Innovation Spurred

Evidence from South Korea's Big R&D Push

Luis F. Jaramillo (University of Maryland, JMP)
Chan Kim (University of Maryland)

Columbia University
New Thinking in Industrial Policy Conference
November 1, 2024

Research Question & Context

- How does innovation policy affect research output and economic outcomes?
  - Scarce literature on large, coordinated R&D programs

Research Question & Context

- How does innovation policy affect research output and economic outcomes?
    - Scarce literature on large, coordinated R&D programs
- We study the G7 Program, Korea’s first ”mission-oriented” R&D program

Research Question & Context

- How does innovation policy affect research output and economic outcomes?
  - Scarce literature on large, coordinated R&D programs
- We study the G7 Program, Korea's first "mission-oriented" R&D program
  - +7 bn USD between 1992 and 2001 (2023 USD), ~100.000 researchers (Kwon, 2021)
  - **The Mission:** Reach frontier-level (G7-country) capabilities in selected technologies by the 2000s

Research Question & Context

- How does innovation policy affect research output and economic outcomes?
  - Scarce literature on large, coordinated R&D programs
- We study the G7 Program, Korea's first "mission-oriented" R&D program
  - +7 bn USD between 1992 and 2001 (2023 USD), ~100.000 researchers (Kwon, 2021)
  - **The Mission:** Reach frontier-level (G7-country) capabilities in selected technologies by the 2000s
  - Policymakers identified the need to compete in higher value-added markets. However…
    - Coordination failures and risk-averse firms in technologies with commercial applications (e.g. HDTV)
    - Suboptimal private provision of R&D in technologies with large externalities (e.g. Nuclear Reactor)

Research Question & Context

- How does innovation policy affect research output and economic outcomes?
  - Scarce literature on large, coordinated R&D programs
- We study the G7 Program, Korea's first "mission-oriented" R&D program
  - +7 bn USD between 1992 and 2001 (2023 USD), ~100.000 researchers (Kwon, 2021)
  - **The Mission:** Reach frontier-level (G7-country) capabilities in selected technologies by the 2000s
  - Policymakers identified the need to compete in higher value-added markets. However…
    - Coordination failures and risk-averse firms in technologies with commercial applications (e.g. HDTV)
    - Suboptimal private provision of R&D in technologies with large externalities (e.g. Nuclear Reactor)
  - A research subsidy would solve these issues. **What's different?**
    - Top-down, centralized approach to project selection
    - A public research institute managed the projects

Research Question & Context

- How does innovation policy affect research output and economic outcomes?
  - Scarce literature on large, coordinated R&D programs
- We study the G7 Program, Korea's first "mission-oriented" R&D program
  - +7 bn USD between 1992 and 2001 (2023 USD), ~100.000 researchers (Kwon, 2021)
  - **The Mission:** Reach frontier-level (G7-country) capabilities in selected technologies by the 2000s
  - Policymakers identified the need to compete in higher value-added markets. However…
    - Coordination failures and risk-averse firms in technologies with commercial applications (e.g. HDTV)
    - Suboptimal private provision of R&D in technologies with large externalities (e.g. Nuclear Reactor)
  - A research subsidy would solve these issues. **What's different?**
    - Top-down, centralized approach to project selection
    - A public research institute managed the projects
  - G7P Unit selected 23 megaprojects from 74 candidates presented by Ministries
    - Only 18 projects were funded due a budget shock

The G7 Program

Selected and Funded Megaprojects (Treatment)		Selected but Unfunded Megaprojects (Control)	
Product Technologies	Base Technologies	Product Technologies	Base Technologies
HDTV	NG Biomaterials	Aircraft	Off-Shore Manufacturing Plant
High-Capacity Semiconductor	NG Energy and Informatic Materials	High-Speed Maritime Ship	Korean Natural Language Processing System
Electric Vehicle	NG Semiconductor		Automated Traffic Control System
NG Flat Panel Display	Environmental Engineering		
B-ISDN Network Device	Fuel Cell		
Medicines	NG Nuclear Reactor		
Medical Engineering	NG Production System		
Precision Machinery	Sensorial Engineering		
High-Speed Train	NG Nuclear Fusion Device		

This paper

- We use newly digitized files from archival sources, patenting, and export data to study how patenting and exports in G7P-targeted technological classes evolved between 1980 and 2015

This paper

- We use newly digitized files from archival sources, patenting, and export data to study how patenting and exports in G7P-targeted technological classes evolved between 1980 and 2015
- We use a language model and rich textual data to determine targeted and control classes

This paper

- We use newly digitized files from archival sources, patenting, and export data to study how patenting and exports in G7P-targeted technological classes evolved between 1980 and 2015
- We use a language model and rich textual data to determine targeted and control classes
- We exploit that some high-potential megaprojects were selected but not funded due to budget shocks

This paper

- We use newly digitized files from archival sources, patenting, and export data to study how patenting and exports in G7P-targeted technological classes evolved between 1980 and 2015
- We use a language model and rich textual data to determine targeted and control classes
- We exploit that some high-potential megaprojects were selected but not funded due to budget shocks
- **Main findings**
    - By the 10^{th} year after receiving program support, targeted technological classes doubled their quality-weighed patenting output and tripled their real exports relative to control classes
    - The effect on patenting output materialized almost immediately. It took more time for exports (~5 years)
    - Technological classes with *less* concentrated scientific output before the program observe *greater* effects

This paper

- We use newly digitized files from archival sources, patenting, and export data to study how patenting and exports in G7P-targeted technological classes evolved between 1980 and 2015
- We use a language model and rich textual data to determine targeted and control classes
- We exploit that some high-potential megaprojects were selected but not funded due to budget shocks
- **Main findings**
  - By the 10^{th} year after receiving program support, targeted technological classes doubled their quality-weighed patenting output and tripled their real exports relative to control classes
  - The effect on patenting output materialized almost immediately. It took more time for exports (~5 years)
  - Technological classes with *less* concentrated scientific output before the program observe *greater* effects
- We compute an IRR of ~ 21% and a Cost-Benefit ratio of 3.3

This paper

- We use newly digitized files from archival sources, patenting, and export data to study how patenting and exports in G7P-targeted technological classes evolved between 1980 and 2015
- We use a language model and rich textual data to determine targeted and control classes
- We exploit that some high-potential megaprojects were selected but not funded due to budget shocks
- **Main findings**
  - By the 10^{th} year after receiving program support, targeted technological classes doubled their quality-weighed patenting output and tripled their real exports relative to control classes
  - The effect on patenting output materialized almost immediately. It took more time for exports (~5 years)
  - Technological classes with *less* concentrated scientific output before the program observe *greater* effects
- We compute an IRR of ~ 21% and a Cost-Benefit ratio of 3.3
- The G7P shifted the direction in which the Korean economy innovated, with important economic consequences

Data

- **Outcomes**
  - (Future-citation-weighed) Patenting and exports at the country-technological class level between 1980 and 2015 from USPTO and UN COMTRADE
  - An example of a technological class:
    - 1 digit: **B – Performing operations, transporting**
    - 3 digit: **B62 – Land vehicles for travelling otherwise than on rail**
    - 4 digit: **B62D – Motor vehicles**

Data

- **Outcomes**
  - (Future-citation-weighed) Patenting and exports at the country-technological class level between 1980 and 2015 from USPTO and UN COMTRADE
  - An example of a technological class:
    - 1 digit: **B – Performing operations, transporting**
    - 3 digit: **B62 – Land vehicles for travelling otherwise than on rail**
    - 4 digit: **B62D – Motor vehicles**
- **Treatment**
  - Wealth of textual information (description, goals, etc.) for +4,800 G7P-related R&D projects
    - We obtained the files from Korea's National Research Foundation through a FOIA-like request
    - We do not observe the technological classes targeted by each research project
  - **Challenge:** How do we map the rich textual information into technological classes?

Data

- **Outcomes**
  - (Future-citation-weighed) Patenting and exports at the country-technological class level between 1980 and 2015 from USPTO and UN COMTRADE
  - An example of a technological class:
    - 1 digit: **B – Performing operations, transporting**
    - 3 digit: **B62 – Land vehicles for travelling otherwise than on rail**
    - 4 digit: **B62D – Motor vehicles**
- **Treatment**
  - Wealth of textual information (description, goals, etc.) for +4,800 G7P-related R&D projects
    - We obtained the files from Korea's National Research Foundation through a FOIA-like request
    - We do not observe the technological classes targeted by each research project
  - **Challenge:** How do we map the rich textual information into technological classes?
  - **Solution:** A language model to classify projects into technological classes
    - We input each project's goals and description of activities in a language model developed to classify patents based on descriptive information
    - We get in return the technological classes related to each project

과제번호	과 제 명	연구기관 (책임자)	참여기업	연구기간	'95 연구개발비(단위:천원) 정부	기업	계	최종목표	연구내용
95-G-02-01-A	교환기술분야개발	전자통신연구소 (임주환)	한화정보통신 동아전기 삼성전자(주) 대우통신(주) 우진전자통신(주) LG정보통신(주)	'92 ~ '97 ('95/01/01 ~'95/12/31)	32,868,000	44,237,000	77,105,000		
95-G-02-01-A-01	ATM 교환기 시스템 개발	전자통신연구소 (한치문)	한화정보통신 동아전기 삼성전자(주) 대우통신(주) 우진전자통신(주) LG정보통신(주)	'92 ~ '97 ('95/01/01 ~'95/12/31)	27,520,000	38,669,000	66,189,000	정보화 사회의 구축에 핵심적인 광대역 ATM기술, 광교환기술 등 차세대 교환기술개발	ㅇ소형 ATM 교환기 개발 완료 ㅇ중형 ATM 교환기 구조 설계
95-G-02-01-A-01-A	ATM 교환기에서의 과부하제어에 관한 연구	한남대학교 (최진규)					15,000		
95-G-02-01-A-01-AA	운용메시지의 음성화에 관한 연구	과학기술원 (오영환)					15,000		
95-G-02-01-A-01-AB	ATM 교환기의 내진동 설계 및 해석에 관한연구	과학기술원 (엄윤용)					25,000		

Empirical Strategy

- We exploit that 5 high-potential mega-projects were selected but not funded to address selection concerns
  - Selected by program experts but not funded due to a budget shock
  - Deemed support-worthy but they would need to be supported outside the G7P
  - The Korean Government (unsuccessfully) explored alternative mechanisms to support them

Empirical Strategy

- We exploit that 5 high-potential mega-projects were selected but not funded to address selection concerns
  - Selected by program experts but not funded due to a budget shock
  - Deemed support-worthy but they would need to be supported outside the G7P
  - The Korean Government (unsuccessfully) explored alternative mechanisms to support them
- We find evidence that supports our identification strategy
  - No pre-trends in patenting or exports
  - Targeting is not informative of underlying economic characteristics before receiving program support
  - Results do not change when we exclude “super-star” technological classes (+95th percentile on outcomes before the G7P) from the sample

Empirical Strategy

- We exploit that 5 high-potential mega-projects were selected but not funded to address selection concerns
    - Selected by program experts but not funded due to a budget shock
    - Deemed support-worthy but they would need to be supported outside the G7P
    - The Korean Government (unsuccessfully) explored alternative mechanisms to support them
- We find evidence that supports our identification strategy
    - No pre-trends in patenting or exports
    - Targeting is not informative of underlying economic characteristics before receiving program support
    - Results do not change when we exclude “super-star” technological classes (+95th percentile on outcomes before the G7P) from the sample
- We provide evidence within Korea and across countries

Outcomes and Treatment

- We define

$$\Delta ihs(patents)_{s,g+h} = ihs(patents)_{s,g+h} - ihs(patents)_{s,g-1}$$

$$\Delta \mathrm{G7P}_{s,g+h} = \mathrm{G7P}_{s,g+h} - \mathrm{G7P}_{s,g-1}$$

- s is an IPC 4-digit level technological class
- g is the year in which a technological class is targeted
- $ihs(patents)_{s,g+h}$ is the (ihs) of future-citation-weighed patents of a technological class *s, h* years after G7P-targeting
- $\mathrm{G7P}_{s,g+h}$ is G7P treatment status for class s, *h* years after targeting

Outcomes and Treatment

- We define

$$\Delta ihs(exports)_{c,g+h} = ihs(exports)_{c,g+h} - ihs(exports)_{c,g-1}$$

$$\Delta \mathrm{G7P}_{c,g+h} = \mathrm{G7P}_{c,g+h} - \mathrm{G7P}_{c,g-1}$$

- c is an IPC 3-digit level technological class
- g is the year in which a technological class is targeted
- $ihs(exports)_{c,g+h}$ is the (ihs) of exports of a technological class *c*, *h* years after G7P-targeting
- $\mathrm{G7P}_{c,g+h}$ is G7P treatment status for class *c*, *h* years after targeting

Patenting

- We use Local Projections Differences in Differences (LP-DiD, Dube et al., 2023) to estimate:

$$\Delta ihs(patents)_{s,g+h} = \alpha + \beta_{g+h}\Delta \mathrm{G7P}_{s,g+h} + \delta_{c,t} + \sum_{j=1987}^{2015} X_s \gamma_j + \varepsilon_{s,g+h}$$

- $ihs(patents)_{s,g+h}$ is the (ihs) of future-citation-weighed patents in technological class *s*, *h* years after G7P-targeting
- $\mathrm{G7P}_{s,g+h}$ is G7P treatment status for class *s*, *h* years after targeting
- $\delta_{c,t}$ is a calendar year-IPC 3-digit level class *c* fixed effect
- X_s is technological class' *s* share of patenting output between 1987 and 1991, γ_j is a calendar-year dummy
- Using LP implies estimating the specification for each year separately and keeping only "newly treated" technological classes ($\Delta \mathrm{G7P}_{s,g+h}$ = 1) or clean controls ($\mathrm{G7P}_{s,g+h} = 0$)

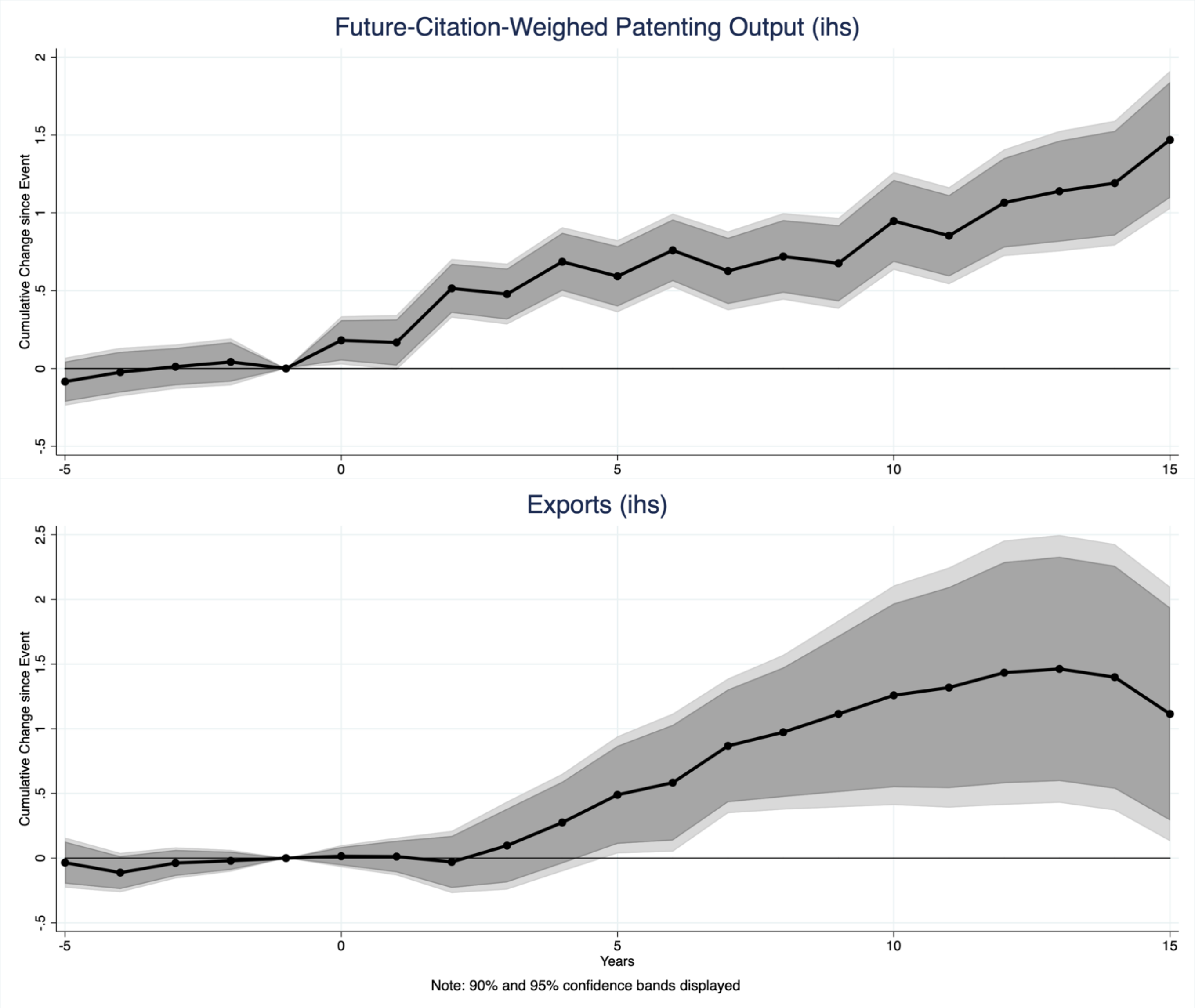
Exports

- We use Local Projections Differences in Differences (LP-DiD, Dube et al., 2023) to estimate:

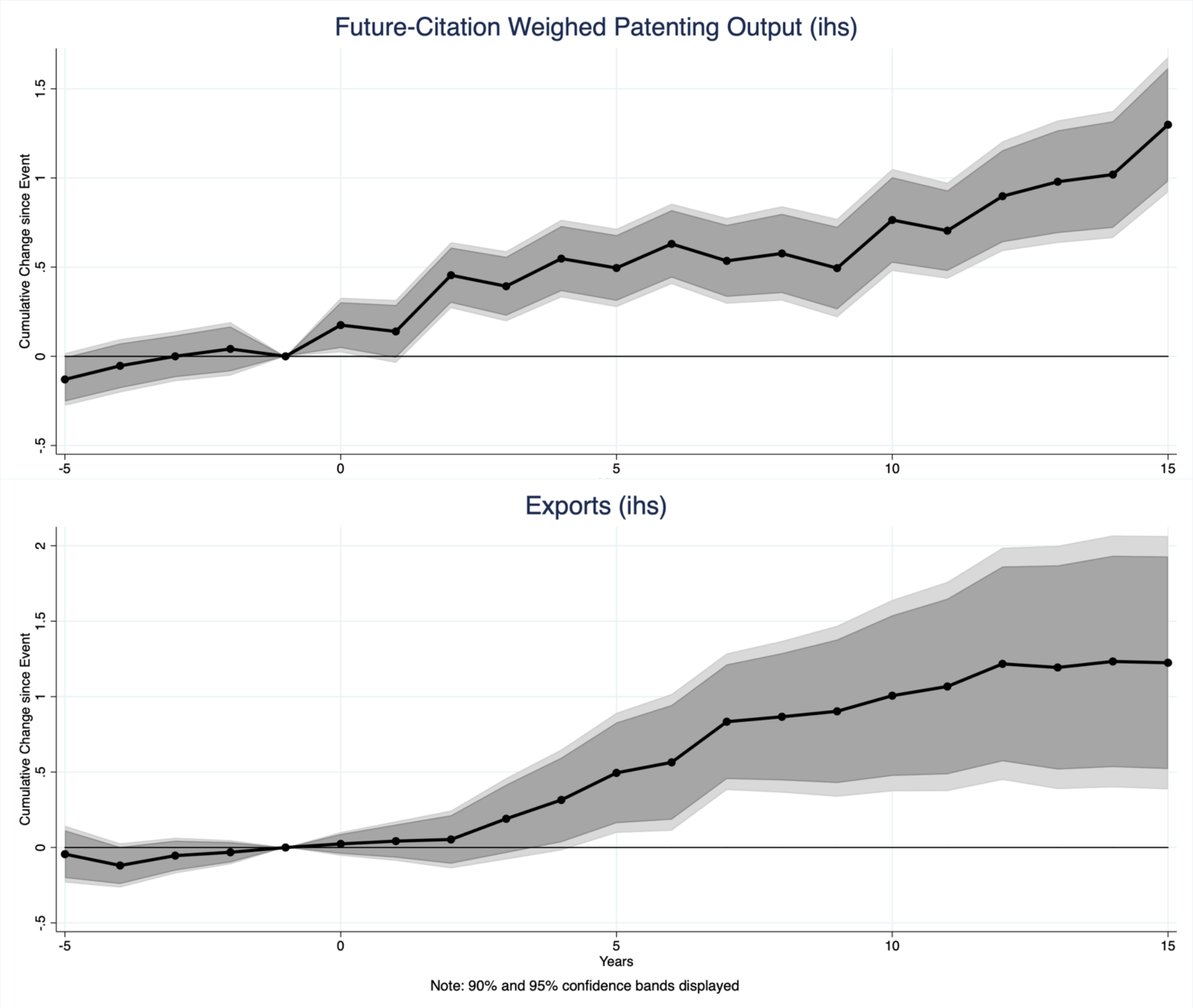
$$\Delta ihs(exports)_{c,g+h} = \alpha + \beta_{g+h}\Delta \mathrm{G7P}_{c,g+h} + \delta_{d,t} + \sum_{j=1987}^{2015} X_c \gamma_j + \varepsilon_{c,g+h}$$

- $ihs(exports)_{c,g+h}$ is the (ihs) of exports in technological class *c, h* years after G7P-targeting
- $\mathrm{G7P}_{c,g+h}$ is G7P treatment status for class *c*, *h* years after targeting
- $\delta_{d,t}$ is a calendar year-IPC 1-digit level class *d* fixed effect
- X_c is technological class' *c* share of exports output between 1987 and 1991, γ_j is a calendar-year dummy
- Using LP implies estimating the specification for each year separately and keeping only "newly treated" technological classes ($\Delta \mathrm{G7P}_{c,g+h}$ = 1) or clean controls ($\mathrm{G7P}_{c,g+h} = 0$)

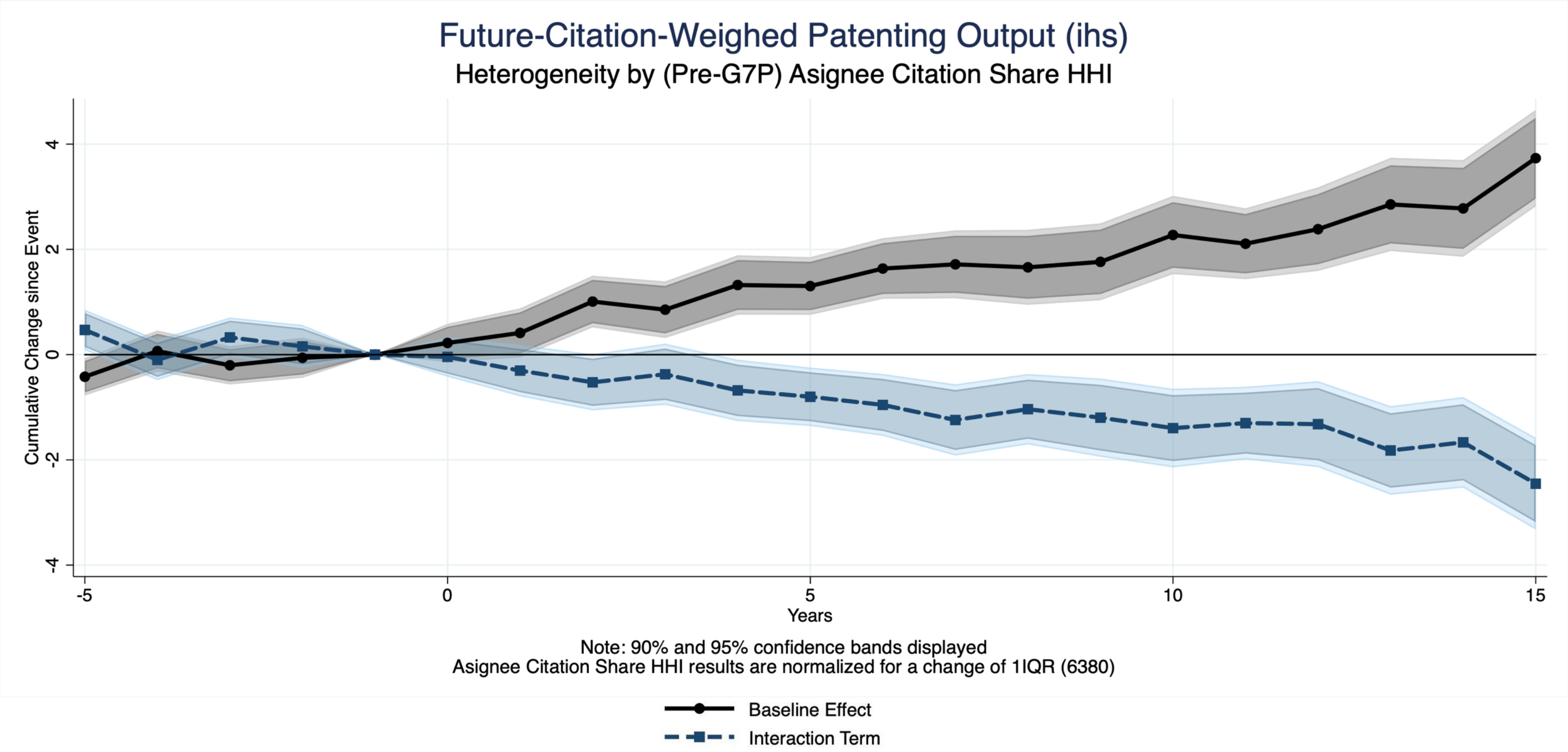
Results – South Korean Sample



Results – Cross-Country Sample



Mechanisms



Future-Citation-Weighed Patenting Output (ihs)
Heterogeneity by (Pre-G7P) Asignee Citation Share HHI
Cumulative Change since Event
4
2
0
-2
-4
-5
0
5
10
15
Years
Note: 90% and 95% confidence bands displayed
Asignee Citation Share HHI results are normalized for a change of 1IQR (6380)
Baseline Effect
Interaction Term

Cost-Benefit Analysis

- **Was the G7P a cost-effective intervention?**

Cost-Benefit Analysis

- **Was the G7P a cost-effective intervention?**
- Benefits
  - We count benefits for 15 years after a technological class was targeted
  - We implement a method to value patents from stock-market reactions to USPTO patent-granting (Kogan, 2017) and combine it with our reduced-form estimates
    - **Step 1:** Get the number of G7P-attributable patents for each treated technological class
    - **Step 2:** Get a Korean Won valuation for USPTO-granted Korean patents
      - We infer the value of a patent from changes in an assignee's market capitalization the three days after USPTO grants a patent, adjusting for market benchmark returns
      - We compute the median of patent valuations for each treated technological class every year
    - **Step 3:** Get a Korean Won valuation for G7P-attributable patents
      - We multiply the results from **Step 1** by those from **Step 2**

Cost-Benefit Analysis

- **Was the G7P a cost-effective intervention?**
- Benefits
  - We count benefits for 15 years after a technological class was targeted
  - We implement a method to value patents from stock-market reactions to USPTO patent-granting (Kogan, 2017) and combine it with our reduced-form estimates
    - **Step 1:** Get the number of G7P-attributable patents for each treated technological class
    - **Step 2:** Get a Korean Won valuation for USPTO-granted Korean patents
      - We infer the value of a patent from changes in an assignee's market capitalization the three days after USPTO grants a patent, adjusting for market benchmark returns
      - We compute the median of patent valuations for each treated technological class every year
    - **Step 3:** Get a Korean Won valuation for G7P-attributable patents
      - We multiply the results from **Step 1** by those from **Step 2**
- Costs
  - We include R&D expenditures and opportunity costs
- We take all values to 1992 Korean Won and discount them using a 5% discount rate

Cost-Benefit Analysis

- **Was the G7P a cost-effective intervention?**
- Benefits
  - We count benefits for 15 years after a technological class was targeted
  - We implement a method to value patents from stock-market reactions to USPTO patent-granting (Kogan, 2017) and combine it with our reduced-form estimates
    - **Step 1:** Get the number of G7P-attributable patents for each treated technological class
    - **Step 2:** Get a Korean Won valuation for USPTO-granted Korean patents
      - We infer the value of a patent from changes in an assignee's market capitalization the three days after USPTO grants a patent, adjusting for market benchmark returns
      - We compute the median of patent valuations for each treated technological class every year
    - **Step 3:** Get a Korean Won valuation for G7P-attributable patents
      - We multiply the results from **Step 1** by those from **Step 2**
- Costs
  - We include R&D expenditures and opportunity costs
- We take all values to 1992 Korean Won and discount them using a 5% discount rate
- **Results**
  - Benefits ~ 3.3x costs
  - IRR = 20.9%

Cost-Benefit Analysis

- **Was the G7P a cost-effective intervention?**
- Benefits
  - We count benefits for 15 years after a technological class was targeted
  - We implement a method to value patents from stock-market reactions to USPTO patent-granting (Kogan, 2017) and combine it with our reduced-form estimates
    - **Step 1:** Get the number of G7P-attributable patents for each treated technological class
    - **Step 2:** Get a Korean Won valuation for USPTO-granted Korean patents
      - We infer the value of a patent from changes in an assignee's market capitalization the three days after USPTO grants a patent, adjusting for market benchmark returns
      - We compute the median of patent valuations for each treated technological class every year
    - **Step 3:** Get a Korean Won valuation for G7P-attributable patents
      - We multiply the results from **Step 1** by those from **Step 2**
- Costs
  - We include R&D expenditures and opportunity costs
- We take all values to 1992 Korean Won and discount them using a 5% discount rate
- **Results**
  - Benefits ~ 3.3x costs
  - IRR = 20.9%
- The program was a (highly) cost-effective intervention

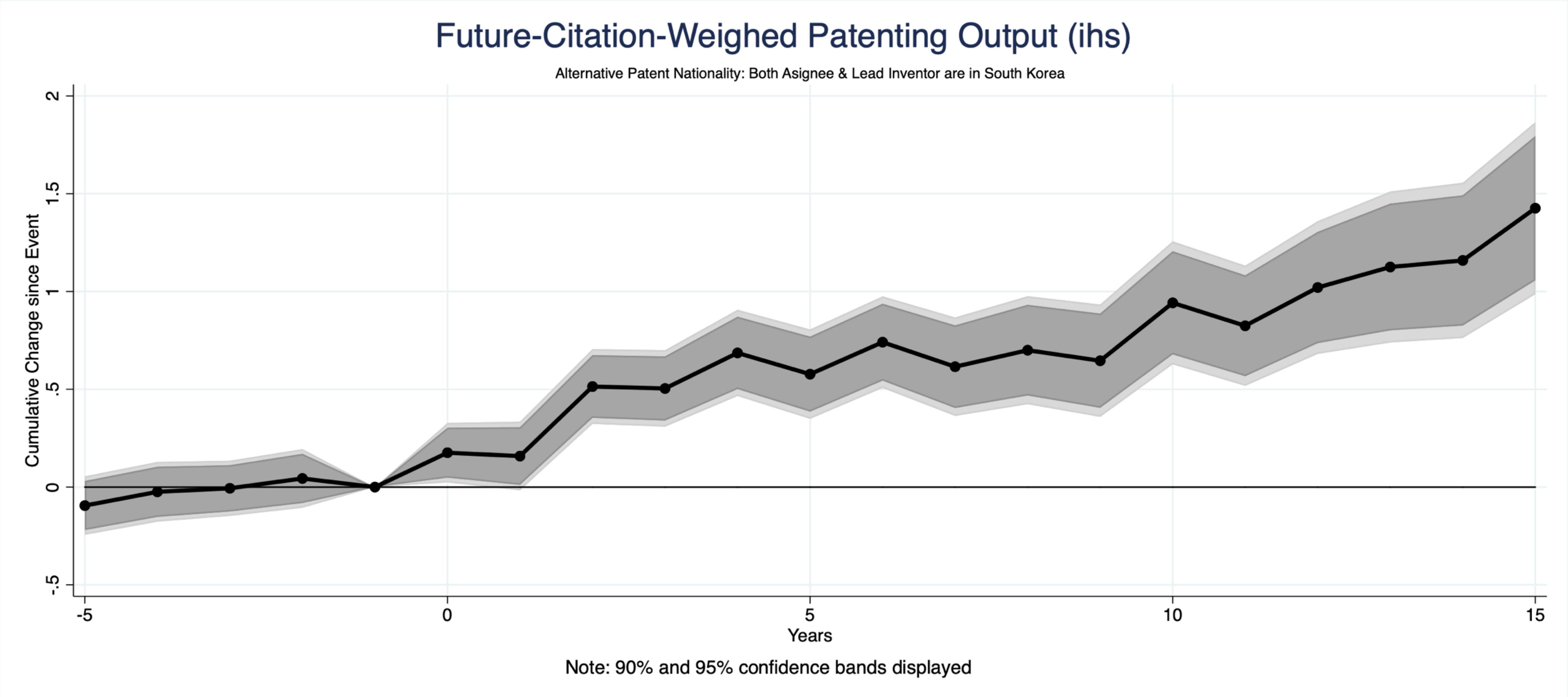
Conclusion

- The G7P shifted the direction in which the Korean economy innovated
    - Large, persistent impact on quality-weighed patenting output for targeted technological classes
    - Almost immediate effects
    - Larger effects in technological classes with *less* concentrated scientific production
- This shift had a relevant impact on the real economy
    - Large, long-lasting impact on exports for targeted technological classes
    - Effects took some time to materialize
- Highly cost-effective intervention
    - Benefits ~ 3.3x costs
    - ~ 21% IRR

감사합니다!

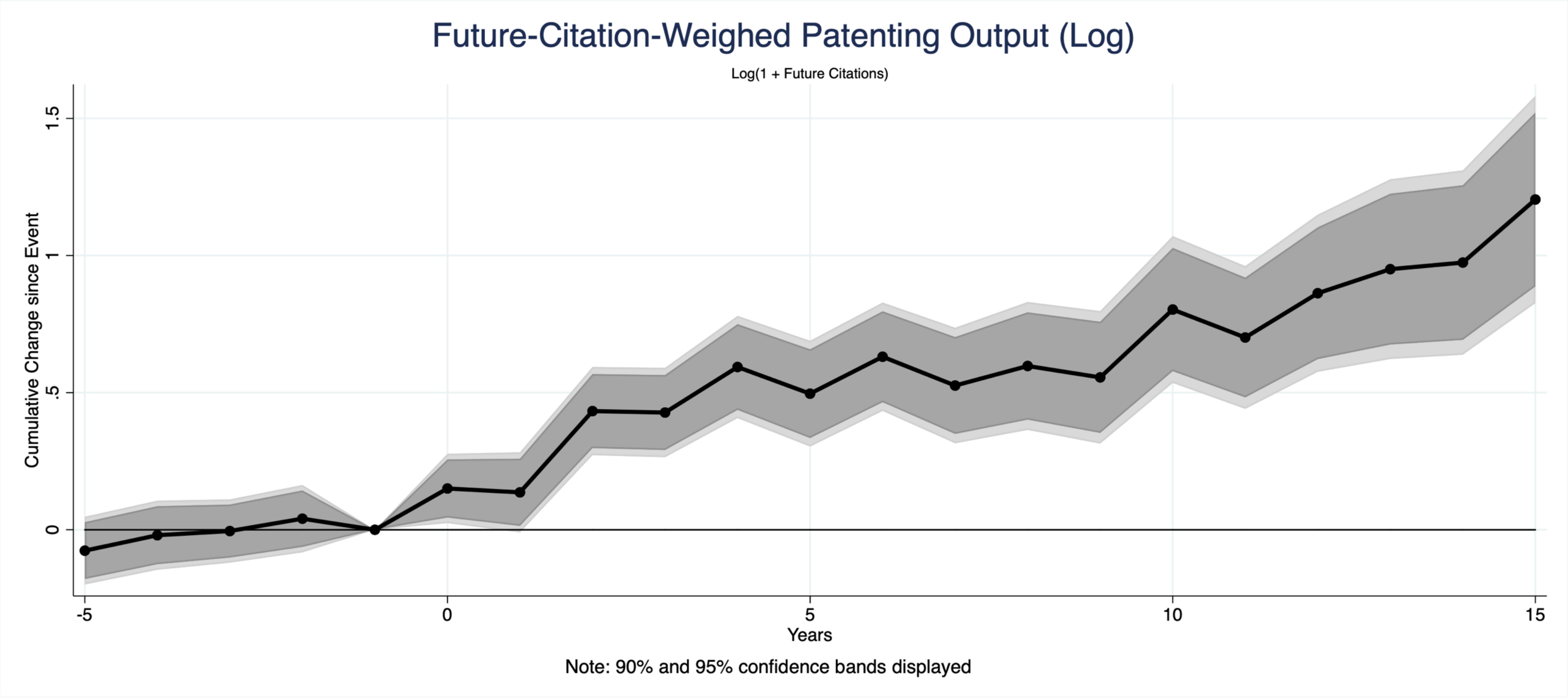
(Thank you!)

Robustness Checks



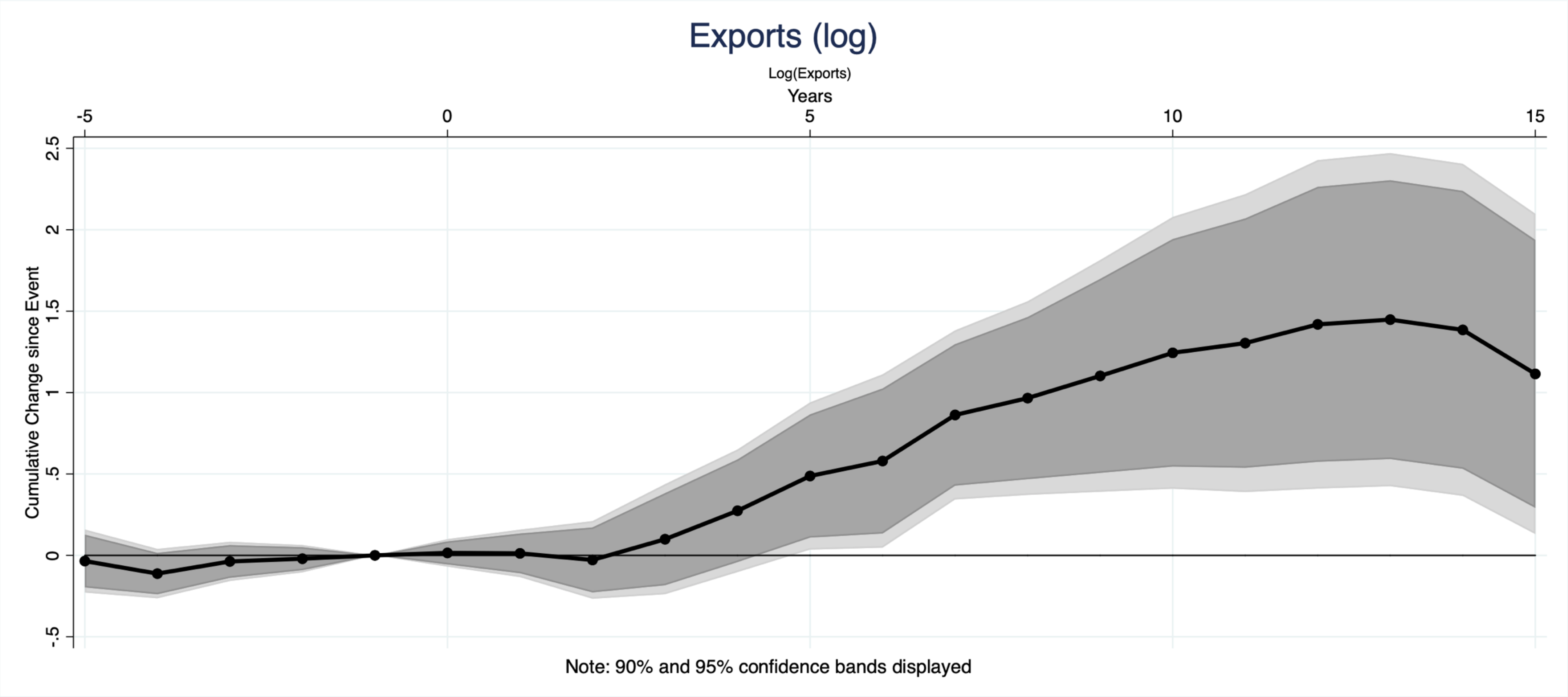
Return

Robustness Checks



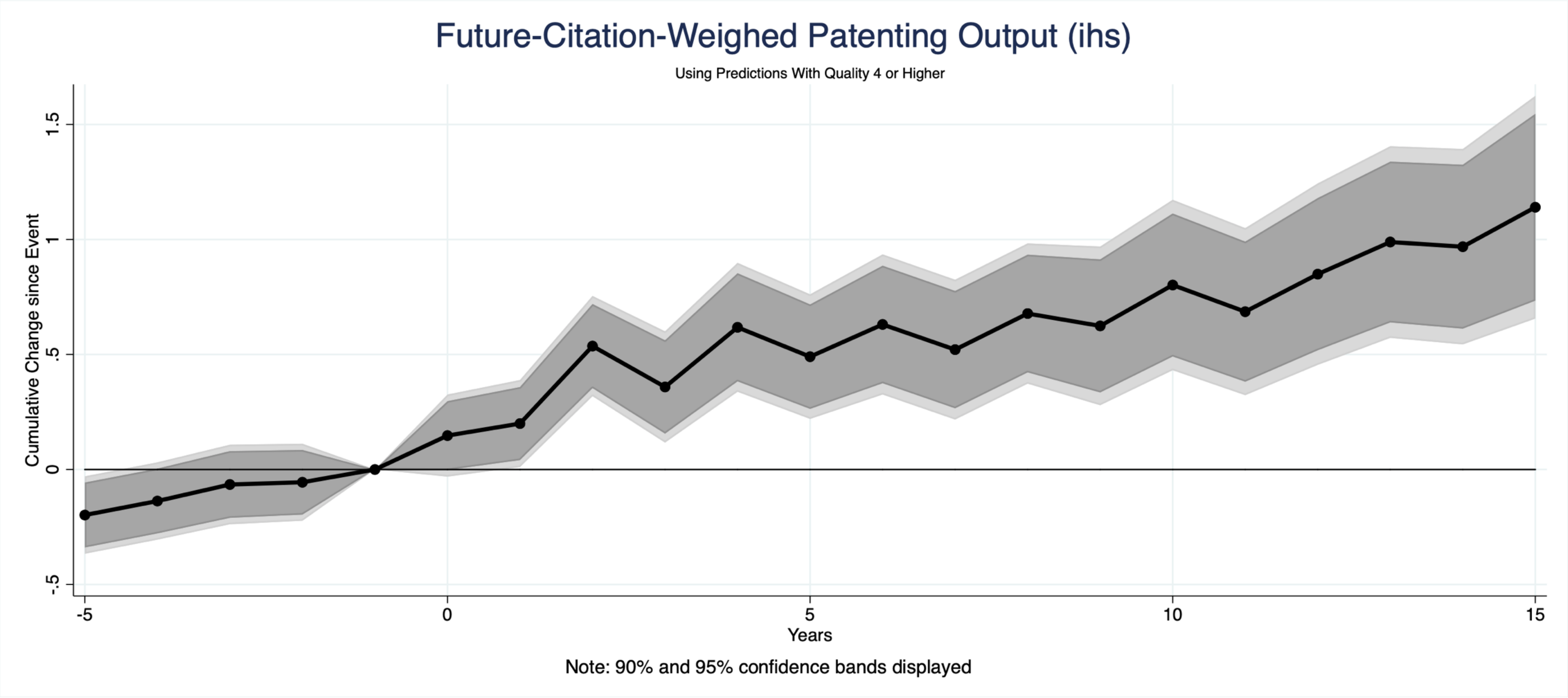
Return

Robustness Checks



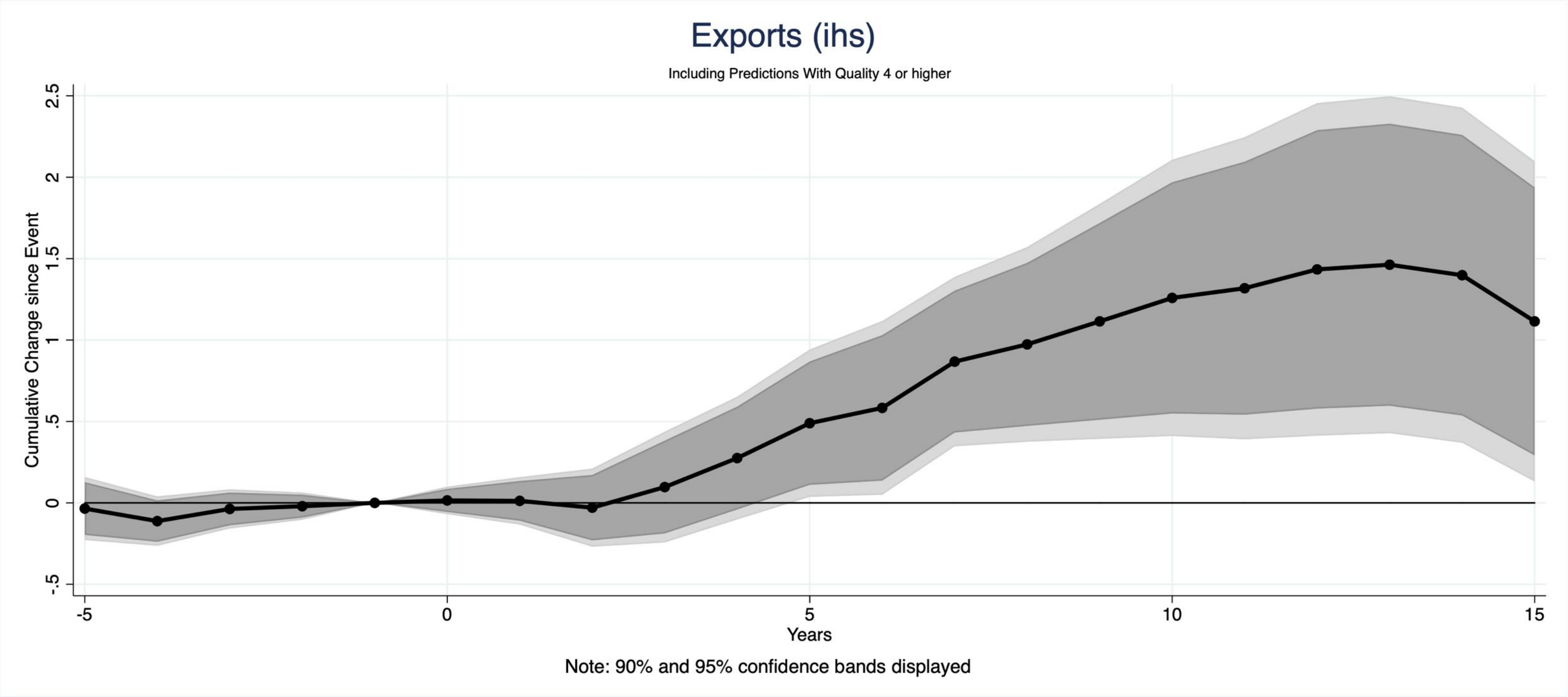
Return

Robustness Checks



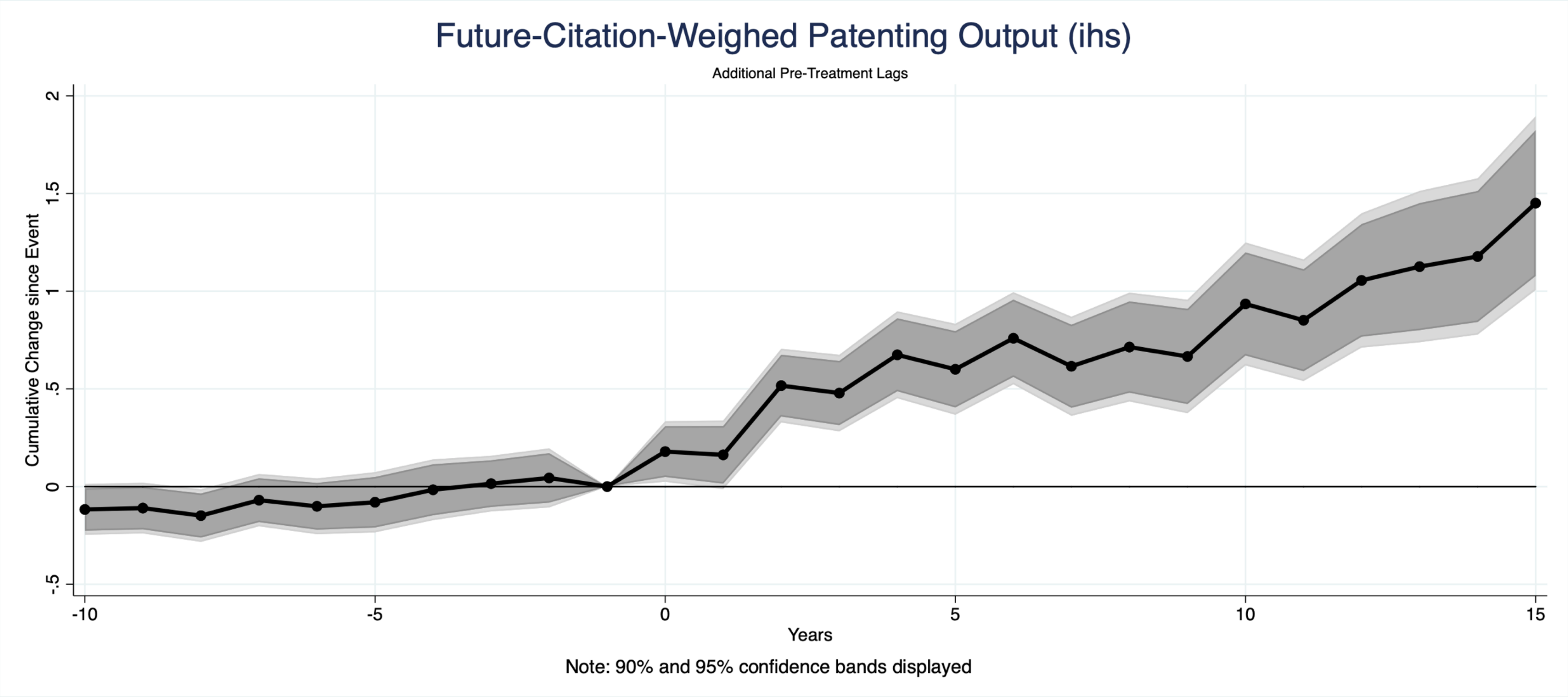
Return

Robustness Checks



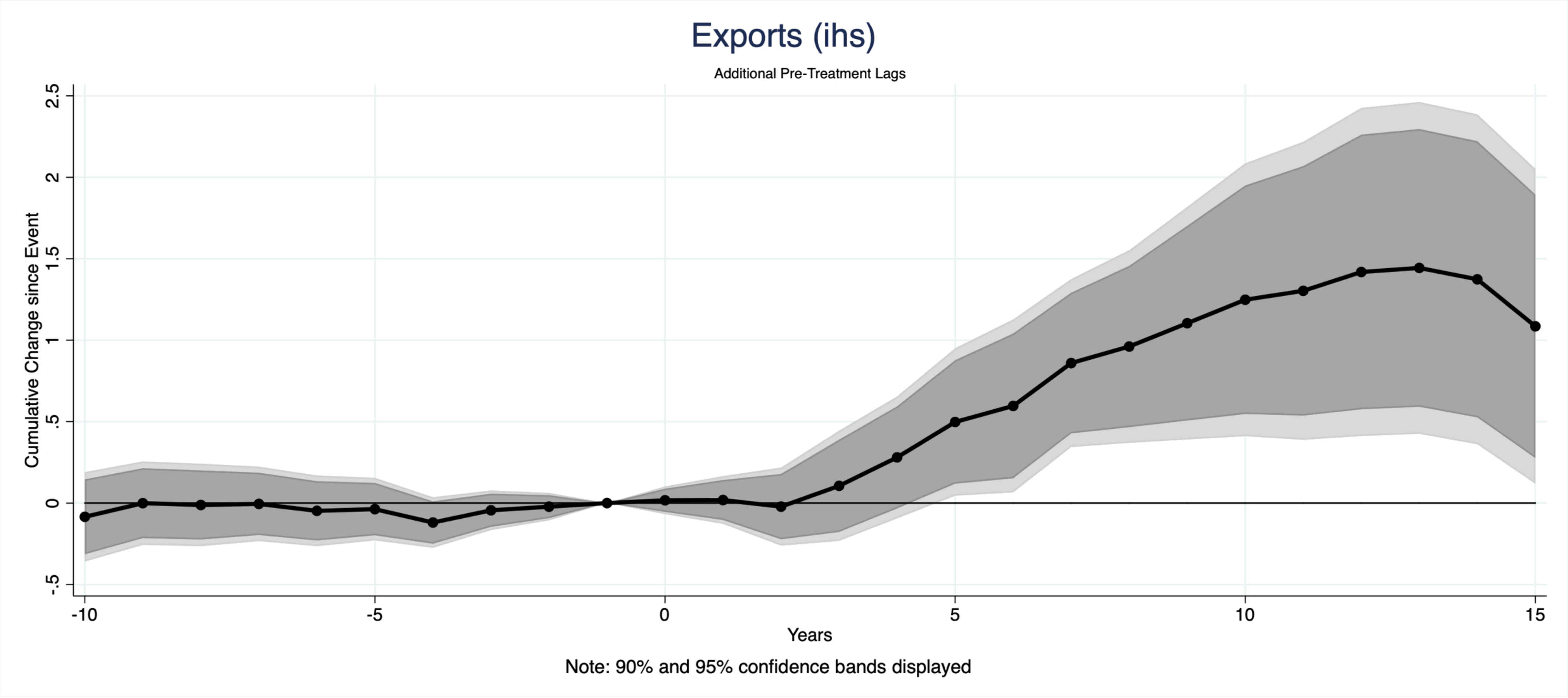
Return

Robustness Checks



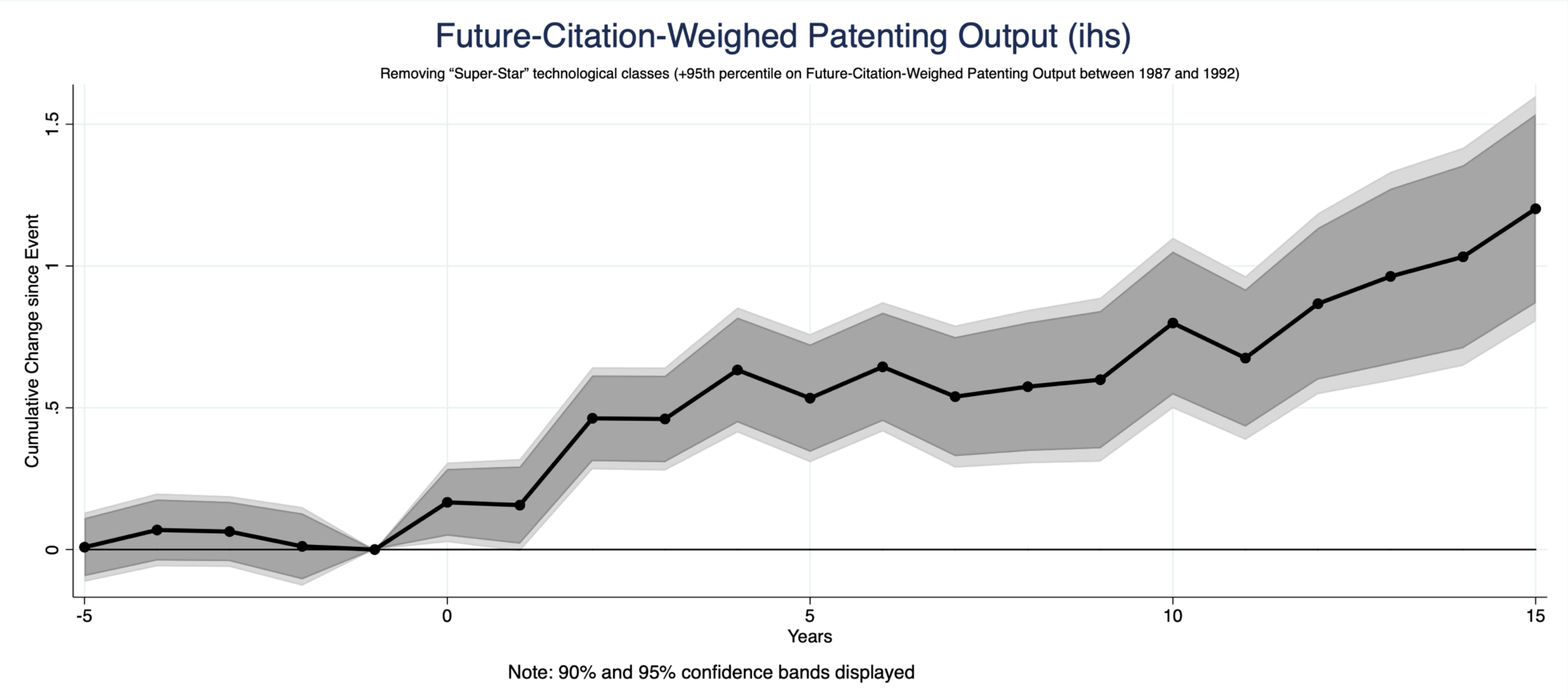
Return

Robustness Checks



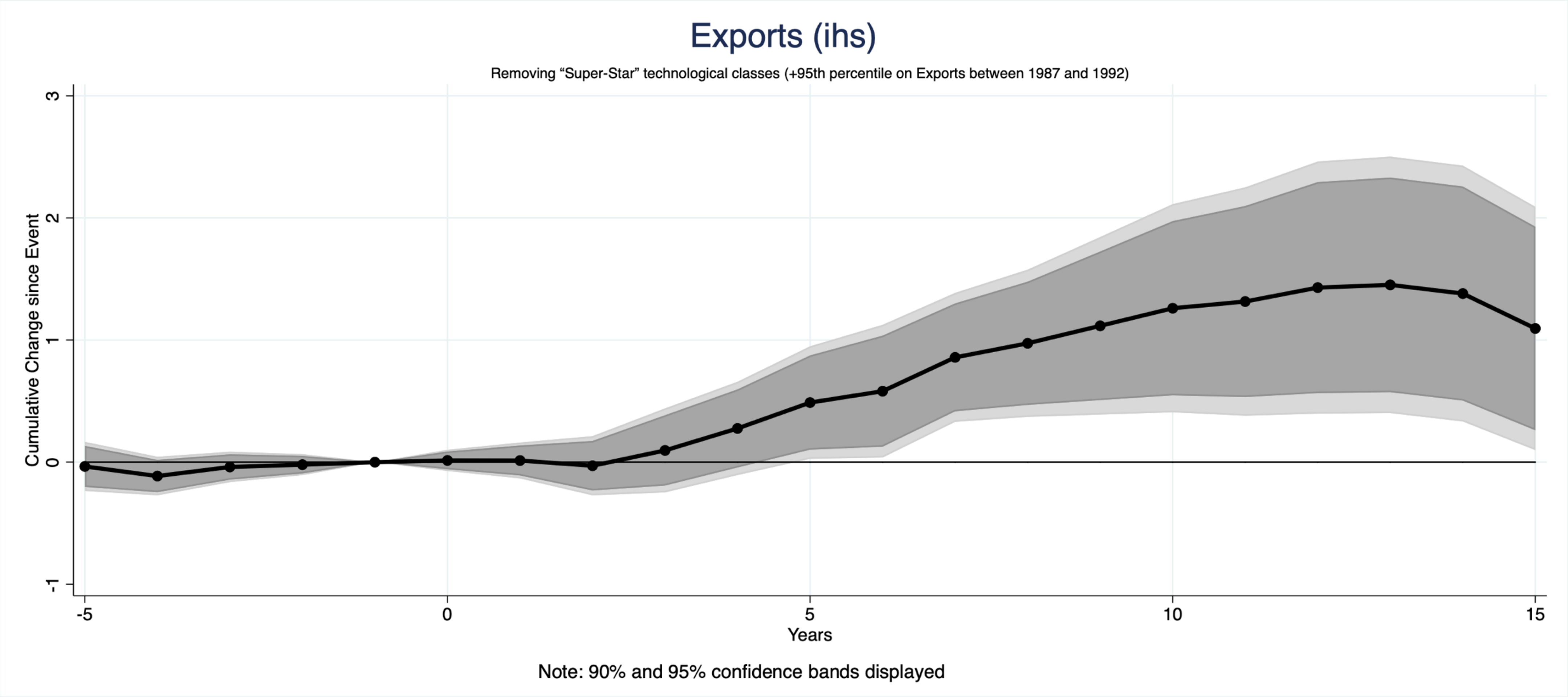
Return

Robustness Checks



Return

Robustness Checks



Return