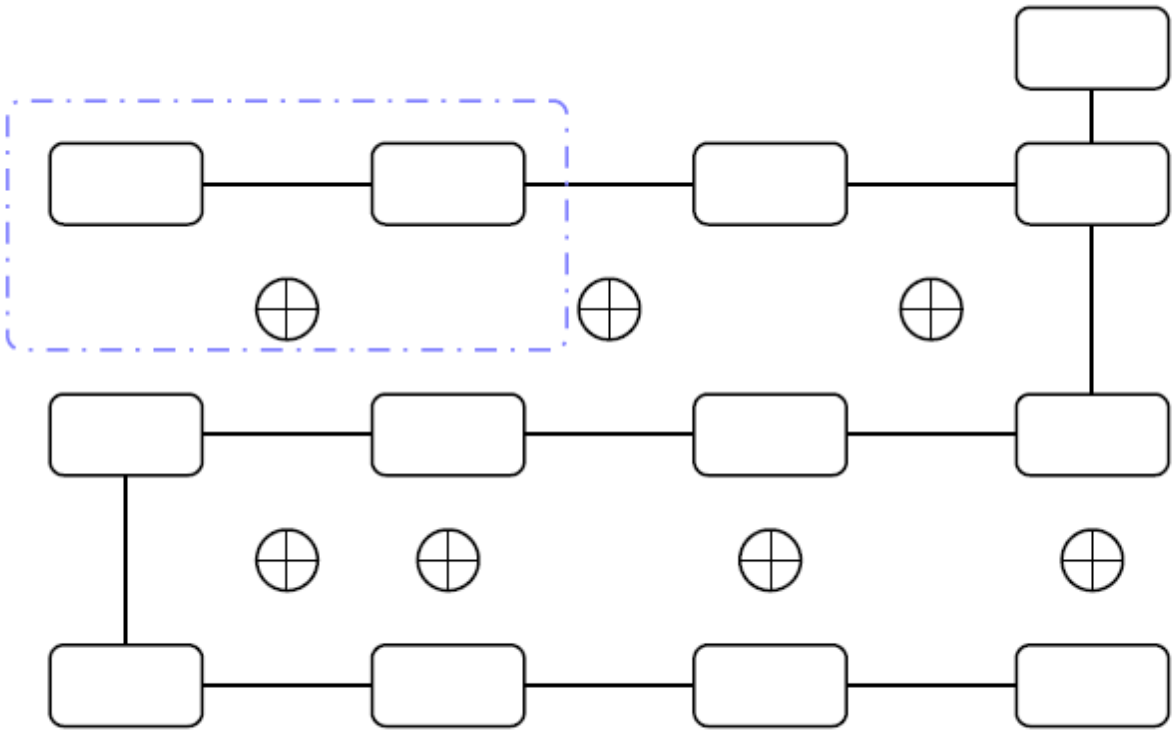
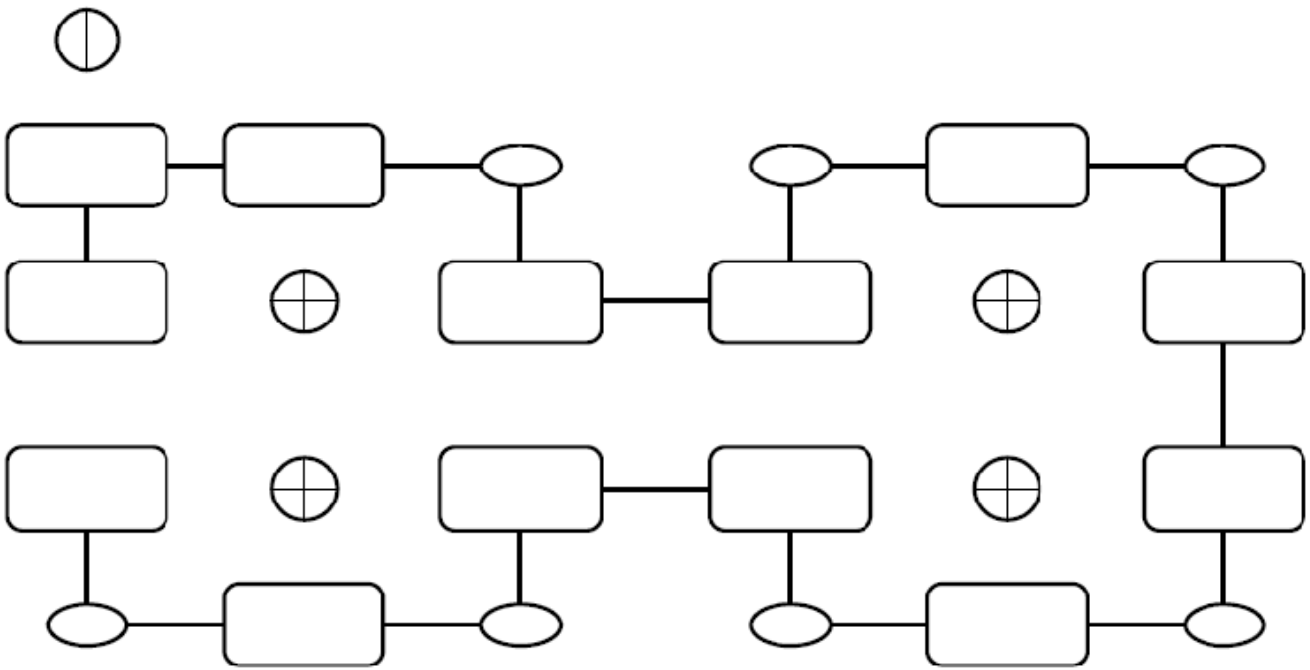


Production Line: An Example of Skill-Augmenting Technology



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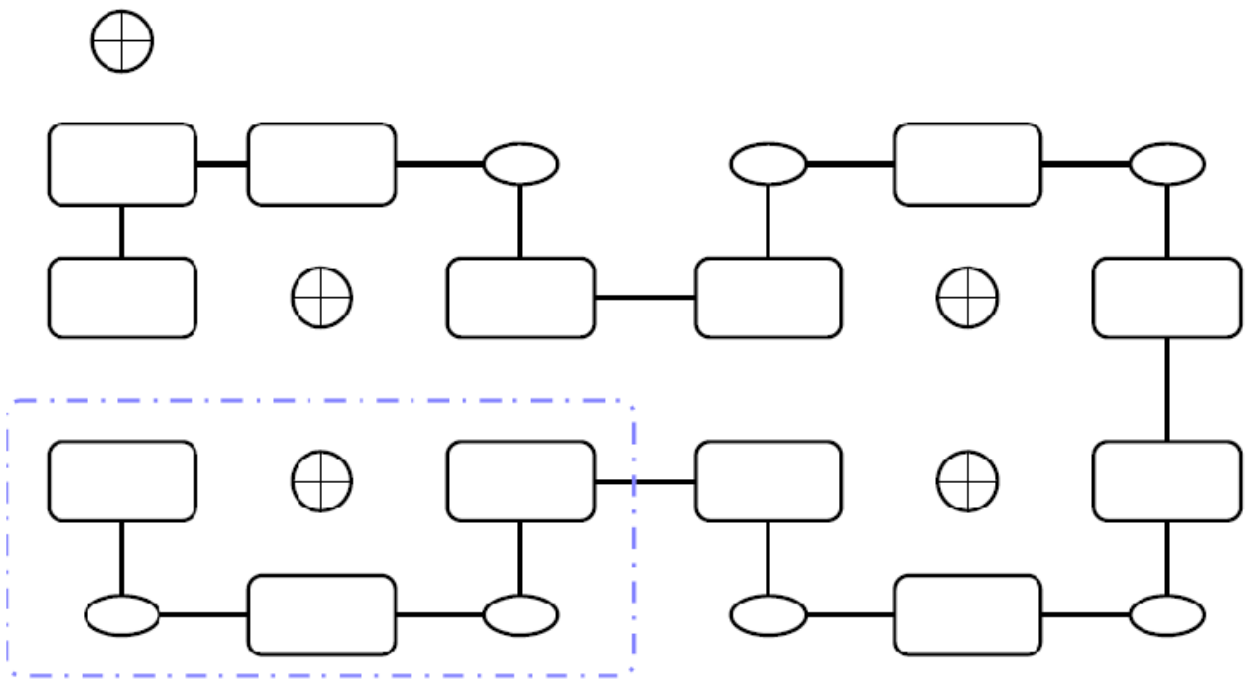


On the Job Training

Skilled Workers

- Extensive pre-job training
- Apprenticeship program for both technicians and supervisors
- Supervisors brought to US to observe plant management

Unskilled Workers

- Taught basic characteristics of the machine that they would operate
- Taught how to assess which technician to contact if machine breaks down

Transfer of Technology

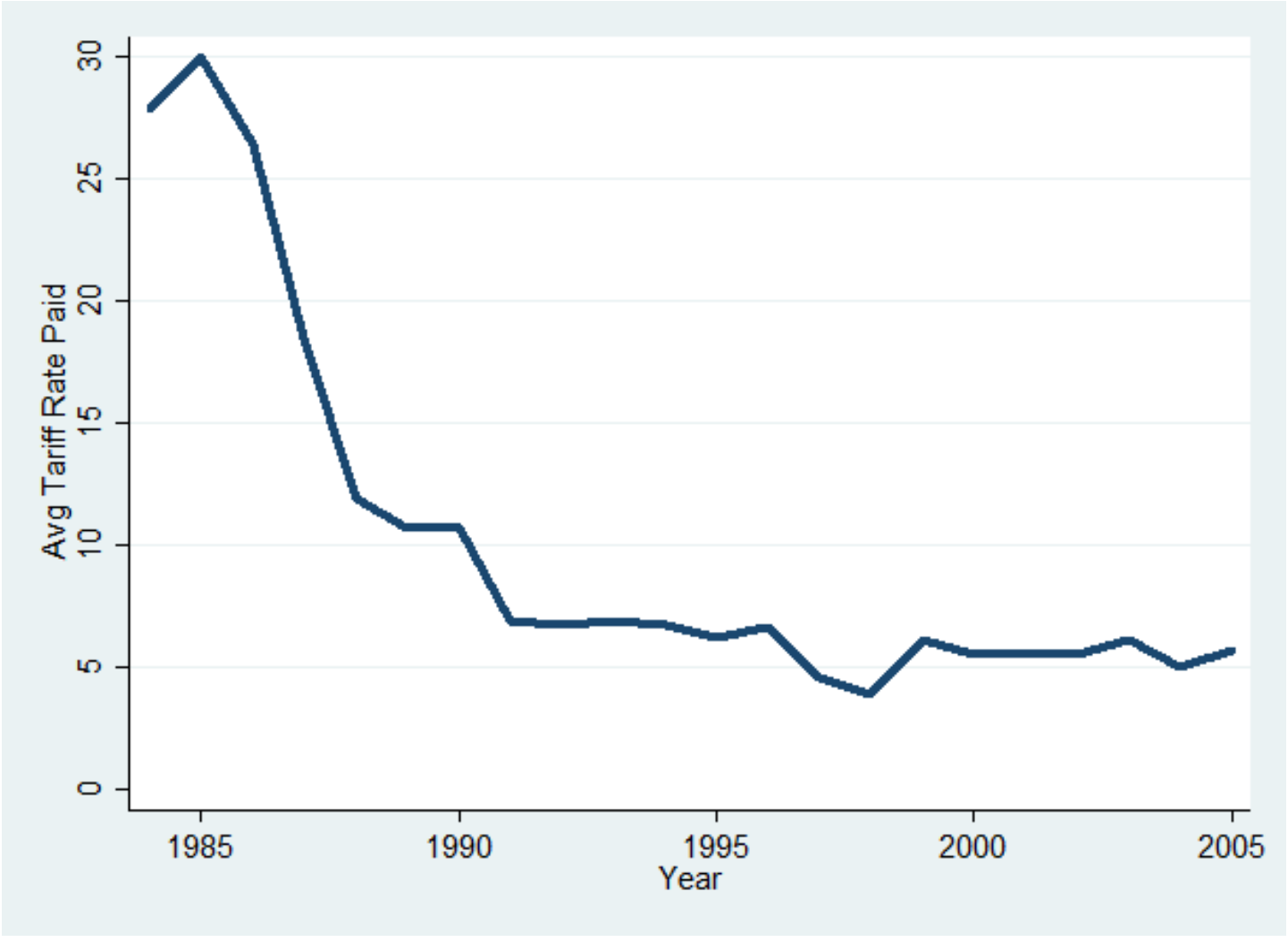
Supply chains served as ways to transfer

- Technology for making parts for final production
  - Blueprints for production of parts
  - Technology embedded in intermediate goods and parts
- Best practices for efficient production
- Organizational capital such as worker training programs

Mexico's Trade Liberalization

- Begins in 1986
- Liberalization during NAFTA is relatively modest in comparison
- Between 1986 and 1990:
  - Average tariff rates fall from 30% to 5%
  - Average license coverage falls from 80% to 3%
- Following NAFTA
  - Average tariff rates fall from 5% to 3%
  - Average license coverage falls from 3% to 1%

TARIFFS


Avg Tariff Rate Paid
0
5
10
15
20
25
30
1985
1990
1995
2000
2005
Year

Mexico: Manufacturing Data

- Manufacturing only - about 80% of manufacturing sector
- Plant-level available from 1984 - 1990
  - Information on production/non-production workers and wages, royalties paid, ownership, and investment
  - Also includes trade and tariffs paid from 1986-1990
- Industry-level available from 1984 - 1994
  - Information on production/non-production workers and wages, royalties paid, ownership, and investment
  - Matched to U.S.-Mexico Trade data from Schott (2008)

Use these data to relate trade liberalization to skill premium

Tariff Reduction and Royalties

Question: Do plants (industries) that face lower tariffs rent more technology?

Using plant-level data, we can relate royalties paid to tariffs faced by plants, as well as connection to U.S.:

$$\left(\frac{R}{Y}\right)_{jt} = \alpha + \beta_1 \tau_{jt} + \beta_2 US_j + \beta_3 \left(\tau * US\right)_{jt} + SI_{j0} + \gamma_j + T_t + \epsilon_{jt}$$

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$$\begin{aligned}\left(\frac{R}{Y}\right)_{jt} &= \alpha - \beta_1 \tau_{jt} + \beta_2 \left(\frac{USExp}{Y}\right)_{jt} + \beta_3 \left(-\tau * \frac{USExp}{Y}\right)_{jt} \\ &+ SI_{j0} + \gamma_j + T_t + \epsilon_{jt}\end{aligned}$$

Tariff Reduction and Royalties

	U.S. Co	U.S. Exports
Constant	0.094	0.030
	(0.133)	(0.133)
τ_{jt}	-0.002^{*}	0.002
	(0.001)	(0.004)
US_j	0.709^{***}	-
	(0.097)	
$(US * \tau)_{jt}$	-0.011^{***}	-
	(0.004)	
$\frac{USExp}{Y}_{jt}$		0.608^{*}
		(0.342)
$\left(-\tau * \frac{USExp}{Y}\right)_{jt}$		0.023^{*}
		(0.011)
SI_{j0}	0.789^{***}	0.806^{***}
	(0.083)	(0.104)
Industry Fixed Effects?	Yes	Yes
Time Fixed Effects?	Yes	Yes
R^2	0.108	0.111

Changes in Trade and the Skill Premium

Question: Do plants that trade more (with the U.S.) and rent more technology have higher skill premia?

$$
\begin{aligned}
SP_{jt} &= \alpha + \beta_1 \left(\frac{Exp}{Y}\right)_{jt} + \beta_2 \left(\frac{Imp}{Y}\right)_{jt} + \beta_3 \left(\frac{R}{Y}\right)_{jt} \\
&+ \beta_4 US_j + \beta_5 \left(\frac{Exp}{Y} * US\right)_{jt} + \beta_6 \left(\frac{Imp}{Y} * US\right)_{jt} \\
&+ \beta_7 \left(\frac{R}{Y} * US\right)_{jt} + SI_{j0} + \gamma_j + T_t + \epsilon_{jt}
\end{aligned}
$$

Changes in Trade and the Skill Premium

Sample	U.S. Only	No U.S.	All
Constant	3.113***	3.197***	3.124***
	(0.116)	(0.114)	(0.116)
$\frac{Exp}{Y}_{jt}$	0.562***	0.391**	0.452***
	(0.130)	(0.183)	(0.100)
$\frac{Imp}{Y}_{jt}$	0.027	0.041	0.027
	(0.079)	(0.123)	(0.065)
$\frac{Royalties}{Y}_{jt}$	0.039***	0.040***	0.039***
	(0.008)	(0.008)	(0.008)
US_{jt}	0.356***	0.420***	0.343***
	(0.067)	(0.065)	(0.069)
$\left(\frac{Royalties}{Y} * US\right)_{jt}$	−0.031	−0.049	−0.037
	(0.032)	(0.032)	(0.032)
$\left(\frac{Exp}{Y} * US\right)_{jt}$	0.804***	−0.042	0.757***
	(0.360)	(0.751)	(0.323)
$\left(\frac{Imp}{Y} * US\right)_{jt}$	−1.204	0.341	−0.423
	(0.765)	(1.027)	(0.503)
SI_{j0}	−1.172***	−1.187***	−1.175***
	(0.078)	(0.078)	(0.078)
R^2	0.155	0.153	0.155

Industry-Level Evidence

Use industry-level evidence to test:

- Impact of tariffs on
  - Royalties

$$\left(\frac{R}{Y}\right)_{it} = \alpha + \beta_1 \tau_{it} + \gamma_i + T_t + \epsilon_{it}$$

  - Skill Premium

$$SP_{it} = \alpha + \beta_1 \tau_{it} + \gamma_i + T_t + \epsilon_{it},$$

- Trade with U.S. on the skill premium:

$$\begin{aligned} SP_{it} &= \beta_1 \left(\frac{Royalties}{Y}\right)_{it} + \beta_2 \left(\frac{Exports}{Y}\right)_{it} + \beta_3 \left(\frac{Imports}{Y}\right)_{it} \\ &+ \beta_4 SI_{i0} + \gamma_i + T_t + \epsilon_{it} \end{aligned}$$

Impact of Tariffs

Variable	$\frac{R}{Y}_{it}$	SP_{it}
Constant	0.289	2.560^{***}
	(0349)	(2.333)
τ_{it}	-0.011^{***}	-0.003^{**}
	(0.004)	(0.001)
Industry Fixed Effects?	Yes	Yes
Time Fixed Effects?	Yes	Yes
R^2	0.388	0.784

Impact of Trade with U.S.

	Level	Change (1984-1994)
$\frac{Royalties}{Y}_{it}$	0.024**	0.082***
	(0.010)	(0.018)
$\frac{Exports}{Y}_{it}$	0.128*	0.358***
	(0.077)	(0.054)
$\frac{Imports}{Y}_{i,t}$	−0.053	−0.079
	(0.040)	(0.050)
SI_{i0}	8.432***	2.742***
	(0.392)	(0.065)
Fixed Effects?	Yes	No
R^2	0.981	0.650

Summary of Data

- Case study points to technology capital transference via supply chains
- Plants/industries facing higher tariffs rent less technology and have lower skill premia
- Plants/industries with increased trade with U.S. and more technology rental have higher skill premia

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Suggests technology transfer may occur through supply chains

Royalties Data

Model

Environment

- Time is infinite and discrete, $t = 0, 1, 2, ...$
- Two countries: US (U) and Mexico (M)
- Two types of workers: High-skill (H) and Low-skill (L)
- Households supply labor inelastically
- I final goods
- Producers of non-traded final goods own and invests in technology and rent it to intermediate goods producers
- Technology is skill-augmenting

Technological Investment and Transfer

$$I_{ki} = Z'_{ki} - (1 - \delta)Z_{ki}$$

- Looks like standard saving decision

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  - Foreign intermediate goods producers when open to trade
- Transfer occurs through technology rental

Intermediate Goods Producers: $y_{jki}(\omega)$

Intermediate goods producers in country k produce for domestic (k) and foreign (j) final goods producers using the technology of the producer they are supplying. They solve:

$$\max \sum_j \left(y_{jki}(\omega) \frac{p_{jki}(\omega)}{\tau_{jki}} - w_k^H h_{jki}(\omega) - w_k^L l_{jki}(\omega) - \tau_{zj} r_{ji} Z_{ji} \right)$$

s.t.

$$y_{jki}(\omega) = A_k \left[\theta_i \left(Z_{ji}^{\alpha} h_{jki}(\omega)^{1-\alpha} \right)^{\frac{\sigma-1}{\sigma}} + (1-\theta_i) l_{jki}(\omega)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$$

$$y_{jki}(\omega) = Y_{ji} \left[\frac{p_{jki}(\omega)}{\mathbf{P_{ji}}} \right]^{1/(\rho-1)}$$

Intermediate Goods Producers: $y_{jki}(\omega)$

The firm's choice is distorted along two dimmensions: a tariff (τ_{jki}) and a distortion to the technology rental rate (τ_{ki})

$$\max \sum_j \left(y_{jki}(\omega) \frac{p_{jki}(\omega)}{\tau_{\mathbf{jki}}} - w_k^H h_{jki}(\omega) - w_k^L l_{jki}(\omega) - \tau_{\mathbf{zj}} r_{ji} Z_{ji} \right)$$

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Trade Liberalization

There are two different forms of liberalization in the model:

1. Reduction in tariffs leads to more trade in intermediates
2. Reduction of τ_z allows for greater inflow of technology

What Is τ_z?

τ_z represents the ease of usi ng foreign technology capital

- Ease of transferring/using U.S. blue-prints in Mexico
- Can be though of as standing in for intellectual property rights protection
- As part of liberalization with the U.S., Mexico began to adopt the intellectual property protection laws that were in place in the U.S.
- Began as part of negotiations in the late 1980's

What Happens when Mexico Liberalizes?

- Cost of using Z_U in Mexico falls
  - Mexican firms adopt more U.S. skill-augmenting technology capital, $Z_U \rightarrow$ Adoption channel
  - All else equal, this drives demand for skilled labor up
  - Offsets standard H-O effect
- Return to investing in Z_U increases for the final goods producer in US
  - U.S. firms increase investment in $Z_U \rightarrow$ Investment channel

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How does this affect the skill premium?

Skill Premium: H-O vs. Supply Chain Model

Basic H-O model:

$$SP_k = \frac{\theta_i}{1-\theta_i}\left(\frac{h_{jki}}{l_{jki}}\right)^{\frac{-1}{\sigma}}$$

Supply Chain model:

$$SP_k = (1-\alpha)\frac{\theta_i}{1-\theta_i}\left(\frac{Z_{ji}}{h_{jki}}\right)^{\alpha\frac{(\sigma-1)}{\sigma}}\left(\frac{h_{jki}}{l_{jki}}\right)^{\frac{-1}{\sigma}}$$

Technology endogenously changes skill-intensity of a sector

Skill Premium: H-O vs. Supply Chain Model

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Supply Chain model:

$$SP_M = (1-\alpha)\frac{\theta_i}{1-\theta_i}\left(\frac{Z_{Ui}}{h_{UMi}}\right)^{\alpha\frac{(\sigma-1)}{\sigma}}\left(\frac{h_{UMi}}{l_{UMi}}\right)^{\frac{-1}{\sigma}}$$

Big rise comes from *adopting* the technology from the U.S.

Results

Experiment

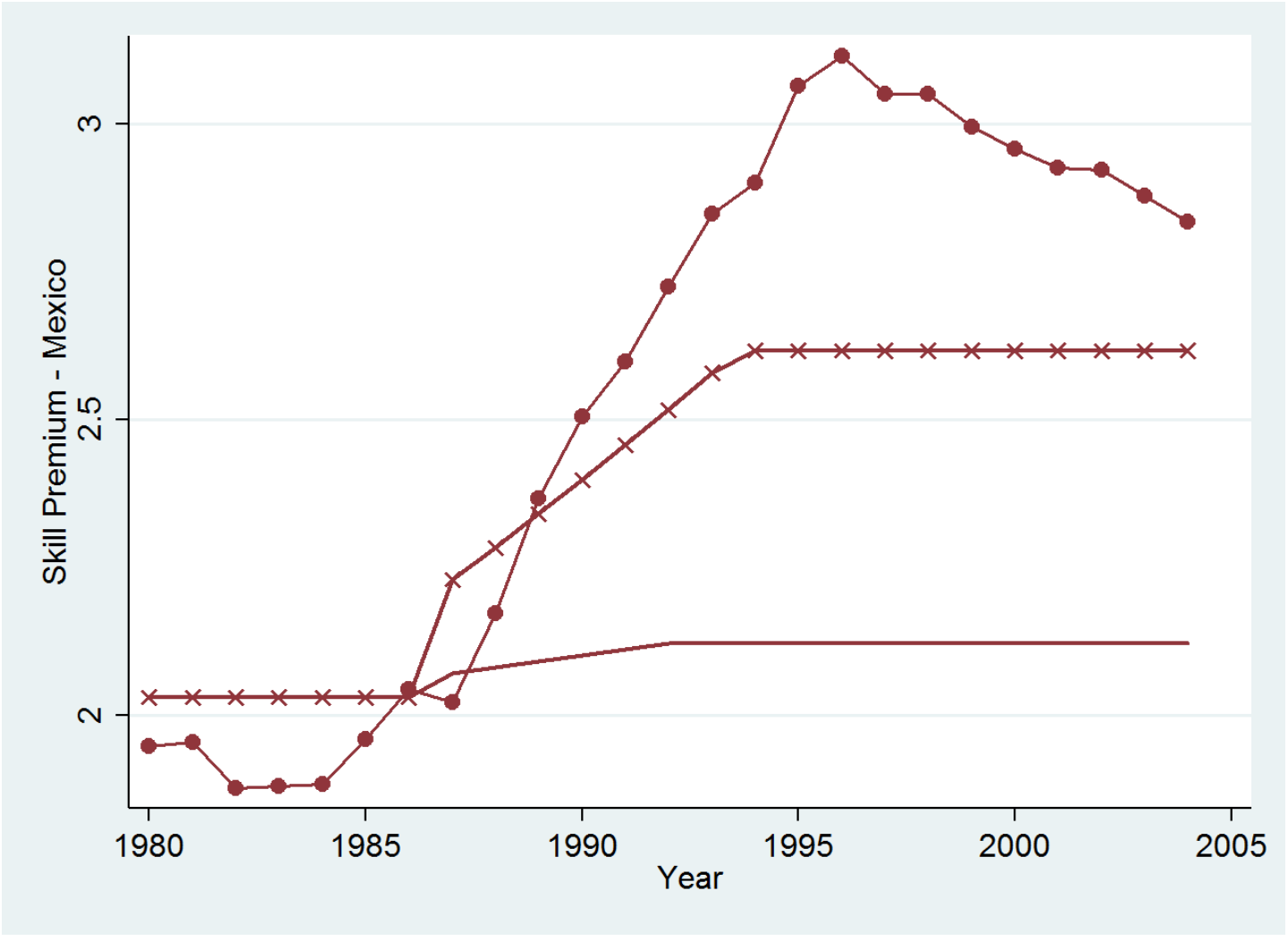
- Calibrate a the model to match key pre-liberalization features of data
- Two Counter-Factual Experiments:
  - Baseline: Set trade costs using tariff data and set τ_z to match industry-level trade flows between U.S. and Mexico both pre- and post-liberalization
  - Extreme: Completely erode barriers to use of foreign technology to see how important they are

What Theory Predicts

Reduction in tariffs and barriers to use of foreign technology will cause

- In Mexico
  - Less specialization
  - Workers flow to producing intermediates for export
  - Adoption of U.S. technology
  - Skill premium $\uparrow\uparrow$
- In U.S.
  - Returns to investing in Sector Y $\uparrow$
  - Skill premium $\uparrow$

Results: Skill Premium



Intuition: Baseline Experiment

- Trade increased from 5% to 16% of Mexican manufactured output from 1986 to 1994
- In the absence of frictions, Mexican firms would like to almost evenly split their production between producing for U.S. supply chain and the Mexican one (50% of output for export)
- To see only 16% of output exported, frictions need to remain relatively high even after liberalization
- We see Mexican firms moving from producing for Mexico to producing for U.S. supply chain but not enough to import much technology

Intuition: Extreme Experiment

Reduce all frictions to use of foreign technology, reduce tariffs as observed in data

- Mexican manufacturers within a given industry shift towards producing more for export, less for domestic production
- This shift varies across industries
- Industries that increase trade with U.S. by more end up renting more technology capital from the U.S.
- This technology is more skill-intensive

Conclusion

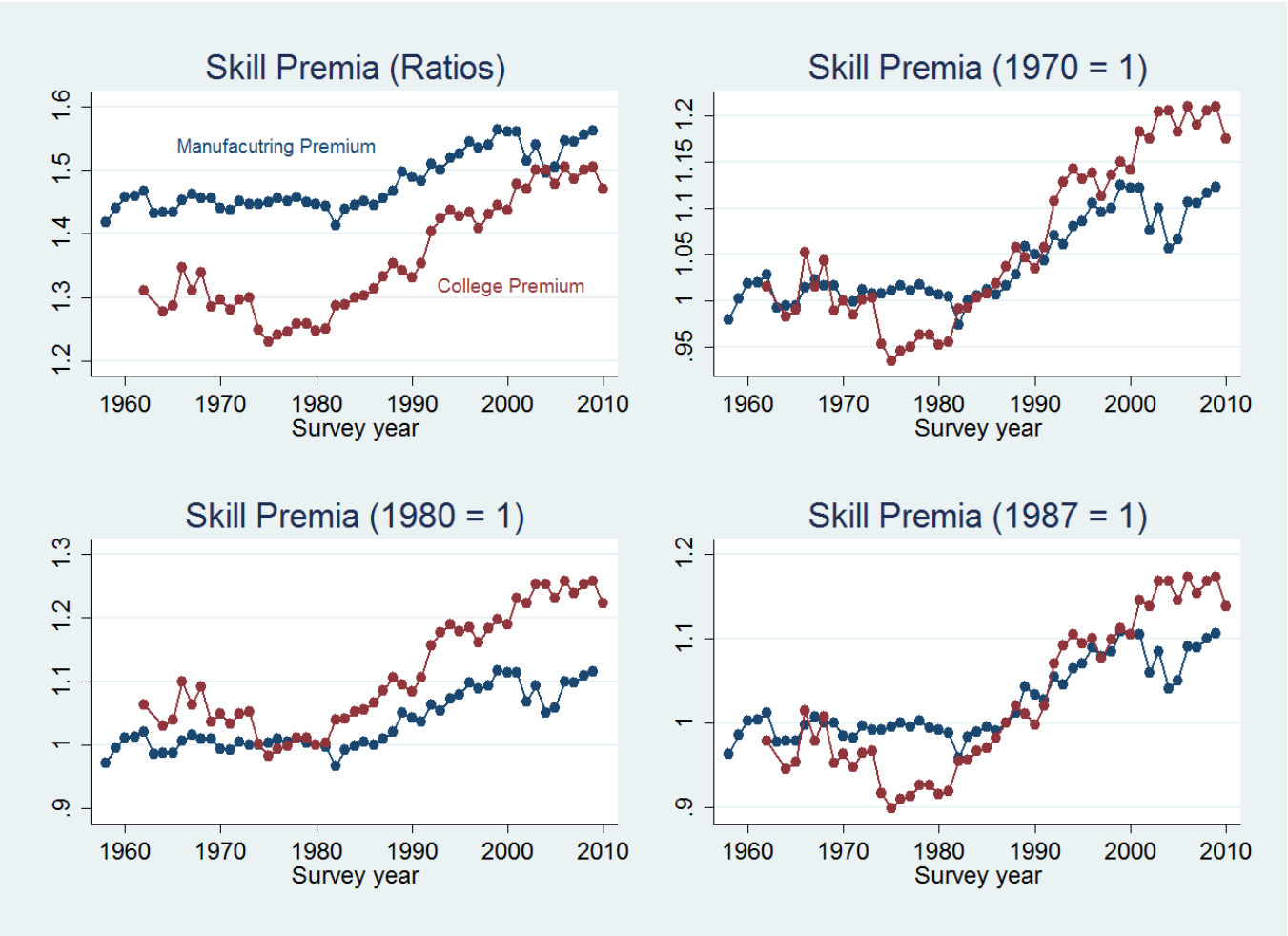
- Argue that trade is a channel by which technology is diffused across countries

Conclusion

- Argue that trade is a channel by which technology is diffused across countries
- This means that it's not trade ***or*** technology that is driving increasing inequality, but rather, both in tandem
- Show that integration with the U.S. supply chainis an important determinant of increasing skill premium in Mexican industries
- Build a model in which integration of supply chains leads to increasing skill premia
- Show that mechanism can account for about 12% of increase in SP in Mexico

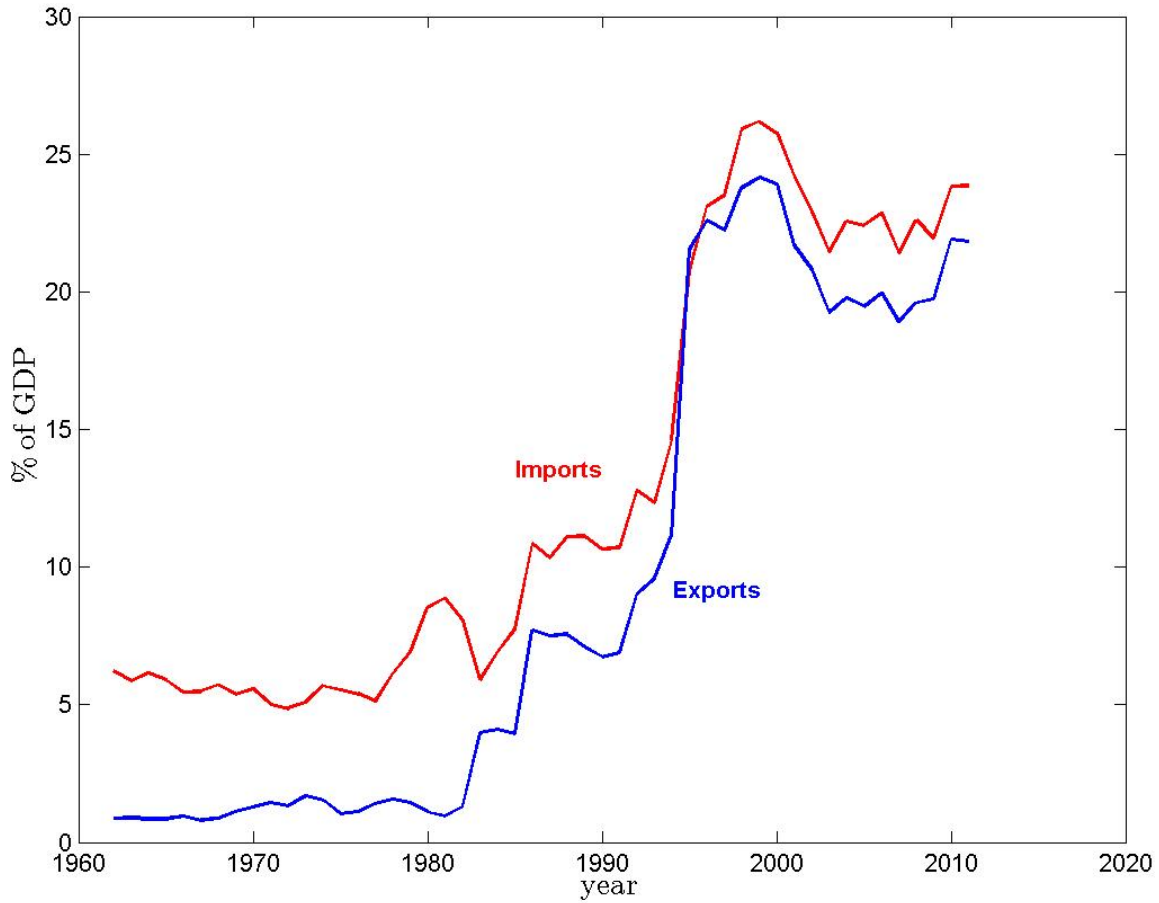
Appendix

US Education & Manufacturing Premium



Back to Manufacturing Premium

Mexican Manufacutring Trade/GDP



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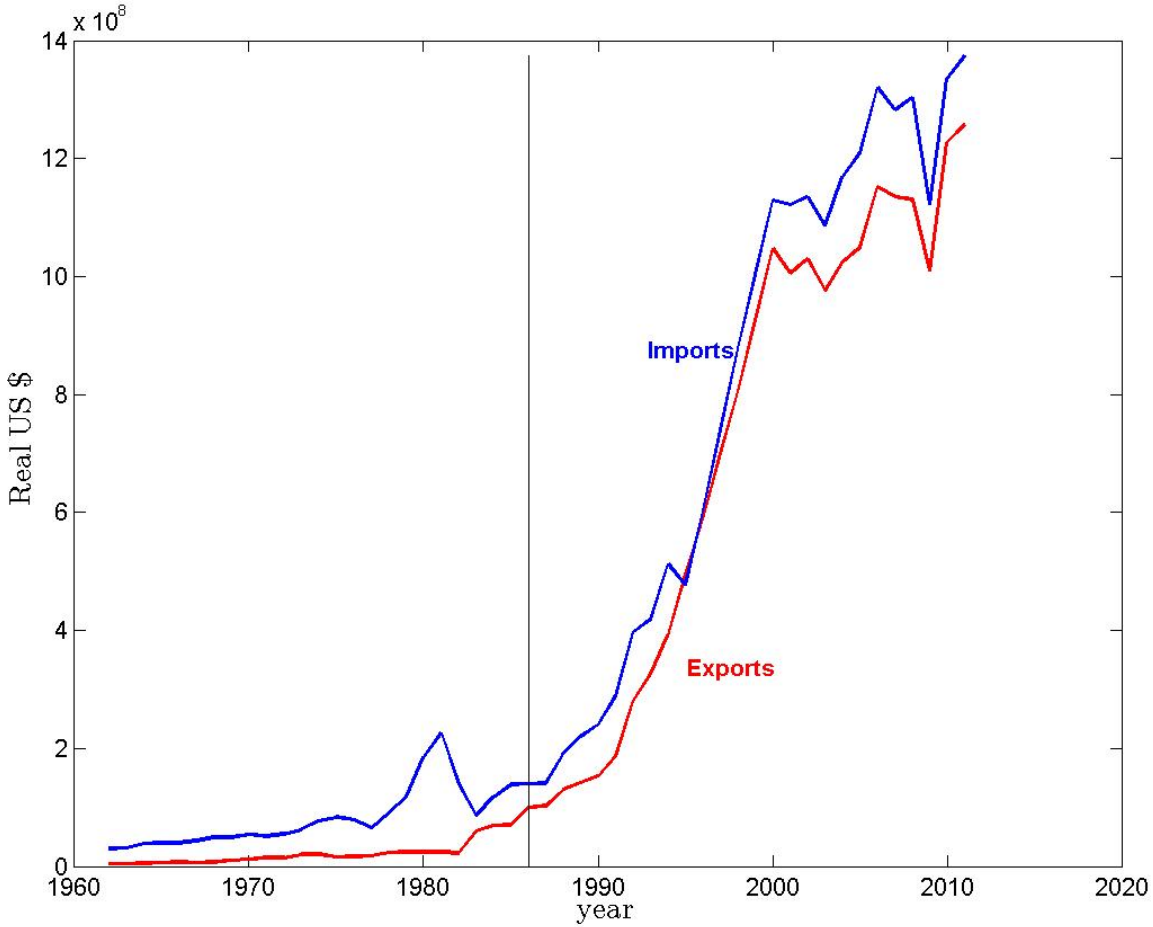

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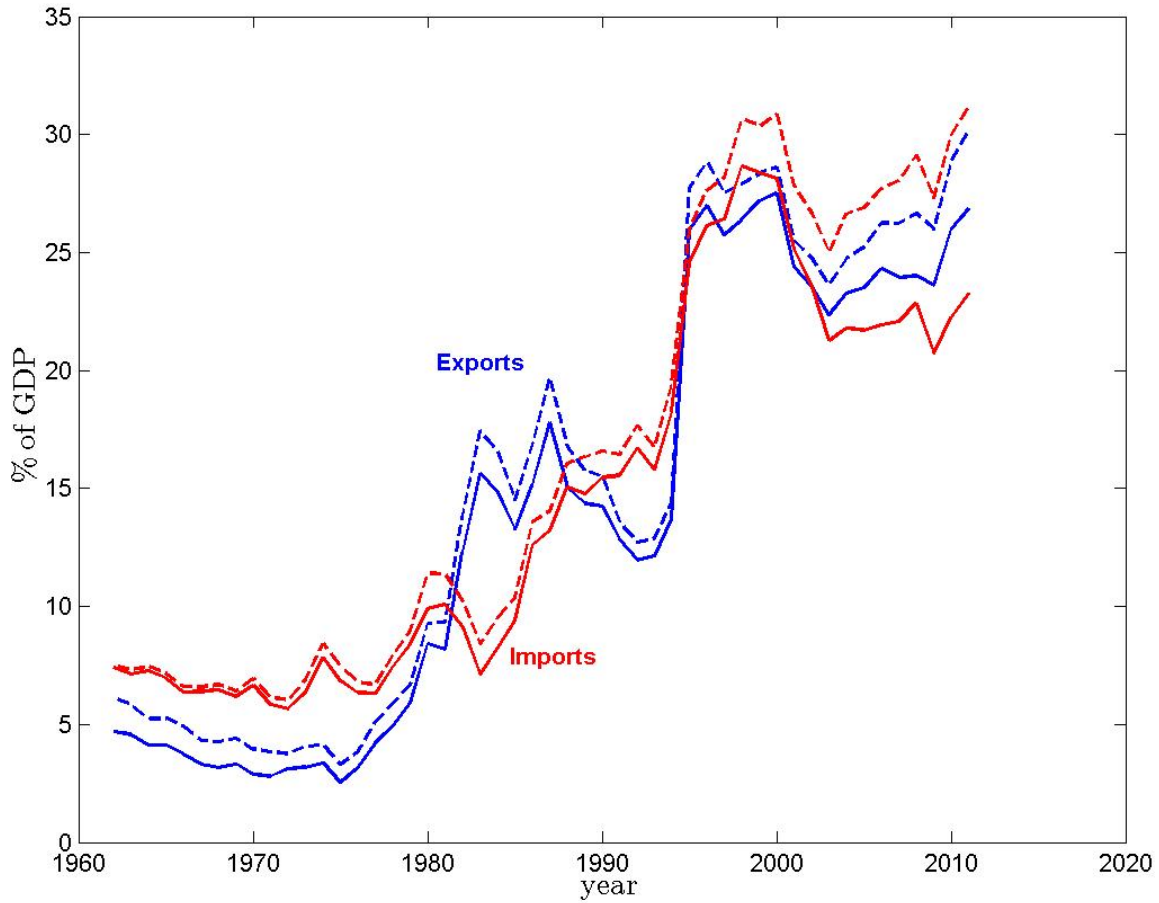
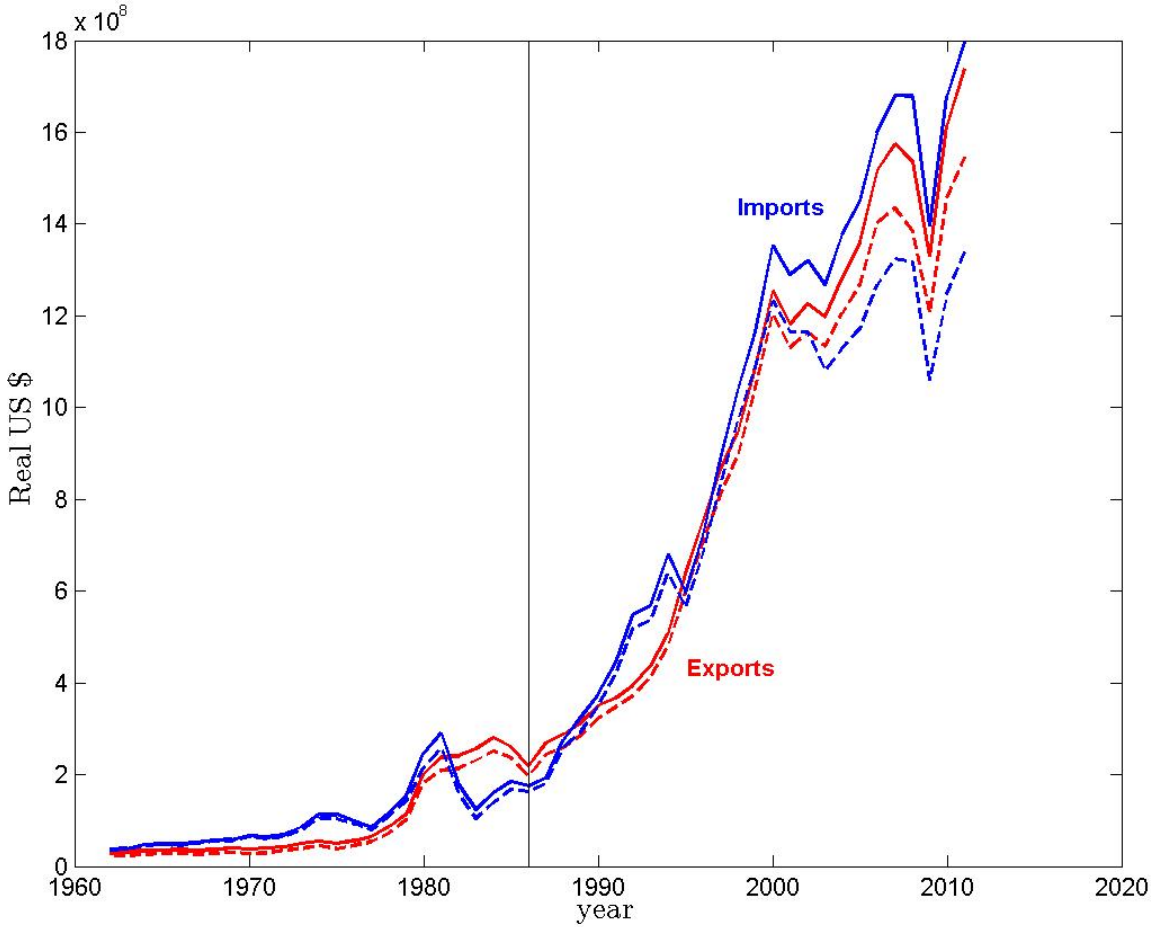


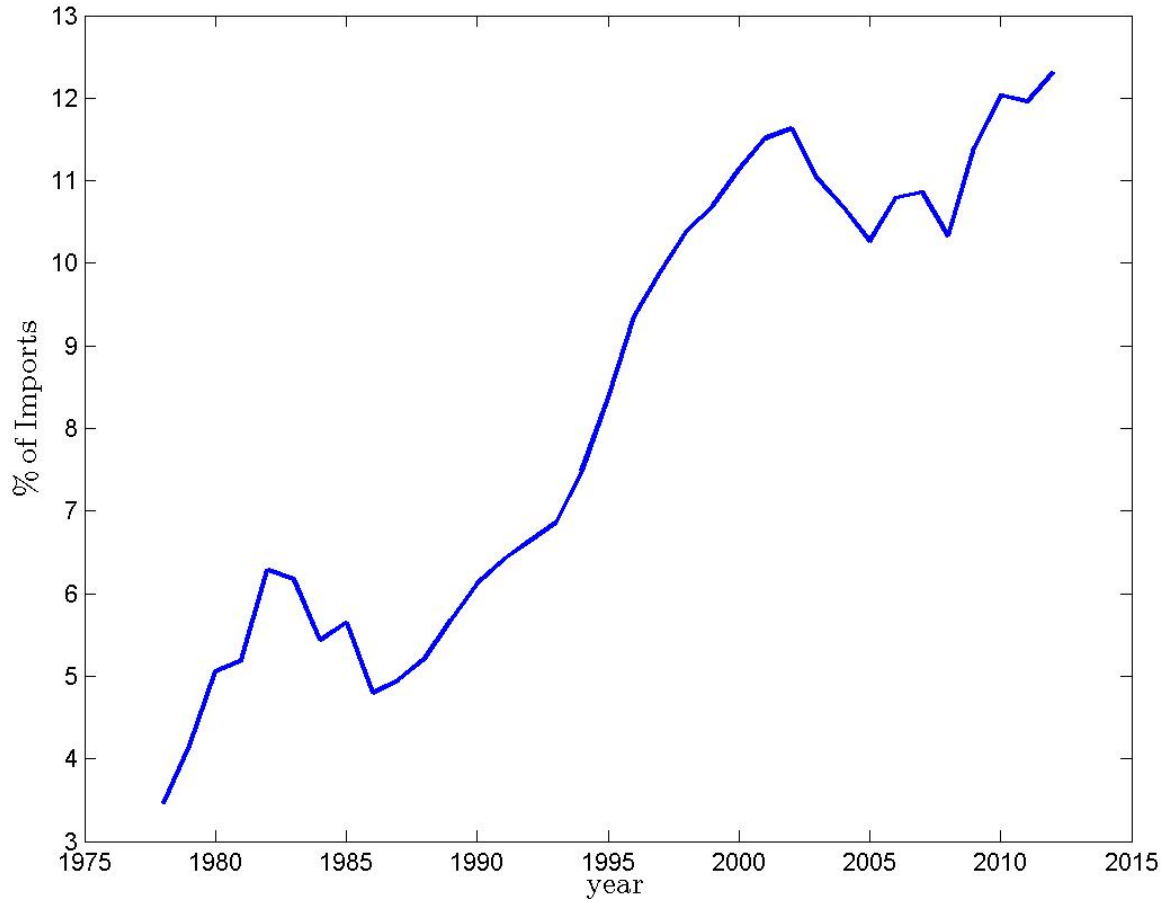
Back to Manufacturing Trade

Mexican Merchandise Trade



Back to Merchandise Trade

US Imports from Mexico



Evidence of Technology Transfer

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- Will use evidence on royalties to pin down key parameter of the model
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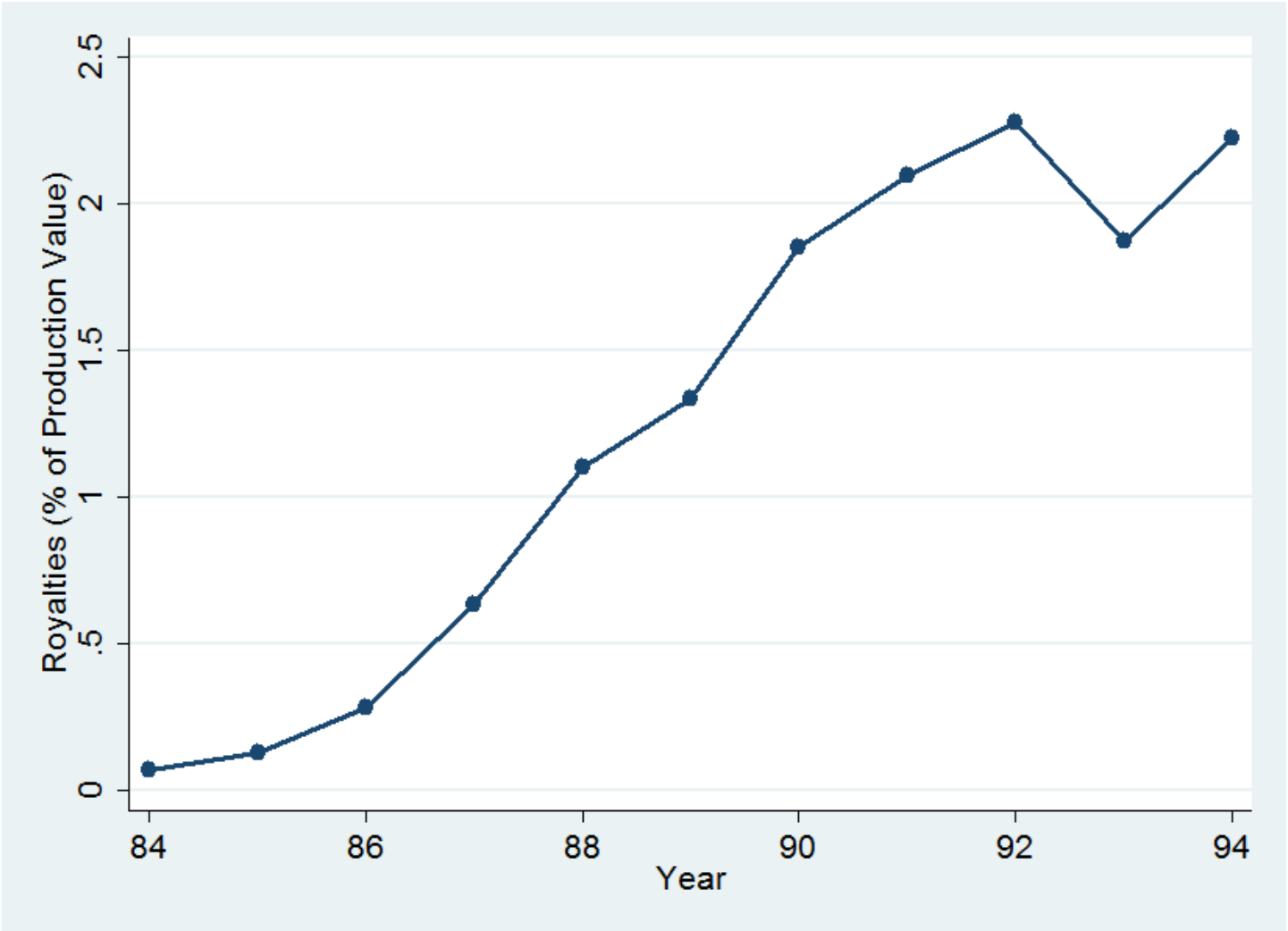
  - Does this happen in the data?

Time Path for Royalties



Z_{ki} AND DISTORTIONS

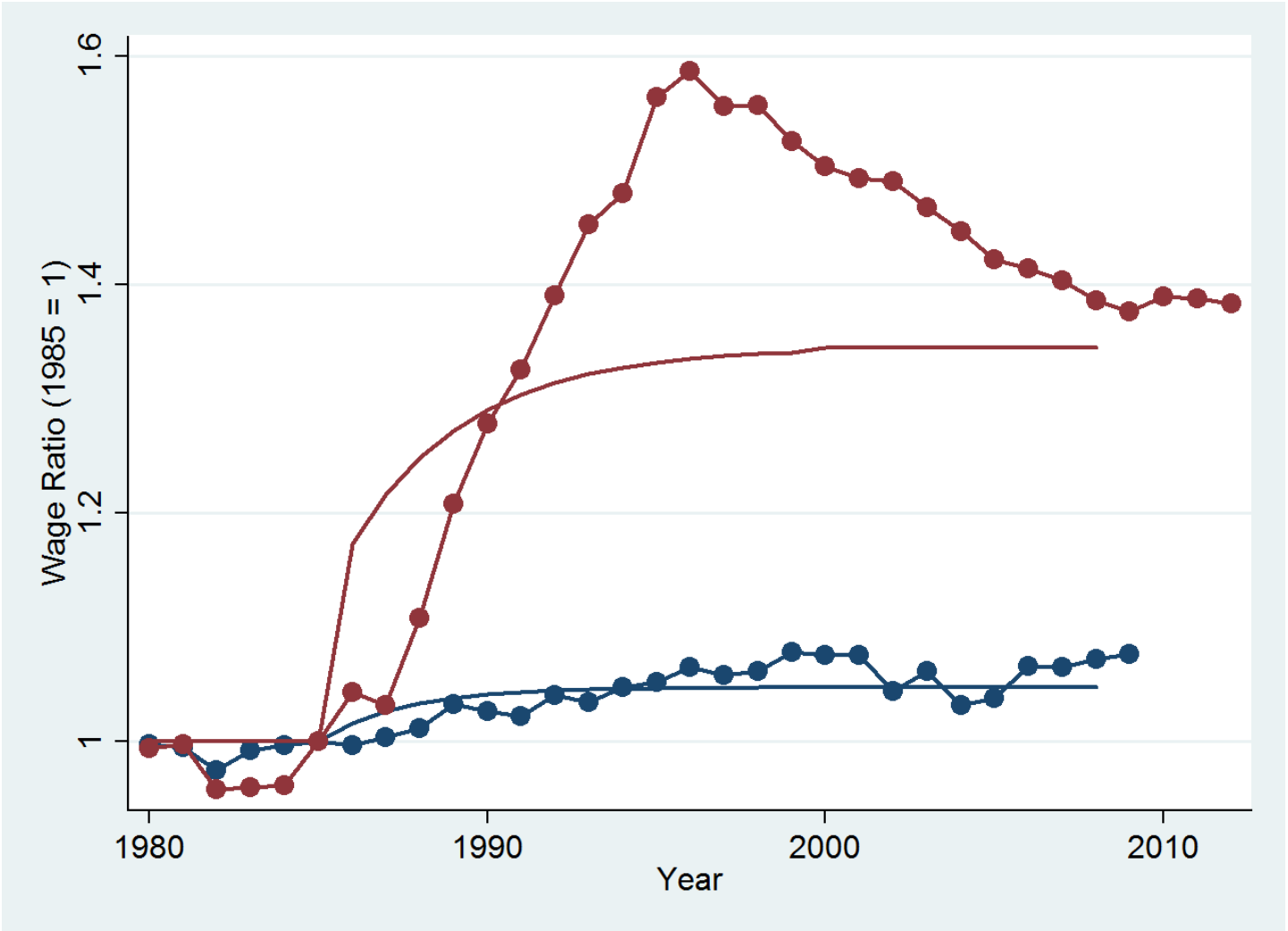
The return to renting Z_{ki} to the intermediate good producer in country j can be expressed as:

$$r_{jki} = \frac{p_{jki}(\omega)(1-\rho)A_k}{\tau_{zj}\tau_{jki}} \left[\theta_i \left(Z_{ki}^{\alpha} h_{jki}(\omega)^{1-\alpha}\right)^{\frac{\sigma-1}{\sigma}} + (1-\theta_i) l_{jki}(\omega)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}-1}$$
$$\alpha\theta_i Z_{ki}^{\frac{\alpha(\sigma-1)}{\sigma}-1} h_{jki}(\omega)^{\frac{(1-\alpha)(\sigma-1)}{\sigma}}$$

So if τ_{zj} or $\tau_{jki} \downarrow$, the return to investing $\uparrow \Rightarrow Z_{ki} \uparrow$

Back to Skill Premium Equations

Results: Skill Premium (1985 =1)



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Discussion of Parameters

Key parameters governing the change in skill premium:

- α: Share of technology in production
  - Impact of trade on skill premium is rising in α
  - Use royalties to discipline
- σ: Substitutability between skilled and unskilled workers
  - Estimates in the data from 1.2 to 2+
  - Impact of trade on skill premium is rising in σ
  - Use initial skill premia to discipline

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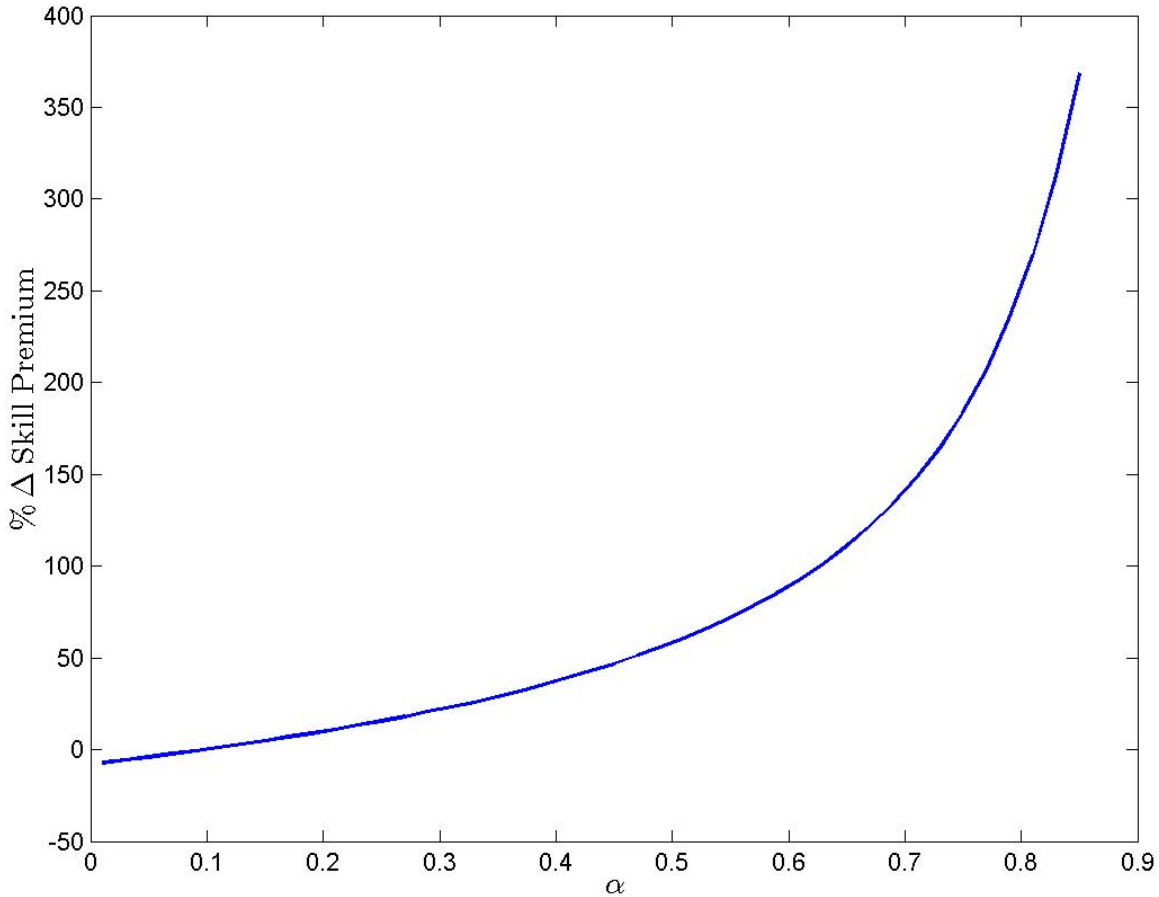
VARYING α



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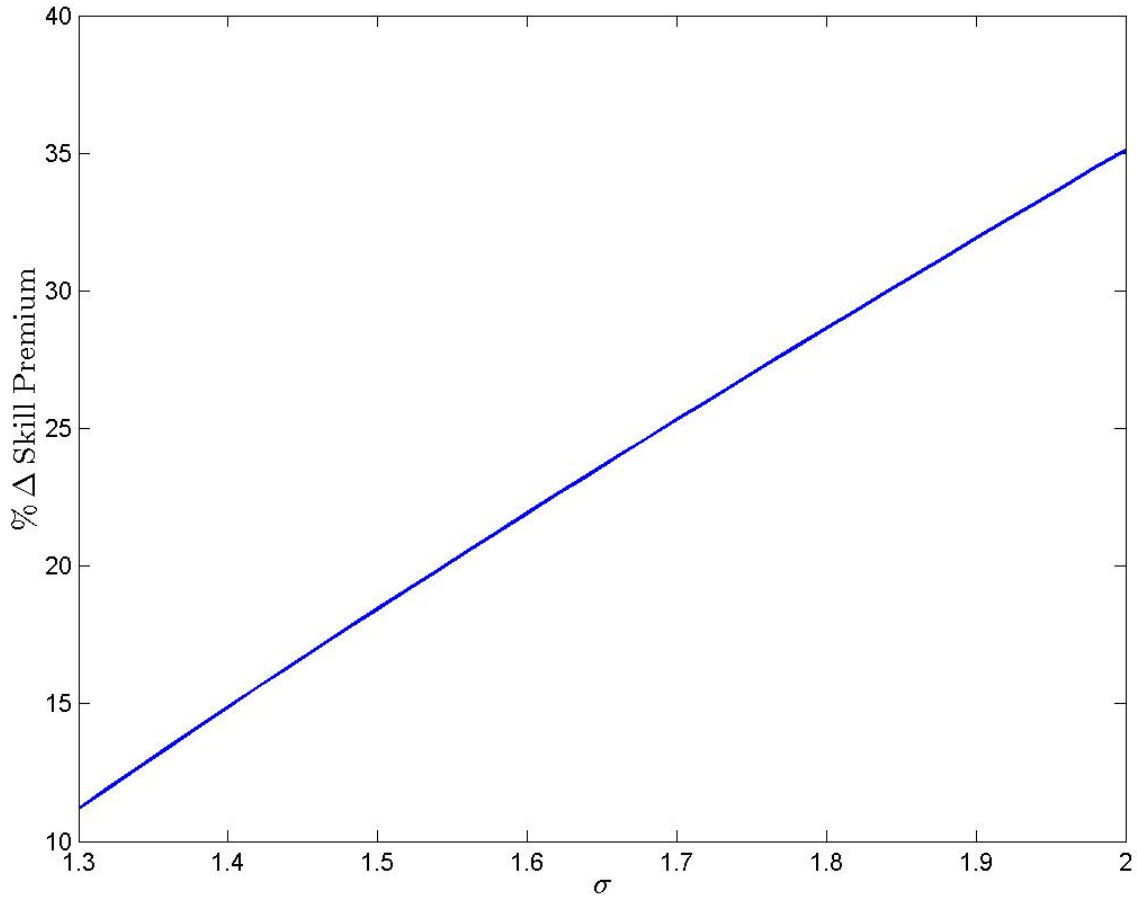
VARYING σ



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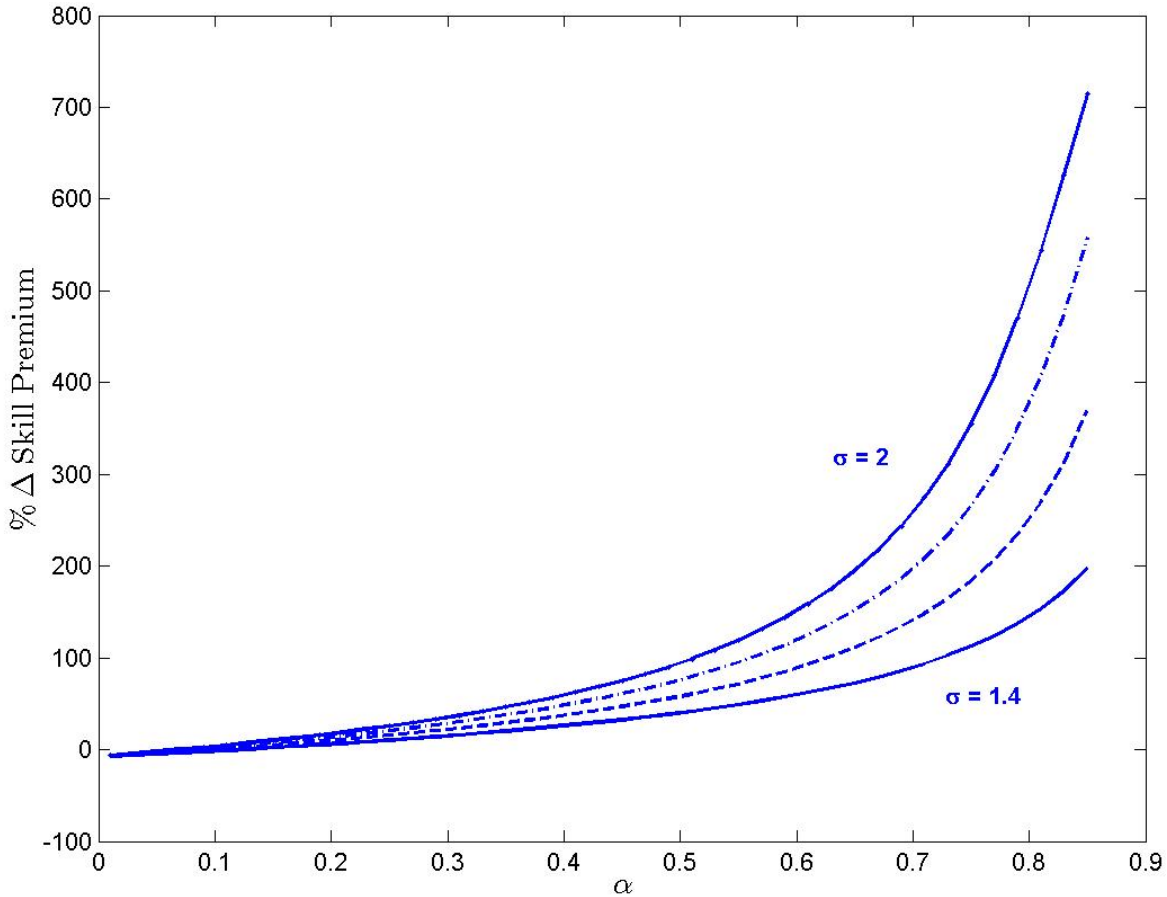
VARYING α AND σ



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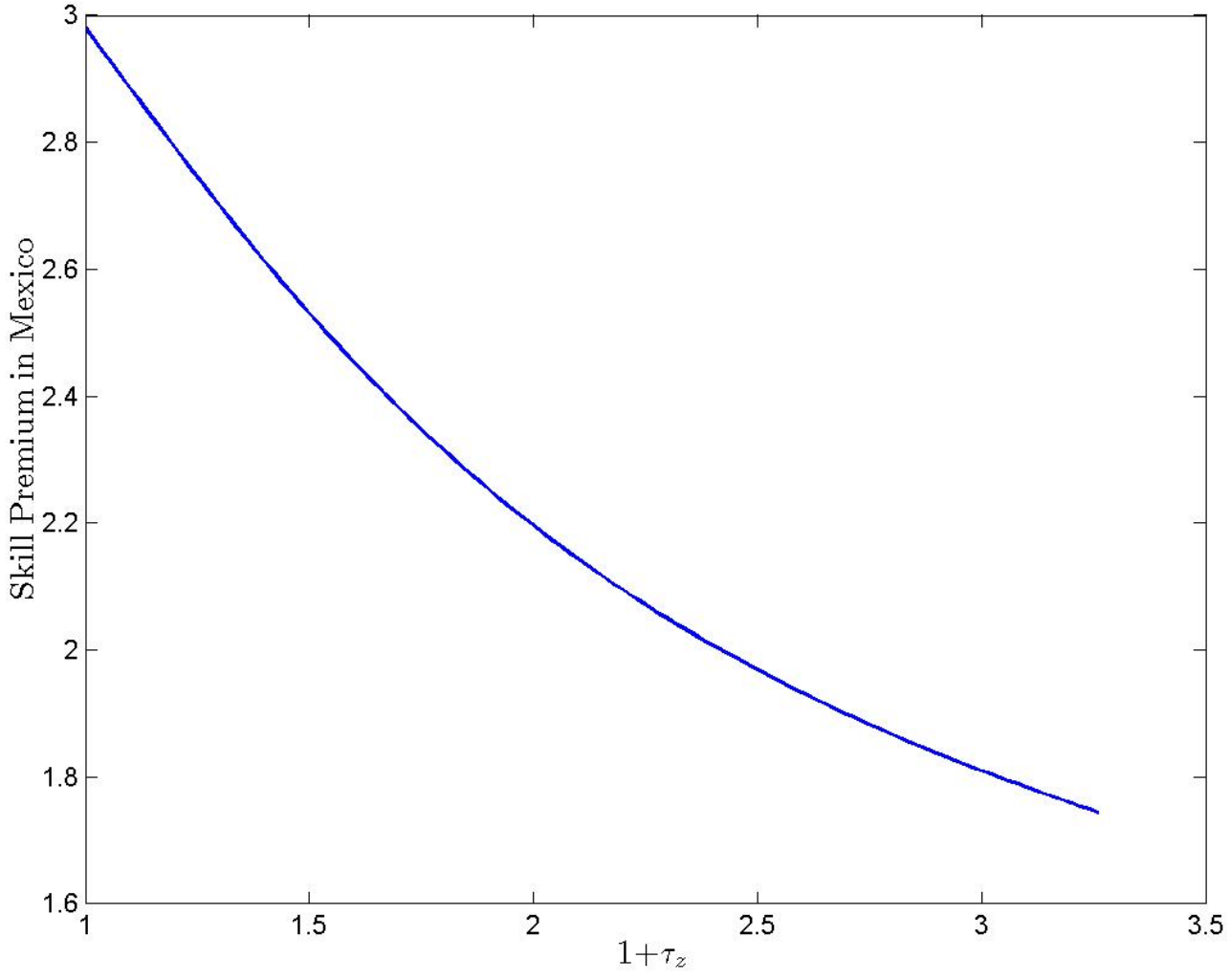
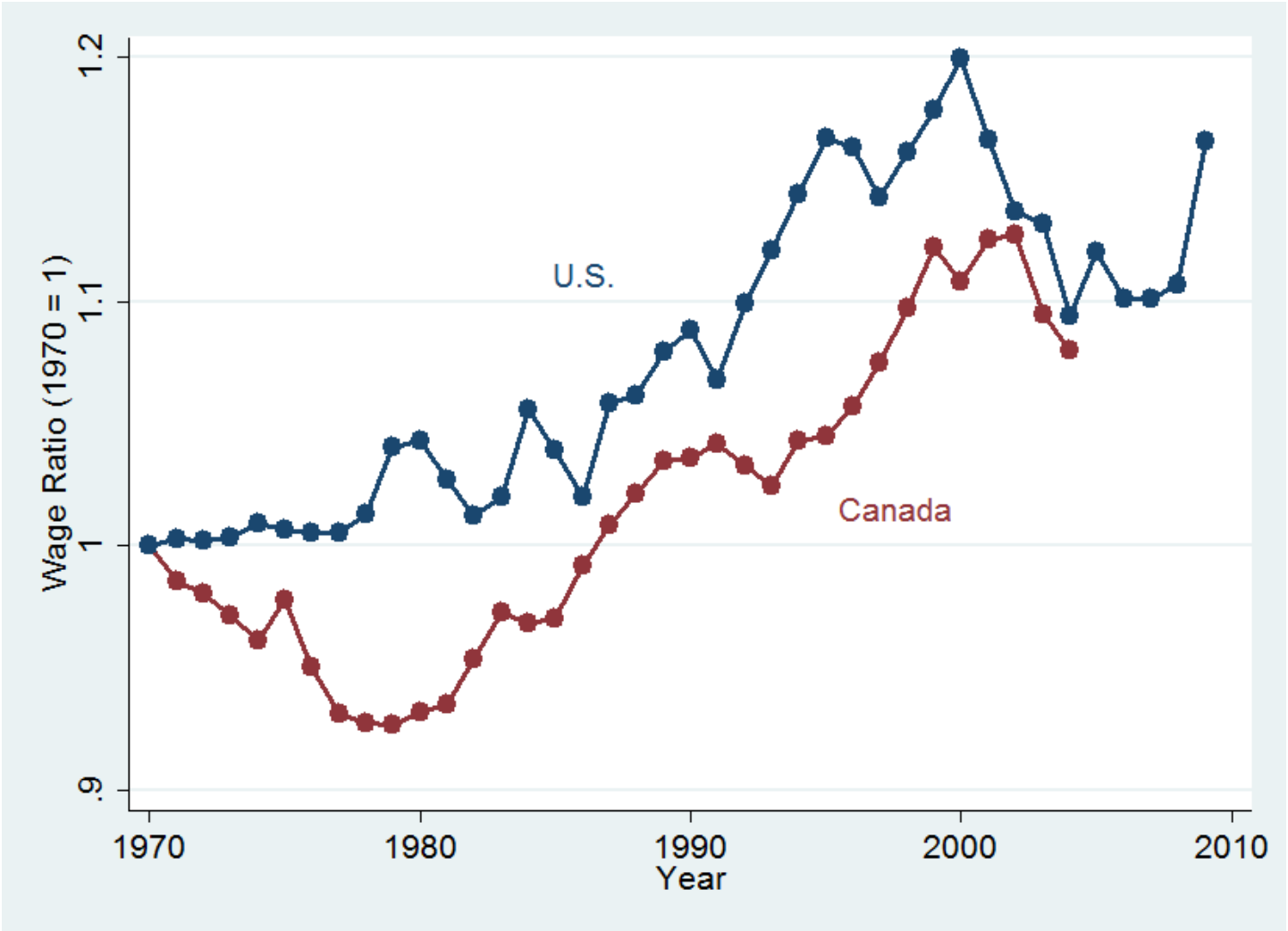
Sensitivity to Changes in τ_z



Data: Canada



Back to Levels

Broader Implications of the Model

Mexico

- Does majority of trade with U.S.
- Very closed before trade liberalization
- Large differences in productivity & supply of skilled workers
- Synchronized policy changes
  - Dramatic reduction of trade barriers
  - Adoption of U.S. IP protection laws

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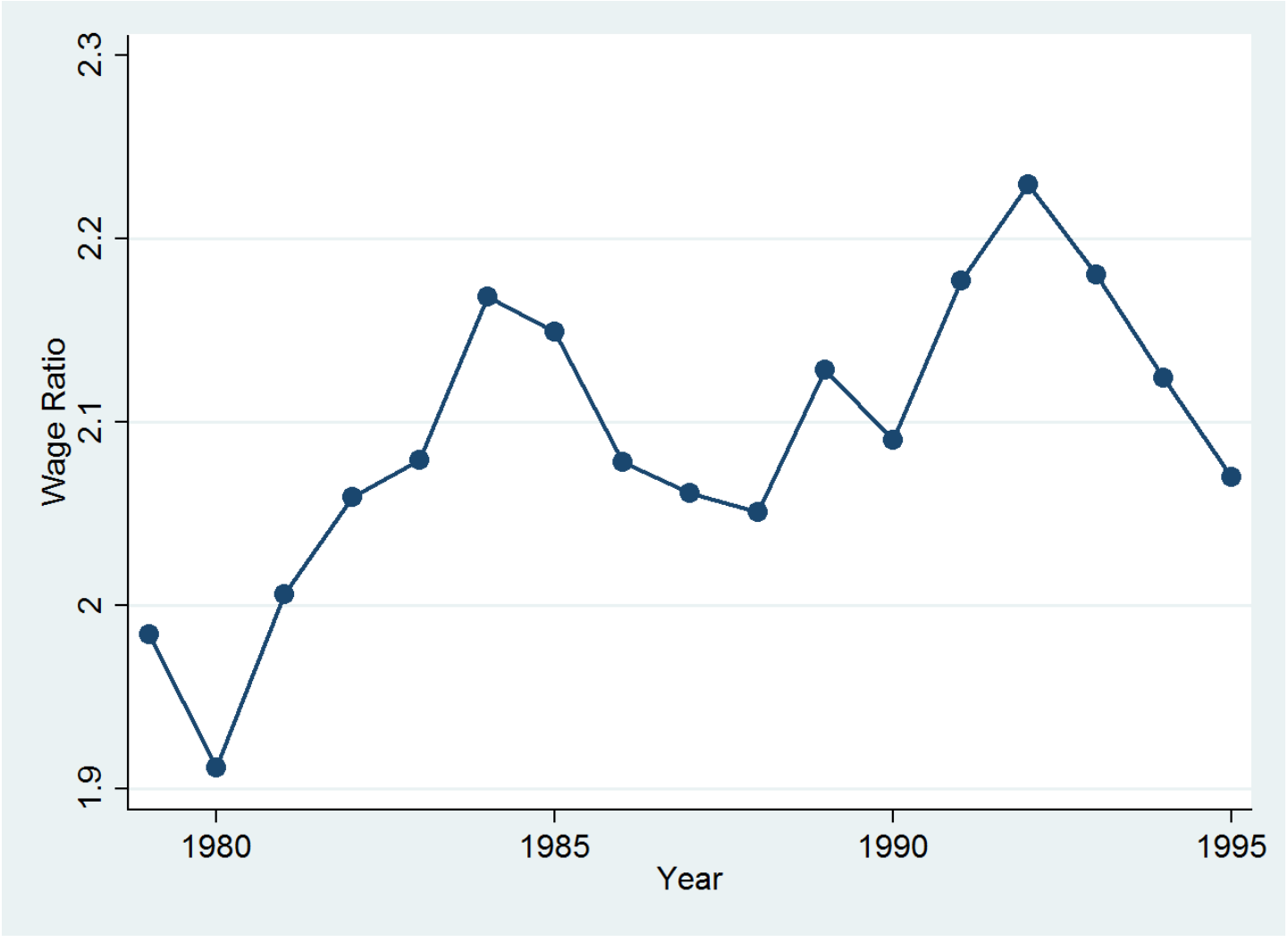
What about other cases, such as Chile and Canada?

Chile

- Many trade partners
- Relatively closed before liberalization
- Lower productivity & supply of skilled workers than U.S.
- Trade liberalization (1979)
  - Reduction of trade barriers
  - No change in IP protection laws

Data: Chile



Experiment: Chile

- Hold fixed parameters of production function
- Match the relative productivity of manufacturing
- Set supply of high-skilled workers to match the data
- Set initial distortions (τ_y, τ_z) to match skill premium in 1979

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- Reduce tariffs in Chile to mimic trade liberalization

Theory Predictions: Chile

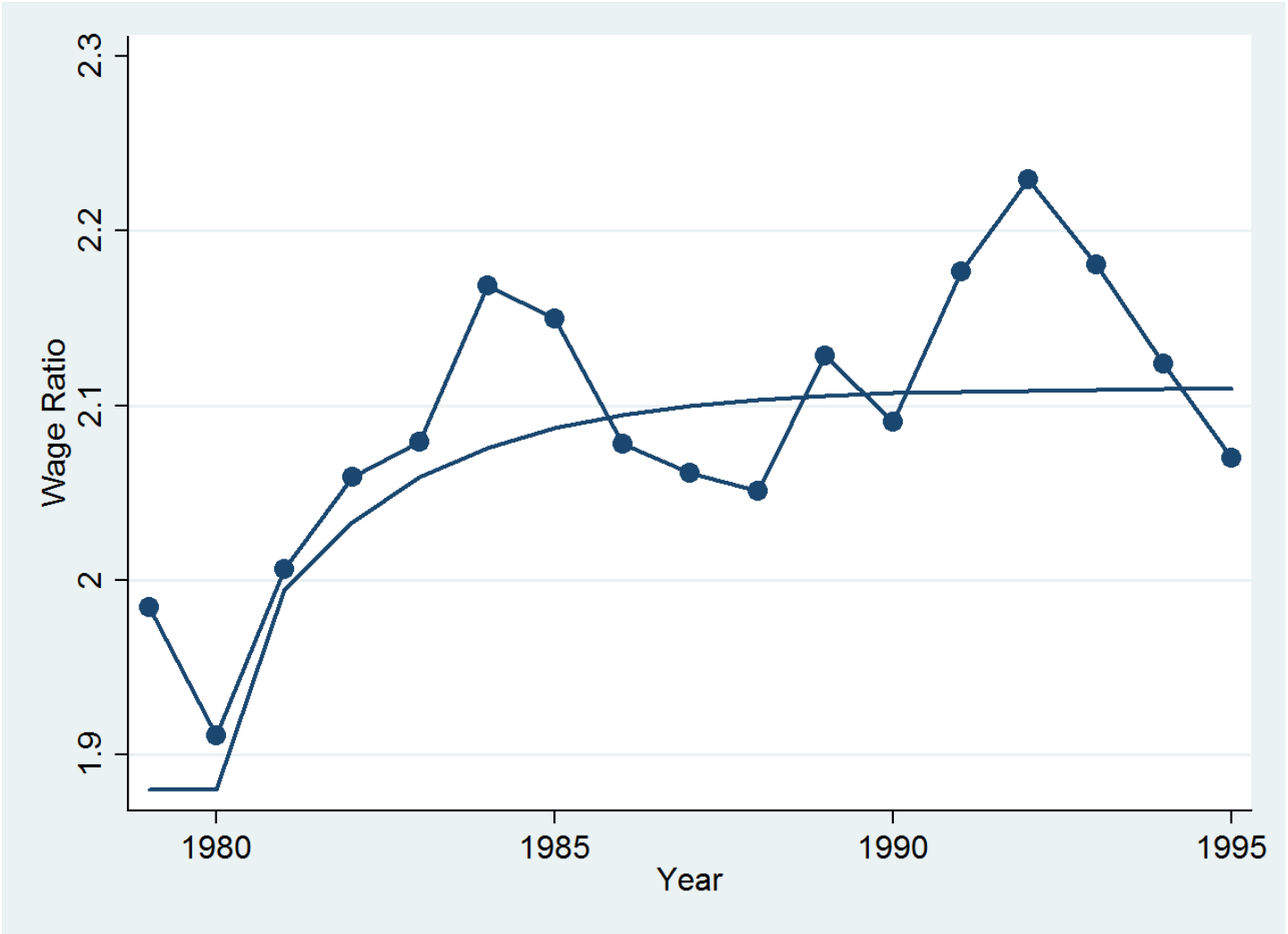
Basic H-O

- Chile specialized in unskilled-intensive good
- Skill premium in Chile $\downarrow$

Supply Chain:

- Less specialization since reduction in tariffs allows Chile to supply to U.S. Sector Y
- Skill premium in Chile $\uparrow$ if sufficient integration

Results: Chile

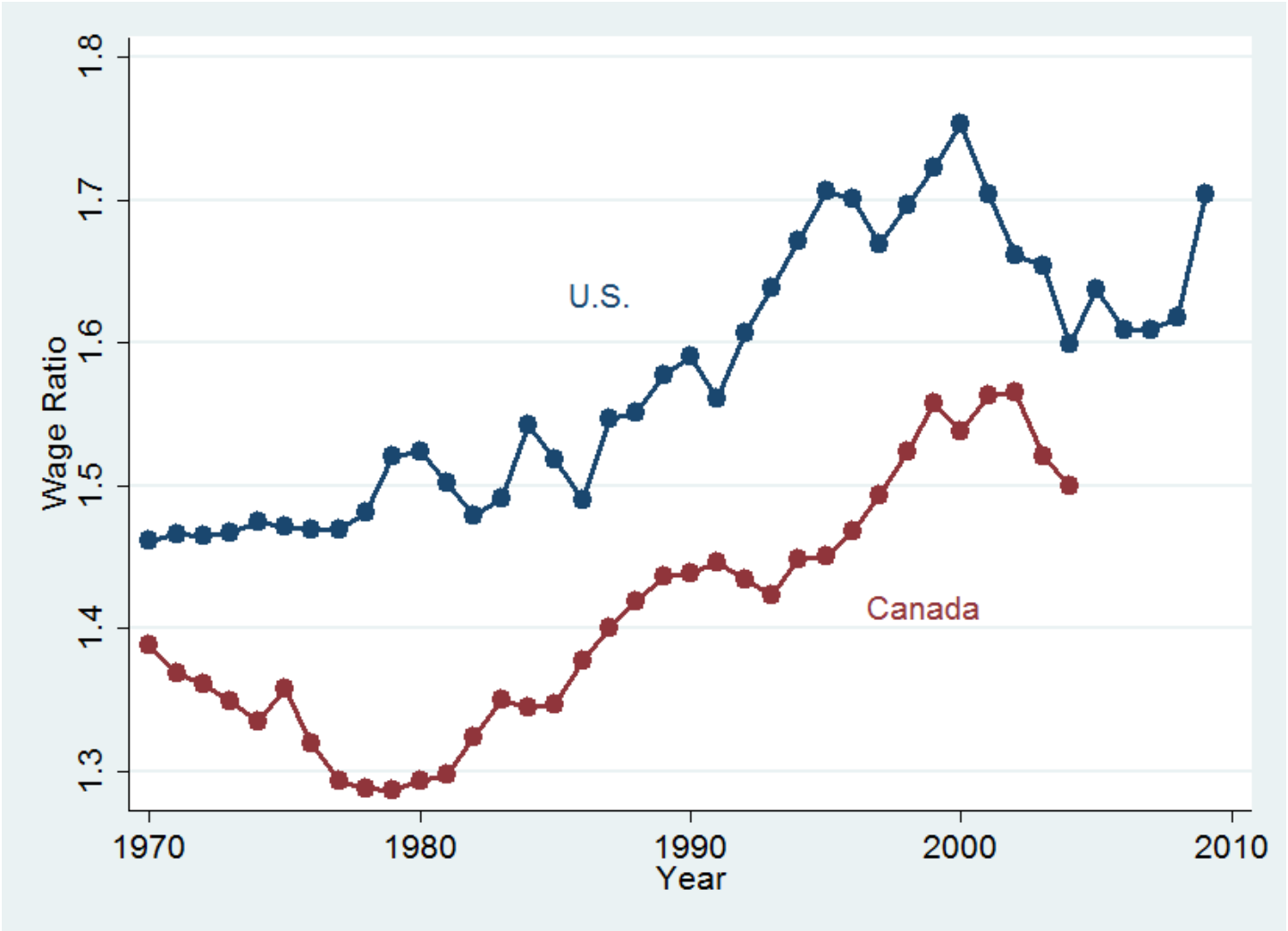


Back to Results Summary

Canada

- Large portion of trade is with U.S.
- Relatively open before liberalization
- Similar productivity & supply of skilled workers as U.S.
- Free trade agreement (1988)
  - Slight reduction of trade barriers
  - Existing IP protection laws similar to those of the U.S.

Data: Canada



Normalized to 1 in 1970

Experiment: Canada

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- Hold fixed parameters of production function
- Match the relative productivity of manufacturing
- Set supply of high-skilled workers to match the data
- Set initial distortions (τ_y, τ_z) to match skill premium in 1985
- Reduce distortions in both countries to mimic FTA

Theory Predictions: Canada

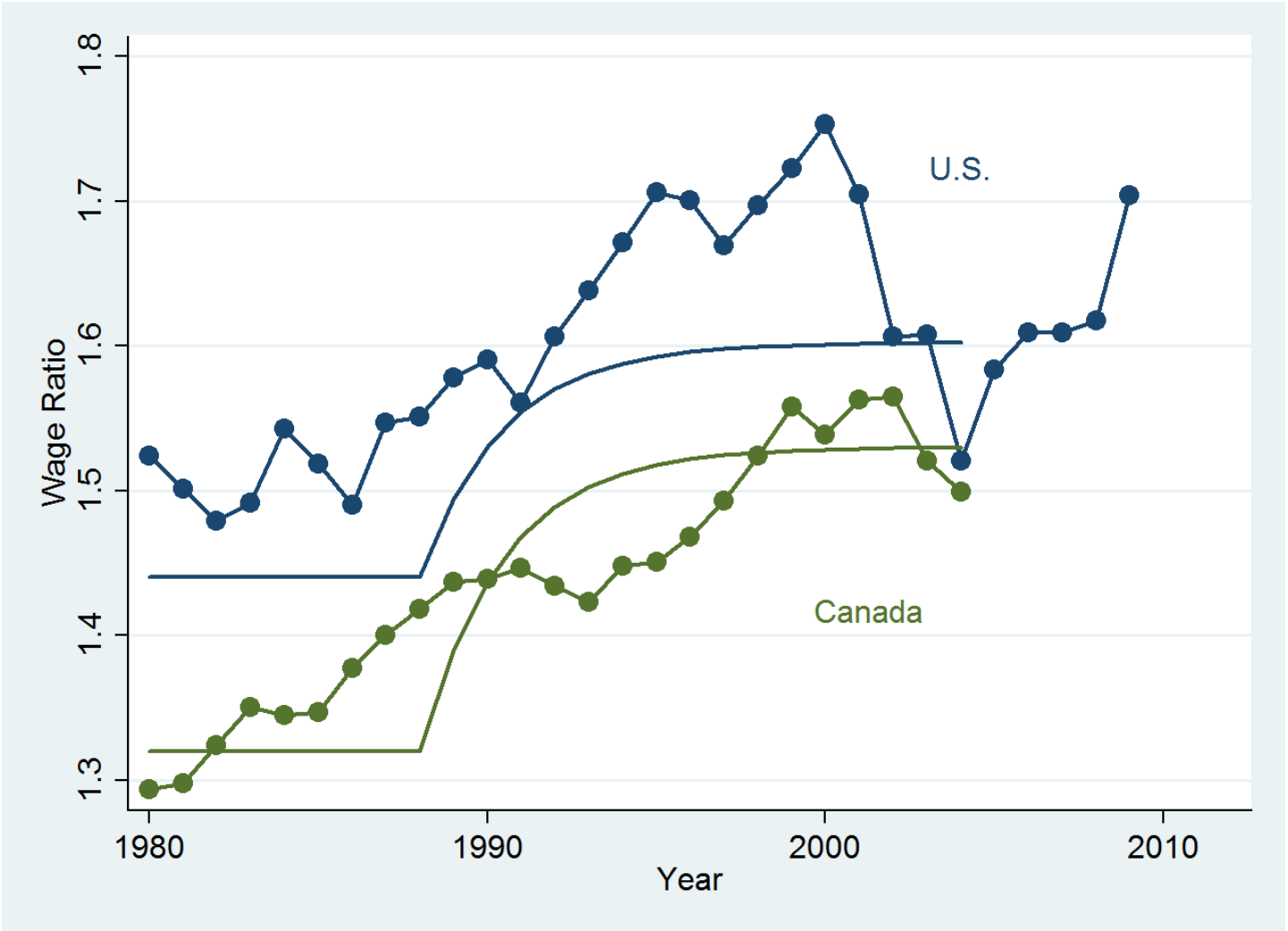
Basic H-O

- No specialization since both countries have same relative supply of skilled labor
- No change in skill premium

Supply Chain:

- Both countries invest more in Sector Y since the technology can be used in more locations once countries open
- Skill premium $\uparrow$ in both countries

Results: Canada



Back to Results Summary