

# The Impact of Export Controls on International Trade: Evidence from the Japan–Korea Trade Dispute in Semiconductor Industry

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# Motivation

- Trade policy used to address national-security concerns
  - U.S. trade restrictions against China; U.S. trade sanction against Russia
  - Research: Fajgelbaum et al. (2020), Bown (2021), and many others
- Global value chain (GVC) has been expanded
  - 50% of world trade crosses at least 2 national borders (World Bank 2020)
    - e.g., semiconductor industry
  - Empirical research on trade policy in GVCs: some but less developed (Antras and Chor, 2022)

# Semiconductors are important



Joe Biden holds up a silicon wafer during a virtual meeting with CEOs to discuss supply chain issues at the White House on Apr. 12: redefining the word "infrastructure" is critical. © AP

Source: Nikkei Asia (2021)

⇒ Ban on semiconductor exports to China in Oct. 2022

# Research Question & What We Do

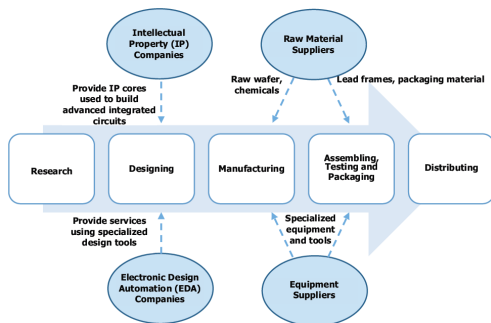
- Research question:  
What is the effect of non-tariff trade policy motivated by national-security threats on trade in the semiconductor industry?
  - Japan-Korea trade dispute in July 2019 as a case study
  - Japan strengthened export controls on three chemical materials essential in semiconductor production
- Utilize a DID approach and the synthetic control method

# Result Preview

1. Japanese exports of hydrogen fluoride
  - to South Korea declined by 87-91%
  - to the U.S. increased by 92-94%
2. South Korea's imports
  - of hydrogen fluoride from U.S. and Taiwan increased by 85-144%
  - of photoresist from Belgium increased by 341%
  - of semiconductor manufacturing equipments from Netherlands and Germany decreased by 54-72%
3. South Korea's exports of semiconductor manufacturing equipments to China increased by 506%

# Background on Semiconductor Industry

- Semiconductors are used in many modern products e.g., cellphones, automobiles, and etc
- Production process: Source: Semiconductor Industry Association (2016)



- Production process was historically vertically integrated → now vertically fragmented and dispersed globally

# Background on Japan-Korea Trade Disputes

- In July 2019, Japan strengthened export control to South Korea of three chemical materials
  1. hydrogen fluoride: used in etching and cleaning
  2. photoresist: used in printing an image of a circuit pattern on a wafer
  3. fluorinated polyimide: used as a high-temperature adhesive
  - due to national-security concern or political reason
  - bulk export license → individual export license

⇒ larger export costs and uncertainty

# Background on Japan-Korea Trade Disputes

- Japanese chemical firms are important suppliers of the three chemical materials in the world semiconductor industry
  - e.g., TOK supplies 26.1% of global semiconductor photoresist (Fuji Keizai, 2022)
- South Korean semiconductor industry depended heavily on the Japanese raw materials
  - two out of the three raw materials are imported more than 90% from Japan
  - semiconductor products comprises of about 20% of South Korea's exports



# Empirical Framework

- Estimation equation:

$$\ln(\text{export})_{kht} = \beta_1 \text{KOR}_k \times \text{hydrogen}_h \times \text{after}_t \\ + \beta_2 \text{KOR}_k \times \text{other}_h \times \text{after}_t + \alpha_{kt} + \alpha_{ht} + \alpha_{kh} + \epsilon_{kht},$$

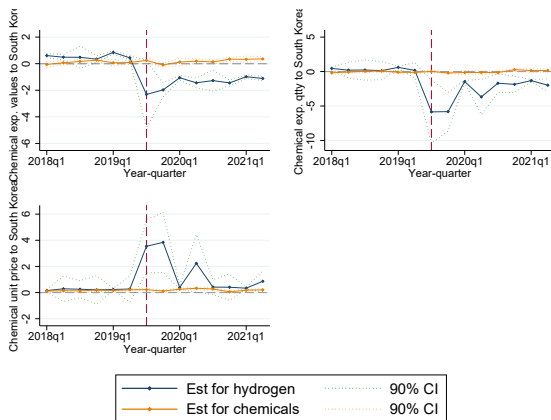
- $\ln(\text{export})_{kht}$ : export of product  $h$  to country  $k$  in year-month  $t$
  - $\text{KOR}_k$ : dummy on export to South Korea
  - $\text{hydrogen}_h$ : dummy on hydrogen fluoride
  - $\text{other}_h$ : dummy on photoresist and fluorinated polyimide
  - $\text{after}_k$ : dummy on after July 2019
  - $\alpha$ : a series of fixed effects
- Data: monthly trade in HS 6-digit level from Jan. 2017 to May 2022 (Global Trade Atlas by IHS Markit)

# Empirical Framework (cont.)

- Identification assumption: common trend assumption
  - trends are the same b/w exports of product  $h$  to Korea and those of other products, if there were no policy
  - covariates: e.g.,  $\alpha_{kt}$  and  $\alpha_{ht}$  control for aggregate COVID-19 effects for each country and product
- Pre-trend tests using event study design
- Rambachan and Roth's (2022) approach
  - sensitivity analysis when parallel trends may be violated
  - how large a post-treatment parallel-trend violation should be to negate the significant effects

# DID results on Japanese Exports

## Japanese exports of raw materials to South Korea



- Decline in exports for hydrogen fluoride, but not for other two materials

# DID results on Japanese Exports

## Japanese exports of hydrogen fluoride to other economies

	(1)	(2)	(3)	(4)	(5)	(6)
Ctry dummy:	USA		China		Taiwan	
Outcome:	Value	Value	Value	Value	Value	Value
after#Ctry#hydrogen	0.666*** (0.0103)		0.597*** (0.0111)		0.550*** (0.00912)	
2018#Ctry#hydrogen		-0.232*** (0.00961)		-0.250*** (0.00945)		1.160*** (0.00902)
2019h1#Ctry#hydrogen		-0.0359*** (0.0133)		0.181*** (0.0125)		1.478*** (0.0121)
2019h2#Ctry#hydrogen		0.657*** (0.0144)		0.329*** (0.0138)		1.613*** (0.0128)
2020#Ctry#hydrogen		0.629*** (0.0144)		0.495*** (0.0154)		1.244*** (0.0127)
2021#Ctry#hydrogen		0.307*** (0.0169)		0.866*** (0.0176)		1.120*** (0.0151)
Series of fixed effects	Yes	Yes	Yes	Yes	Yes	Yes

- Increase in exports of hydrogen fluoride to U.S. by 92.9%
- Consistent with roundabout export (combining w/ next findings)

# DID results on Korean Imports

## South Korea's imports of hydrogen fluoride from other economies

Ctry dummy:	(1)	(2)	(3)	(4)
Outcome:	USA		Taiwan	
	Value	Value	Value	Value
after#Ctry#hydrogen	1.339*** (0.0146)		0.893*** (0.0216)	
2018#Ctry#hydrogen		-1.541*** (0.0161)		1.367*** (0.0264)
2019h1#Ctry#hydrogen		-2.608*** (0.0198)		1.786*** (0.0332)
2019h2#Ctry#hydrogen		0.618*** (0.0213)		2.918*** (0.0341)
2020#Ctry#hydrogen		-0.167*** (0.0206)		1.943*** (0.0345)
2021#Ctry#hydrogen		0.342*** (0.0241)		1.635*** (0.0398)
Series of fixed effects FE	Yes	Yes	Yes	Yes

- Increase in hydrogen-fluoride imports from U.S. and Taiwan
- Consistent w/ roundabout imports at least in short run

# DID results on Korean Imports

South Korea's imports of two other raw materials from other economies

	(1)	(2)
Ctry dummy:		Belgium
Outcome:	Value	Value
after#Ctry#other	1.696*** (0.546)	
2018#Ctry#other		-0.175 (0.194)
2019h1#Ctry#other		0.00481 (0.636)
2019h2#Ctry#other		1.486*** (0.323)
2020#Ctry#other		1.636*** (0.276)
2021#Ctry#other		1.776*** (0.529)
Series of fixed effects FE	Yes	Yes

- Increase in imports of photoresist from Belgium
- Samsung reportedly started importing photoresist from a Japanese joint-venture in Belgium

# DID results on Korean Imports

## South Korea's imports of semiconductor manufacturing equipments

	(1)	(2)	(3)	(4)
Ctry dummy:	Netherlands		Germany	
Outcome:	Value	Value	Value	Value
after#Ctry#equipment	-0.791*** (0.0257)		-1.295*** (0.0162)	
2018#Ctry#equipment		-0.840*** (0.0294)		-0.611*** (0.0173)
2019h1#Ctry#equipment		-0.573*** (0.0347)		-1.697*** (0.0230)
2019h2#Ctry#equipment		-3.368*** (0.0376)		-2.132*** (0.0230)
2020#Ctry#equipment		-0.713*** (0.0364)		-1.355*** (0.0227)
2021#Ctry#equipment		0.0453 (0.0431)		-2.662*** (0.0256)
Series of fixed effects	Yes	Yes	Yes	Yes

- Short-run decline in imports of equipments
- ASML's (Netherlands) lithography equipment is used together w/ Japanese photoresist to produce the most advanced chips

# DID results on Korean Exports

## South Korea's exports of semiconductor manufacturing equipments

	(1)	(2)
Ctry dummy:	China	
Outcome:	Value	Value
after#Ctry#equipment	1.802*** (0.0164)	
2018#Ctry#equipment		0.563*** (0.0154)
2019h1#Ctry#equipment		0.989*** (0.0208)
2019h2#Ctry#equipment		2.176*** (0.0221)
2020#Ctry#equipment		2.056*** (0.0223)
2021#Ctry#equipment		2.697*** (0.0259)
Series of fixed effects	Yes	Yes

- Increase in exports of semiconductor manufacturing equipment to China
- Korean firms possibly reallocate some chip-production toward Chinese affiliates to securely import raw materials from Japan



- Use different control groups
  - focusing the control groups on the same HS 4-digit products
  - excluding top 5 trading partners from the control groups
- Rambachan and Roth's (2022) approach to mitigate pre-trends violation concern
  - significant effect even if the post-treatment parallel-trends violation is 9 times larger than the pre-treatment violation
- Synthetic control method by Abadie et al. (2010)
  - data-driven procedure to choose weights for control units  
→ "synthetic" control group

# Conclusion

- Analyze the effect of Japan strengthening export controls to South Korea on exports and imports
  1. Japan decreased exports of hydrogen fluoride to South Korea, but increased to U.S.
  2. South Korea increased imports of raw materials from U.S., Taiwan, and Belgium, but decreased imports of equipments
  3. South Korea increased exports of equipments to China
- Trade policy under national-security concerns causes adjustment in importing and MNE's production patterns along GVC
- Unilateral export controls may not be effective in the current global economy

- Protectionist trade policy on trade and domestic economies
  - Amiti et al., 2019; Benguria and Saffie, 2019; Fajgelbaum et al., 2020; Fajgelbaum et al., 2021; Hayakawa et al., 2022
  - ⇒ ours: focusing on the effect of non-tariff trade policies
  
- Trade policy along GVCs
  - Flaaen et al. 2020; Chen et al, 2021; Bown et al., 2021
  - ⇒ ours: focusing on non-tariff trade policy in semiconductor industry

# DID results on Japanese Exports

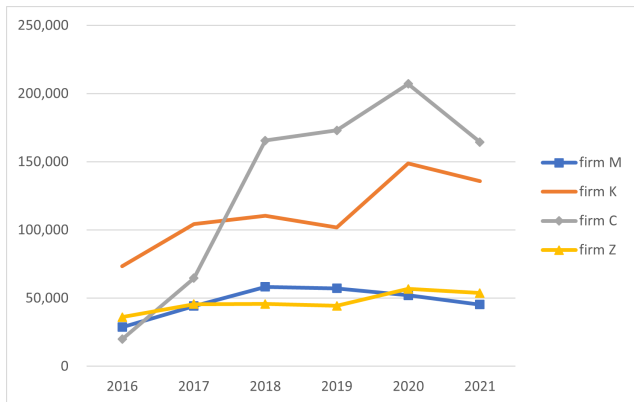
## Japanese exports of hydrogen fluoride to South Korea

Outcome:	(1) Value	(2) Value	(3) Qty	(4) Qty	(5) Uval	(6) Uval
after#KOR#hydrogen	-2.111*** (0.0107)		-3.685*** (0.0132)		1.573*** (0.00759)	
2018#KOR#hydrogen		0.317*** (0.00921)		-0.364*** (0.0124)		0.681*** (0.00772)
2019h1#KOR#hydrogen		0.0663*** (0.0126)		-0.929*** (0.0164)		0.992*** (0.0107)
2019h2#KOR#hydrogen		-2.482*** (0.0143)		-7.206** (0.0183)		4.722** (0.0113)
2020#KOR#hydrogen		-1.787*** (0.0140)		-3.081*** (0.0179)		1.293*** (0.0106)
2021#KOR#hydrogen		-1.898** (0.0161)		-3.076*** (0.0203)		1.176*** (0.0120)
Series of fixed effects	Yes	Yes	Yes	Yes	Yes	Yes

- Sharp decline in hydrogen-fluoride export value by 87.9% and quantity by 97.5% after 2nd half of 2019

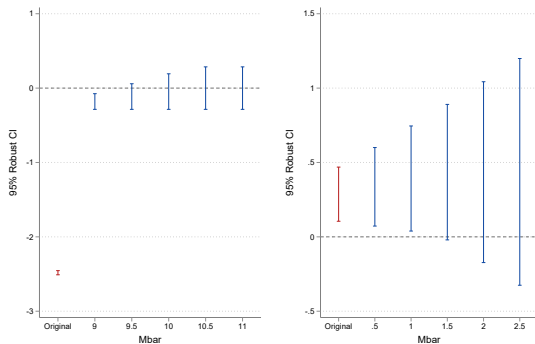
# Results on Korean Production

Sales of Japanese affiliates in South Korea



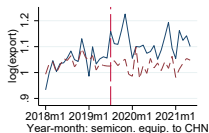
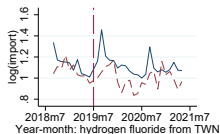
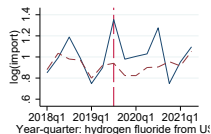
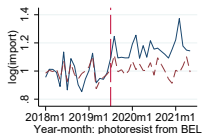
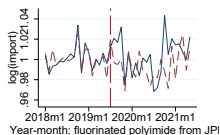
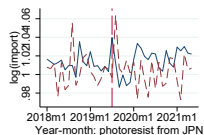
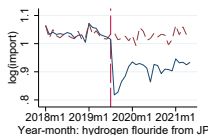
- Increase in Japanese affiliates' sales in South Korea after July 2019 (though some pre-trends)

# Robustness: Rambachan and Roth (2022) method



- 95% CI doesn't include zero even if the post-treatment violations of parallel trends are 9 times larger than the maximum pre-treatment violations

# Robustness: synthetic control method



- Treated groups experience a discontinuous change in trade at July 2019, compared to the synthetic control group

- Export controls on three raw materials are lifted in March 2023  
→ the effect disappear?
- Analysis using firm-level data is beneficial to pin down the mechanism