

More Trade, Less Diffusion: **Technology Transfers and the Dynamic Effects of Import Liberalization**

Gustavo de Souza, Ruben Gaetani, and Marti Mestieri

The ideas presented here do not represent those of the Federal Reserve System or the Federal Reserve Bank of Chicago.

Motivation: Trade and Diffusion

- **Canonical View:** More trade, More diffusion

- Firms learn from exporters or international suppliers

Eaton and Kortum (1999); Buera and Oberfield (2020); Santacreu (2015, 2022); Cai, Li and Santacreu (2020); Lind and Ramondo (2019, 2023); among many others

- Implication: larger gains from trade in the long-run

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 - Implication: larger gains from trade in the long-run
- **Empirical Evidence to the Canonical View:**
 - Correlation between openness to trade and technology adoption
Comin and Hobijn (2004, 2010); Comin et al. (2013); Comin and Mestieri (2018)
 - Trade increases firm-level TFP
Pavcnik (2002), Harrison and Rodríguez-Clare (2010)
 - no causal evidence linking exposure to foreign products to diffusion

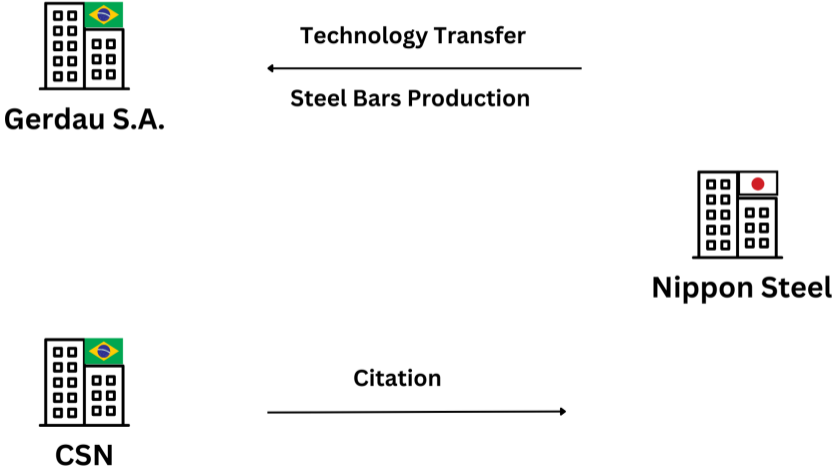
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 - citation across countries (PATSTAT)
 - international intellectual property transferred to Brazil (de Souza (2023))

Example of Technology Transfer and Citation



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 - How does trade policy affect the diffusion of technologies across countries?
- **Data:** measures diffusion across countries
 - patent and citation across countries (PATSTAT)
 - international intellectual property transferred to Brazil (de Souza (2023))
- **Policy Variation:**
 - Brazilian trade liberalization (Dix-Carneiro and Kovak (2017))

This Paper: Effect of Tariffs on the Diffusion of Technology

- **Result: More** Trade, **Less** Diffusion
 - Tariffs increase international technology transfers and citations to foreign patents
 - E.g.: tariff against Japanese steel increases tech. transf. f/ and citations to Nippon Steel

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- **Model:** adding technology transfers to Buera and Oberfield (2020)
 - *Trade-off:* technology transfer \times export to Brazil

Firms Transfer Technology if Tariffs are High

High Import Tariffs



Foreign Firms:

- Profit of Transferring technology > Profit Exporting
- Technology Transfer to Brazil ↑

Low Import Tariffs

Firms Transfer Technology if Tariffs are **High**

High Import Tariffs



Nippon Steel

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Gerdau S.A.



CSN

Brazilian Firms:

- Learn and build on foreign technology
- Foreign technology diffuses
- Citation to foreign patents ↑

Firms Export if Tariffs are **Low**

High Import Tariffs



Nippon Steel

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Dynamic gains from trade are **60%** smaller

Contribution

- **Trade and Diffusion:** Openness to trade increases diffusion

- Eaton and Kortum (1999); Buera and Oberfield (2020); Santacreu (2015, 2022); Cai, Li and Santacreu (2020); Lind and Ramondo (2019, 2023); Rodriguez-Clare (2007), Ramondo and Rodriguez-Clare (2011); Lind et al. (2023); Cai et al. (2022)

⇒ **Contribution:** tariff increases diffusion through technology transfers

- **Trade, Technology Adoption, and Industrial Policy:**

- Bustos et al. (2016); Comin and Mestieri (2018); Juhasz (2018); Verhoogen (2023); Cirera et al. (2024); Lashkaripour and Lugovskyy (2023); Farrokhi and Pellegrina (2024)

⇒ **Contribution:** subsidy to technology transfers

DATA

Data: Measures Knowledge Diffusion Across Countries

PATSTAT

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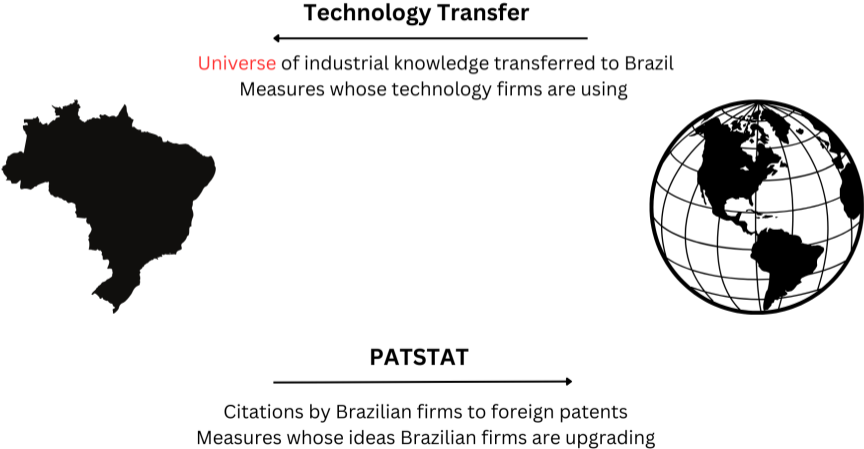


PATSTAT



Citations by Brazilian firms to foreign patents
Measures whose ideas Brazilian firms are upgrading

Data: Measures Knowledge Diffusion Across Countries



Data: Universe of Technology Transfers

- **Why does this data exist?**
 - Capital control in the 60s limited profit payments to foreigners
 - Requirement for firms to register any industrial knowledge transfer
 - International royalty payment authorized only with Patent Office Approval

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 - possibility to settle disputes in the court system

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⇒ Universe of technology transfers

Data: Three Types of Technology Transfers

- **Patent Transfer:**
 - licensing or transfer of patent ownership
- **Trademark Transfers:**
 - licensing or transfer of trademarks
- **Know-How:**
 - Transfer of knowledge not protected by a patent
 - Ex.: Nippon Steel supported Gerdau S/A on the design of a production line of steel round bars

EMPIRICS

Empirics: Gravity of Citations and Tech. Transfers

- **Empirical Model:**

$$y_{o,s,t} = \beta \tau_{o,s,t} + \eta_{o,s} + \eta_{s,t} + \eta_{o,t} + X'_{o,s,t} \mathbf{K} + \epsilon_{o,s,t}$$

where

- $y_{o,s,t}$: outcome of origin country o , sector s , in year t
- technology transfers in next 3 years from country o to sector s
- citations in next 3 years to country o by sector s

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where

- $\tau_{o,s,t}$: import tariff in Brazil against country o , sector s , in year t

Empirics: Fixed Effects Isolate Diffusion

- **Empirical Model:**

$$y_{o,s,t} = \beta\tau_{o,s,t} + \eta_{o,s} + \eta_{s,t} + \eta_{o,t} + X'_{o,s,t}\kappa + \epsilon_{o,s,t}$$

where

- $\eta_{s,t}$: identification and isolating channel
- Identification
 - productivity shock, industrial policy, technological progress
- Isolating diffusion:
 - removes effect of tariff on competition, firm exit, and other margins unrelated to diffusion

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where

- $\eta_{o,t}$: captures intellectual property agreements and country shocks

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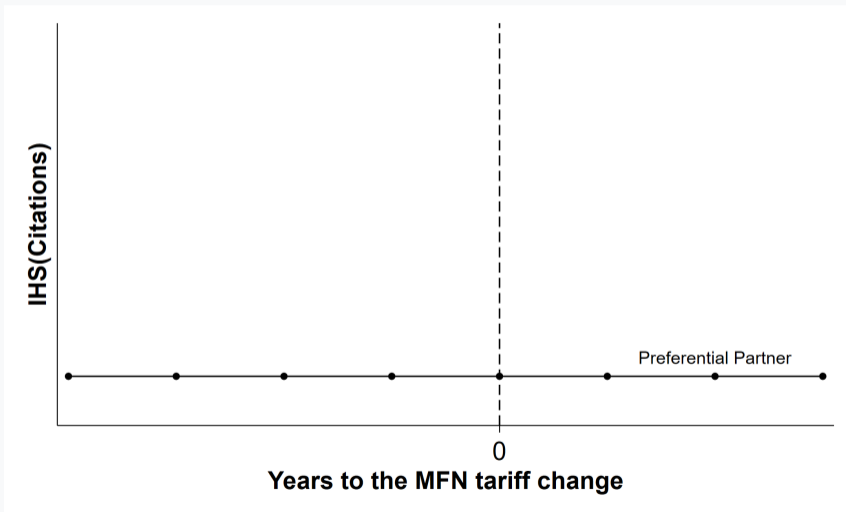
where

- β : effect of tariff on diffusion from a particular country-sector pair
- **Canonical View:** $\tau_{o,s,t} \uparrow \implies \text{imports} \downarrow \implies \text{learning from foreigners} \downarrow \implies \beta < 0$
(Eaton and Kortum (1999); Buera and Oberfield (2020); Santacreu (2015, 2022); Cai, Li and Santacreu (2020); Lind and Ramondo (2019, 2023), Ramondo and Rodríguez-Clare (2010), among many others)

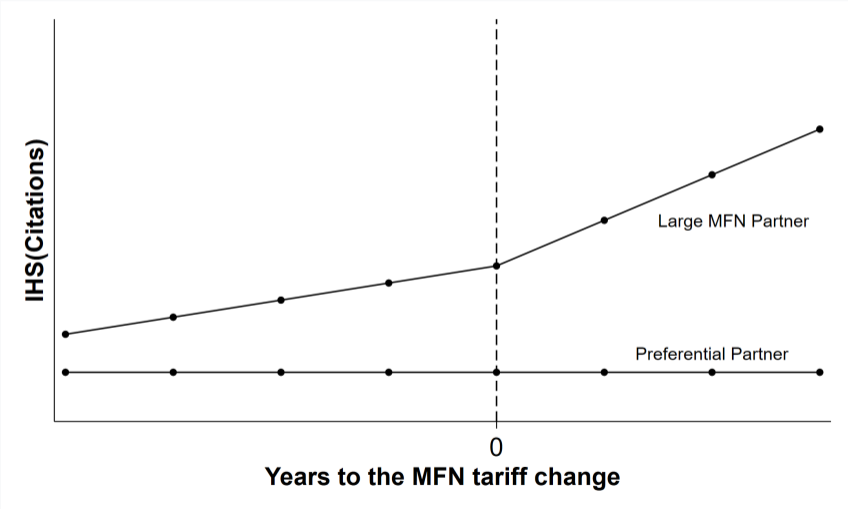
Empirics: Identification by Instrument

- **Endogeneity:**
 - political interference
 - trade \implies tariffs
- **Instrument:** Boehm, Levchenko, and Pandalai-Nayar (2023)
 - After a MFN tariff change, compare small MFN partners to preferential partners

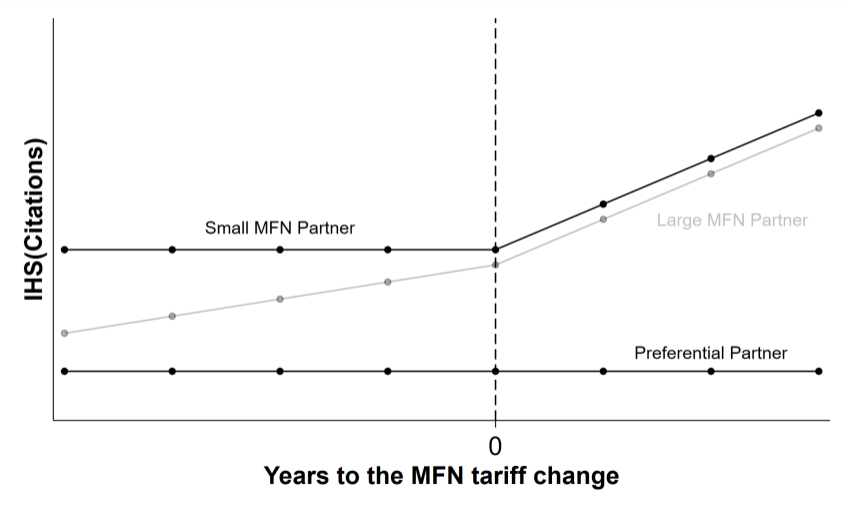
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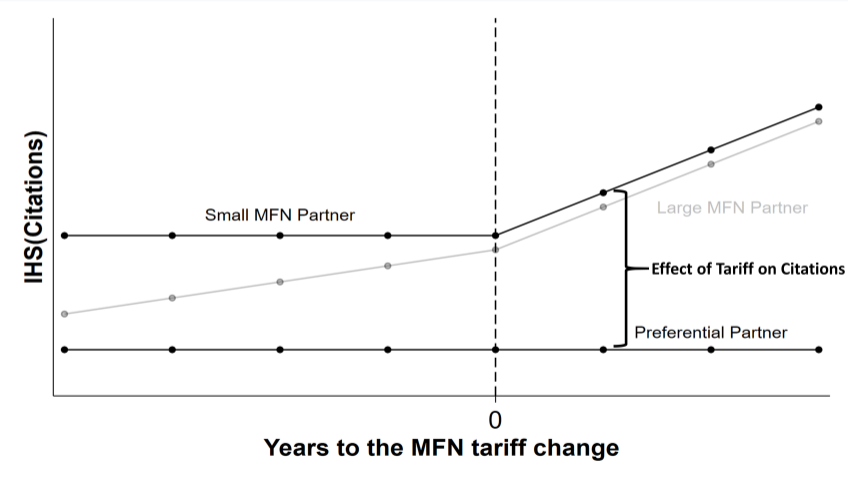
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- **Formal Instrument and Sample Selection:**
 - Instrument:

$$\tau_{o,p,t}^{instr} = \mathbb{I}_{o,p,t} \{MFN Partner at t\} \times \mathbb{I}_{o,p,t-1} \{MFN Partner at t - 1\} \times \tau_{p,t}^{MFN}$$

- Sample selection: drop largest partners of product p in t and $t - 1$

Validation

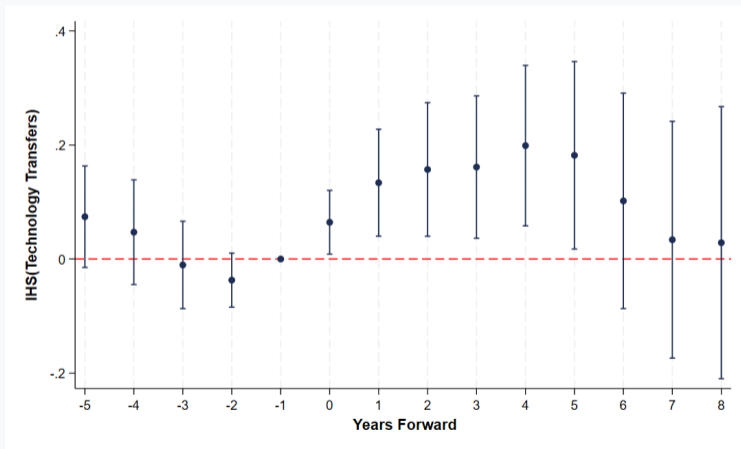
- i. **Concern:** *Government targets particular markets*
- i. **Validation:**
 - ★ the instrument don't correlate with patents, citations, TFP, or production of the origin market
- ii. **Concern:** *Political interference*
- ii. **Validation:**
 - ★ the instrument don't correlate with campaign contribution
- iii. **Concern:** *Correlation with other policies*
- iii. **Validation:**
 - ★ the instrument don't correlate with subsidized loans, public procurement, and subsidies
- iv. **Concern:** *Trends on citation or technology transfers*
- iv. **Validation:**
 - ★ pre-period parallel trends

EMPIRICAL RESULTS

Tariffs Increase Technology Transfers

	(1)	(2)	(3)
	<i>IHS N.</i>	<i>IHS</i>	<i>IHS N.</i>
	<i>Tech.</i>	<i>N.Unique</i>	<i>Unique</i>
		<i>Licensees</i>	<i>Licensors</i>
Tariff	0.157**	0.131**	0.154**
	(0.0712)	(0.0643)	(0.0707)
N	1,229,689	1,229,689	1,229,689

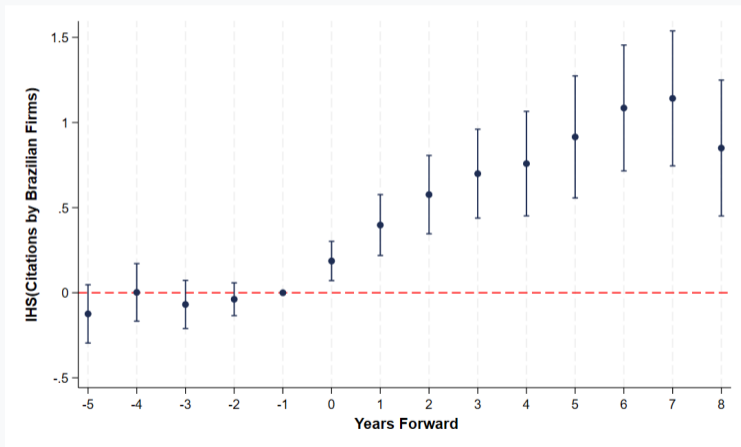
Impulse Response of Technology Transfers to Tariffs



Tariffs Increase Citation to Foreign Firms

	(1) <i>IHS Citations</i>	(2) <i>At Least One Cit.</i>
Tariff	0.577*** (0.140)	0.411*** (0.0825)
<i>N</i>	1,229,689	1,229,689

Impulse Response of Citations to Tariffs



Empirical Results

- Tariffs increase:
 - international technology transfers
 - citations to foreign patents

⇒ **More Trade, Less Diffusion**

Citations are Directed to Firms Transferring Technologies

	(1) <i>IHS. Cit. to Licensor</i>	(2) <i>IHS Cit. to Non-Licensor</i>
Tariff	0.565*** (0.132)	0.206 (0.126)
<i>N</i>	1,229,689	1,229,689

Citations are Made by Firms without Connection to Foreign Markets

	(1) <i>IHS Cit. by Tech. Licensees</i>	(2) <i>IHS Cit. by Non-Tech. Licensees</i>	(3) <i>IHS Cit. by Importers</i>	(4) <i>IHS Cit. by Non- Importers</i>	(5) <i>IHS Cit. by Exporters</i>	(6) <i>IHS Cit. by Non- Exporters</i>
Tariff	0.164 (0.106)	0.452*** (0.133)	0.179 (0.110)	0.461*** (0.133)	0.173 (0.110)	0.460*** (0.133)
N	1,229,689	1,229,689	1,229,689	1,229,689	1,229,689	1,229,689

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Technology Transfers Diffuse Locally

	(1)	(2)	(3)	(4)
	<i>IHS. Cit.</i>	<i>IHS. Cit.</i>	<i>IHS Cit.</i>	<i>IHS Cit.</i>
	<i>Same Zip</i>	<i>Diff. Zip</i>	<i>Same City</i>	<i>Diff. City</i>
Tariff	0.312*** (0.120)	0.206* (0.121)	0.351*** (0.122)	0.136 (0.120)
N	1,229,689	1,229,689	1,229,689	1,229,689

Are Markets that Send More Technology Receiving More Citations?

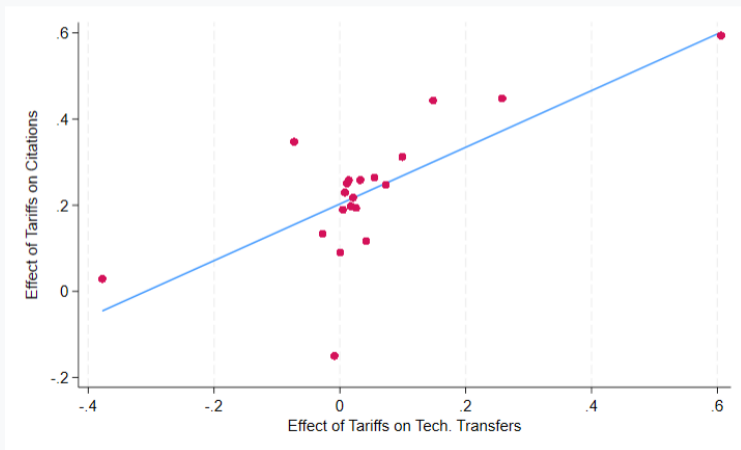
- Results suggest that citation to foreign firms increase because of technology transfers
- If that is true, markets sending more technologies should receive more citations
- Long difference model:

$$\Delta y_{o,s} = \beta(Z_{o,s}) \Delta \tau_{o,s}^{inst} + \eta_{o,s} + X'_{o,s} \kappa + \epsilon_{o,s}$$

- $\beta(Z_{o,s})$ reduced form effect as function of $Z_{o,s}$
- $\beta(Z_{o,s})$ estimated using random-forest (Wagner and Athey (2018), Athey and Imbens (2019))

Markets Sending **More** Technology Receive **More** Citations

Figure: Correlation Between the Effect of Tariffs on Technology Transfers and on Citations



Empirical Results

- Tariffs increase:
 - international technology transfers
 - citations to foreign patents
 - technological similarity to foreign patents

⇒ **More Trade, Less Diffusion**

- Citations are:
 - directed to firms transferring technology to Brazil
 - made by firms in the same zip code of those receiving technology
 - markets sending more technology receive more citations

⇒ **Transferred technology spreads among Brazilian firms**

Alternative Explanations

- **FDI:**
 - tariffs do not affect FDI

Alternative Explanations

	(1) <i>IHS N.For. Partners</i>	(2) <i>IHS N.Firms F.Owned</i>	(3) <i>II(At Least 1 Firm)</i>	(4) <i>IHS N.For. Partners,3y</i>	(5) <i>IHS N.Firms F.Owned,3y</i>	(6) <i>II(At Least 1 Firm,3y)</i>
Tariff	-0.0436 (0.0287)	-0.0249 (0.0239)	-0.0236 (0.0227)	-0.0495 (0.0636)	-0.0284 (0.0542)	0.00282 (0.0476)
N	1,053,236	1,053,236	1,053,236	1,053,236	1,053,236	1,053,236

Alternative Explanations

- **FDI:**
 - tariffs do not affect FDI
- **Tariffs on Inputs:**
 - results are the same after controlling for input tariff
- **Tariffs Against Brazil:**
 - results are the same after controlling for tariffs against Brazil

MODEL

Model: Bird's Eye View

- Important elements:
 1. foreign firms face a trade-off between transferring technology and exporting to Brazil
 2. Brazilian firms learn from exporters and from technology transfers
- A increase in tariff:
 - increases technology transfers;
 - increases diffusion if firms learn more from foreign technologies

Model: Demographics and Production

- There are three countries: Brazil (B), high-income (H), and low-income (L)
- $k \in K$ sectors and $s \in [0, 1]$ varieties
- Infinitely lived representative consumer in country $i \in \{B, H, L\}$
- Production technology:

$$y_t^{i,k} = q_t^{i,k}(s) l_t^{i,k}(s)$$

Model: High-Income Country Chooses Between Exporting or Licensing

- Firms in the developed country chooses between transferring tech to Brazil or exporting
- If firm export (or produce in house):
 - iceberg trade cost: $\tau_{H \rightarrow B}^k$
 - productivity: $q_t^{X,k}(s)$
- If firm transfer technology:
 - iceberg transfer cost: d^k
 - productivity: $q_t^{T,k}(s)$
 - captures all the surplus
- $\left(q_t^{X,k}(s), q_t^{T,k}(s) \right)$ is a joint Fréchet with correlation ρ

Model: Production and Prices in Brazil

- Distribution of highest productivity in Brazil

$$\Pr(q_t^{B,k}(s) \leq z) = \exp\left(-\lambda_t^{B,k} z^{-\theta}\right)$$

- Price faced for variety s by consumers in Brazil after two-stage pricing:

$$p_t^{B,k}(s) = \frac{\epsilon}{\epsilon - 1} \times \min \left\{ \frac{w_t^B}{q_t^{B,k}(s)}, \frac{w_t^B d^k}{q_t^{T,k}(s)}, \frac{w_t^H \tau_{H \rightarrow B}^{k,t}}{q_t^{X,k}(s)}, \frac{w_t^L \tau_{L \rightarrow B}^{k,t}}{q_t^{L,k}(s)} \right\}$$

- $\lambda_t^{B,k}$ grows endogenously depending on the exposure to foreign ideas

Model: Diffusion of Ideas

- Brazilian entrepreneurs combine personal insight with ideas from:
 - exporters (as in Buera and Oberfield (2020))
 - technology transfers
- Contact rate with foreigners exporters:

$$a_{X \rightarrow B}^{k,t} = \alpha_t^k \pi_{X \rightarrow B}^{k,t}$$

- Contact rate with licensors:

$$a_{T \rightarrow B}^{k,t} = \alpha_t^k \omega_T \pi_{T \rightarrow B}^{k,t}$$

Model: Diffusion of Ideas

- Arrival rate of insights larger than z is

$$A_{i \rightarrow B}^{k,t}(z) \equiv a_{i \rightarrow B}^{k,t} z^{-\theta}, \quad i \in \{X, L\}$$

- New idea:

$$q' = zq^\beta$$

where

- z : local insight
- q : idea draw from foreigner
- β : weight of learning from foreigner

Model: Productivity Growth in Brazil

- Law of motion of $\lambda_t^{B,k}$:

$$\dot{\lambda}_t^{B,k} = \alpha_t^k \left[\omega_T \pi_{T \rightarrow B}^{k,t} E \left[\left(q_t^{T,k} \right)^{\beta \theta} \right] + \pi_{X \rightarrow B}^{k,t} E \left[\left(q_t^{X,k} \right)^{\beta \theta} \right] \right]$$

- where:
 - **learning from technology transfer**
 - learning from exporters (Buera and Oberfield (2020))

Model: Productivity Growth in Brazil

- Law of motion of $\lambda_t^{B,k}$:

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- where:

- ω_T : meeting rate from technology transfers
- $\pi_{T \rightarrow B}^{k,t}$: share of varieties with tech. transfers
- $E \left[\left(q_t^{T,k} \right)^{\beta \theta} \right]$: avg quality of technology transfer, function of ρ

Model: Productivity Growth in Brazil

- Law of motion of $\lambda_t^{B,k}$:

$$\dot{\lambda}_t^{B,k} = \alpha_t^k \left[\omega_T \pi_{T \rightarrow B}^{k,t} E \left[\left(q_t^{T,k} \right)^{\beta \theta} \right] + \pi_{X \rightarrow B}^{k,t} E \left[\left(q_t^{X,k} \right)^{\beta \theta} \right] \right]$$

- If import tariffs increase:
 - iceberg trade cost increase: $\tau_{H \rightarrow B}^k \uparrow$
 - increase technology transfers and decrease exports: $\pi_{T \rightarrow B}^{k,t} \uparrow, \pi_{X \rightarrow B}^{k,t} \downarrow$
 - productivity in Brazil increases depending on ω_T and ρ

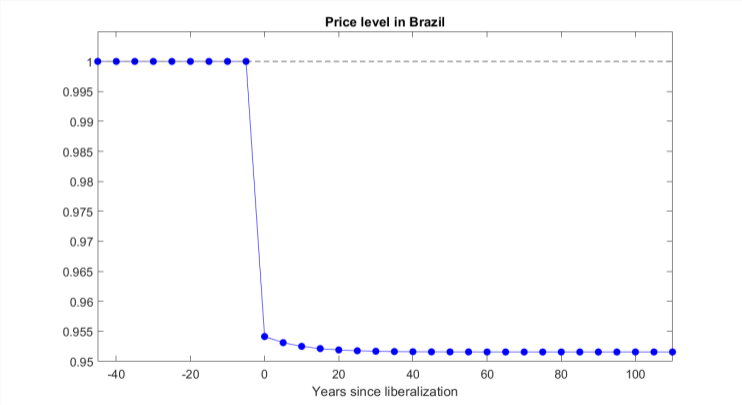
CALIBRATION

Calibration: Key Parameters

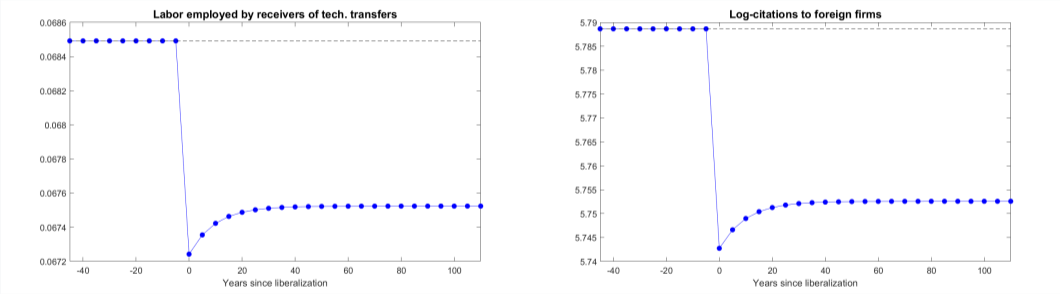
- **Key Parameters:**
 - ρ : correlation between productivity of exporting or transferring technology
 - ω_T : arrival rate of ideas from technology transfers
- **Identification:** effect of tariffs on:
 - the number of technology transfers
 - the number of citations

QUANTITATIVE RESULTS

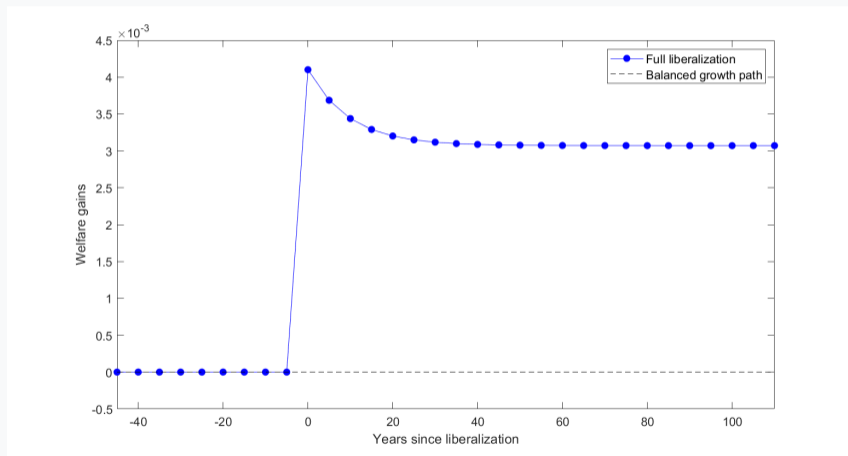
Brazilian Liberalization led to Lower Prices



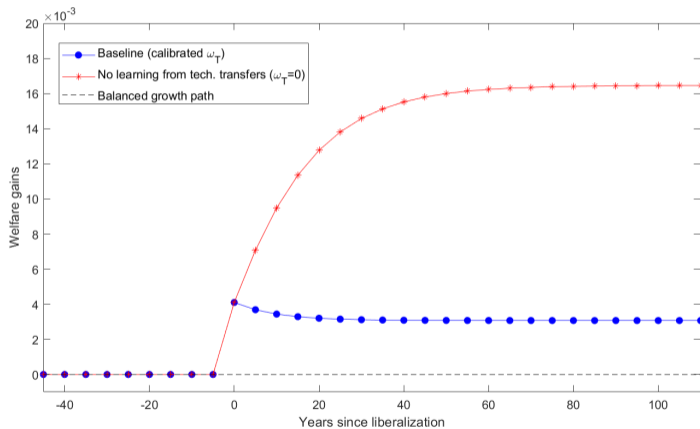
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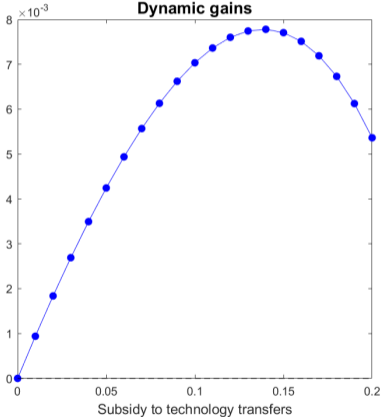
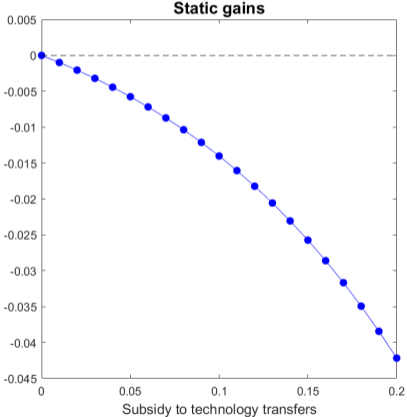
Liberalization: Static Gains but Dynamic Losses



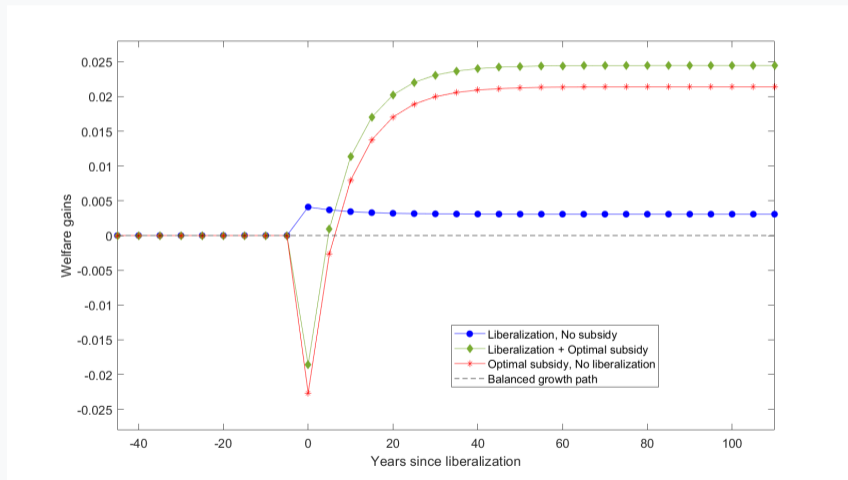
Diffusion from Technology Transfers Matter for Welfare!



Subsidy to Technology Transfers



Gains from Trade are Larger with Subsidy to Technology Transfers



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- **Implication for policy:**
 - industrial policy subsidizing technology transfer