Intermediate Input Imports and Innovation: Evidence from Chinese Firms

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Questions

- Innovation is a key determinant of economic growth.
  - Endogenous growth theory.
  - Policy makers: "the nation that goes all-in on innovation today will own the global economy tomorrow" — Barack Obama (2014).
- The past few decades have witnessed substantial globalization around the world.
  - The World Is Flat: A Brief History of the Twenty-first Century

Questions

- How does trade liberalization influence firms' incentive to engage in innovation activities?
  - Important question and large literature.
  - Trade and investment is an important driver of innovation (Onodera, 2009).
- A special and specific angle in this paper: *the impacts of intermediate input tariff liberalization on domestic firms' innovation activities, with China data.*

Motivations

- Trade in intermediate inputs becomes more and more important (Onodera, 2009).
  - Share of capital goods: from 21.0% in 1970 to 26.5% in 2006, by **29.19%**
  - Share of intermediate goods: from 7.5% to 13.0%, by **73.33%**
- Input imports in China:
  - Drastic input tariff cut due to WTO: average input tariff dropped from 13.74% in 1998 to 8.13% in 2007, by **40.83%**
  - Imports in capital goods and intermediate goods increased by **256%** and **151%** from 2000 to 2006, respectively.
- Innovation in China:
  - Share of R&D in the world jumped from 2.2% in 2000 to 14.5% in 2011.
  - Became the country with largest patent applications in 2011.
- Any effect of input imports on innovation?

What we do and find:

- Methodology:
  We employ China's WTO accession as a quasi-natural experiment and conduct a DID analysis
  - i) Drastic input tariff reduction after 2001
  - ii) Drastic variation of the reduction across industries
- Findings:
  The input tariff reduction significantly *decreases* firms' innovation activities, measured by patent filings.
  - i) 1% cut in input tariff rate leads to about 0.15-0.28% percent drop in innovation.
  - ii) Robust to different considerations.

What we do and find:

- Surprising?
- But understandable: complements or substitutes between imports and innovation (say, for the purpose of productivity or quality improvement).
- Input tariff cut: conflicting forces
  - *Innovation-cost effect (+)*: lowers the cost of doing innovation due to the availability of cheap and/or new technology embedded in intermediates imports (growth theory).
  - *Price effect (-)*: enables a firm to obtain what it wants at a lower price thus reduces the incentives for innovation (i.e., effective protection, Corden 1971)
- Our empirical results imply that the price effect dominates the innovation-cost effect in China, a developing country.

Literature

- Firstly, trade and innovation (e.g., Grossman and Helpman, 1991, among many others).
  - Mostly on final good market, such as market competition or economies of scale (Bustos (2011), Burstein and Melitz (2013), etc), spillovers (Coe and Helpman (1995) and Coe, Helpman and Hoffmaister (2009)), trapped factor releasing (Bloom, Romer, Terry, and Van Reenen (2013))
  - We look at the intermediate input trade liberalization.

Literature

- Secondly and more closely, intermediate input imports and firm performance with micro data.
  - Positive productivity effect: Amiti and Konings (2007) for Indonesia, Topalova and Khandelwal (2011) for India.
  - No productivity effect: Van Biesebroeck (2003) Columbia and Muendler (2004) for Brazilian firms
  - Product scope: Goldberg et al. (2010) for India
  - Exports: Bas (2012) for Argentina, Chevassus-Lozza (2013) for France high-productivity firms.
  - China data: Yu (2014) on productivity, Ge, Lai and Zhu (2011) on channels; Fan et al. (2014) on quality of products exported; Feng, et al. (2012) on the connection between firm imports and exports

Literature

- All those performance measures are related but not equivalent to innovation
  - Could be results of innovation
  - Could be results of other mechanisms, particularly, Ethier (1982): due to complementarities between domestic and foreign inputs, and utilization of technology embeded in imported inputs.
- Differences from our paper:
  - First, no touch on innovation directly.
  - Second, these results have no clear implications for innovation:
  - Third, we do find results opposite to those in the literature with regard to their innovation aspect.

Outline

- Background of policy change
- Empirical strategy
- Data and variables
- Empirical results, validity, robustness, heterogeneity, mechanism
- A simple model
- Conclusion

Background of the policy change: WTO accession

- China started to apply for GATT/WTO membership in 1986.
- China cut its tariffs unilaterally many times during the long negotiation period, especially during 1992-1997.
- China eventually got accepted by the end of 2001.

Background of the policy change: Input tariff change

- Input tariff trends: Figure 1
  - 1) Substantial drop in 1997, and then kept stable before 2001: *pre-determined* before the sample period 1998-2007
  - 2) *Sudden drop* in 2002 until reaching a steady state in 2005
- Variation in input tariff change: Figure 2
  - 3) *Large variation* across industries
  - 4) Higher initial tariff, larger tariff cut from the WTO accession: *positive correlation*.

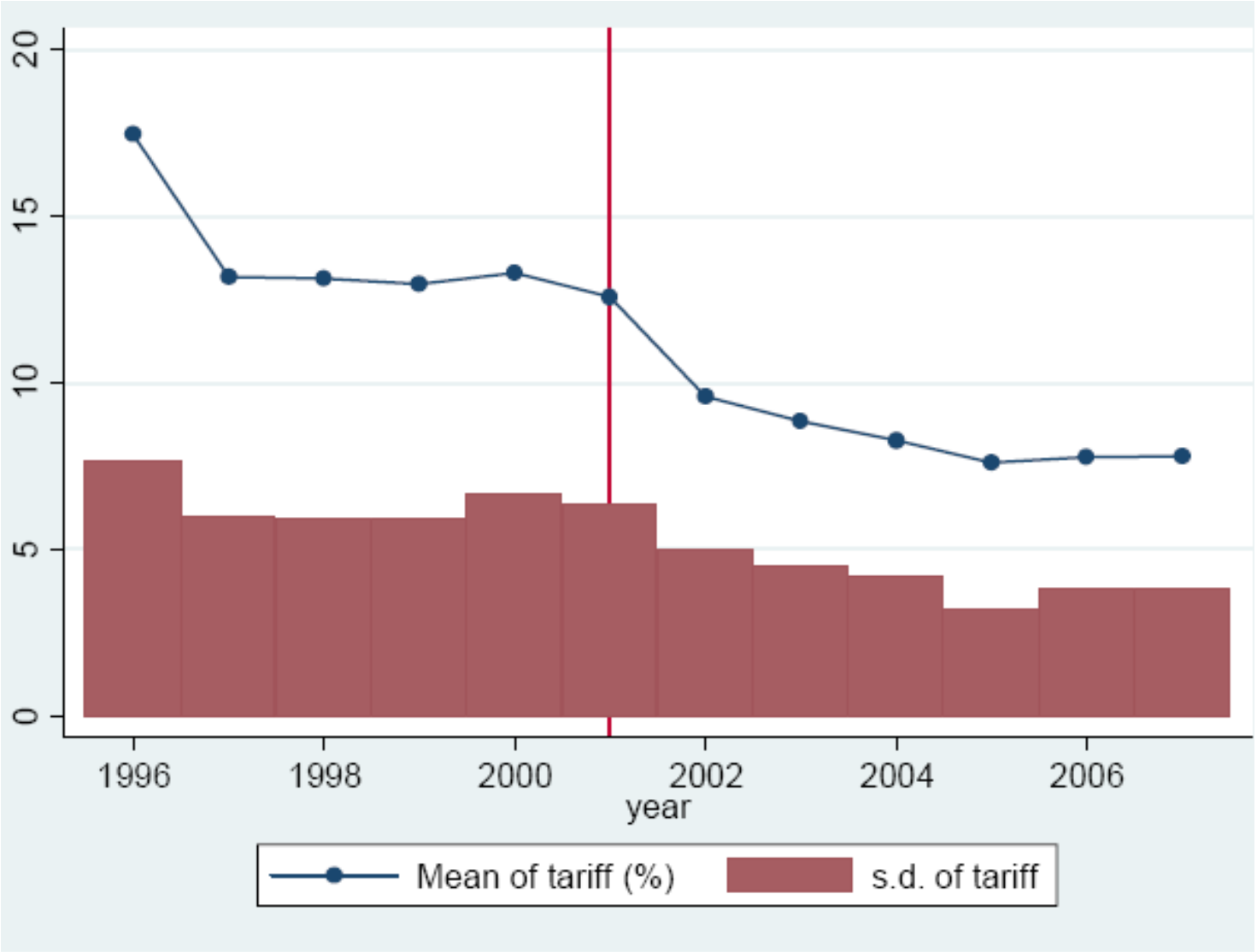

Figure 1. China's input tariff trends: 1996-2007

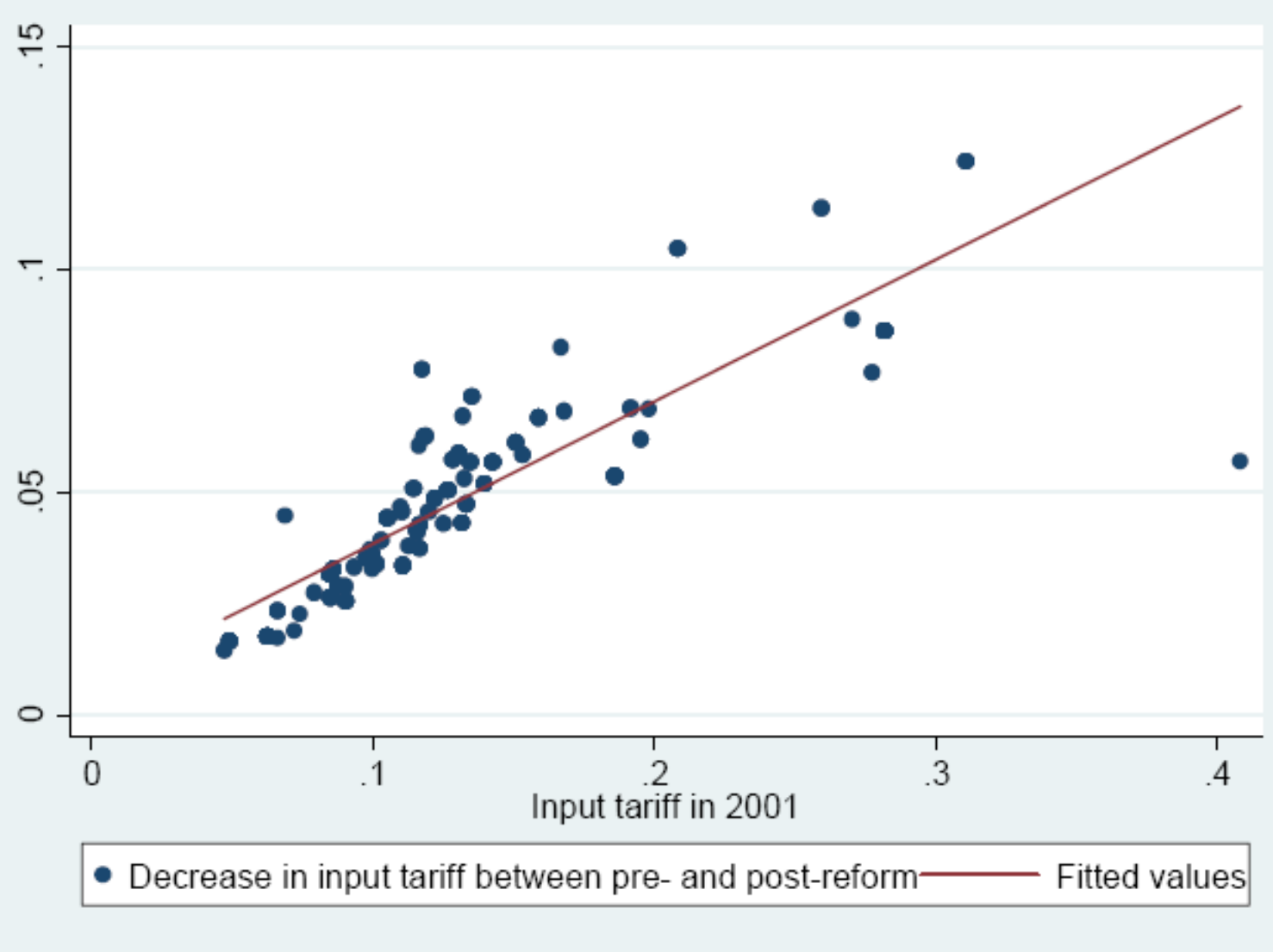

Figure 2. The correlation between initial input tariff and the decrease in input tariff

Identification strategy

- Thanks to the quasi-natural experiment setting, we employ the DID framework:

$$y_{fit} = \beta InT01_i \cdot Post02_t + \mathbf{X}'_{fit}\gamma + \lambda_f + \lambda_t + \varepsilon_{fit},$$

  - y_{fit} : patent filings of firm f in industry i in year t;
  - $InT01_i$ is the average tariff rate of inputs employed in the production of industry i in year 2001, or *tariff cut due to WTO accession*;
  - $Post02_t$ is an indicator of post-WTO period;
  - λ_f and λ_t are firm and year fixed effects;
  - $\mathbf{X}_{fit}$: time-varying firm characteristics that may affect innovation activities, including firm age, size, capital–labor ratio, exporting status, foreign share holding;
  - ε_{fit} : robust errors clustered at firm level.

- β : the treatment effect of input tariff liberalization

Identification strategy

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$$y_{fit} = \beta InT01_i \cdot Post02_t + \mathbf{X}'_{fit}\gamma + \lambda_f + \lambda_t + \varepsilon_{fit},$$

- Initial tariff $InT01_i$ *vs* actual input tariff reduction $DInT_i$ *vs* yearly input tariff InT_{it}?
  - The schedule of tariff reductions upon WTO accession was released in 2002, and hence the phase-out process could be exploited by the firms; endogeneity of the process (Guadalupe and Wulf, 2010).
  - Amiti and Konings (2007) also use initial tariff as instrument of tariff change.
  - Robust to $DInT_i$ and InT_{it}.

Validity of the specification

- First, $InT01_i$ is not set randomly and may be correlated with pre-WTO innovation activities.
  - Figure 1: $InT01_i$ is largely pre-determined in the actural liberalization process
  - Table 1: uncorrelated in the pre-WTO period (Goldberg, et al. (2010))
- Second, conditional comparability in trends between groups
  - Unobservable industry-specific trends? Further control for industry-specific linear trend $\lambda_i \cdot t$
- Third, placebo test using only the pre-WTO period data (as in Topalova, 2010)
- Fourth, placebo test using processing firms
- Fifth, flexible estimation with $InT01_i \cdot \lambda_t$: groups are comparable up to 2001?

Table 1. Correlation Between Input Tariff and Pre-WTO Industrial Performance

VARIABLES	(1) Patent	(2) Output	(3) Output Share of Domestic Firms	(4) Value-add per capita	(5) Capital-labor Ratio
Input Tariff in 2001	-1.6748	-0.0636	-0.0072	0.0357	-0.1041
	(1.2713)	(0.1118)	(0.0353)	(0.0776)	(0.0897)
Observations	280	280	280	280	280
R-squared	0.0058	0.0010	0.0002	0.0007	0.0031

Data

- First, Annual Survey of Manufacturing Enterprises 1998-2007
  - Large panel data with national representativeness by NBS
  - Detailed firm operation information from accounting statements
  - Clean the data following Brandt, et al. (2012) and Feenstra, et al. (2013)
  - Drop non-manufacturing: mining, tobacco, and public utility industries
  - Drop processing firms: different firms by nature
- Second, patent filings from the State Intellectual Property Office (SIPO) of China
  - Detailed information of each patent filing since 1985: name, address, date, etc.
  - Type of the patent: invention, utility model, or design.

Data

- Mergered NBS and SIPO by name, double check by address
  - Matched 4% *vs.* 8.8%.
  - Consistent criterion: no systematic mismatch across industries
- Third, tariff from World Integrated Trade Solution (WITS)
  - Use China's Input-Output Table 2002 to calculate input tariff
- Main dataset: unbalanced panel of 337,257 firms, around 1.3 million observations, 1998-2007
- China Customs Data (2000-2006) to construct some additional variables: eg, processing ratio, importing status, etc.
  - NBS+Customs data? No, only the subsample of importing firms, cannot capture the overall impact. (Also see Goldberg, et al 2010)
  - Robust to this subsample.

Key variables

- Patent filings as measure of innovation (e.g., Aghion, et al., 2005; Hashmi, 2013):

$$y_{fit} = \ln\left[Y_{fit} + \left(Y_{fit}^2 + 1\right)^{1/2}\right] \quad \text{or} \quad y_{fit} = \ln(Y_{fit} + 1)$$

- Input tariff of industry i in year t (Goldberg et al. (2010)):

$$InT_{it} = \sum_j CostShare_{ij} \cdot OutT_{jt},$$

  - $OutT_{jt}$ is the output tariff of industry j in year t
  - $CostShare_{ij}$ is the cost share of industry j in the production of a good in industry i, from the I-O Table.
  - i, j are industries classified in the I-O Table.
- Drawback of using I-O Table is widely realized (Amiti and Konings (2007)): aggregated
  - $CostShare_{ij}$: the share of industry j inputs imported by manufacturing firms in industry i, 4-digit CIC, using Customs Data.

Other variables

- Definitions and summary statistics: Table 2

Empirical findings: rough presentation in graph

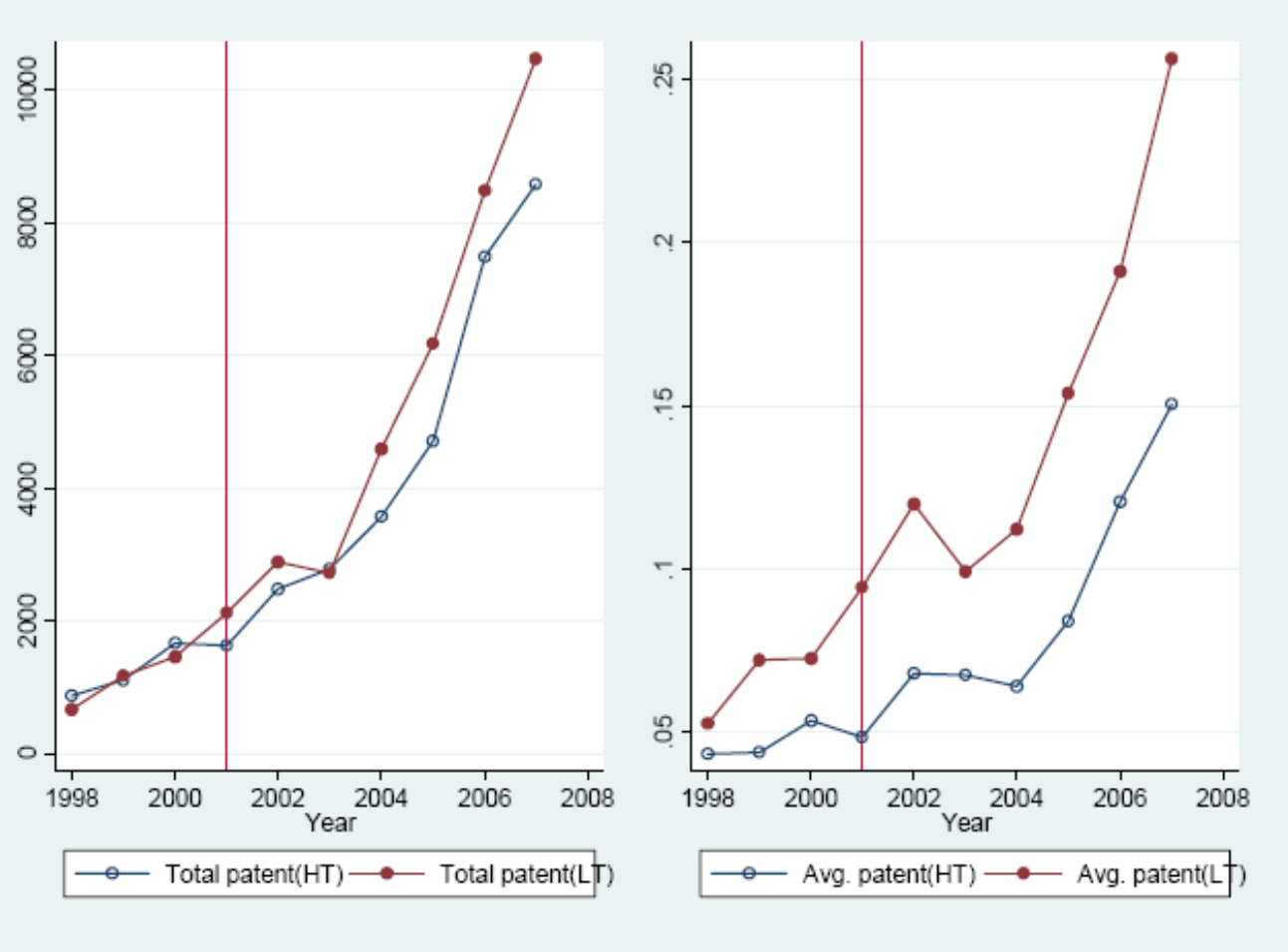

Figure 3. Time Trends of Innovation for High and Low Initial Input Tariff Industries (98-07)

Empirical findings: main results

- Table 3
- Output tariff change
- Simultaneous policy changes?
  - SOE reform
  - FDI entry regulation
- Decrease of input tariff: $DInT_i = InT_{i1998-2001} - InT_{i2002-2007}$
- Yearly input tariff
- More disaggregated input tariff
- Economically significant
  - Actual input tariff cut $4.64\% \times 0.2847 = 0.0132$
  - Average patent filings 0.1507
  - Droped by 8.76% due to input tariff liberalization with WTO

Empirical findings: validity of the specification

- Table 4
  - Industry-specific linear time trend.
  - Placebo test I: Pre-WTO period.
  - Placebo test II: subsample of processing-trade firms.
  - Flexible estimation.

Empirical findings: robustness

- Table 5
  - Industrial competition: HHI
  - Export opportunity: control for industrial total exports; subsample of non-exporters.
  - Subsample of single-product firms
  - Subsample of surviving firms
  - Two-period estimation: serial autocorrelation of error term (Bertrand, et al., 2004)

Table 5. Robustness Checks

VARIABLES	(1) Patent	(2) Patent	(3) Patent	(4) Patent	(5) Patent	(6) Patent
Sample	All	All	non-Exporters	Single-product	Surviving firms	Two-period
InT01*Post02	-0.1887***	-0.1851***	-0.1151***	-0.1737***	-0.2000***	-0.1627***
	(0.0203)	(0.0205)	(0.0185)	(0.0210)	(0.0203)	(0.0273)
HHI	-0.0037					
	(0.0402)					
Total Exports		0.0042***				
		(0.0013)				
Post02						0.0210***
						(0.0039)
Firm controls	Y	Y	Y	Y	Y	Y
Industrial controls	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	
Observations	1,268,326	1,267,582	913,640	1,174,680	572,405	475,172
R-squared	0.5141	0.5141	0.5110	0.5100	0.4497	0.7913

Empirical findings: Heterogeneity of the impact

- Table 6
  - Innovation types: invention, utility model, design
  - Capital intensity.
  - Distance from technology frontier (Aghion, et al., 2007)
  - Ownership
  - Direct importers and non-importers.

Table 6. Heterogeneous Effects

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Invention	Utility	Design	Patent	Patent	Patent
Sample	All	All	All	Low K/L	High K/L	Low TFP
lnT01*Post02	-0.0821***	-0.1027***	-0.0464***	-0.0961	-0.3564***	-0.0267
	(0.0082)	(0.0109)	(0.0160)	(0.0643)	(0.0533)	(0.0228)
Firm controls	Y	Y	Y	Y	Y	Y
Industrial controls	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Observations	1,268,326	1,268,326	1,268,326	357,154	334,867	112,972
R-squared	0.4871	0.4928	0.4690	0.4837	0.5630	0.3670

	(7)	(8)	(9)	(10)	(11)	(12)
VARIABLES	Patent	Patent	Patent	Patent	Patent	Patent
Sample	High TFP	SOEs	Private	Foreign	Importer	non-Importer
lnT01*Post02	-0.2963***	-0.1272***	-0.1476***	-0.2678***	-0.3246***	-0.0928***
	(0.0516)	(0.0466)	(0.0230)	(0.0605)	(0.1192)	(0.0180)
Firm controls	Y	Y	Y	Y	Y	Y
Industrial controls	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Observations	771,325	116,023	902,130	250,173	112,983	843,283
R-squared	0.5535	0.4996	0.5259	0.5472	0.6872	0.5642

Mechanism

- Input tariff liberalization decreases firm innovation: input imports substitute innovatioin through
  - Importing more inputs and/or Importing higher quality inputs?
- The response of input imports to tariff change (Goldgerg, et al 2010):

$$y_{ijt} = \alpha \, Tariff01_i \cdot Post02_t + \lambda_i + \lambda_t + \lambda_j \cdot t + \varepsilon_{ijt},$$

  - y_{ijt} is the logarithm of import value, quantity or unit value of *intermediate input* i (at HS6, BEC) in year t.
  - $Tariff01_i$ is the tariff of product i in year 2001.
  - λ_i, λ_j and λ_t : dummy for HS6, HS2, and year, respectively.
- Table 7: higher quality of inputs (higher unit value; more from OECD).

Mechanism

Table 7. Effects on Import Value, Quantity and Price

	Import value				Import quantity				Import price		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Sample	All sources	From OECD	From nonOECD	Share from OECD	All sources	From OECD	From nonOECD	Share from OECD	All sources	From OECD	From nonOECD
Tariff01*Post02	-0.0072***	-0.0063**	-0.0135***	0.0007**	-0.0123***	-0.0129***	-0.0218***	0.0004	0.0046***	0.0063***	0.0063***
	(0.0028)	(0.0031)	(0.0037)	(0.0003)	(0.0030)	(0.0034)	(0.0038)	(0.0004)	(0.0014)	(0.0015)	(0.0014)
Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
HS6 FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
HS2 Trend	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	25,233	24,876	23,576	24,876	25,212	24,845	23,533	24,855	25,212	24,845	23,533
R-squared	0.9058	0.9058	0.8499	0.6870	0.9240	0.9176	0.8914	0.6666	0.9676	0.9642	0.9459

A Simple Model: Setup

- Consider a representative firm.
- The firm purchases intermediate inputs to produce the final good:
  - Domestic input: x_d
  - Imported input x_i ($i = l$ or h): low-quality input, x_l, *or* high-quality input, x_h.
  - The production function $f_i(x_d, x_i)$ has the following properties

$$\frac{\partial f_i}{\partial x_d} > 0, \quad \frac{\partial f_i}{\partial x_i} > 0, \text{ and } f_h(x_d, x_h) > f_l(x_d, x_l) \text{ for all } x_d \text{ and } x_h = x_l$$

- The firm may also purchase another type of imported input for R&D, call it capital good for convenience: x_r.
  - If conducts R&D, its new production function

$$F_i(x_d, x_i, x_r) = f_i(x_d, x_i) + r(x_r)$$

  - $r(\cdot)$ is the R&D output function with the usual properties: $r(0) = 0$, $r'(x_r) > 0$ and $r''(x_r) < 0$.

A Simple Model: Setup

- To obtain explicit solutions, we specify the following functions

$$\begin{aligned} f_i(x_d, x_i) &= x_d^{\alpha}(\beta_i x_i)^{1-\alpha}, \text{ where } \beta_l = 1 \text{ and } \beta_h > 1 \\ r(x_r) &= r_0\sqrt{x_r}. \end{aligned}$$

- Denote prices for each factor input as p_d, p_l, p_h and p_r, respectively, and normalize $p_d = 1$. Assume $p_h > p_l$.
- Assume tariff levle $\tau > 1$ for all imported inputs in *ad valorem* term.
- Assume the quality difference large enough, i.e.,

$$\frac{p_l}{\beta_l} > \frac{p_h}{\beta_h} \cdot \tau^{\frac{\alpha}{1-\alpha}}.$$

A Simple Model: Firm Optimization

- If the firm chooses to import input $i = l$ or h, its optimization problem is

$$\min C_i = x_d + \tau(p_i x_i + p_r x_r) \quad \text{s.t.} \quad F_i(x_d, x_i, x_r) \geq 1.$$

- Denoting $B_i \equiv A_i^{\alpha} \beta_i^{1-\alpha} = (\frac{\alpha}{1-\alpha})^{\alpha} \tau^{\alpha} p_i^{\alpha} \beta_i^{1-\alpha}$, we obtain optimal inputs:

$$\begin{aligned} x_d &= \frac{A_i}{B_i} - \frac{A_i p_i r_0^2}{2B_i^2(1-\alpha)p_r}, \quad x_i = \frac{1}{B_i} - \frac{p_i r_0^2}{2B_i^2(1-\alpha)p_r}, \quad \text{and} \\ x_r &= \left[\frac{p_i r_0^2}{2B_i(1-\alpha)p_r}\right]^2. \end{aligned}$$

A Simple Model: Firm Optimization

- The (minimized) unit cost is thus:

$$C_i = \frac{\tau^{1-\alpha}}{\Phi}\left(\frac{p_i}{\beta_i}\right)^{1-\alpha} - \frac{\tau^{1-2\alpha}}{4\Phi^2}\frac{r_0^2}{p_r}\left(\frac{p_i}{\beta_i}\right)^{2(1-\alpha)},$$

  with $\Phi \equiv \alpha^{\alpha}(1-\alpha)^{1-\alpha}$.

- The firm then compares C_l and C_h to decide all input variables:
  - Quality choice (l or h ?)
  - R&D choice (x_r^H and x_r^L, accordingly).

A Simple Model: Analyses

- Under some assumptions, it is easy to show: $\frac{\partial C_i}{\partial \tau} > 0$, and $C_l(\tau)$ and $C_h(\tau)$ have a single crossing.

Proposition: *There exists a τ^* such that: i) $C_L(\tau) > C_H(\tau)$ for $\tau < \tau^*$ and $C_L(\tau) < C_H(\tau)$ for $\tau > \tau^*$. ii) $x_r^H < x_r^L$, where x_r^H is defined for $\tau < \tau^*$ and x_r^L for $\tau > \tau^*$.* **Therefore, when tariff drops from above τ^* to below τ^*, import price increases (switching from p_l to p_h) and innovation drops.**

- Intuition: at certain tariff level, a tariff cut induces a quality switch in imported inputs.

A Simple Model: An example

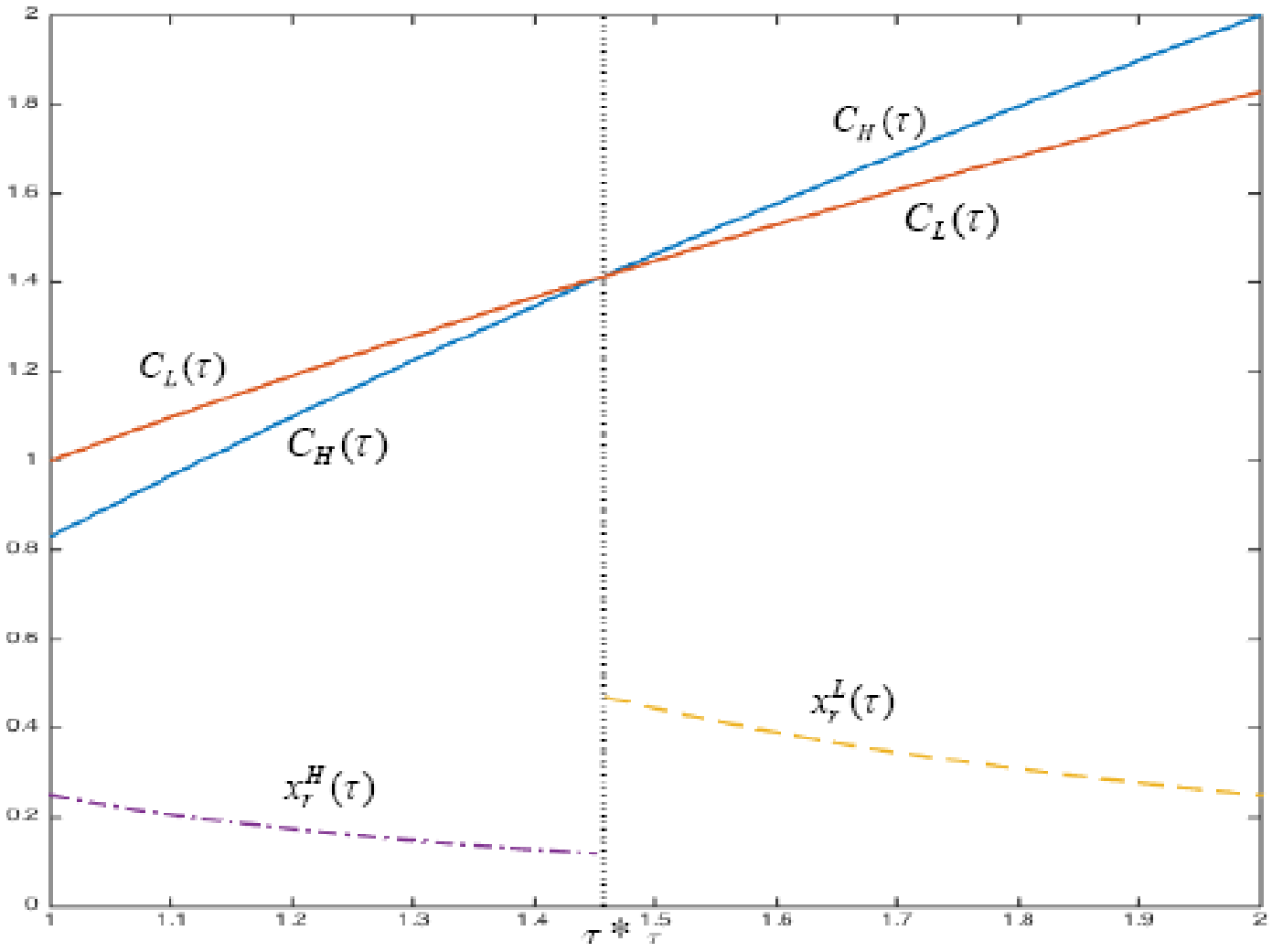

Figure 1: Cost and Innovation Comparisons

Conclusions

- The impact of input tariff liberalization on firm innovation.
- We exploit the quasi-natural experiment setting due to China's WTO accession and conduct a DID analysis.
- We find that the input tariff reduction *decreases* significantly firms' innovation.
    - Firms import higher quality inputs, and do less innovation.
    - Complements-or-*Substitutes* between input imports and innovation?

Thank you!