



**GREEN INNOVATION AND DIFFUSION:
POLICIES TO ACCELERATE THEM AND EXPECTED
IMPACT ON MACROECONOMIC AND FIRM-LEVEL
PERFORMANCE**

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Motivation and questions

Green innovation:

- A key ingredient in the fight against climate change and its adverse consequences for economic and financial stability.
- Potential to buffer the possible direct adverse impact of climate policies on economic activity.

Question 1:
What is the impact of
green innovation on
economic activity?

Question 2:
Which climate
policies stimulate
green innovation?

Question 3:
Do climate policies
stimulate deployment
of green technologies
through trade and
FDI?

Question 4:
What are the cross-
border spillovers of
climate policies?

Main findings I

Green innovation has a positive impact on economic activity, buffering the potential adverse impact of climate policies

- Innovation, as measured by patents, yields **higher GDP levels** over the medium-term; mitigating the potential costs of compliance with climate policies.
- The economic impact of green innovation is **comparable to that of nongreen** and to the one seen in previous technological breakthroughs (ICT).
- The impact of low-carbon technology (LCT) patents on GDP works **through investment**; productivity gains may appear at longer horizons, as production processes become greener.

Domestic and international climate policies incentivize green patenting

- Climate policies have a positive impact on **both green and overall patent filings**—not just a substitution from carbon-intensive to green technology—amplifying economic benefits.
- Regulatory, emission trading systems (ETS) that limit the quantity of emissions, and expenditure measures (R&D subsidies and FITs), are effective in stimulating green innovation.
- International climate policy agreements and **global climate policies have a large effect** on domestic green patent filings, highlighting importance of policy certainty, global market size and spillovers for innovation.

Main findings II

Climate policies are also key to increasing the deployment of LCTs through trade and FDI, and should be complemented by efforts to reduce trade barriers

- **Climate policies** cause a rise in LCT imports and higher levels of green FDI inflows
 - ▶ The effect is stronger for green FDI into EMDEs, and climate policies do not appear to have an adverse impact on total FDI.
- **Lowering LCT tariffs** also raises LCT trade and green FDI inflows—important for EMDEs, who have higher tariffs, and highlights the potential adverse impact of protectionism on LCT deployment.

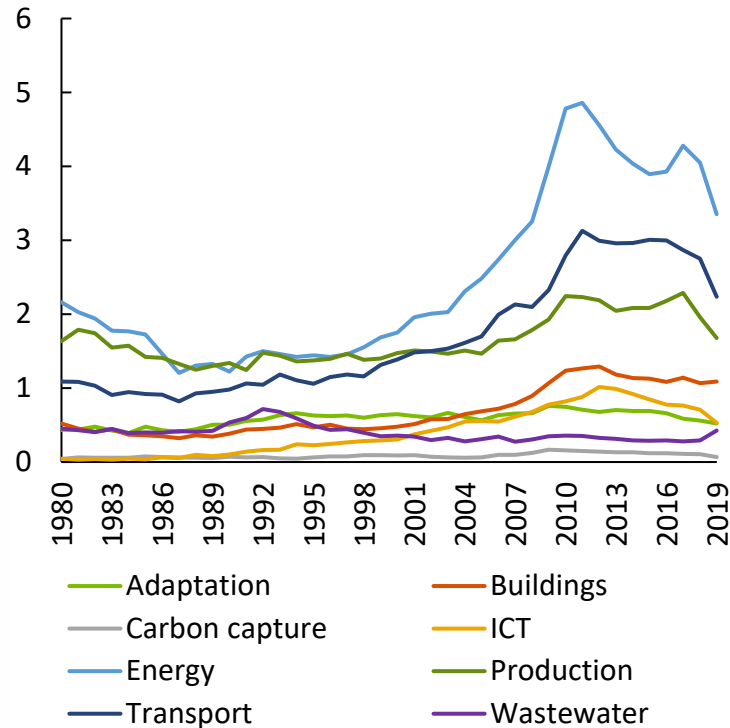
The positive effects of innovation are enhanced by international coordination and cooperation

- Climate policies in AEs stimulate global deployment through LCT trade and green FDI; but some policies, notably **subsidies**, can **hamper green FDI outflows**.
 - ▶ Potential tension between domestic and international climate objectives
- Thus, AEs need to **weigh their potential negative spillovers**, especially for EMDEs with lower fiscal space, to avoid a race-to-the-bottom, and ensure consistency of their policies with international rules.

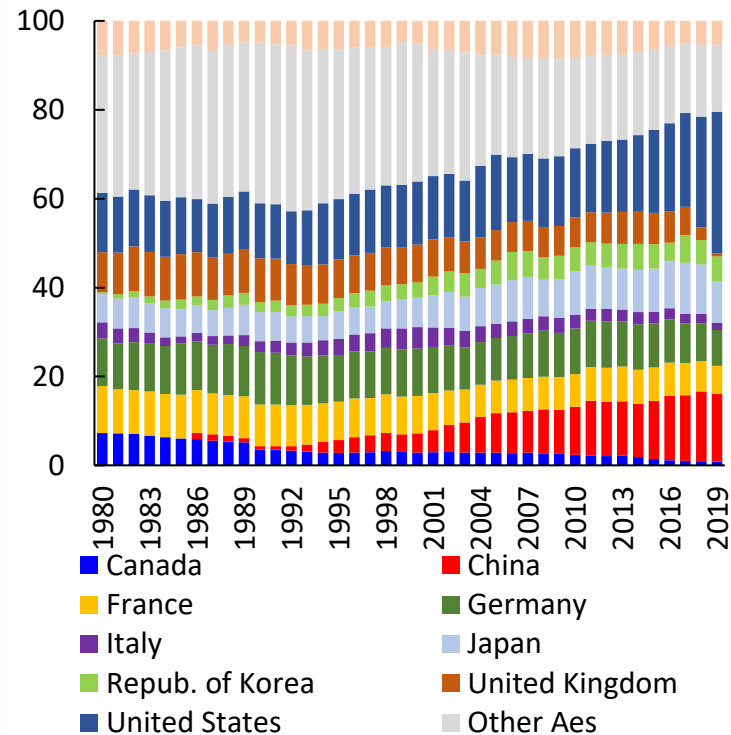
Innovation in LCTs: Recent Trends and Economic Impact

After increasing for over 30 years, green patent filings hit a plateau in recent years.

Green Patent Filings by Subcategory as Share of Total Filings
(unique patent filings, thousands)



Breakdown by Country
(percent)



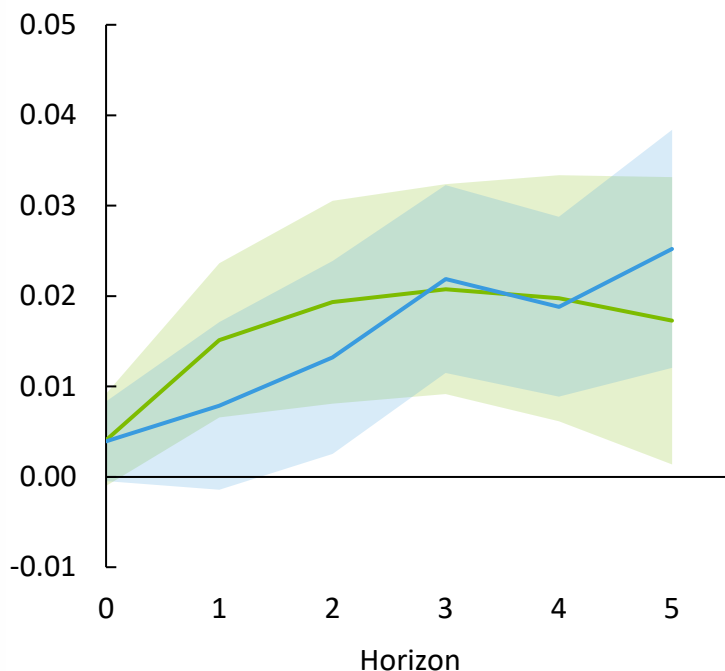
- Most important sectors are energy, transport, and production
- Since the 2000s, emerging markets have been gaining momentum in green patent filings
- The slowdown is related to the rise of hydraulic fracking that has lowered oil prices and to technological maturity for some technologies.

Source: : PATSTAT, Hasna and others (forthcoming).

Note: Green patents are related to climate change mitigating technologies, covering technologies to (1) control, reduce or prevent GHG emissions, or (2) help with adaption. To control for patent quality, the analysis uses granted patents filed in at least two countries.

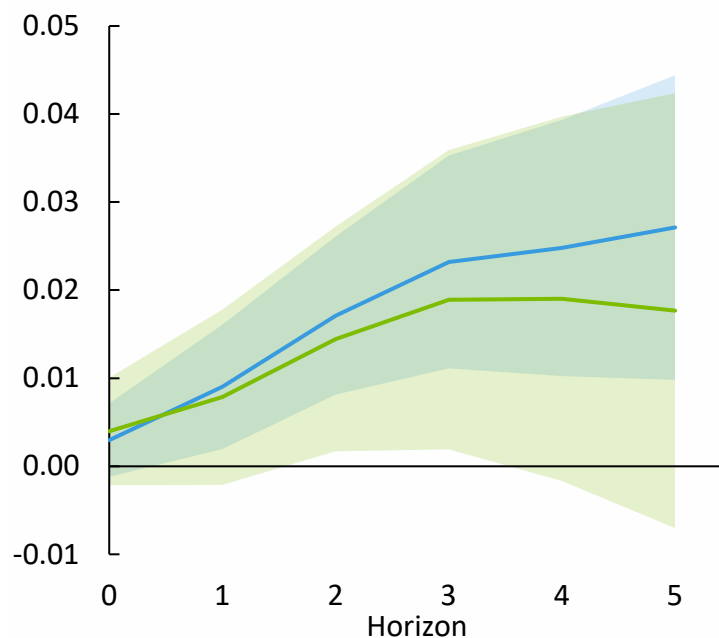
As with past breakthroughs, green patents have a positive impact on GDP (comparable to nongreen patents), which works through higher investment

Impact of Patents on Real GDP (percent)



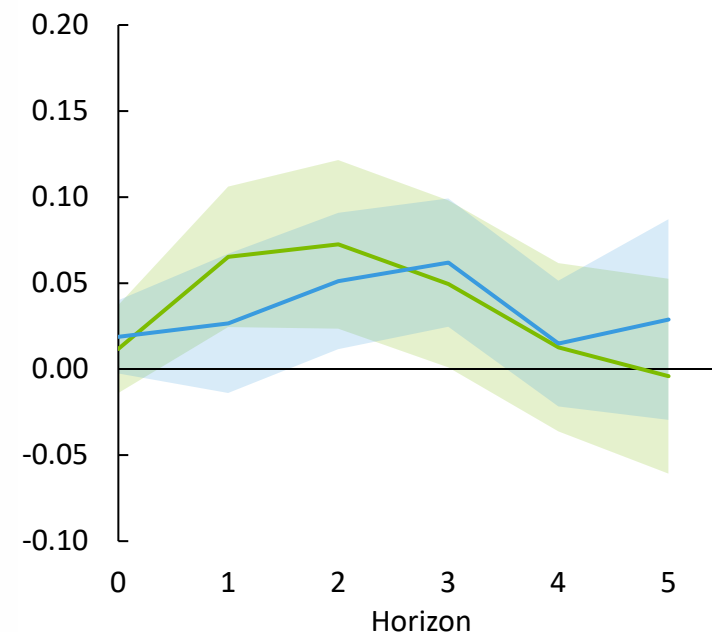
- 90% CI, green
- 90% CI, nongreen
- Effect of Green Patent Filings
- Effect of Nongreen Patent Filings

Impact of ICT Patents on Real GDP (percent)



- Average effect on GDP excluding ICT revolution
- Total effect on GDP including ICT revolution

Impact of Patents on Real Investment (percent)



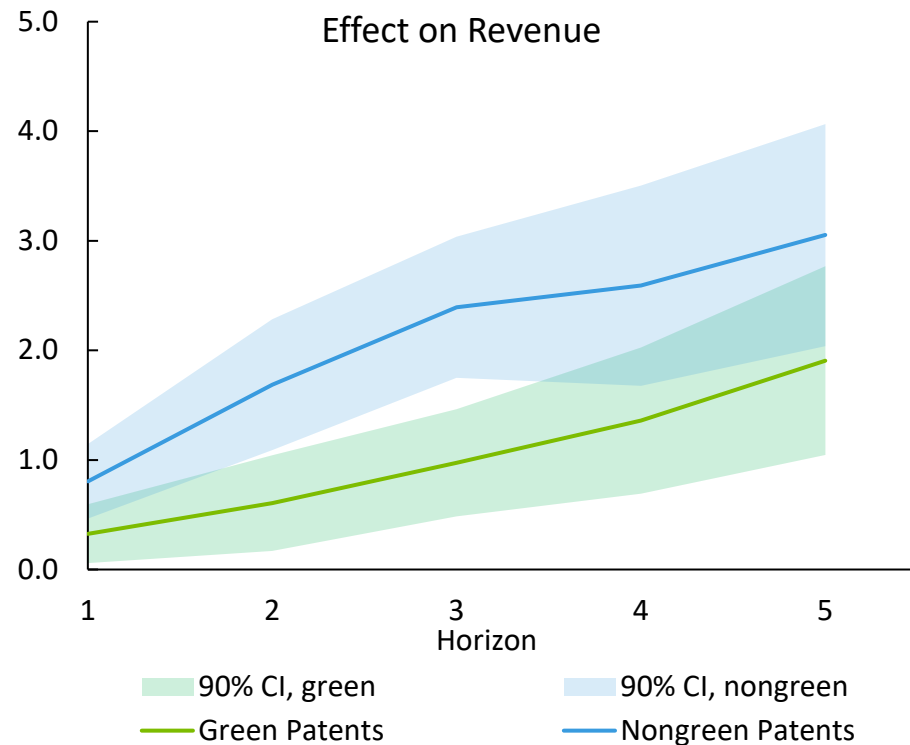
- 90% CI, green
- 90% CI, nongreen
- Effect of Green Patent Filings
- Effect of Nongreen Patent Filings

Source: PATSTAT and Hasna and others (forthcoming).

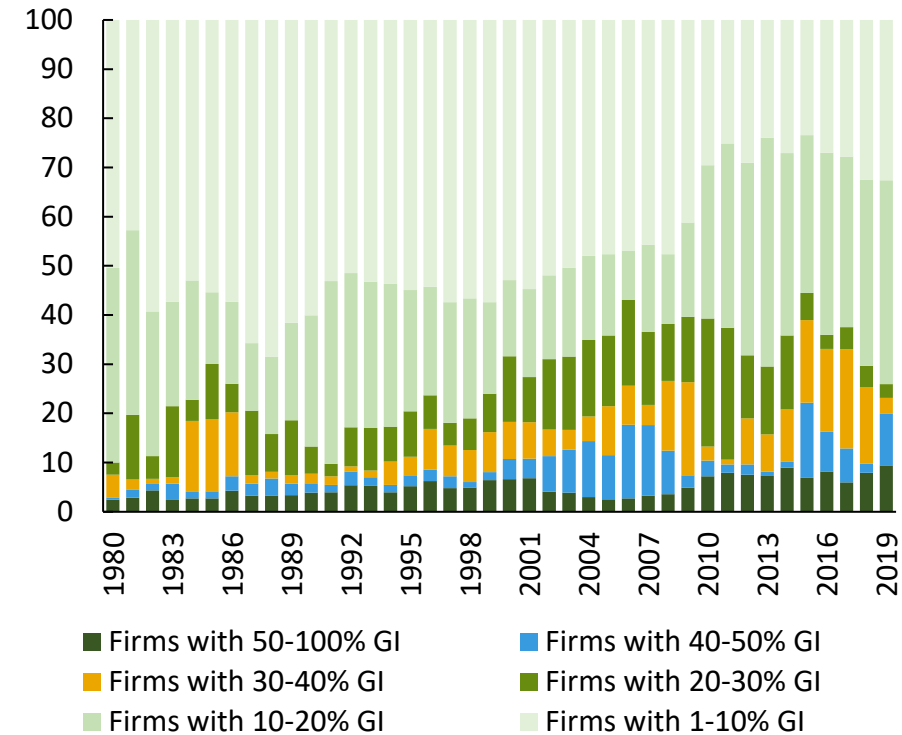
Note: The analysis focuses on OECD and BRICS countries between 1990 and 2019 due to data availability. CI=Confidence Interval

Green patents boost firm revenue, but less so than nongreen ones, reflecting production systems' reliance on nongreen technologies

Impact of Green and Nongreen Patents on Firm Revenue of US Publicly Listed Firms (percent)



Firm-level Heterogeneity: Breakdown of US Publicly Listed Firms along Green Intensity



Source: Compustat, USPTO, and Ferrerira and others (forthcoming).

Note: GI=green intensity, defined as share of green patent filings in total patent filings. CI=Confidence Interval

Measuring Policies

Measuring climate policies

- Main data source: **Climate Policy Database**—policy count variable with comprehensive coverage across measures, sectors, countries (including EMDEs)
- Complemented by **OECD Environmental Stringency Index (EPS)**—better captures intensity of policies but for small set of countries and policies.
- Three types of measures:

Generating government revenues:

- Carbon taxes and other taxes/fees
- Emission trading schemes

Generating government expenses

- Subsidies (feed-in tariffs, R&D)
- Other (e.g., loan programs)

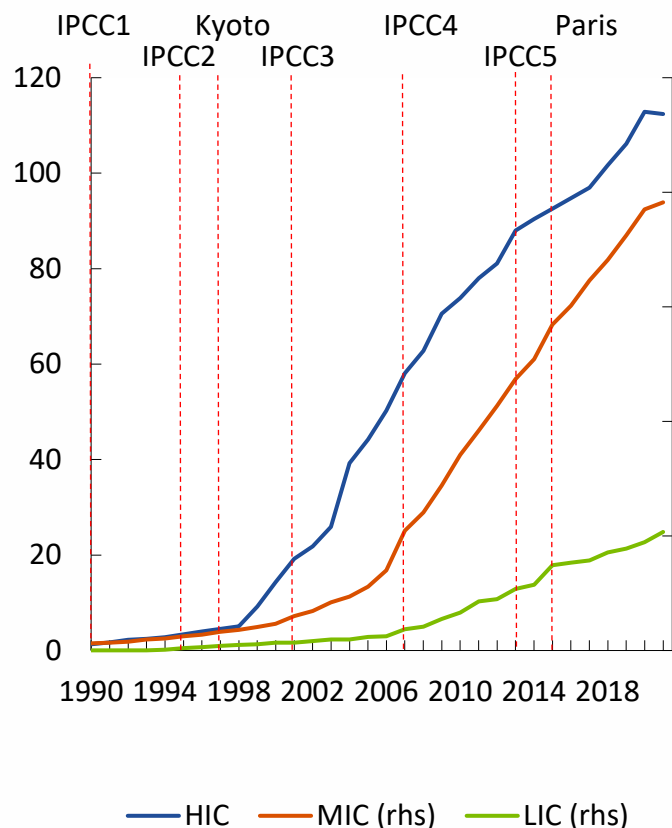
Budget neutral

- Regulations
- Other less binding (e.g., government strategy documents and voluntary emission reduction targets)

Countries have introduced new climate policies to face the challenges of climate change; LCT goods still face high tariffs in some countries

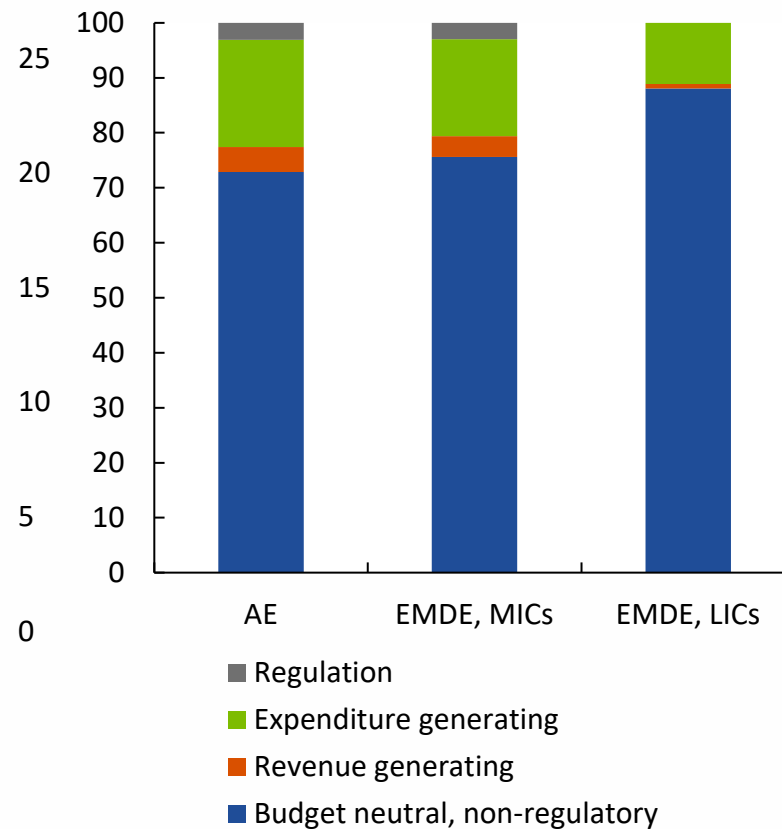
Evolution of Climate Policies by Income Group

(average number of policies)



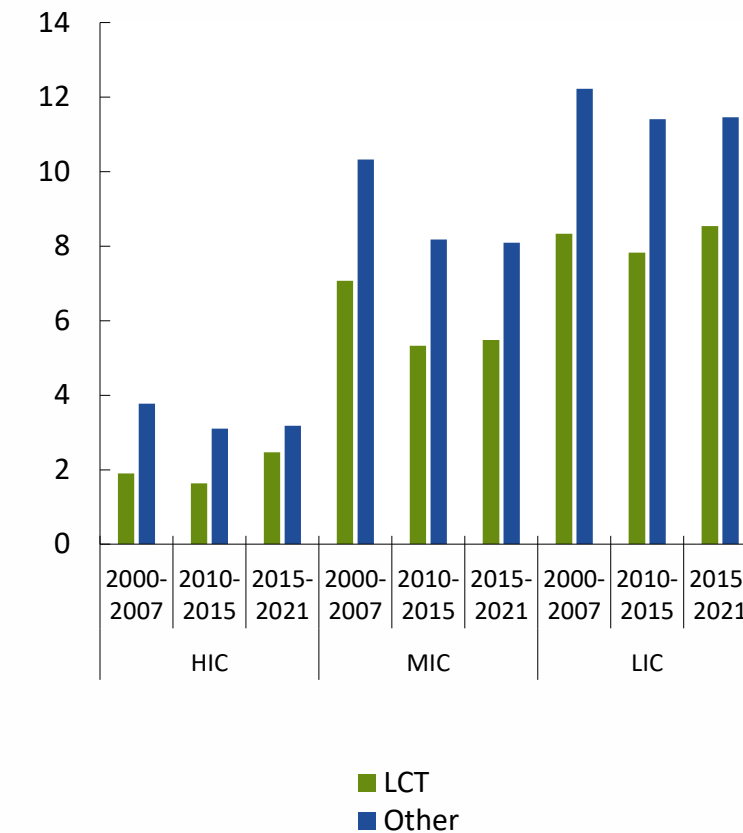
Heterogeneity Across Income Groups, by Policy Instrument

(percent)



Applied Tariffs Across Income Groups

(percent)

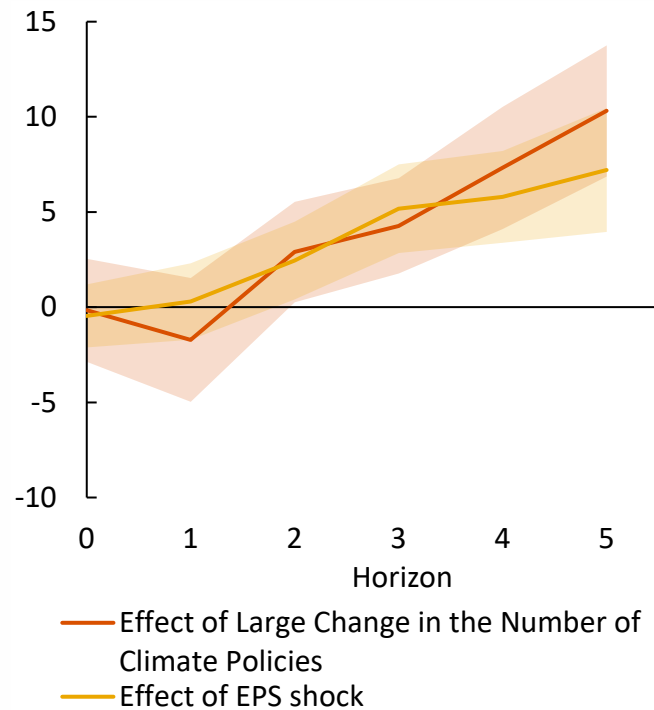


Source: Climate Policy Database, IMF's climate policy dashboard; UNCTAD's TRAINS database; and IMF staff calculations.

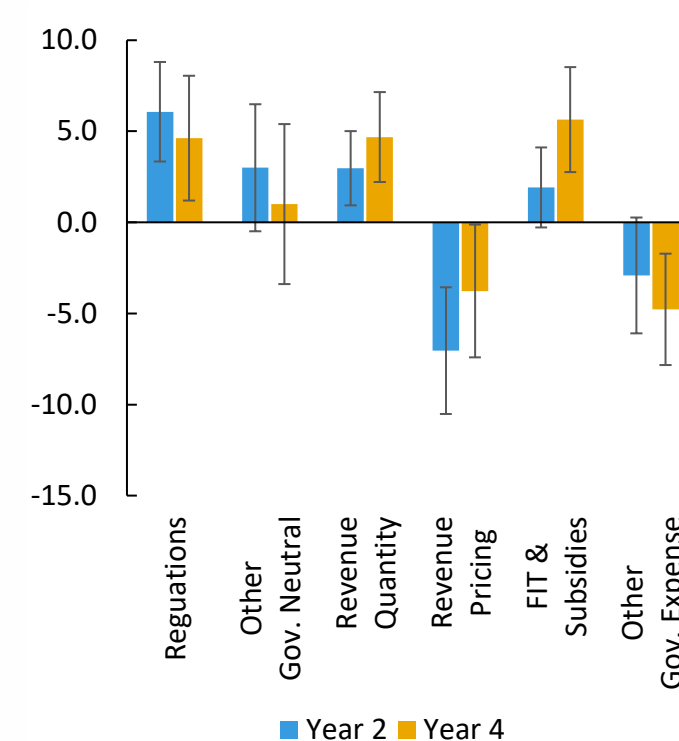
Climate Policies and Patent Filings

Adoption of climate policies boosts green patent filings and overall innovation

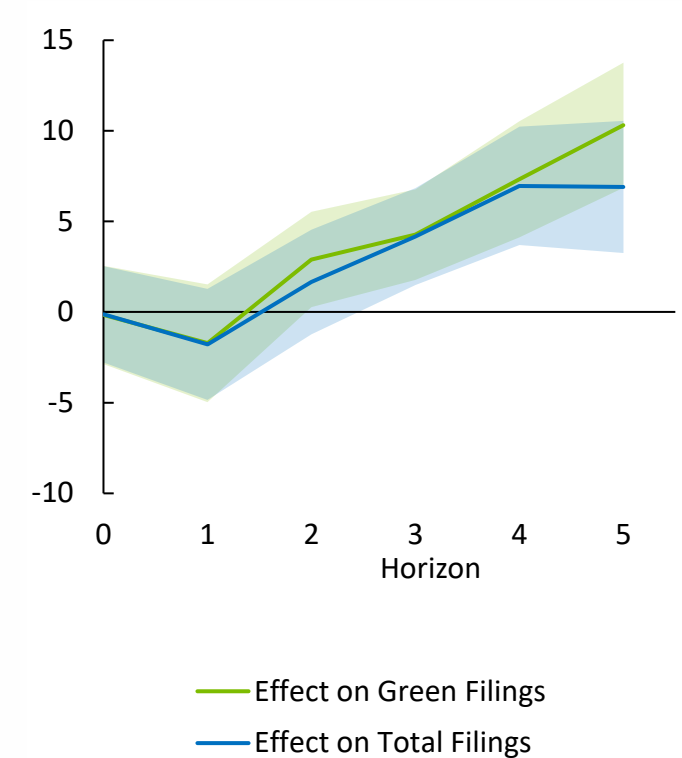
Impact of Climate Policies on Green Patent Filings (percent)



Impact of Different Climate Policies on Green Patent Filings (percent)



Impact of Climate Policies on Green and Overall Patent Filings (percent)



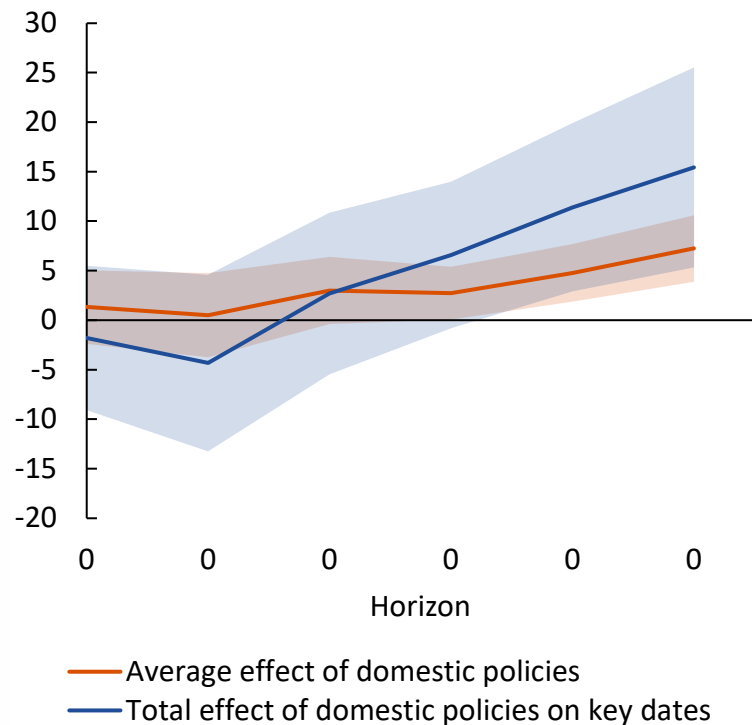
Source : PATSTAT, Climate Policy Database, and Hasna and others (forthcoming).

Note: Sample of OECD and BRICS countries; 1990-2019 period due to data availability. Shocks are one standard deviation. Shaded areas/whiskers are 90 percent confidence intervals.

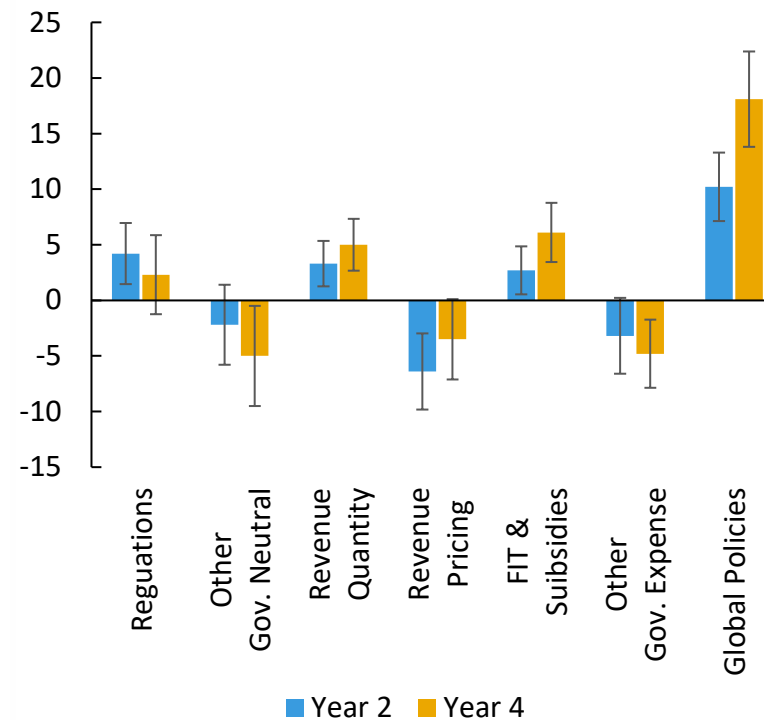
- Regulations, policies restricting emission quantities, and FITs/subsidies, boost green patents

Global policies have a significant impact on green patent filings and key climate policy landmarks boost the impact of domestic policies

Impact of key climate events on green patent filings (percent)



Impact of domestic and global climate policies on local green patent filings (effects after 4 years, percent)



- The higher impact of domestic policies around key climate policy landmarks reflects the importance of policy certainty
- Global policies have a larger effect than domestic policies, pointing to the key role of market size and technological spillovers for innovation.

Source: : PATSTAT, Climate Policy Database, and Hasna and others (forthcoming).

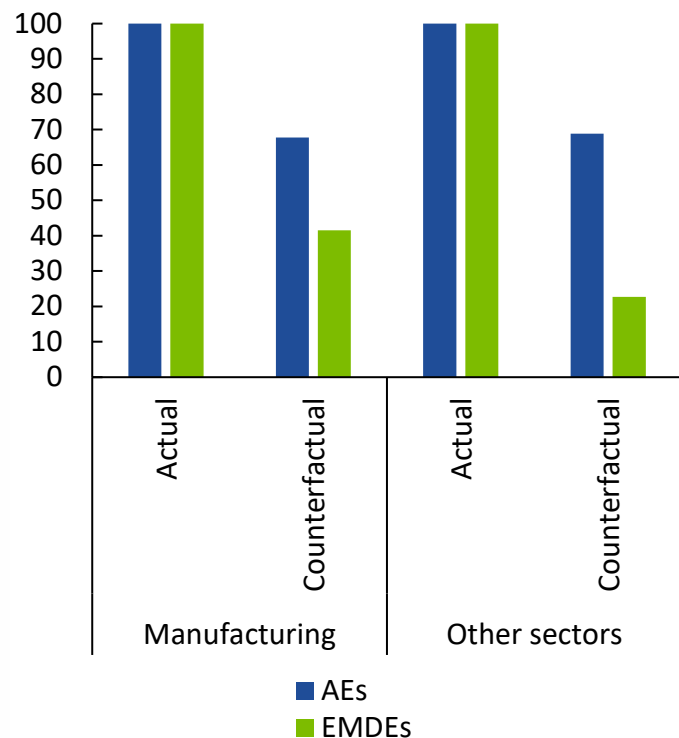
Note: Sample of OECD and BRICS countries for the 1990-2019 period due to data availability. Shaded areas/whiskers are 90 percent confidence intervals.

Impact of Climate Policies on the Deployment of LCTs Through Trade and FDI

Deployment of LCTs is crucial to close EMDEs' emissions gaps; positive signs of deployment through LCT trade and green FDI

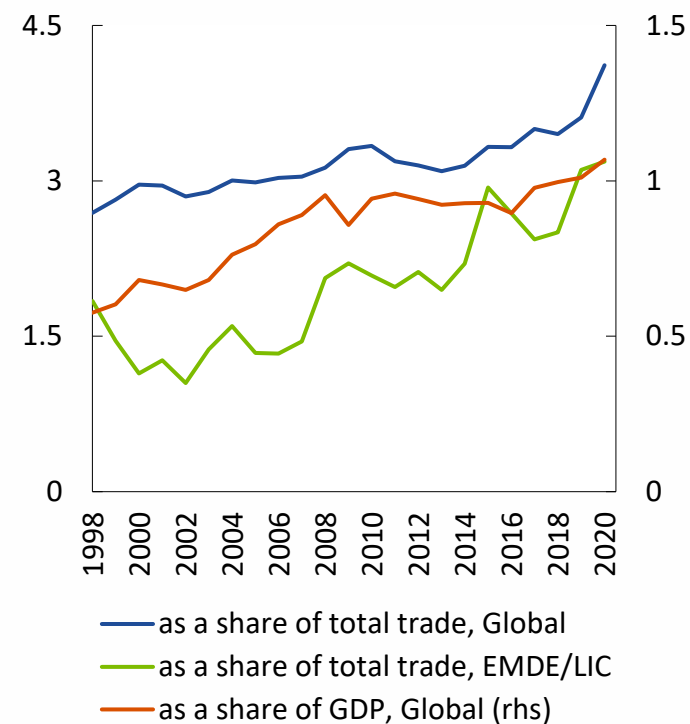
Emission counterfactuals for AEs and EMDEs

(percentage of actual emissions)



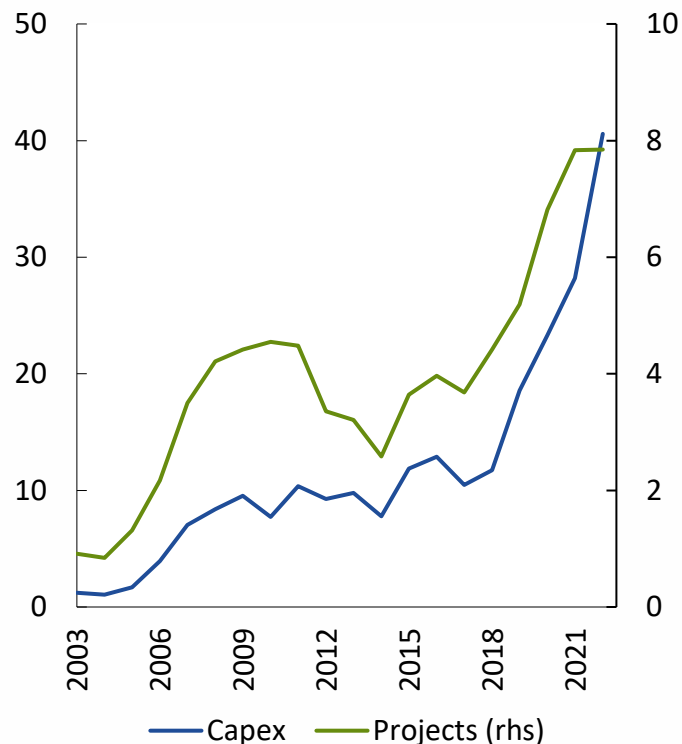
Evolution of LCT trade; global and LICs

(percent)



Evolution of global green FDI flows and projects

(percent of total)

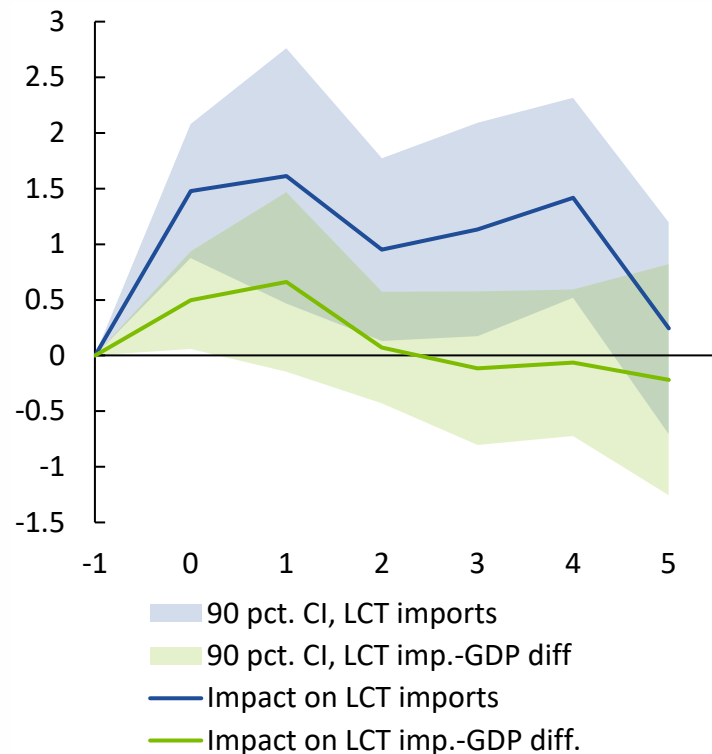


Source: Capelle and others, 2023; IMF's Climate Dashboard; World Bank, World Development Indicators; and IMF staff calculations.

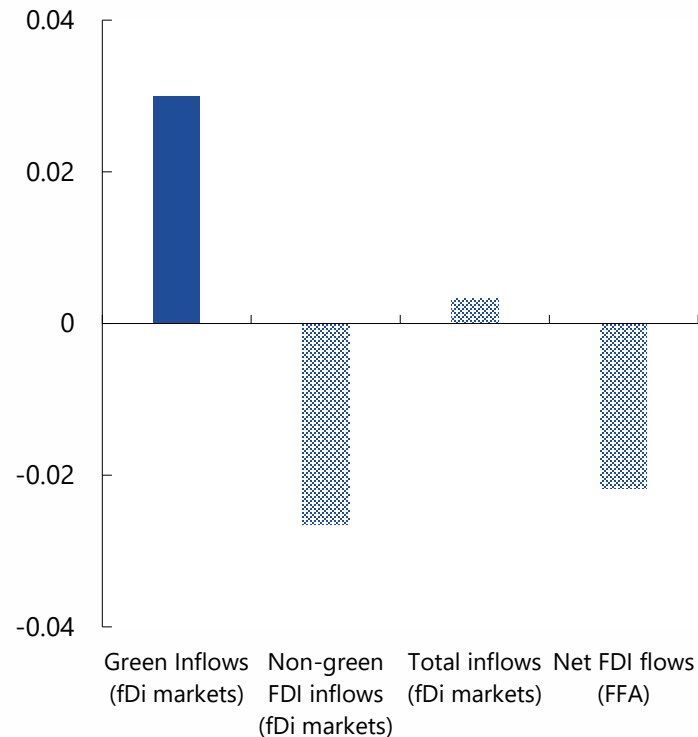
Note: AE=Advanced Economies; EMDE, LIC = Emerging markets and developing economies, low income. AEs and EMDEs are classified according to the IMF income classification. Low-income classification follows the World Bank's classification. In LHS, counterfactuals constructed assuming firms with emission intensities above the AE median firm emission intensities reach the level of the median AE firm, keeping their production constant.

Climate policies accelerate the deployment of LCT technologies through trade and FDI inflows

The Dynamic Impact of Climate Policies on LCT Imports and the LCT Import-to-GDP Ratio
(percent)



Impact of Climate Policies on Green and Aggregate FDI inflows
(percent of GDP)

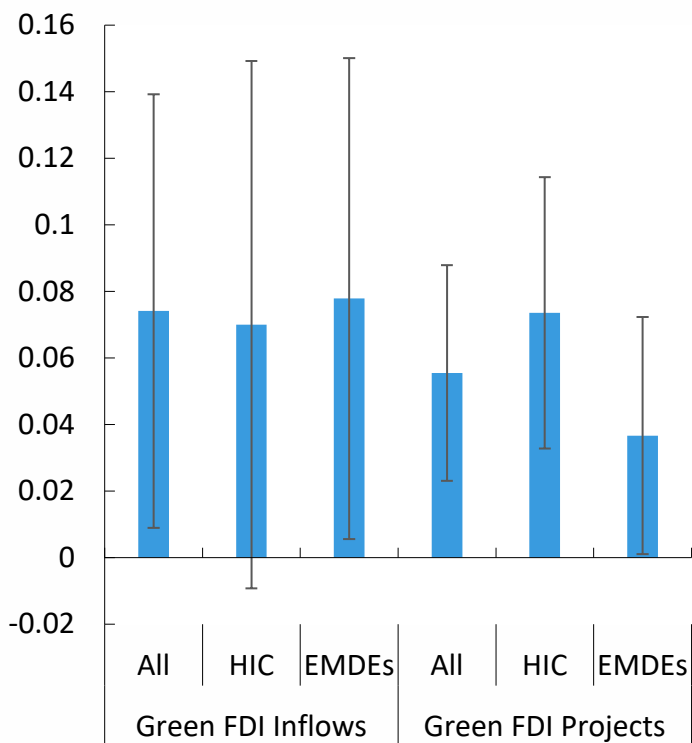


- Climate policies are associated with higher LCT imports
- Climate policies also incentivize green FDI inflows, with no robust adverse impact on overall FDI
- FDI into some sectors may be adversely affected though

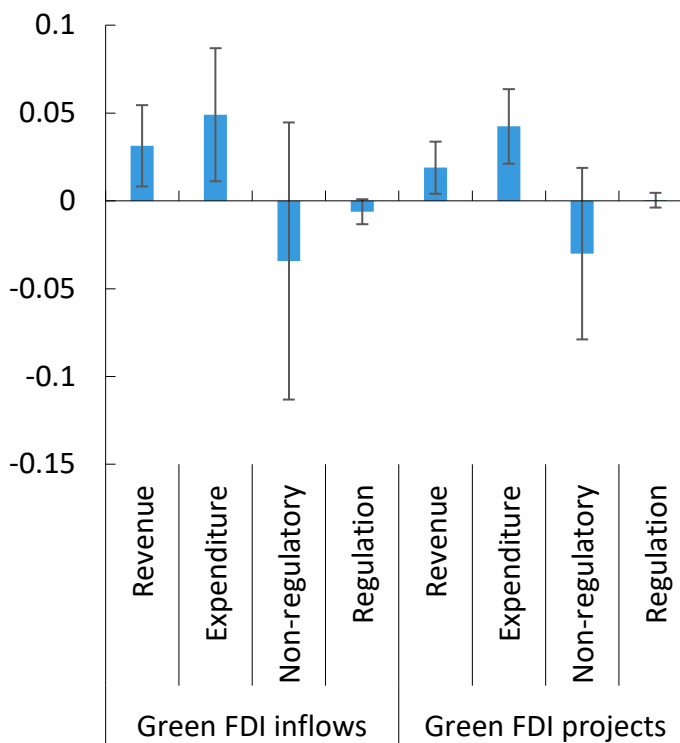
Source: Climate Policy Database, Financial Time's fDi markets database, IMF's climate policy dashboard; UNCTAD's TRAINS database; and IMF staff calculations
Note: Estimation from a global sample. CI=confidence interval. RHS: Solid bars are significant at the 90 percent CI; otherwise not significant.

Impact of climate policies on green FDI is stronger for EMDEs and revenue and expenditure measures are effective to promote green FDI inflows

Impact of Climate Policies on Green FDI, by Income Group of the Destination Country
(bilateral flows, in real US dollars)



Impact of Climate Policies on FDI by Policy Instrument
(bilateral flows, in real US dollars)

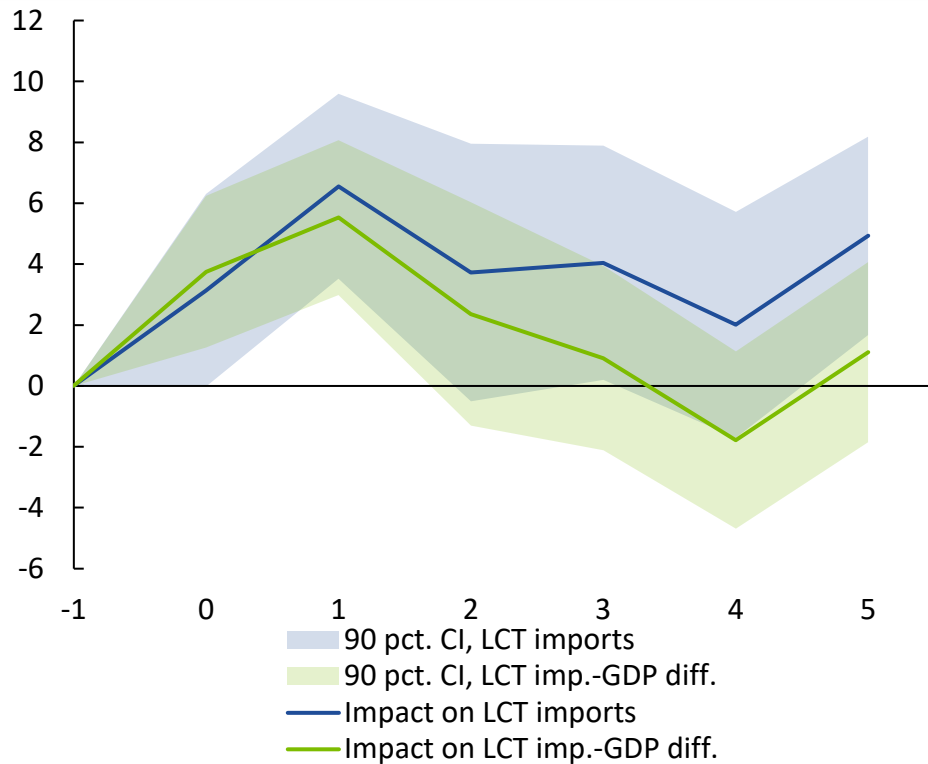


- Bilateral flows analysis shows that climate policies incentivize green FDI inflows, especially into EMDEs
- Revenue measures (taxes and emission trading schemes) and expenditure measures (subsidies/FITs) are effective in boosting green FDI inflows.

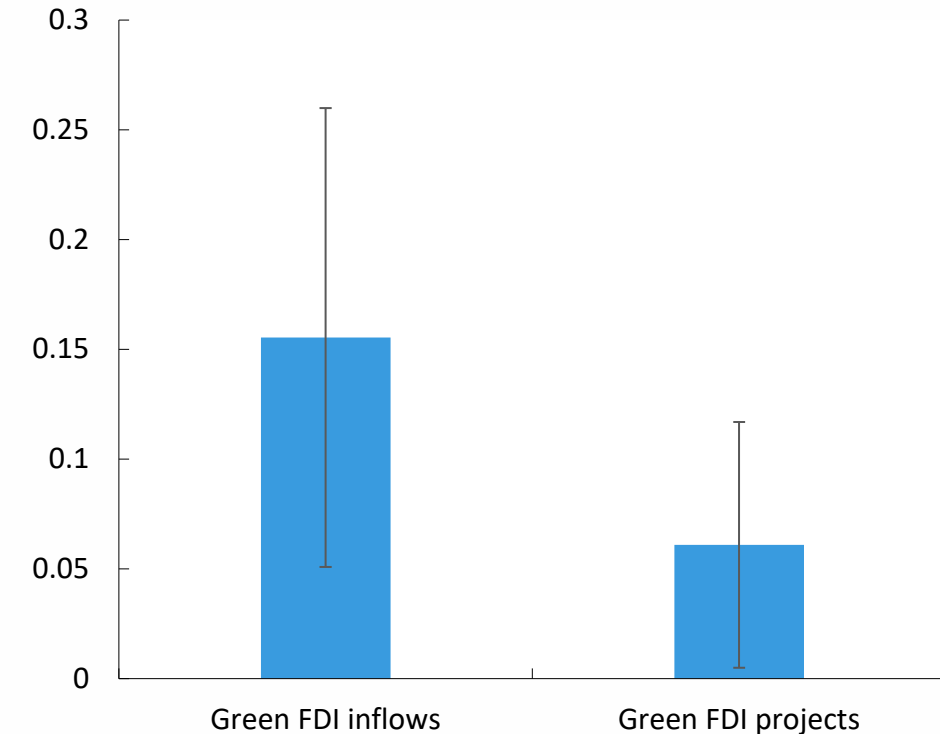
Source: Climate Policy Database, Financial Time's fDI markets database, IMF's climate policy dashboard; UNCTAD's TRAINS database; and IMF staff calculations
Note: Estimations from a global sample. Whiskers are 90 percent confidence intervals.

Lower tariffs on LCT goods can also accelerate both LCT imports and green FDI inflows

Impact of Lower LCT Tariffs on LCT Imports
(percent)



Impact of Lower LCT Tariffs on Bilateral Green FDI
(percent)

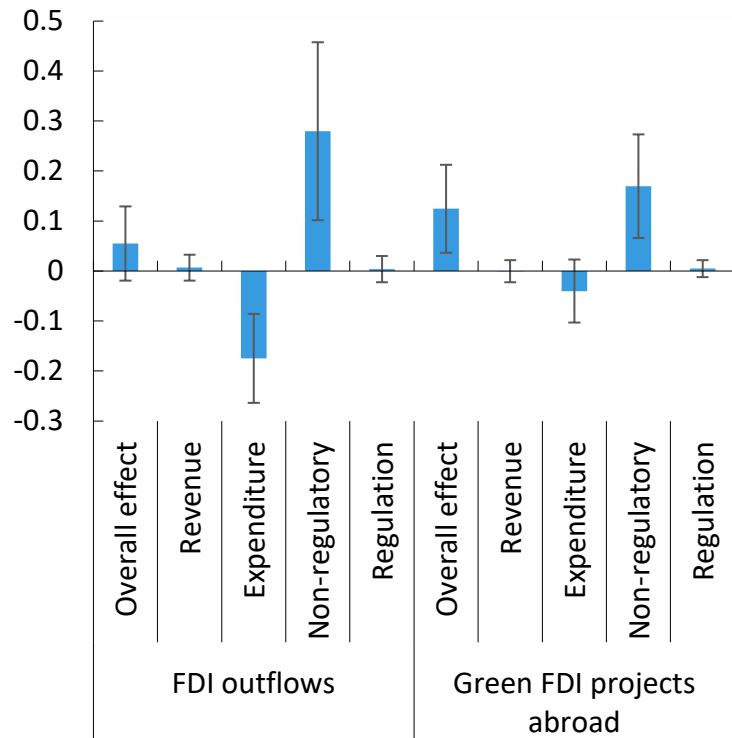


Source: Climate Policy Database, IMF's climate policy dashboard; UNCTAD's TRAINS database; and IMF staff calculations. Whiskers are 90 percent CI. CI=confidence interval.

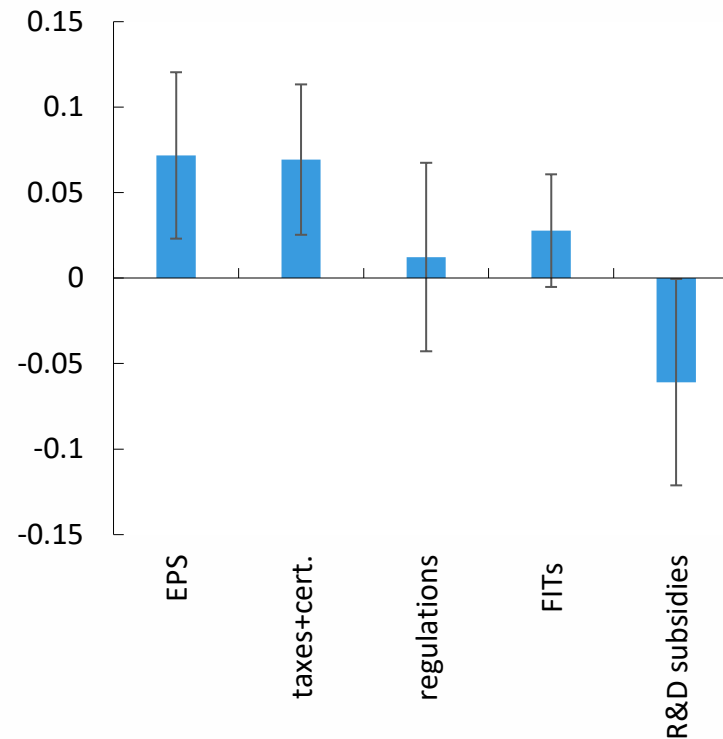
- There is scope for accelerating deployment to EMDEs, given high LCT tariffs
- More broadly, results point to risks of protectionism for LCT deployment

Climate policies have cross-border spillovers

Impact of Climate Policy Count on Green FDI Outflows
(percent)



Impact of EPS on FDI Outflows
(percent)



- Climate policies, broadly defined, boost the green FDI outflows of countries that implement them
- One exception is expenditure measures which reduce green FDI outflows in the short to medium run.

Source: CPD, Financial Time's fDi markets database, IMF's climate policy dashboard; UNCTAD's TRAINS database; and IMF staff calculations.

Note: Estimation on right hand-side panel based on a limited sample of source countries with available EPS data (mostly OECD). Whiskers are 90 percent confidence intervals.

Beyond trade and FDI, there is scope for direct technology transfers

There is a large potential for reducing the emission intensity in EMDEs through technology transfers

- Higher emission intensity in EMDEs; large emission reductions if high emission intensity firms in EMDEs close gap to 25th percentile of AE distribution (Capelle et al., 2023).
- Potentially large economic benefits for EMDEs if new capital vintages are subsidized.

Past experiences highlight the potential role for government-led technology transfers managed through IOs

- Two notable examples are the Montreal protocol and the “green revolution”
- Montreal protocol: AE funded technology transfer to EMDEs, administered by the World Bank.
- Green revolution: Critical role of CGIAR in transferring high-yielding varieties to EMDEs.
- Some initiatives are currently ongoing in the case of LCT technologies (CTCN; GCF; TEC).

Compensation to innovators is crucial

- Government-sponsored technology transfers would require one of two alternatives: Buying patent rights from innovators, which can be expensive, or publicly funded R&D in LCTs.

Conclusions

Conclusions I

In addition to being key to curb emissions, green innovation can boost medium-term economic growth

- Green innovation promotes economic activity in the short to medium term, especially through investment, limiting the potential costs of compliance with climate policies.
 - ▶ It can also ease societal concerns about the adoption of a strong climate agenda (Dabla-Norris et al. 2023).
- Effects of green innovation comparable to nongreen and to economic impacts of previous technological breakthroughs (ICT).
- Productivity gains of greater energy efficiency and cheaper energy sources likely to take longer to materialize, as the restructuring of production systems can initially be disruptive.

Boosting green innovation and accelerating deployment of LCTs requires an expansion in the stock of climate policies and lowering trade costs affecting LCTs

- Climate policies, especially revenue measures limiting emission quantities and expenditure measures such as subsidies, foster green innovation and deployment through trade/green FDI.
- Lower tariffs on LCT goods strongly promote deployment through trade and FDI.

Conclusion II

International coordination and cooperation are crucial to accelerate innovation and the deployment of LCTs, as there are significant cross-border climate policy spillovers.

- Synchronize global climate action to boost green patenting by leveraging market size effects/technology spillovers.
- Avoid growing protectionism that would stifle innovation and deployment.
 - ▶ Subsidies may create tensions between domestic and global climate objectives by reducing green FDI outflows.
 - ▶ Need to mitigate the adverse impact of subsidies, avoid a subsidy race that hampers deployment to EMDEs with lower fiscal space, and ensure that policies are consistent with WTO rules, including by avoiding local content requirements.
- Explore the route of direct technology transfers.

Thank you!