# INDUSTRIAL POLICY: MANAGING TRADE-OFFS TO PROMOTE GROWTH AND RESILIENCE

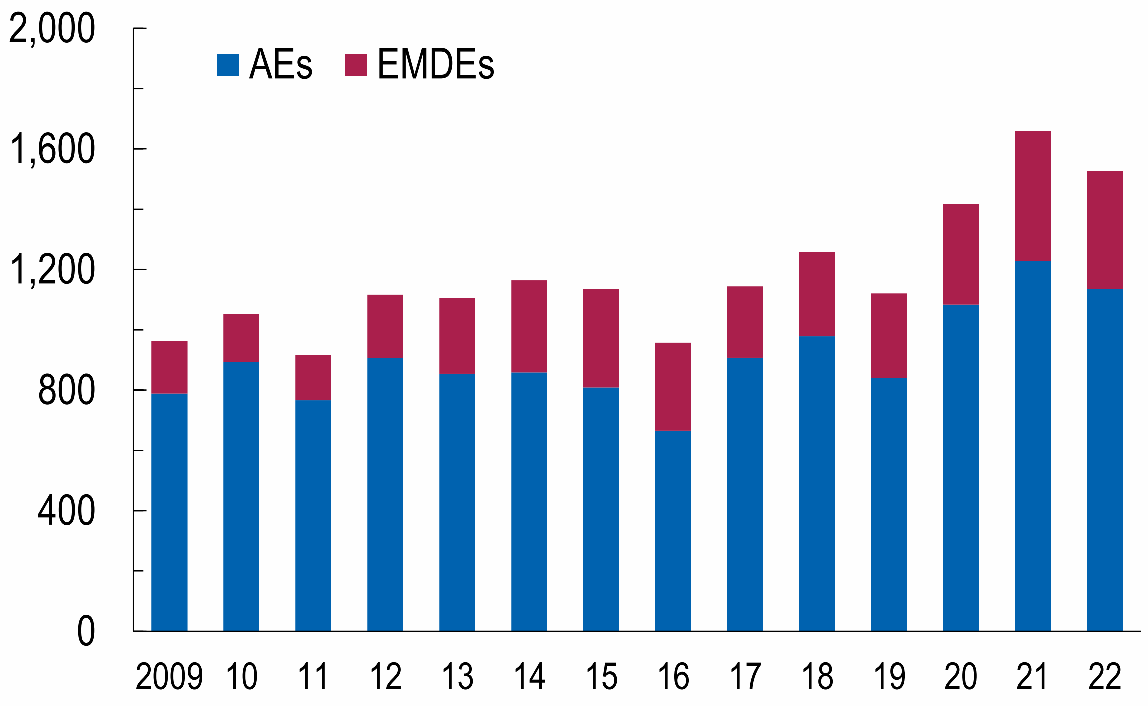
Shekhar Aiyar (co-lead), Hippolyte Balima, Mehdi Benatiya Andaloussi (co-lead), Thomas Kroen, Rafael Machado Parente, Chiara Maggi, Shrihari Ramachandra, Yu Shi, Yarou Xu, and Sebastian Wende with contributions from Lorenzo Rotunno and Simon Voigts

# Industrial Policy returns in pursuit of growth and resilience objectives, including self-reliance and energy security

## Rise in Usage Globally

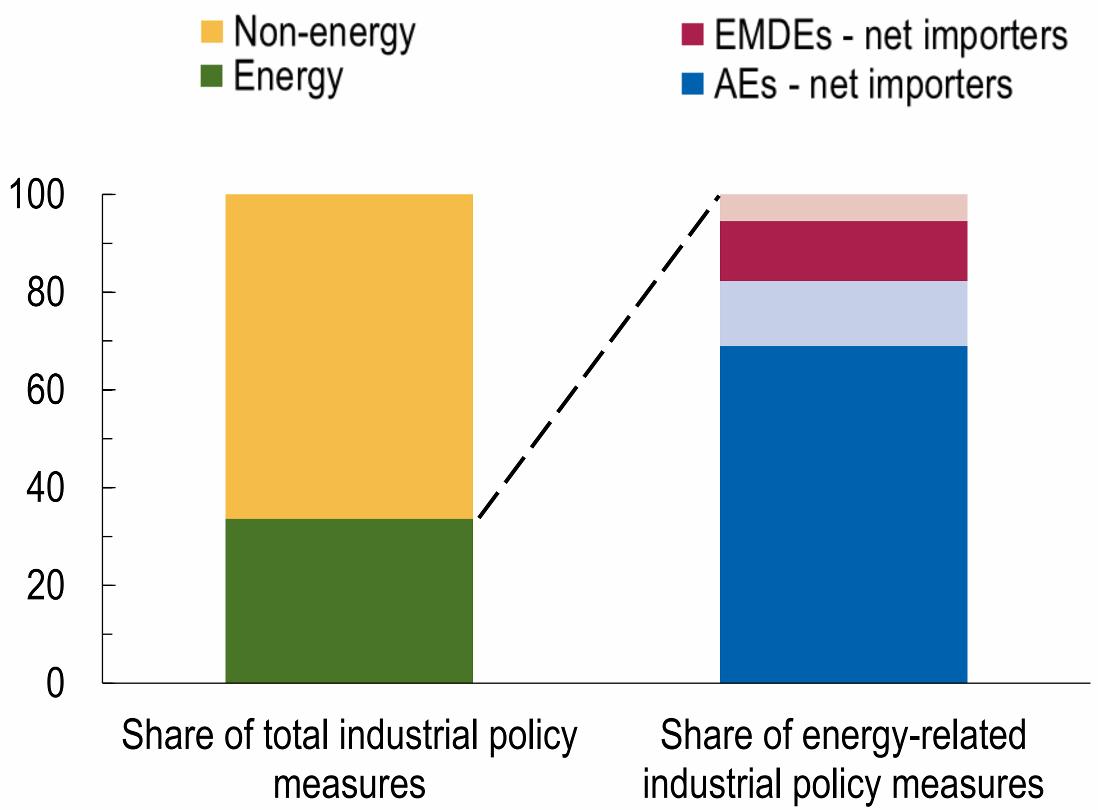
*(Number of new interventions)*

*Industrial Policies by income groups*




## Energy-Sector Industrial Policy

*(Percent, 2009–22)*




Sources: Global Trade Alert; Juhász and others 2022, 2025; U.S. Energy Information Administration; and IMF staff calculations.

Note: Industrial policy (IP) is defined as state action directed at changing the structure of the domestic economy, following the text-based approach of Juhász and others (2022, 2025). In the left-hand side figure, the bars show the number of new IP interventions introduced by AEs and EMDEs. In the right-hand side figure, the first bar shows the share of IP interventions targeting energy-related products, defined as those including at least one energy product at the 6-digit Harmonized System (HS) code. The second bar breaks down these interventions by countries' energy dependence and income group. Countries are net energy importers (exporters) if their energy consumption exceeds (is less than) production

# Questions

1. **At the sector level**

   → **Conceptually**, under what conditions can IP boost sectoral outcomes, and what are some key trade-offs at the sector level?

   → **Empirically**, how have IP affected sector-level outcomes, including productivity, production?

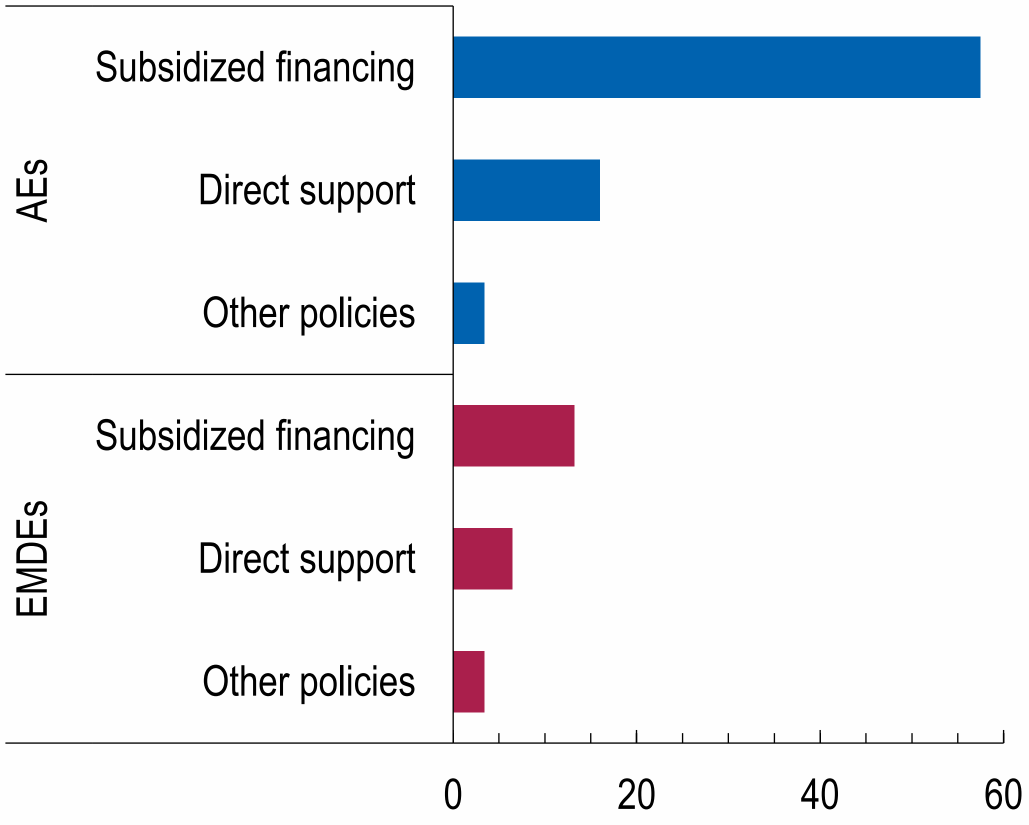
2. **In aggregate,** what are the GE effects of IP on the domestic economy, including cross-sector spillovers?

# Industrial Policy In Practice

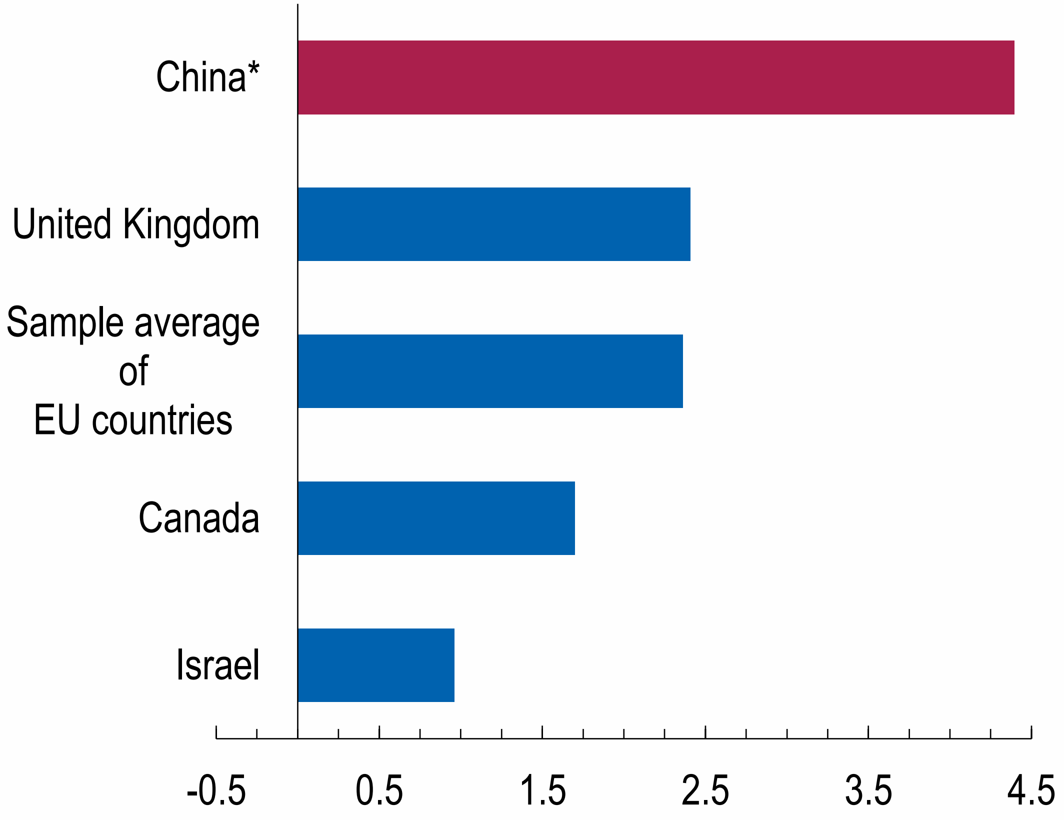
## Overview of recent industrial policies

# Subsidies dominate IP instruments and can generate sizeable fiscal costs

## Interventions by Instrument
*(Percent implemented globally, 2009-22)*




## Estimate of the Annual Fiscal Costs of IP
*(Percent of GDP, 2021)*

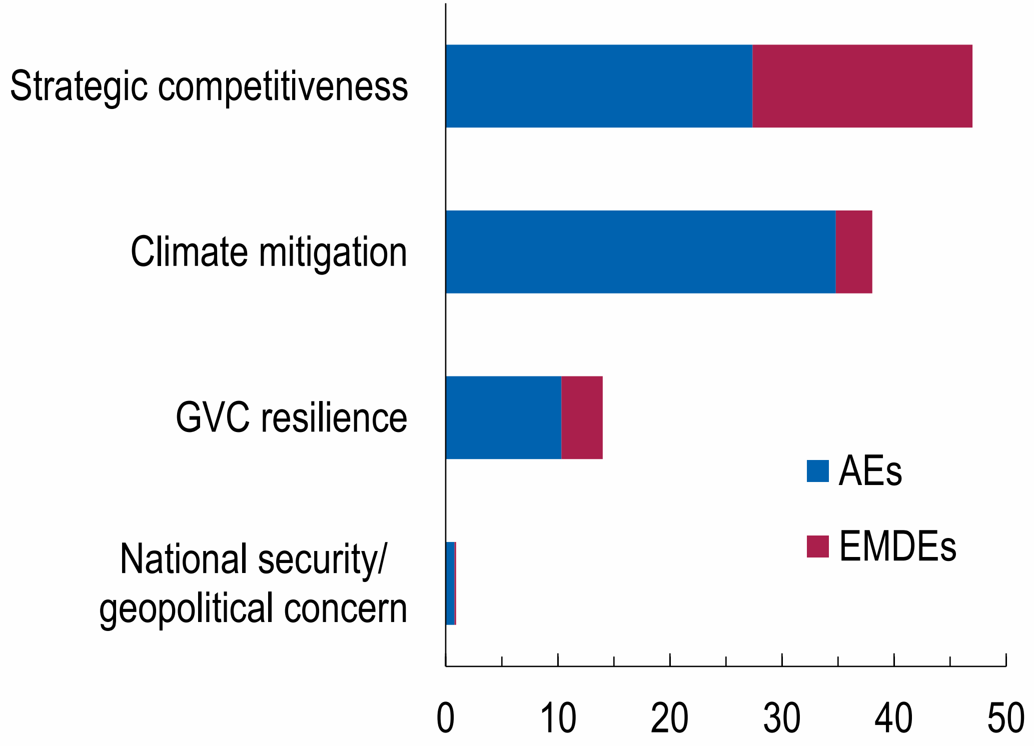



Sources: Garcia-Macia, Kothari, and Tao 2025; Global Trade Alert; Juhász and others 2022, 2025; OECD 2025; and IMF staff calculations.
Note: The left-hand side figure highlights the distribution of industrial policies implemented between 2009 and 2022 by instrument used, for AEs and EMDEs. "Subsidized financing" and "direct support" refer to subsidy-based measures. "Other policies" encompasses both tariff and nontariff trade barriers. The right-hand side figure shows the estimated fiscal costs of industrial policy measures as a share of GDP for selected economies with available data. These costs include support provided through grants, tax expenditures, and financial instruments. China* data refer to 2023 and include subsidized land. EU countries plot the simple average across Denmark, France, Ireland, Italy, The Netherlands, and Sweden.

# IP is driven by economic and non-economic motives and mostly targets manufacturing and commodities

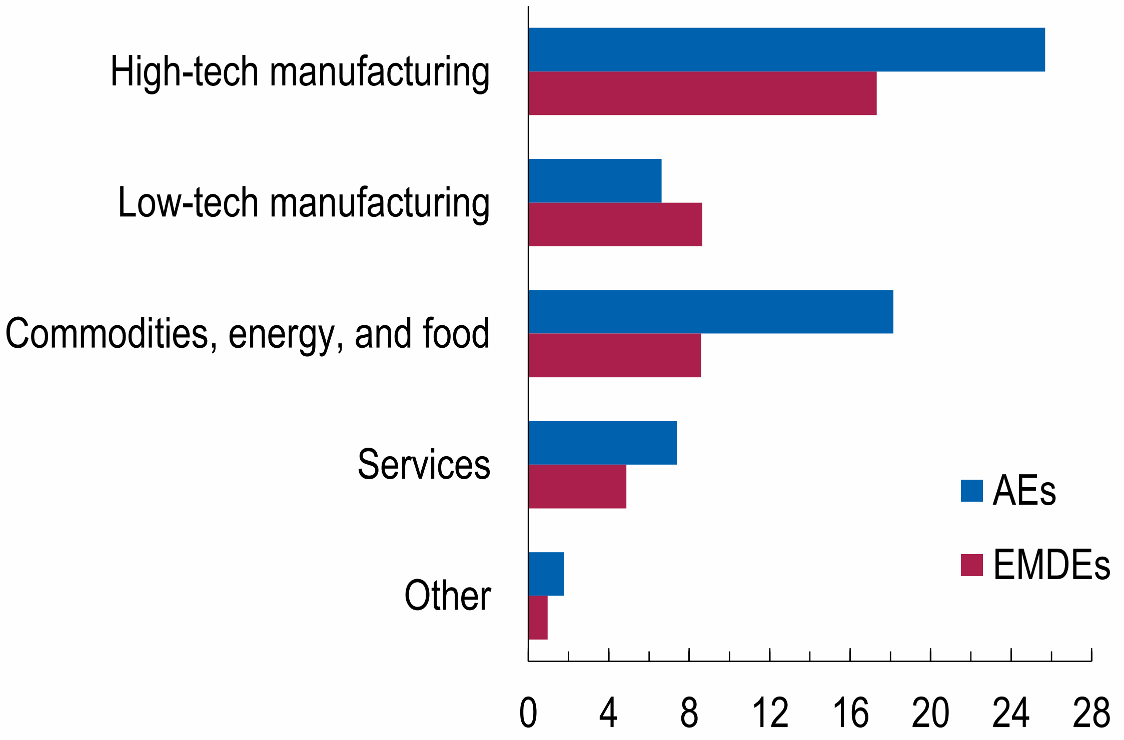
## Stated Motivation

*(Share of measures, 2009–22, percent)*




## Targeted Sectors

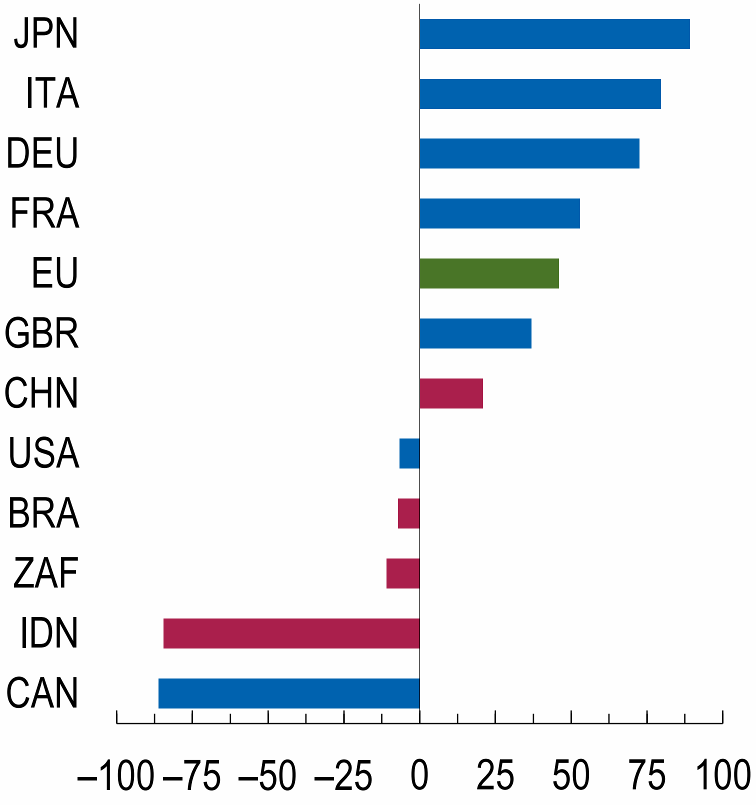
*(Percent implemented globally, 2009–22))*



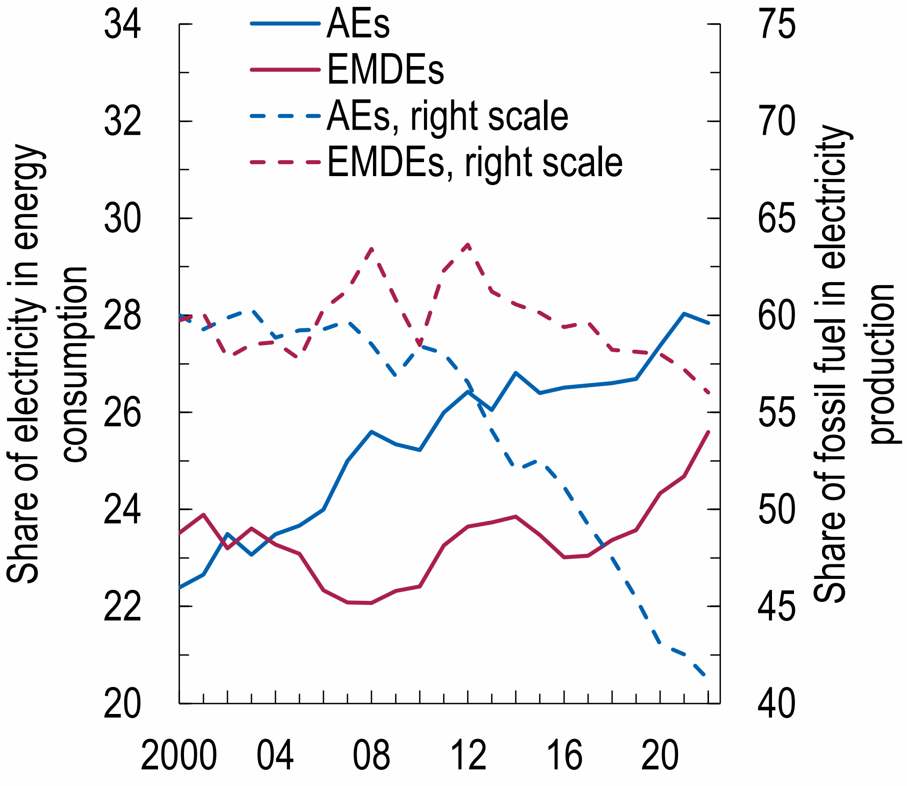

Sources: Evenett and others 2024; Evenett and others 2024, forthcoming; Global Trade Alert; Juhász and others 2022, 2025; and IMF staff calculations.
Note: The left-hand side figure highlights the stated motivations provided by governments for introducing new IP between 2009 and 2022, based on the subset of measures with available data. The right-hand side figure shows the distribution of IP interventions by targeted sector in AEs and EMDEs between 2009 and 2022. Sectors are classified according to NACE Rev. 2 (2-digit level). High-technology manufacturing includes computer, electronic and optical products; electrical equipment; chemical products; pharmaceuticals; basic and fabricated metals; machinery and equipment; and motor vehicles and other transport. Low-tech manufacturing includes wood; paper; printing; textiles; apparel; leather; rubber, plastic, and nonmetallic mineral products; furniture; other manufacturing; and repair.  AEs = advanced economies; EMDEs = emerging market and developing economies; GVC = global value chain.

# IP for energy security and increasing needs for electricity

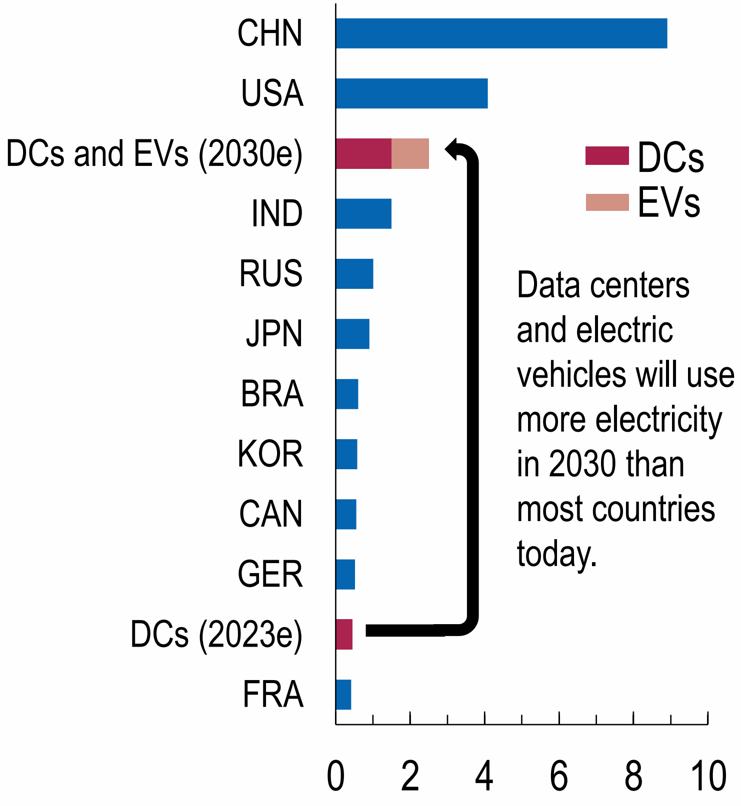
**Fossil Fuel Imports as a Share of Energy Demand in 2022**
*(Percent)*




**Electricity Share of Final Energy Consumption**
*(Percent)*




**Electricity Demand: Total by Country (2023) and New Needs (2030-estimates)**
*(Thousands of terawatt-hours)*



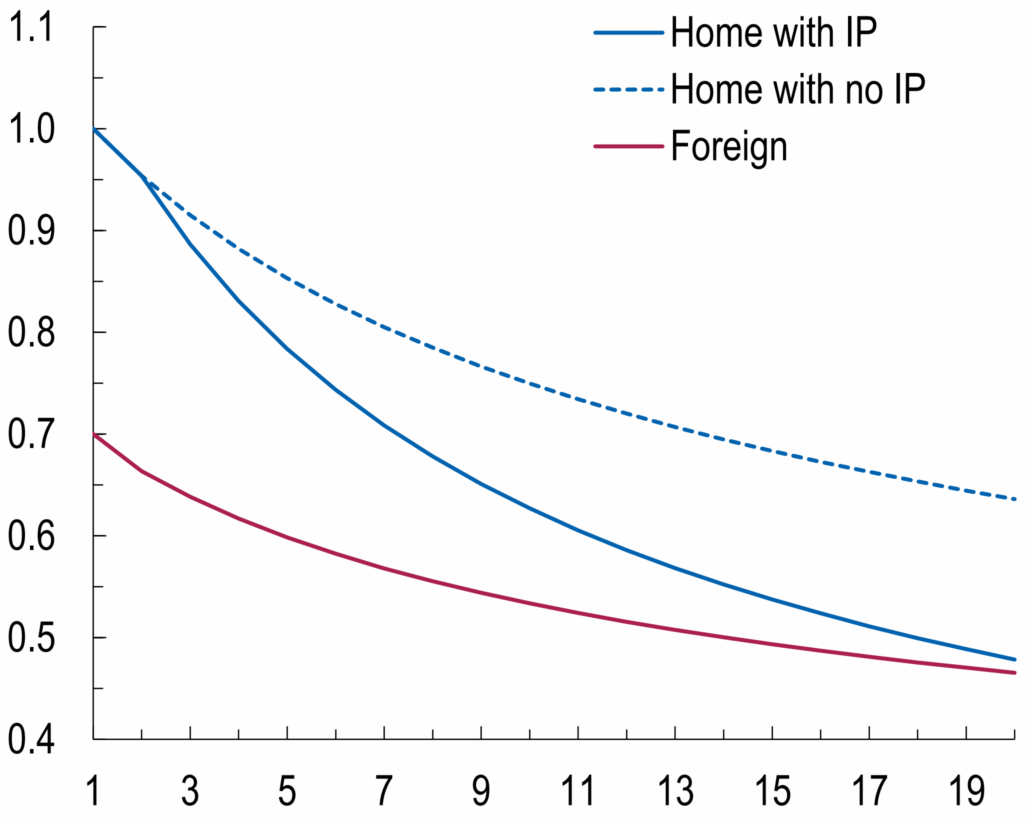

Sources: Eurostat; International Energy Agency (IEA); Organization of the Petroleum Exporting Countries (OPEC); U.S. Energy Information Administration; and IMF staff calculations.
Note: The left-hand side figure plots energy imports over energy demand. Energy demand = production + imports - exports - international marine bunkers - international aviation bunkers +/- stock changes. Fossil fuel includes coal, peat, and oil share; crude, natural gas liquids, and feedstocks; natural gas; and oil products. Fossil fuel imports are measured as net imports, with positive values indicating net importers and negative values indicating net exporters. In the middle figure, the sample includes 34 AEs and 27 EMDEs. The lines represent the simple average across countries within each group. In the right-hand side figure, estimates for data centers (DCs) and electric vehicles (EVs) are for the world and come from OPEC and the IEA, respectively. Data labels in the figure use International Organization for Standardization (ISO) country codes. AEs = advanced economies; EMDEs = emerging market and developing economies; EU = European Union.

# Sector Level Effects of Industrial Policy

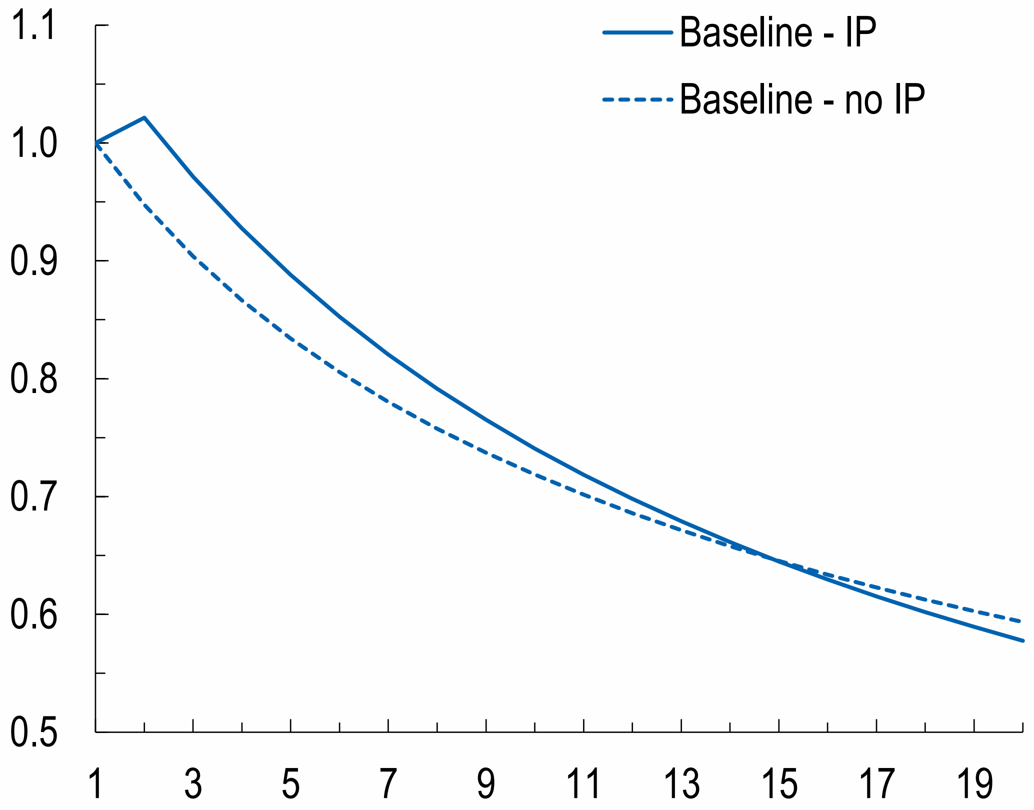
## Model predictions and country experience

# IP can help infant industries develop, leading to a reduction in domestic production costs, while consumer prices remain higher

**Production Costs**
*(Baseline in period 1 = 1; time on x-axis)*




**Consumer Prices**
*(Baseline in period 1 = 1; time on x-axis)*




Source: IMF staff calculations.
Note: Period 1 simulates model outcomes for one period assuming no IPs. Thus, period 1 outcomes are identical across both scenarios. IP scenario assumes that home economy imposes trade protections and production subsidies (12 percent production subsidy and 10 percent tariff) in period 2 and onward. The “no IP” scenario assumes that no Ips are in place from period 1 onward. The learning rate is 19 percent. Normalizations in period 1 are as follows: production costs, production volumes, and consumer prices are each normalized to 1. IP = industrial policy.

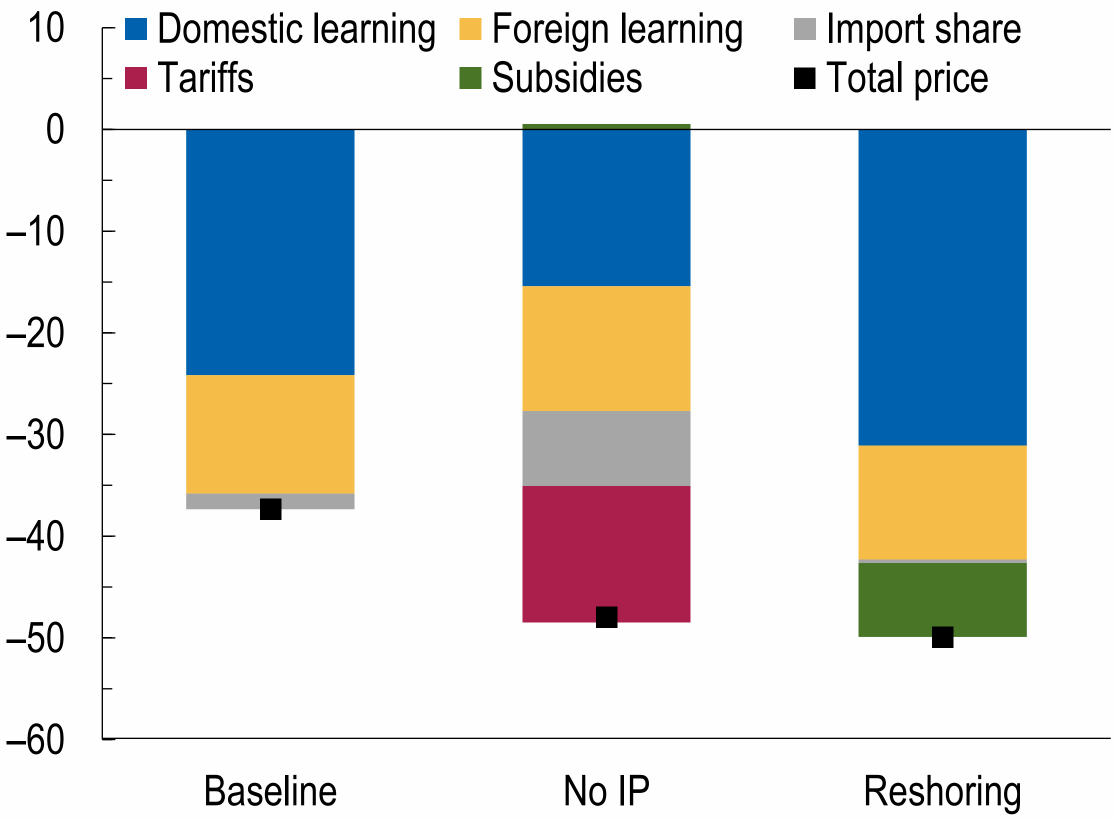
# Scenario analysis: industrial policy for energy security in Europe

- **The case of EVs and renewables**
  - Infant industry model augmented with a macro model
  - Calibrated to data on clean tech

- **3 policy scenarios over 2024-2035**
  - <u>Baseline</u>: 2024 observed subsidies and tariffs are maintained through 2035
  - <u>No IP</u>: All subsidies and tariffs are removed
  - <u>Reshoring</u>: EU deploys more subsidies to reshore production

**Decomposition of EU Electric Vehicle Price Decline**

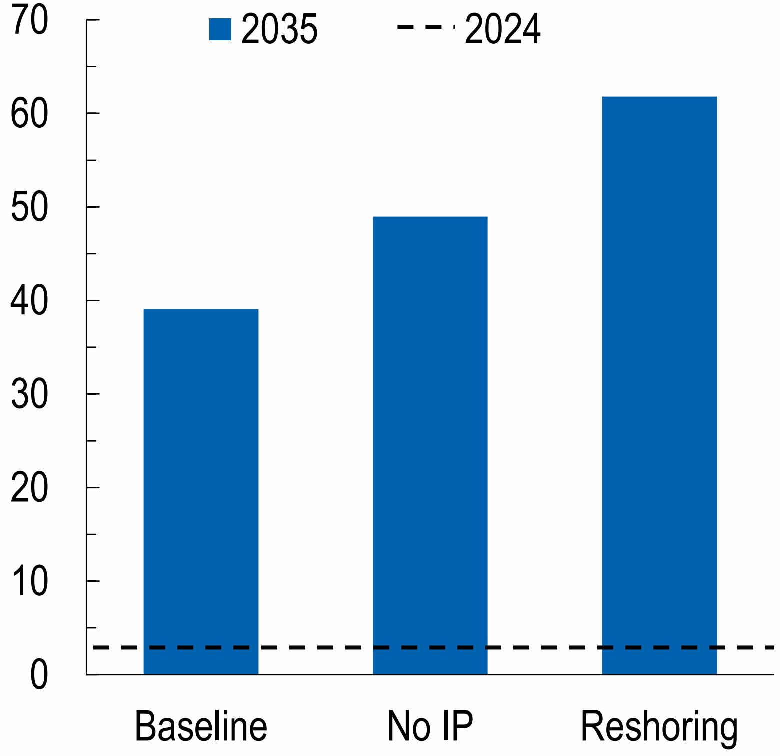
*(Percent change between 2024 and 2035)*



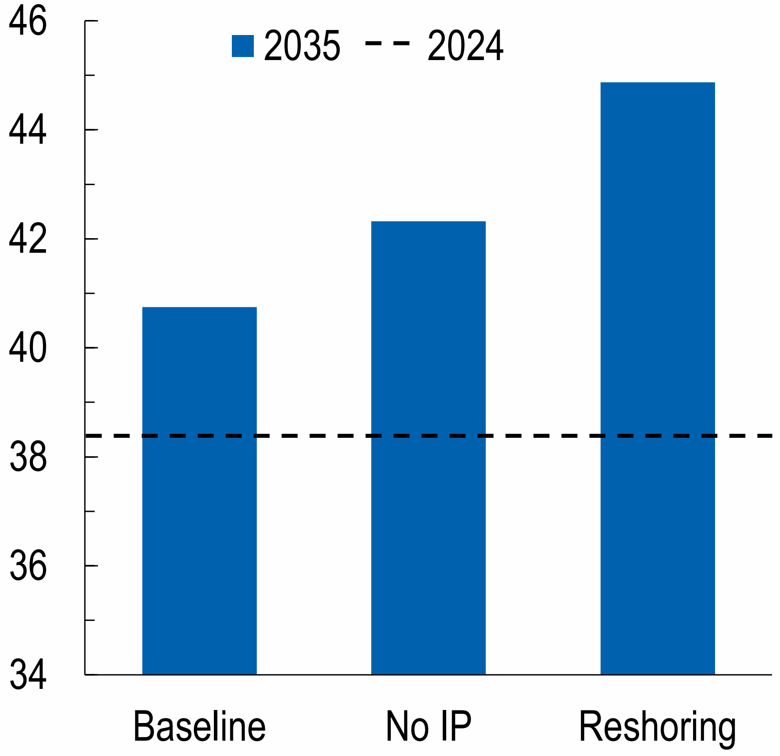

Sources: Bloomberg New Energy Finance; International Renewable Energy Agency; and IMF staff calculations.
Note: The figure shows illustrative price change for electric vehicles in the EU under business as usual, and two hypothetical scenarios, derived by a four-country version of the infant industry model, calibrated to current policies, production, and trade patterns of clean technologies. Under baseline scenario, the EU maintains status quo IPs. Under no-IP scenario, all IPs are removed starting in 2025. Under reshoring scenario, a 15 percent production subsidy is introduced in addition to status quo trade protections. EU = European Union; IP = industrial policy.

# Policies options lead to cost reductions and accelerate take up, but with different impacts on domestic production.

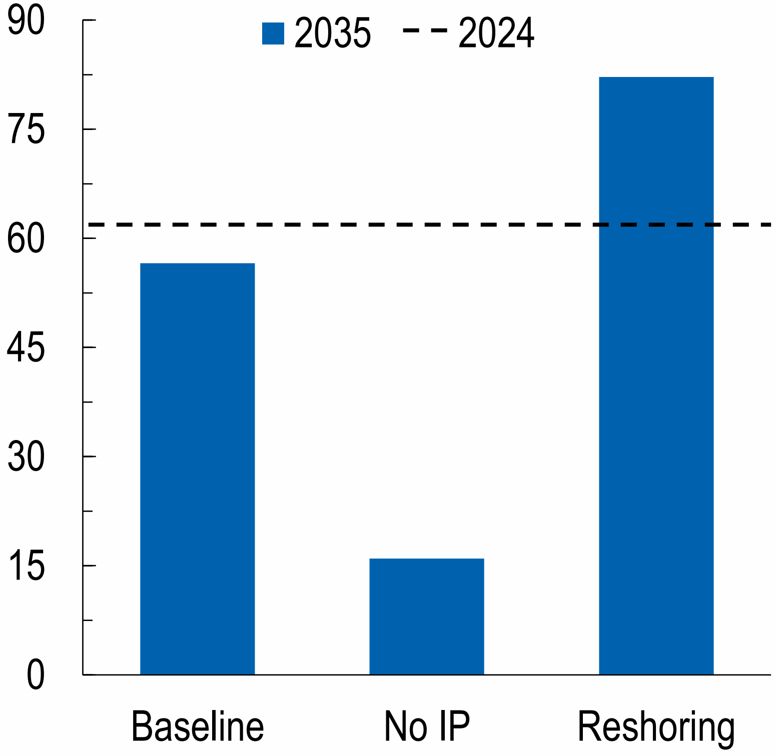
**European EVs Shares**
*(Percent of passenger fleet)*




**European Renewable Generation Excluding Hydroelectric**
*(Percent of generation)*



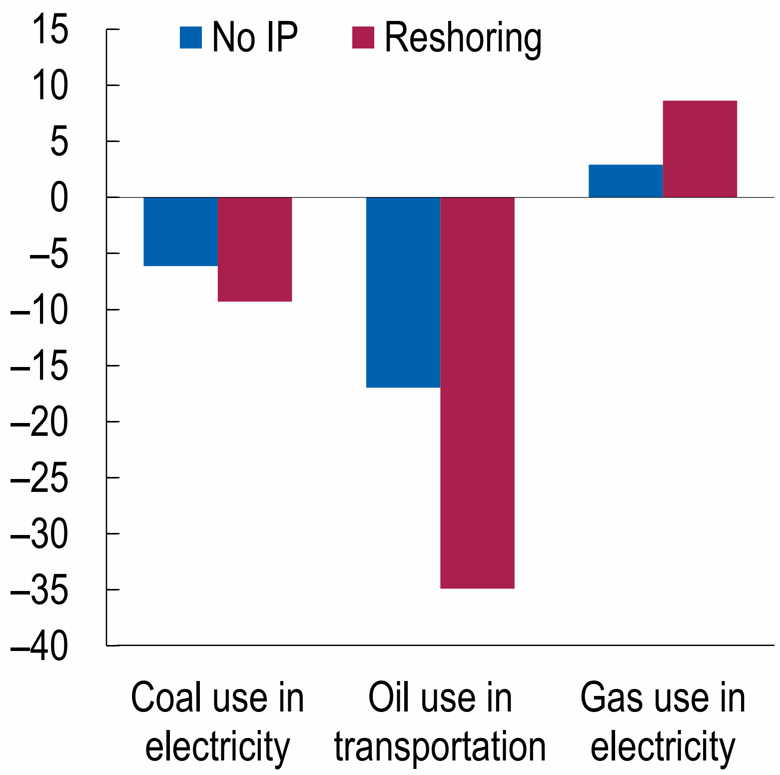

**European Clean Tech Production**
*(Percent of domestic use)*



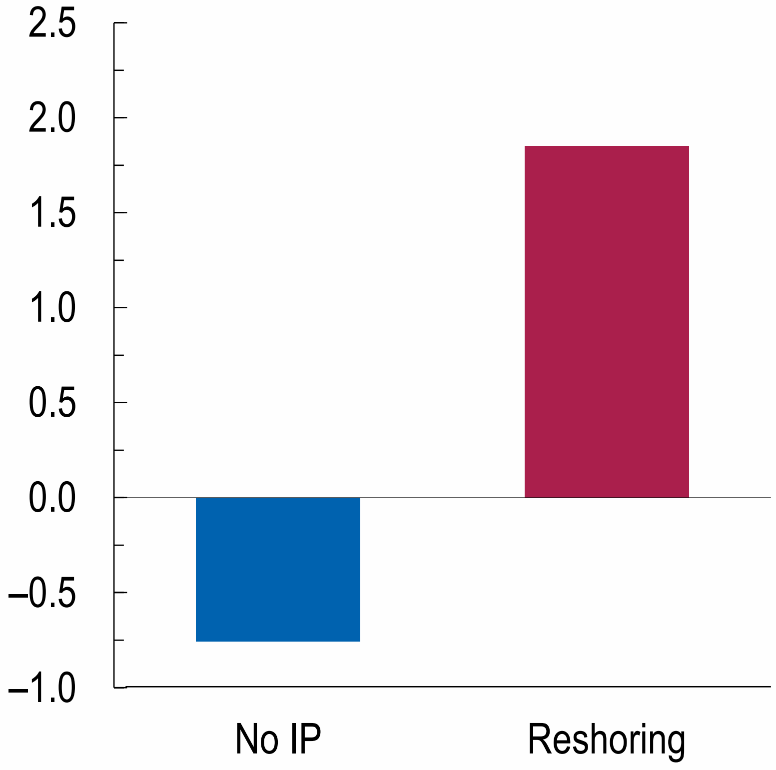

Sources: Global Macroeconomic Model for the Energy Transition; and IMF staff calculations.
Note: Under the baseline scenario, the EU continues to impose status quo industrial policies. Under the no-IP scenario, all industrial policies are removed starting in 2025. Under the reshoring scenario, 15 percent electric vehicle and 30 percent renewable production subsidies are introduced starting in 2025. EV = electric vehicle; IP = industrial policy.

# Reducing energy dependence through cheaper clean technologies
## Trade-offs of policy options: IP vs. no IP scenario

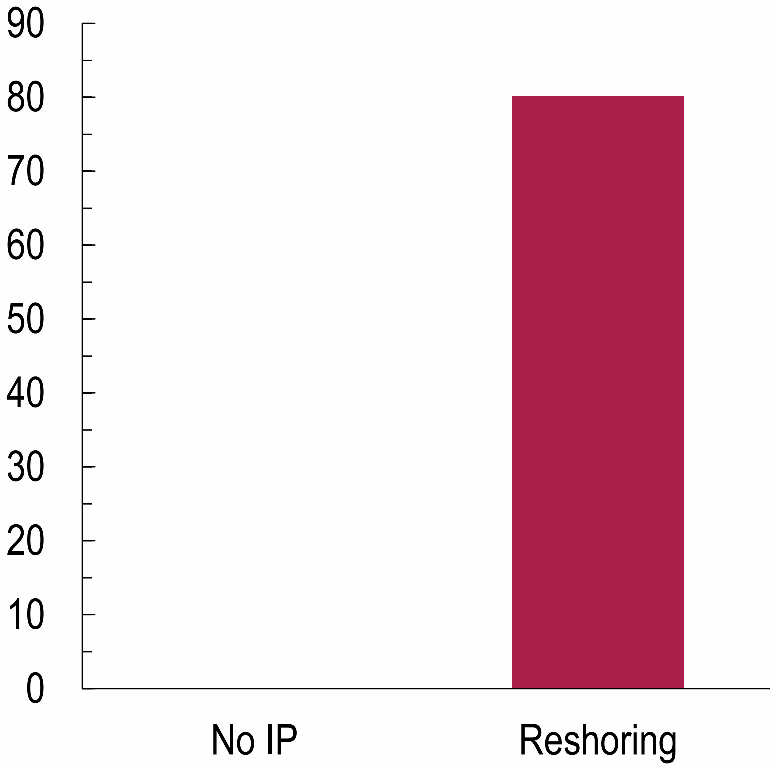
### European Fuel Use in 2035
*(Deviation from baseline, percent)*




### EU Clean Tech Labor in 2035
*(Deviation from baseline, percent of labor market)*



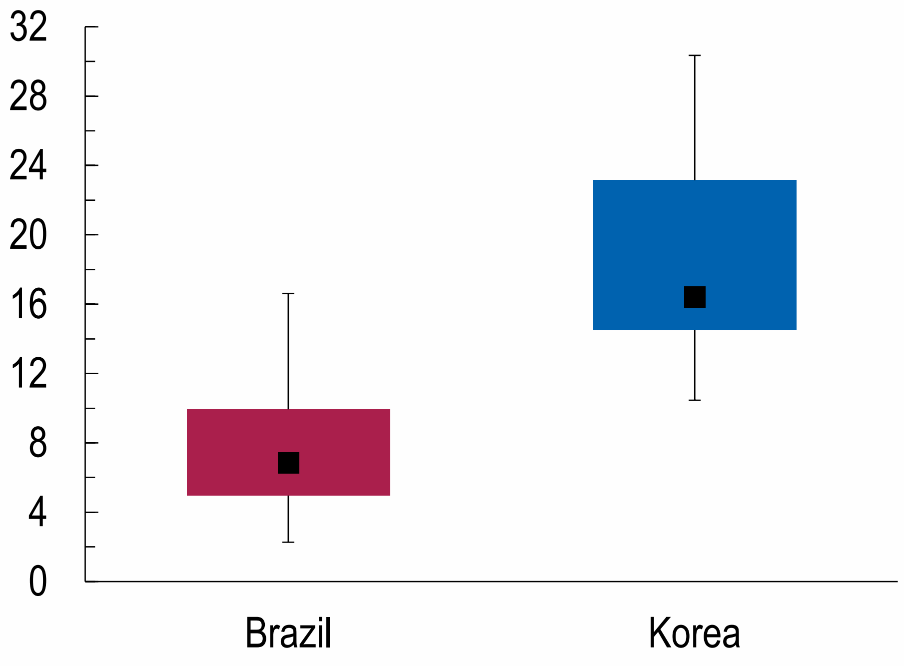

### European Subsidy Cost
*(2025–35, annual average, billion euros)*




Sources: Global Macroeconomic Model for the Energy Transition; and IMF staff calculations.
Note: Under the baseline scenario, the EU continues to impose status quo industrial policies. Under the no-IP scenario, all industrial policies are removed starting in 2025. Under the reshoring scenario, 15 percent electric vehicle and 30 percent renewable production subsidies are introduced starting in 2025. In panel 3, the European subsidy cost under the no-IP scenario is zero. IP = industrial policy.

# Case studies: Lessons from Brazil and South Korea IP experience in the 1970s
## Design & implementation challenges, essential role of complementary policies

**Manufacturing Value Added**
*(Annual growth rate)*




Sources: World Bank, World Development Indicators; and IMF staff calculations.
Note: The figure shows the annual growth rate of real manufacturing value added and real GDP for Brazil and Korea during the periods 1973–79. Manufacturing includes industries classified under ISIC divisions 15–37. The boxes denote the interquartile range, the squares denote the median, and the whiskers denote the range of maximum and minimum values.

- **Design**
  - ✓ Boost learning by doing
  - ✓ Large market size, essential for firms to achieve economies of scale
  - ✓ Target sectors with high expected economic returns / externalities
  - ✗ Overreliance on small and protected domestic demand
- **Implementation**
  - ✓ Competition, both domestically and abroad, as market discipline
  - ✓ IP Governance: competent implementing agencies, and continuous engagement with private sector
  - ✓ Safeguards to limit the costs of failure (e.g., sunset clauses)
  - ✗ Lack of performance benchmarks / IP without accountability
- **Complementary policies**
  - ✓ Structural reforms, and infrastructures
  - ✓ Stable macroeconomic policy
  - ✗ Runaway deficits or unchecked borrowing from SOEs

# Sector Level Effects of Industrial Policy

## Empirical investigation

# IPs and sectoral performance: empirical investigation

- Local projections (Baquie and others, 2025)

$$ln\, y_{cs,t+h} - ln\, y_{cs,t-1} = \delta_{cs}^{h} + \delta_{ct}^{h} + \delta_{st}^{h} + \sum_{instr\ k} \boldsymbol{\beta_{1,k}^{h}}\left(\Delta IP_{cs,t}^{k}\right) + \boldsymbol{\beta_{2}^{h}}\left(\Delta Upstr_{cs,t}\right)$$

$$+\sum_{j=1}^{p} \gamma_j^h y_{cs,t-j} + \sum_{j=1}^{p} \sum_{instr\ k} \lambda_{t-j}^{h} \quad IP_{cst-j}^{k} + \sum_{j=1}^{p} \lambda_{t-j}^{h} Upstr_{cst-j} + \zeta^h X_{cs,t} + \epsilon_{cs,t}^{h}$$

- Main shock of interest: $\Delta IP_{cs,t}^{k}$
  - *Industrial Policies:* derived from GTA through text-mining (Juhász and others, 2023)
  - Main instruments (k): subsidized financing and direct support

- Main outcomes of interest: $ln\, y_{cs,t+h} - ln\, y_{cs,t-1}$
  - Sector-level value added, productivity and allocative efficiency (Orbis; Hsieh and Klenow, 2009).
  - Targeted sectors and cross-industry spillovers.

- Main coefficients of interest:
  - $\boldsymbol{\beta_{1,k}^{h}}$ : Dynamic relationship between outcomes and a change in the stock of IPs
  - $\boldsymbol{\beta_{2}^{h}}$: Relationship between outcomes and a change in the stock of IPs in upstream sectors



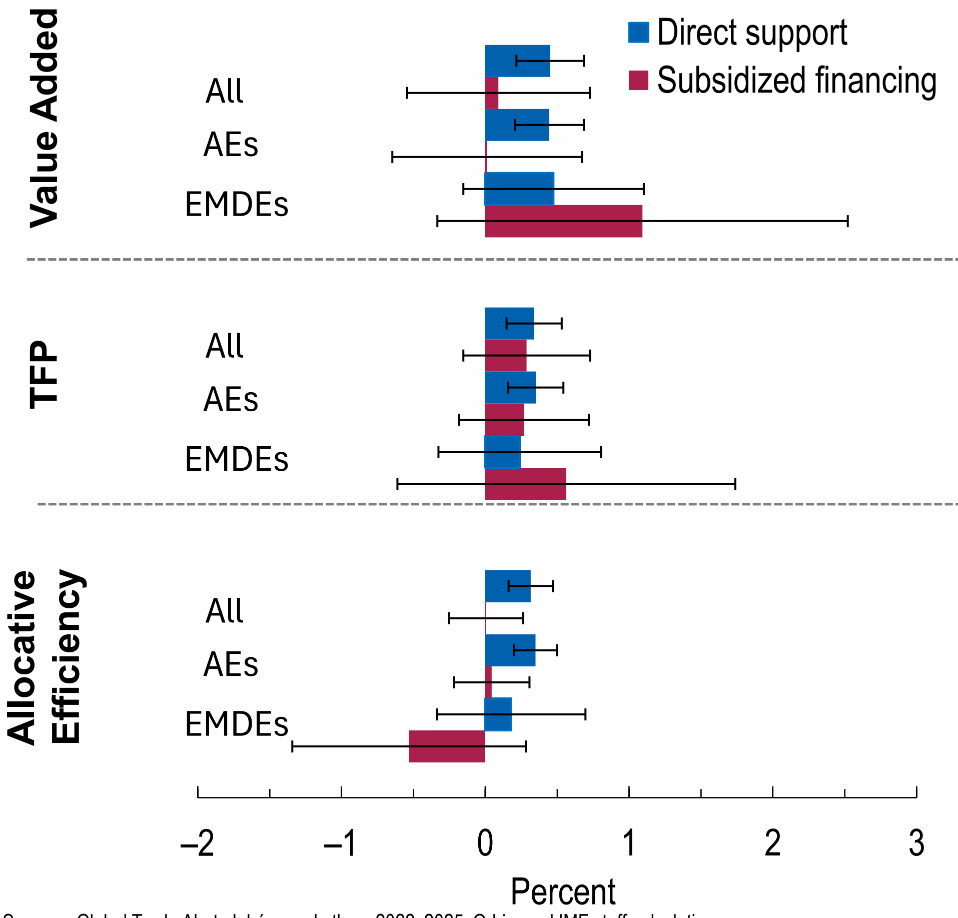
Back-up

# Modest link between IPs and targeted sector economic performance

## Both country and sector characteristics matter

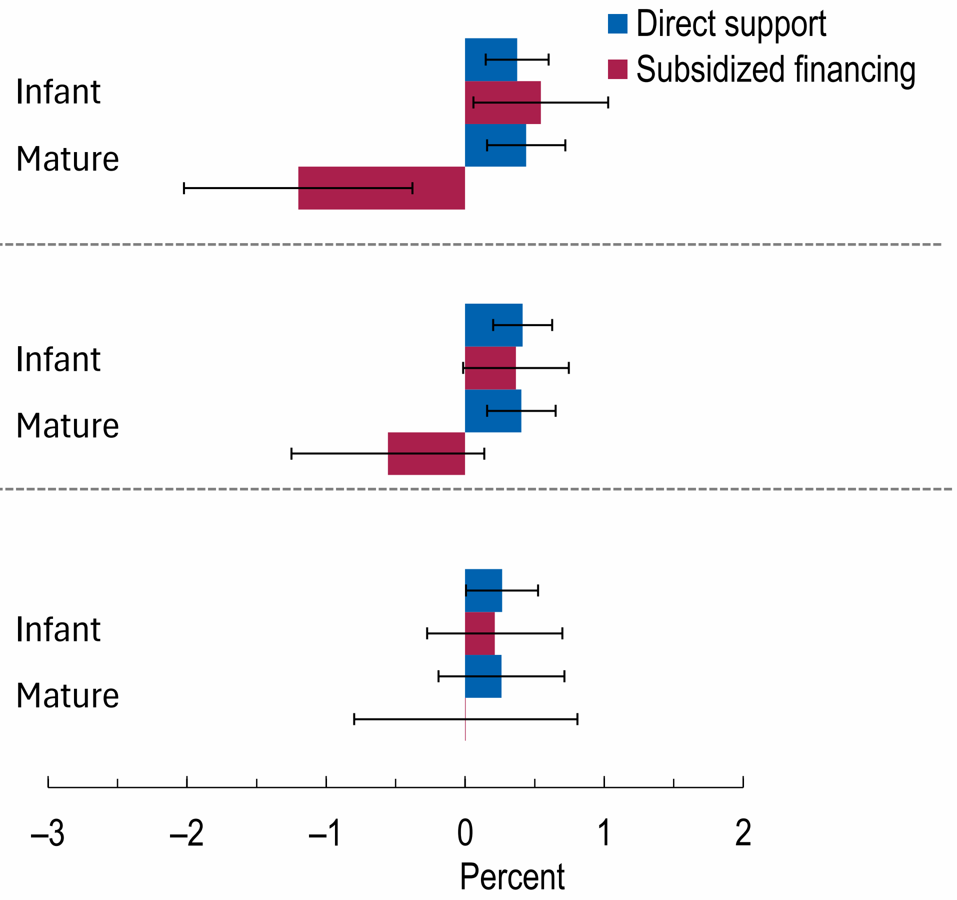
### AEs and EMDEs: IPs and Medium-Term Performance of Targeted Sectors

*(Percent)*




### Infant and Mature Industries: IPs and Medium-Term Performance of Targeted sectors

*(Percent)*

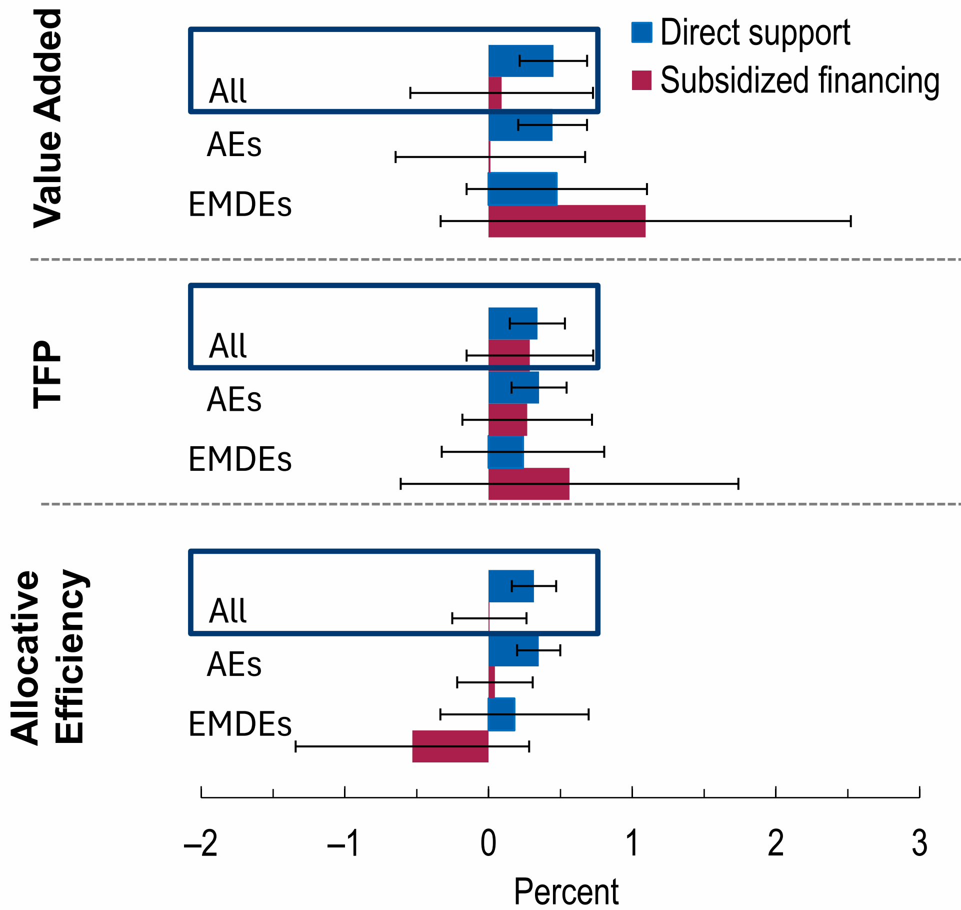



Sources: Global Trade Alert; Juhász and others 2022, 2025; Orbis; and IMF staff calculations.

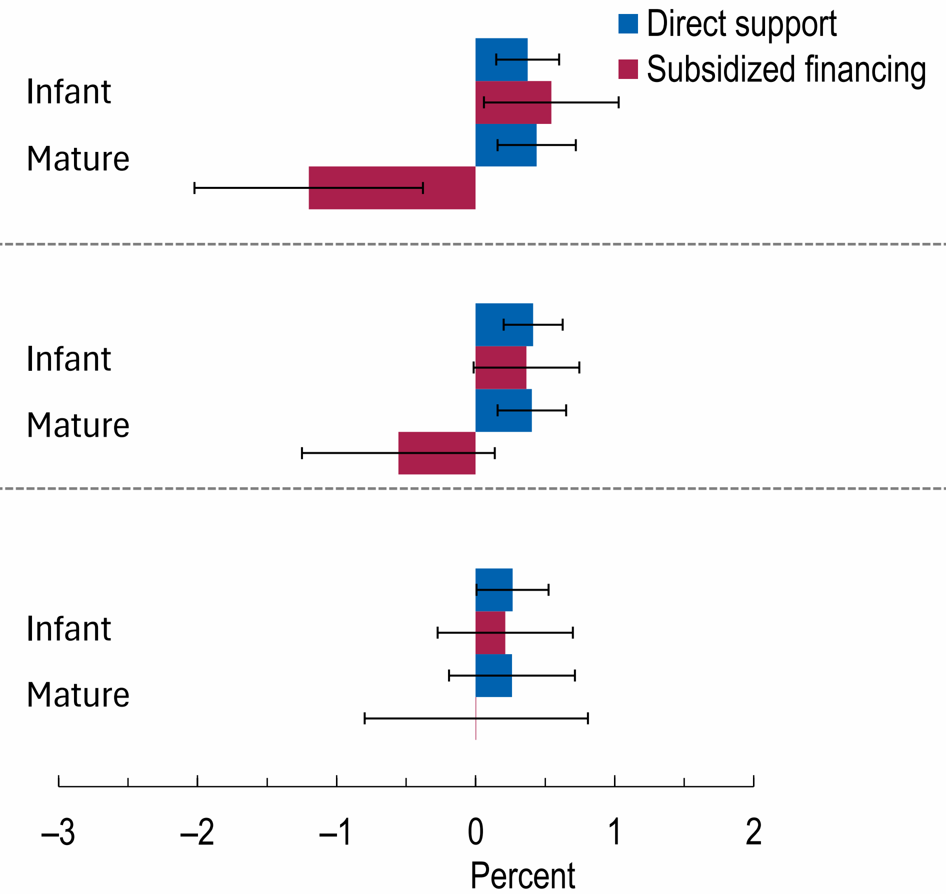
Note: The figure estimates the impact of industrial policies (IPs) using the local projection method. The dependent variables are the log difference in sectoral value added, TFP, or allocative efficiency three years after policy implementation. The key independent variables are the change in the number of subsidized financing and direct support IPs targeting the sector. Regional coefficients are estimated by interacting IPs with a dummy for AEs or EMDEs. Infant/mature industry coefficients are estimated by interacting IPs with a dummy for each industry being infant/mature. In each country, infant industries are industries with above-average share of young and leveraged firms and above-average distance to the world productivity frontier. All specifications control for one lag of dependent and independent variables and include country-sector, country-year, and sector-year fixed effects. Whiskers represent 90 percent confidence intervals. See online annex table 3.6.2 for further details on the data underlying each bar. AEs = advanced economies; EMDEs = emerging market and developing economies; TFP = total factor productivity.

# Modest link between IPs and targeted sector economic performance
## Both country and sector characteristics matter

### AEs and EMDEs: IPs and Medium-Term Performance of Targeted Sectors
*(Percent)*



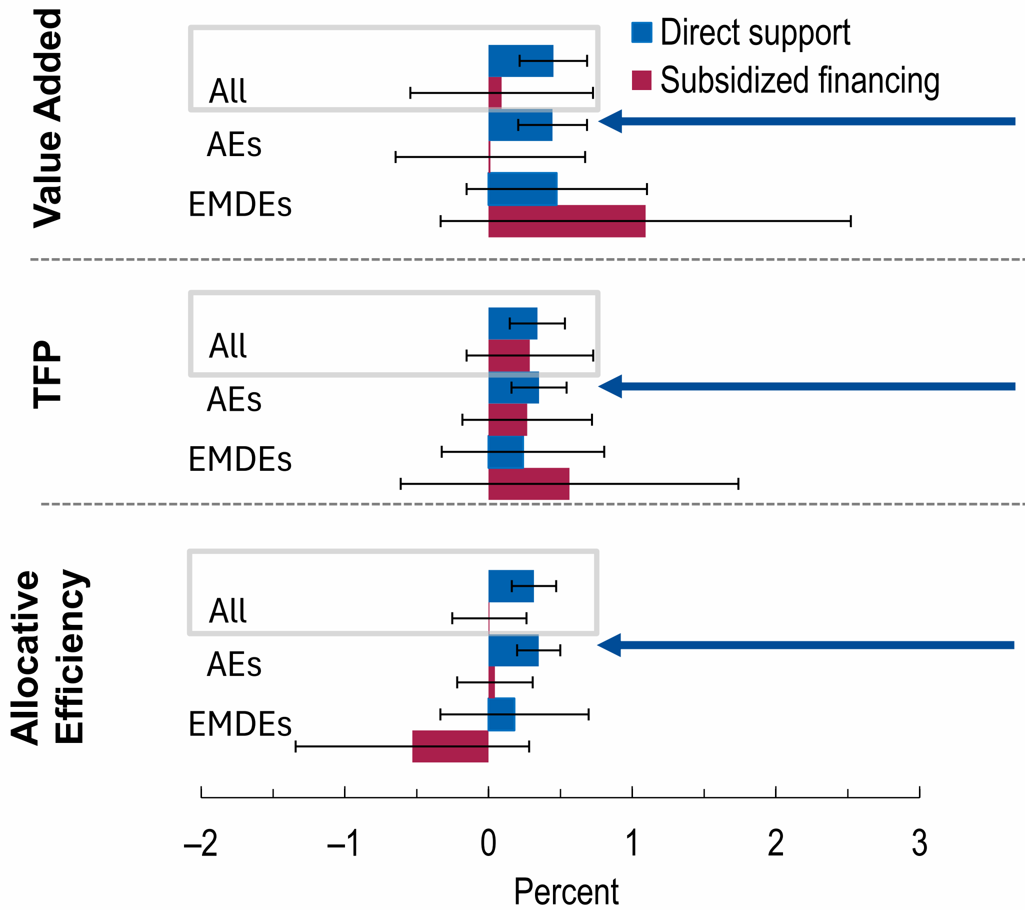

### Infant and Mature Industries: IPs and Medium-Term Performance of Targeted sectors
*(Percent)*



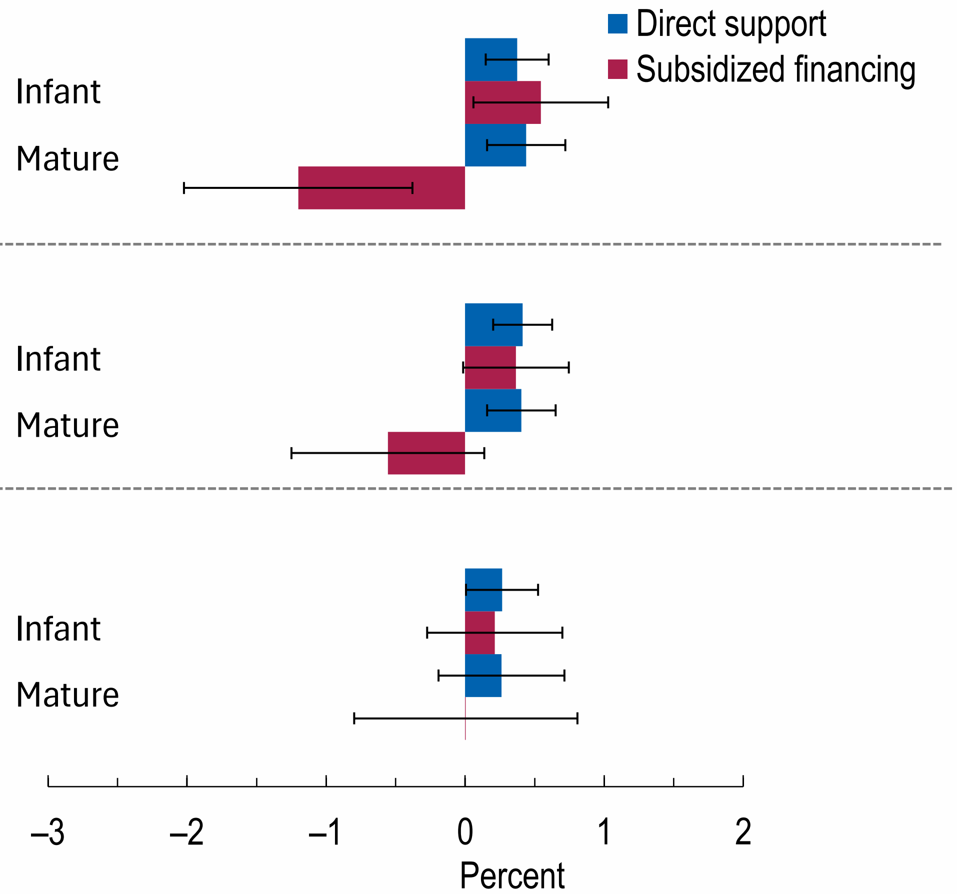

Sources: Global Trade Alert; Juhász and others 2022, 2025; Orbis; and IMF staff calculations.
Note: The figure estimates the impact of industrial policies (IPs) using the local projection method. The dependent variables are the log difference in sectoral value added, TFP, or allocative efficiency three years after policy implementation. The key independent variables are the change in the number of subsidized financing and direct support IPs targeting the sector. Regional coefficients are estimated by interacting IPs with a dummy for AEs or EMDEs. Infant/mature industry coefficients are estimated by interacting IPs with a dummy for each industry being infant/mature. In each country, infant industries are industries with above-average share of young and leveraged firms and above-average distance to the world productivity frontier. All specifications control for one lag of dependent and independent variables and include country-sector, country-year, and sector-year fixed effects. Whiskers represent 90 percent confidence intervals. See online annex table 3.6.2 for further details on the data underlying each bar. AEs = advanced economies; EMDEs = emerging market and developing economies; TFP = total factor productivity.

# Modest link between IPs and targeted sector economic performance
## Both country and sector characteristics matter

### AEs and EMDEs: IPs and Medium-Term Performance of Targeted Sectors
*(Percent)*



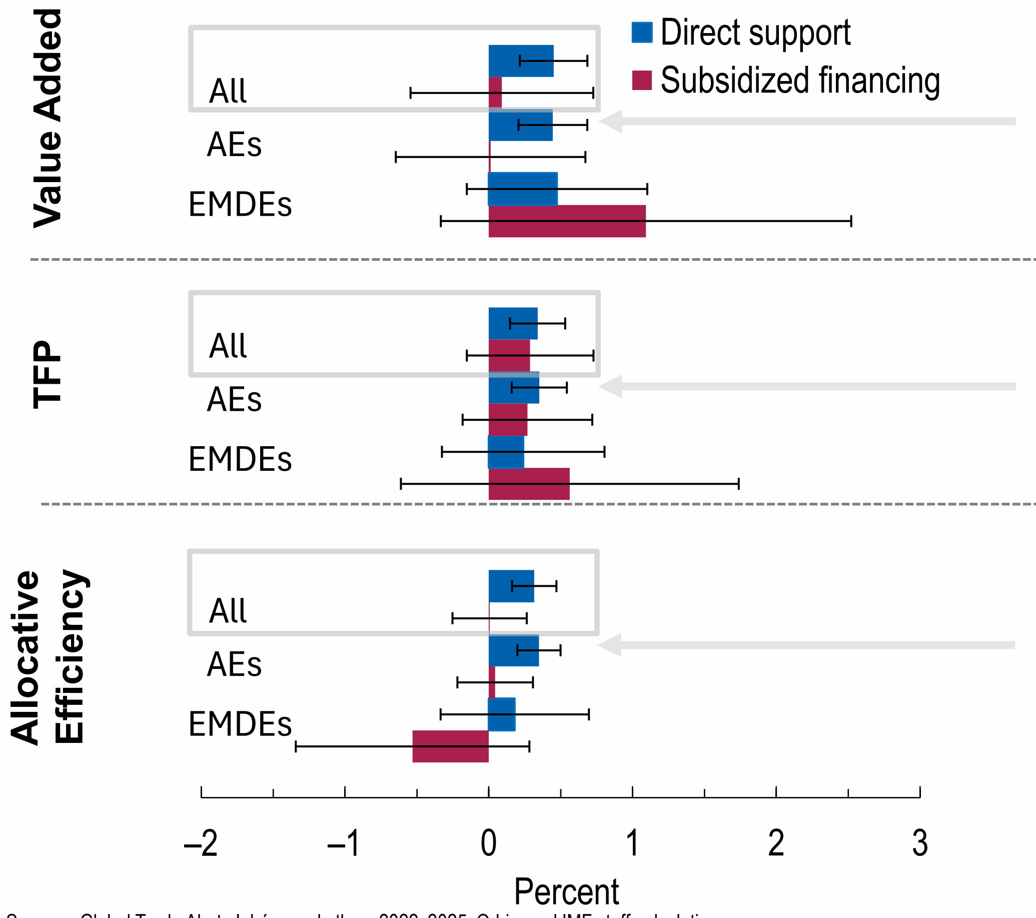

### Infant and Mature Industries: IPs and Medium-Term Performance of Targeted sectors
*(Percent)*



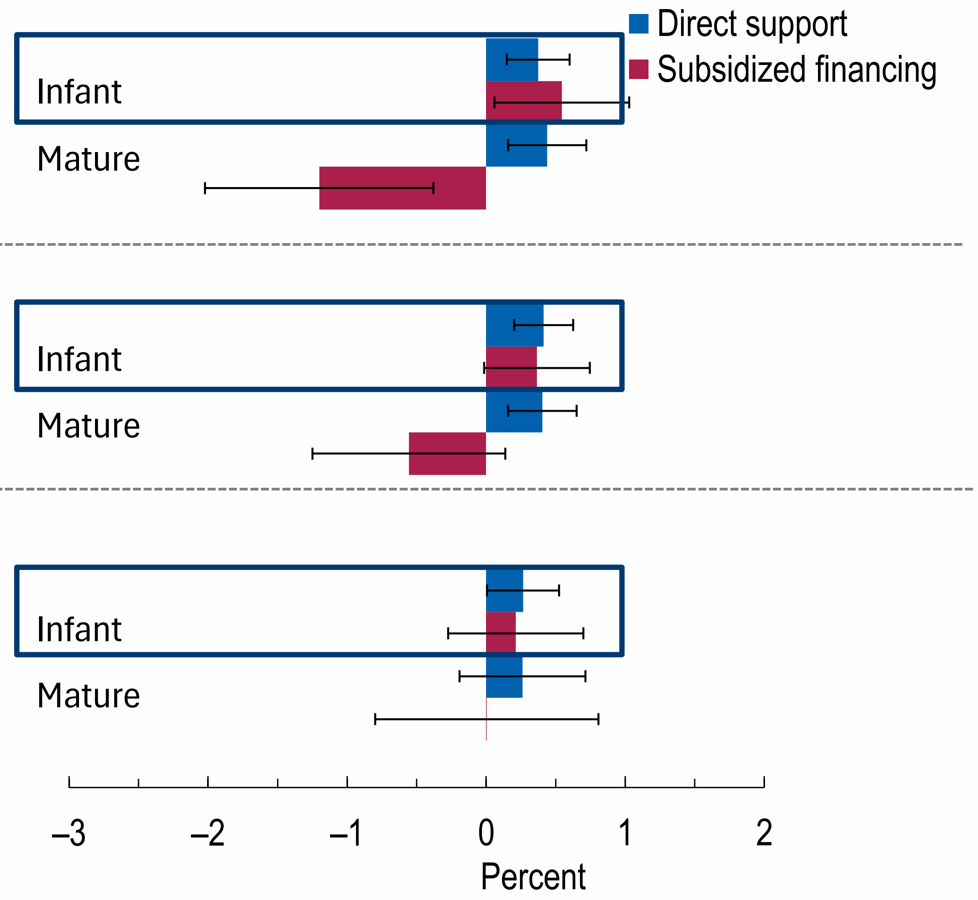

Sources: Global Trade Alert; Juhász and others 2022, 2025; Orbis; and IMF staff calculations.
Note: The figure estimates the impact of industrial policies (IPs) using the local projection method. The dependent variables are the log difference in sectoral value added, TFP, or allocative efficiency three years after policy implementation. The key independent variables are the change in the number of subsidized financing and direct support IPs targeting the sector. Regional coefficients are estimated by interacting IPs with a dummy for AEs or EMDEs. Infant/mature industry coefficients are estimated by interacting IPs with a dummy for each industry being infant/mature. In each country, infant industries are industries with above-average share of young and leveraged firms and above-average distance to the world productivity frontier. All specifications control for one lag of dependent and independent variables and include country-sector, country-year, and sector-year fixed effects. Whiskers represent 90 percent confidence intervals. See online annex table 3.6.2 for further details on the data underlying each bar. AEs = advanced economies; EMDEs = emerging market and developing economies; TFP = total factor productivity.

# Modest link between IPs and targeted sector economic performance
## Both country and sector characteristics matter

### AEs and EMDEs: IPs and Medium-Term Performance of Targeted Sectors
*(Percent)*



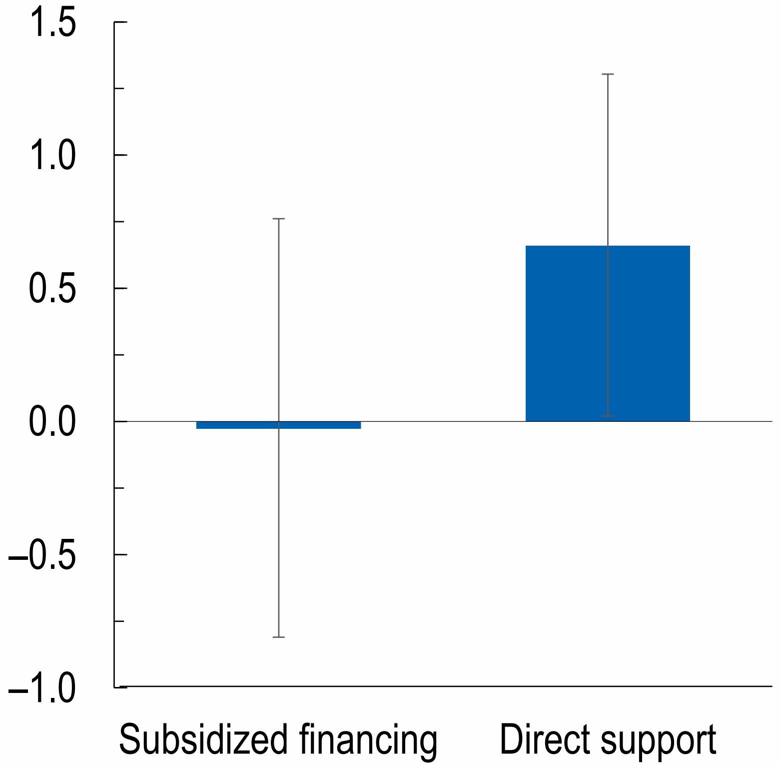

### Infant and Mature Industries: IPs and Medium-Term Performance of Targeted sectors
*(Percent)*



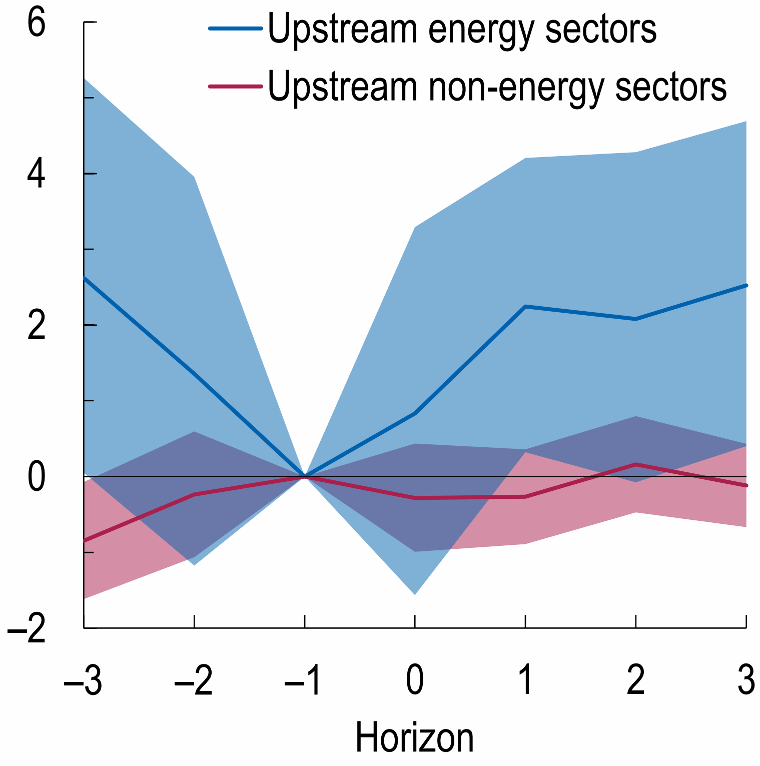

Sources: Global Trade Alert; Juhász and others 2022, 2025; Orbis; and IMF staff calculations.
Note: The figure estimates the impact of industrial policies (IPs) using the local projection method. The dependent variables are the log difference in sectoral value added, TFP, or allocative efficiency three years after policy implementation. The key independent variables are the change in the number of subsidized financing and direct support IPs targeting the sector. Regional coefficients are estimated by interacting IPs with a dummy for AEs or EMDEs. Infant/mature industry coefficients are estimated by interacting IPs with a dummy for each industry being infant/mature. In each country, infant industries are industries with above-average share of young and leveraged firms and above-average distance to the world productivity frontier. All specifications control for one lag of dependent and independent variables and include country-sector, country-year, and sector-year fixed effects. Whiskers represent 90 percent confidence intervals. See online annex table 3.6.2 for further details on the data underlying each bar. AEs = advanced economies; EMDEs = emerging market and developing economies; TFP = total factor productivity.

# Direct support to upstream energy sectors linked to increased energy TFP
# Downstream impact: increased value added, but lower allocative efficiency

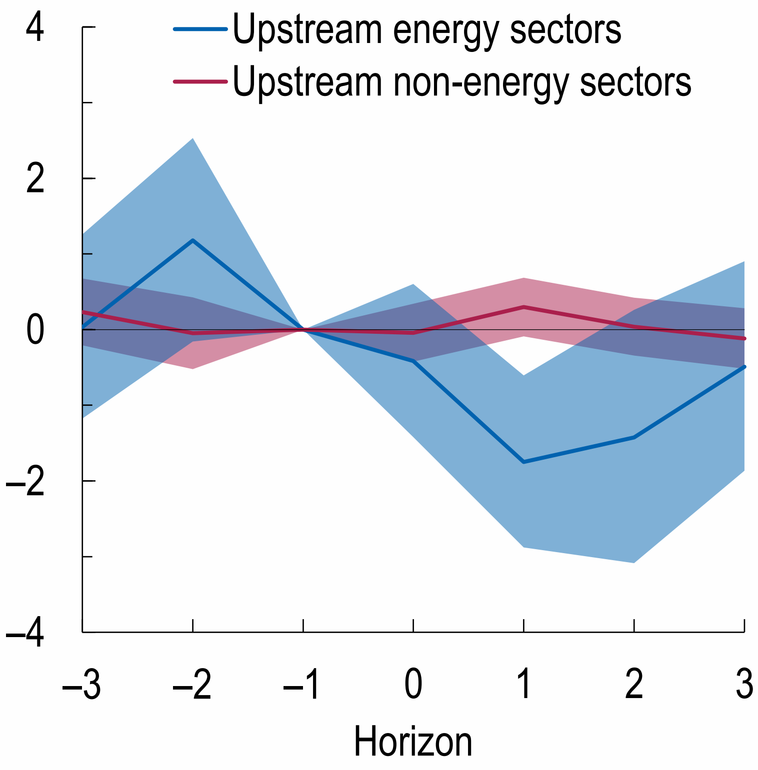
**IPs and TFP of Energy Sectors in the Short Term**
*(Percent)*




**Direct Support to Upstream Energy Sectors and Downstream Value Added**
*(Percent)*




**Direct Support to Upstream Energy Sectors and Downstream Allocative Efficiency**
*(Percent)*




Sources: Global Trade Alert; Juhász and others 2022, 2025; Orbis; and IMF staff calculations.
Note: The figure estimates the impact of IPs using the local projection method. The dependent variables are the log difference in TFP, value added, and allocative efficiency over the specified horizon. 0 = the short-term horizon corresponding to when industrial policies are introduced. In panel 1, the key independent variables are the change in the number of subsidized financing and direct support IPs targeting energy sectors. Whiskers represent 90 percent confidence intervals. In panel 2 and panel 3, the key independent variables are the change in the number of direct support IPs in upstream energy (yellow) and non-energy (gray) sectors. All specifications control for one lag of dependent and independent variables, for IPs implemented in downstream sectors, and include country-sector, country-year, and sector-year fixed effects. Shaded areas represent 90 percent confidence intervals. TFP = total factor productivity.

# Aggregate Effects of Industrial Policy

## Model-based investigation

# Cross-sector spillovers and aggregate effects of IP
## Analysis through a quantitative trade model

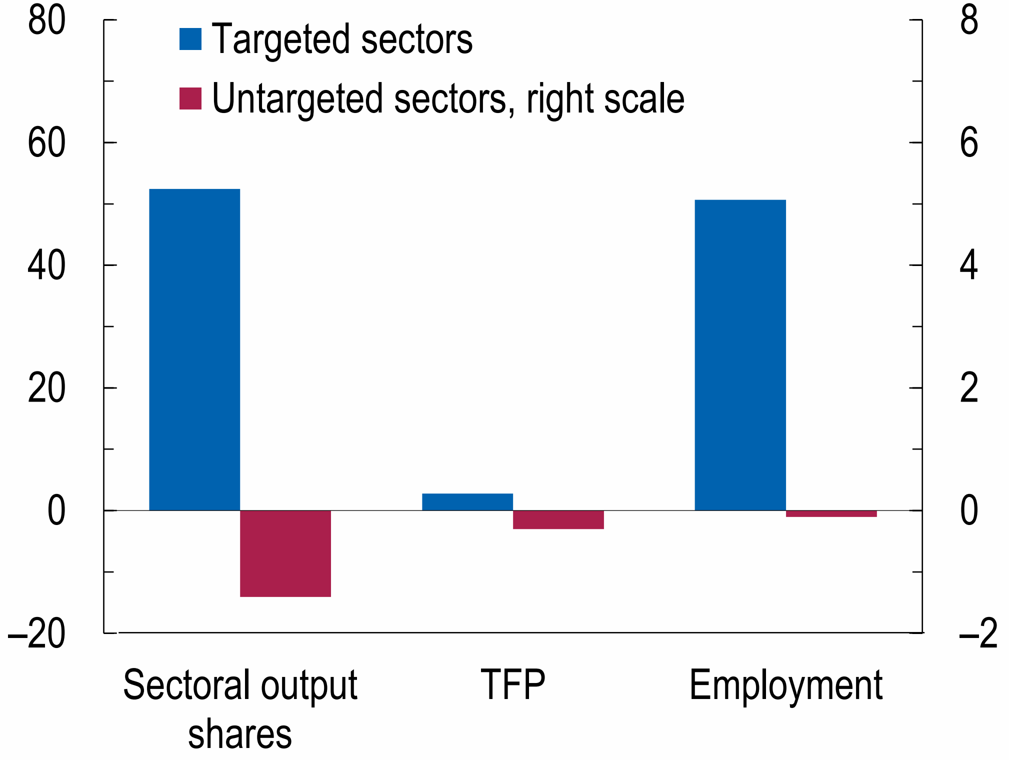
- **Quantitative trade model will analyze aggregate effects of IP and cross-sector spillovers over long term**
- 20 sectors, increasing returns to scale, input-output linkages (Rotunno et al. (forthcoming))
- Labor is unique factor of production
- Calibration to 2024 policies and 2019 production data in 4-country version (US – EU – China – RoW)

- **Comparison of equilibria across three policy scenarios:**
  - <u>Scenario 1:</u> Targeted production subsidies to correct externality in **one sector** (energy)
  - <u>Scenario 2:</u> Targeted production subsidies to correct externality **across all manufacturing sectors**
  - <u>Scenario 3:</u> **Untargeted** production subsidies (same fiscal envelope as (2), but homogeneously distributed)

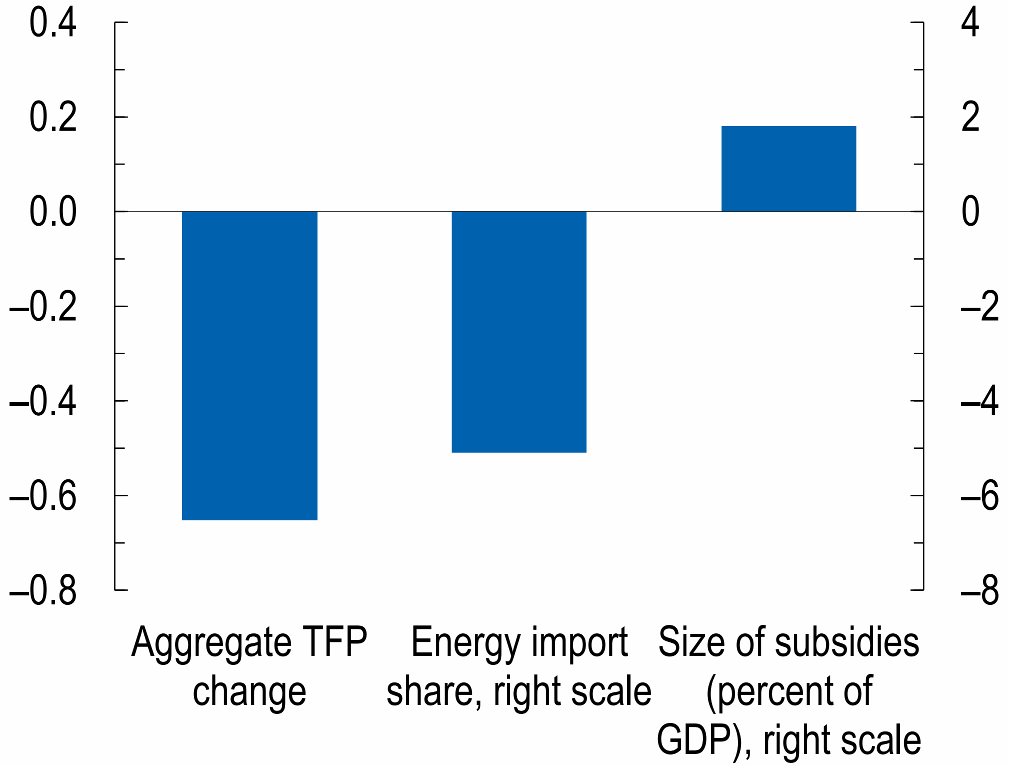
- **Outcome:**
- Aggregate productivity, allocation of labor across sectors, production levels, and welfare
- Highlight aggregate effects along with key channels (production, reallocation of resources, spillback)

# Energy sector IP
## Cross-sector spillovers can create negative aggregate effects

### Sectoral Effects on Targeted and Untargeted Sectors
*(Percent)*



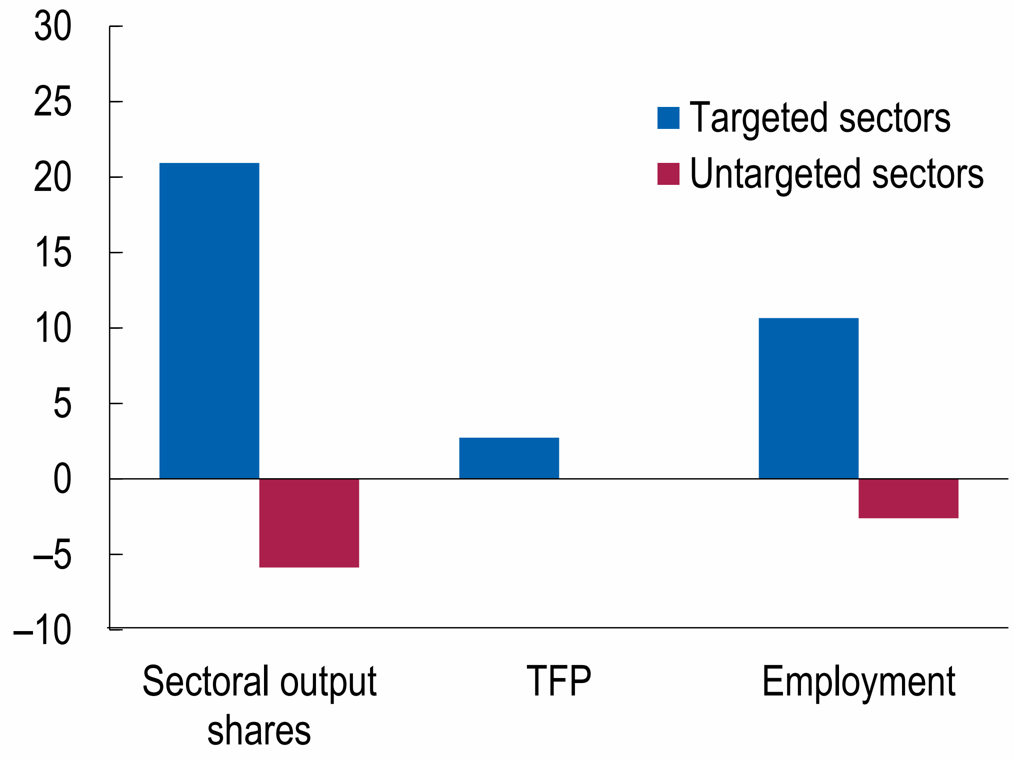

### Aggregate Effects
*(Percentage points, unless noted otherwise)*



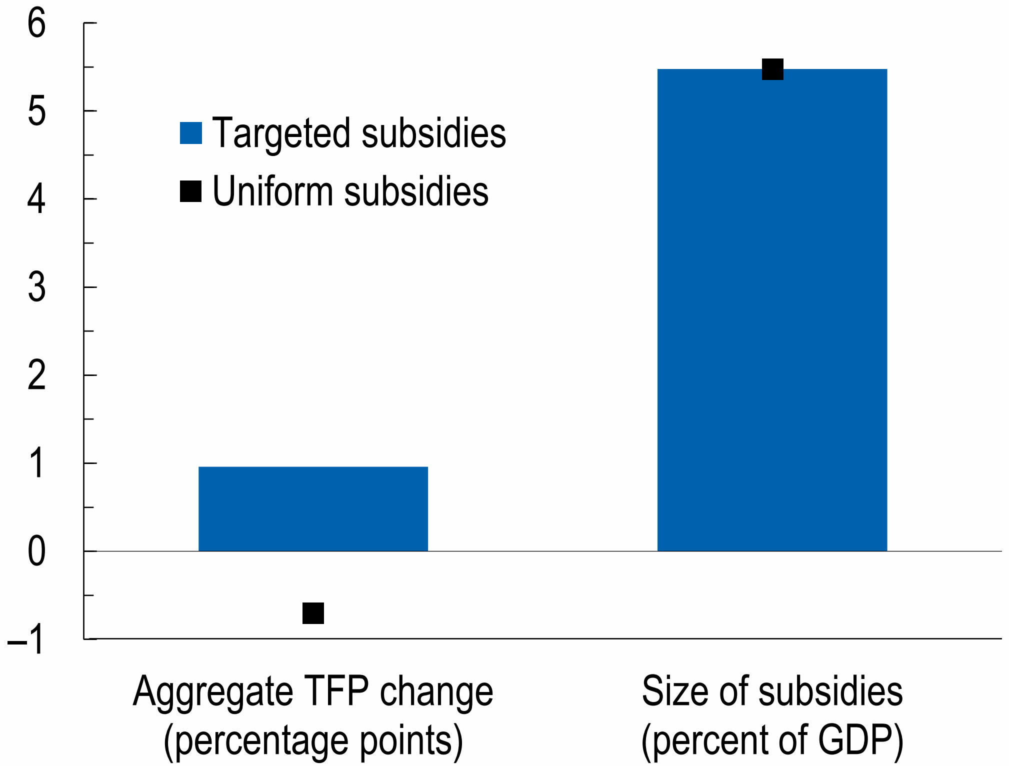

Sources: Global Trade Alert; Market Access Map; Organisation for Economic Co-operation and Development, Inter-Country Input-Output tables and Trade in Value-Added indicators; and IMF staff calculations.
Note: Figure shows changes in energy industrial policy (IP) scenario relative to the status quo baseline from estimates of quantitative trade model. Energy IP scenario simulates introduction of optimal subsidies in the energy sector. IPs are introduced for the AEs in the sample (Australia, Canada, EU, Iceland, Israel, Japan, Korea, New Zealand, Norway, Switzerland, United Kingdom, United States), and results are reported as weighted average effect across all AEs, unless noted otherwise. Weights are shares in total output by AEs. Targeted energy sectors are “energy mining,” “coke and petroleum refining,” and “electrical equipment.” IPs in all other sectors (untargeted sectors) remain unchanged. Panel 1 reports percentage change in sectoral output, TFP, and employment calculated as the weighted sum across targeted and untargeted sectors. Panel 2 reports percentage changes in aggregate TFP. Subsidy costs are reported as change relative to the status quo baseline. AEs = advanced economies; TFP = total factor productivity.

# IP across all manufacturing sectors would be fiscally costly
## Aggregate effects depend on targeting

### Sectoral Effects on Targeted and Untargeted Sectors
*(Percent)*




### Aggregate Effects




Sources: Global Trade Alert; Market Access Map; Organisation for Economic Co-operation and Development, Inter-Country Input-Output tables and Trade in Value-Added indicators; and IMF staff calculations.
Note: Figure shows changes in heterogeneous industrial policy (IP) scenario relative to the status quo baseline from estimates of quantitative trade model. Heterogeneous IP scenario simulates introduction of optimal subsidies in all sectors with increasing returns to scale, that is, manufacturing sectors. IPs are introduced for the AEs in the sample (Australia, Canada, EU, Iceland, Israel, Japan, Korea, New Zealand, Norway, Switzerland, United Kingdom, United States), and results are reported as weighted average effect across all AEs, unless noted otherwise. Weights are shares in total output by AEs. The left-hand side figure reports percentage change in sectoral output, TFP, and employment calculated as the weighted sum across targeted and untargeted sectors. The right-hand side figure reports percentage changes in aggregate TFP. Subsidy costs are reported as change relative to the status quo baseline. AEs = advanced economies; TFP = total factor productivity.

# Conclusion

# Key takeaways

- Well-targeted subsidies can **correct market failures** and boost production and productivity overtime, as demonstrated by successful cases (e.g., Korea)

- High **risks of policy mistakes**:
  - Sector level **success depends on key sector / country characteristics**, which are hard to measure ex-ante. Policy design and execution are also key.
  - **Fiscal costs:** The fiscal costs of even well-targeted IP can be considerable. If IP is poorly targeted, scarce public funds may be squandered without achieving desired results.

- IP presents **trade-offs**, even when designed and executed properly.
  - **Targeted sectors vs non-targeted sectors.** Cross-sectoral spillovers imply that positive aggregate outcomes are not guaranteed even if the targeted sector benefits unambiguously.
  - **Efficiency vs resilience**: IP could succeed in onshoring targeted industries while increasing costs for consumers during the transition.

# Policy implications

- Be mindful of the **risk of wasteful spending** from **poorly targeted and poorly governed IP**, particularly in the current context of elevated public debts and limited fiscal space.

- Carefully consider
  - **Opportunity costs**: horizontal measures / infrastructure might deliver superior outcomes.
  - **Trade-offs** between competing goals from IP.

- If IP is pursued, **focus on good design and implementation**, which entails:
  - identifying the **market failure / targeting** appropriately,
  - regularly assessing effectiveness to **recalibrate** the appropriate level of public support, and
  - including **safeguards** to avoid the piling up of wasteful subsidies (e.g., via sunset clauses).

- Effective IP requires **strong institutions** (including fiscal institutions), **transparent governance**, and **macroeconomic stability**.

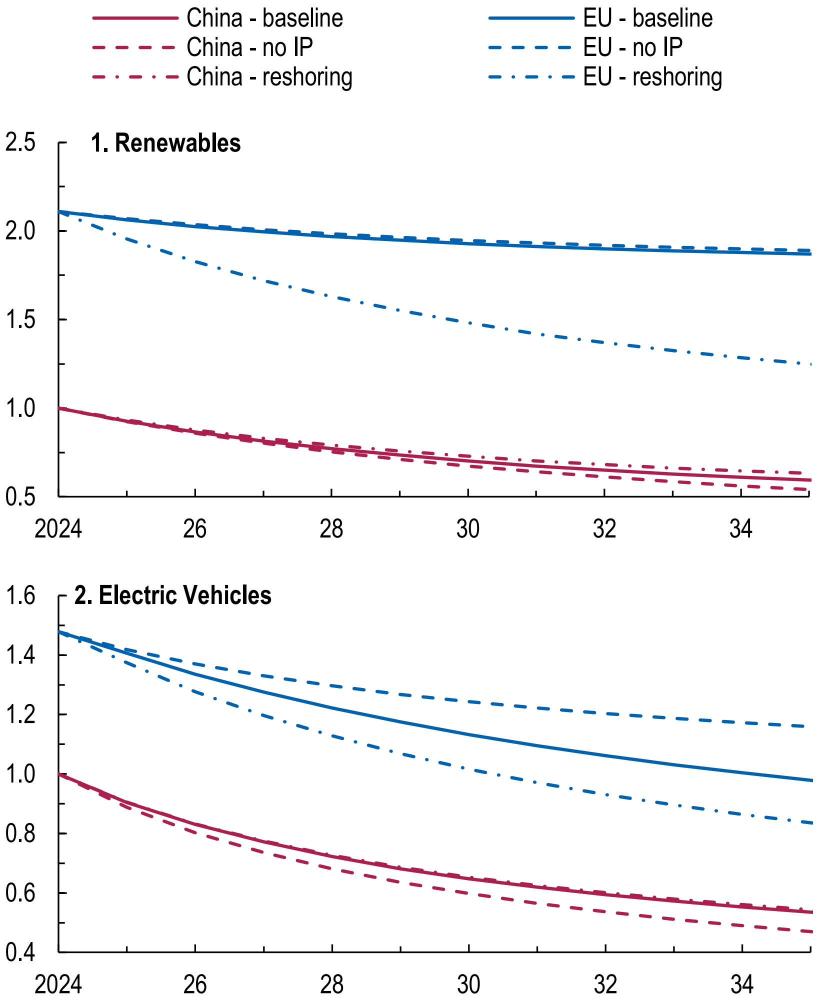
# World Economic Outlook
# October 2025

**THANK YOU!**

# Scenario analysis: industrial policy for energy security in Europe

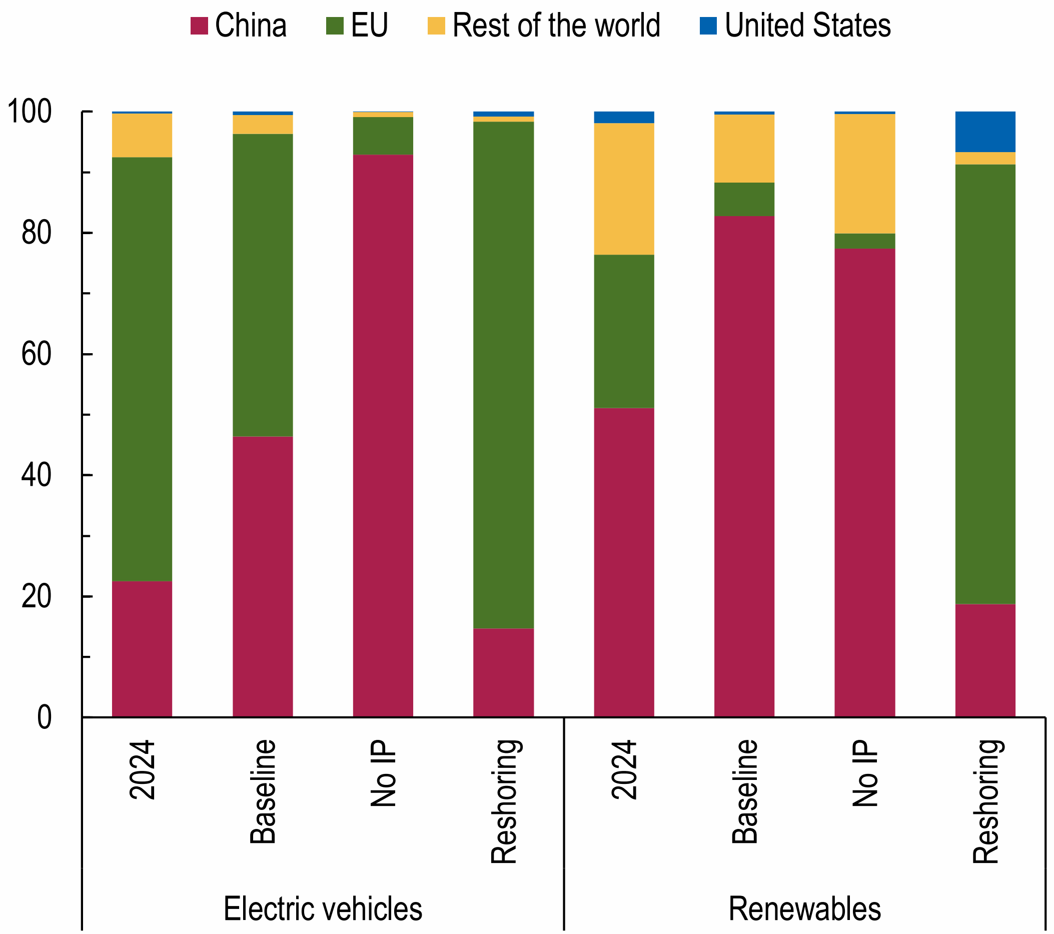
## Production costs over time by scenario

*(Normalized, China costs = 1 in 2024)*




## EU clean tech sourcing by scenario in 2035

*(Percent)*



# Stylized Learning-by-doing Model
## Set up

- The partial equilibrium model (Harrison and Rodriguez-Clare 2009, Melitz 2005, Redding 1999).
  - two countries – tech leader and tech laggard
  - two goods – a high-tech good in the infant industry and an outside good.

- Consumers have quasilinear preferences with a CES aggregator over varieties of the high-tech good:

$$u^i\left(x_{i.1}, x_{i,2}, V\right) = V + \ a^{\frac{1}{\sigma}} \frac{\sigma}{\sigma - 1} C_i^{\frac{\sigma-1}{\sigma}}$$

$$C_i = (\ \alpha_1{}^{\frac{1}{\varepsilon}} \left(x_{i,1}\right)^{\frac{\varepsilon-1}{\varepsilon}} \ + \ \alpha_2{}^{\frac{1}{\varepsilon}} \left(x_{i,2}\right)^{\frac{\varepsilon-1}{\varepsilon}} \ )^{\frac{\varepsilon}{\varepsilon-1}}$$

- Country-level learning-by-doing $(\beta)$ based on accumulated experience determine production costs

$$c_{i,t}\left(Q_{i,t}^{hist}\right) = \ k_i {Q_{i,t}^{hist}}^{-\beta} \text{ where } \ Q_{i,t}^{hist} = \sum_{s=0}^{t-1} Q_{i.s} \quad \text{for given } \ Q_{i,0}^{hist}$$

- Each period, total production must satisfy $Q_{i.t} = \sum_z x_{z,i,t}$

# Stylized Learning-by-doing Model
## Policy instruments and calibration

- Two policy instruments
  - an ad-valorem import tariff, $\tau_i$.
  - countries may impose domestic production subsidies, $\theta_j$

- Perfect competition

$$p_{i,j,t} = c_{j,t}\,(1 + \tau_i)(1 - \theta_j)$$

- Household budget constraint

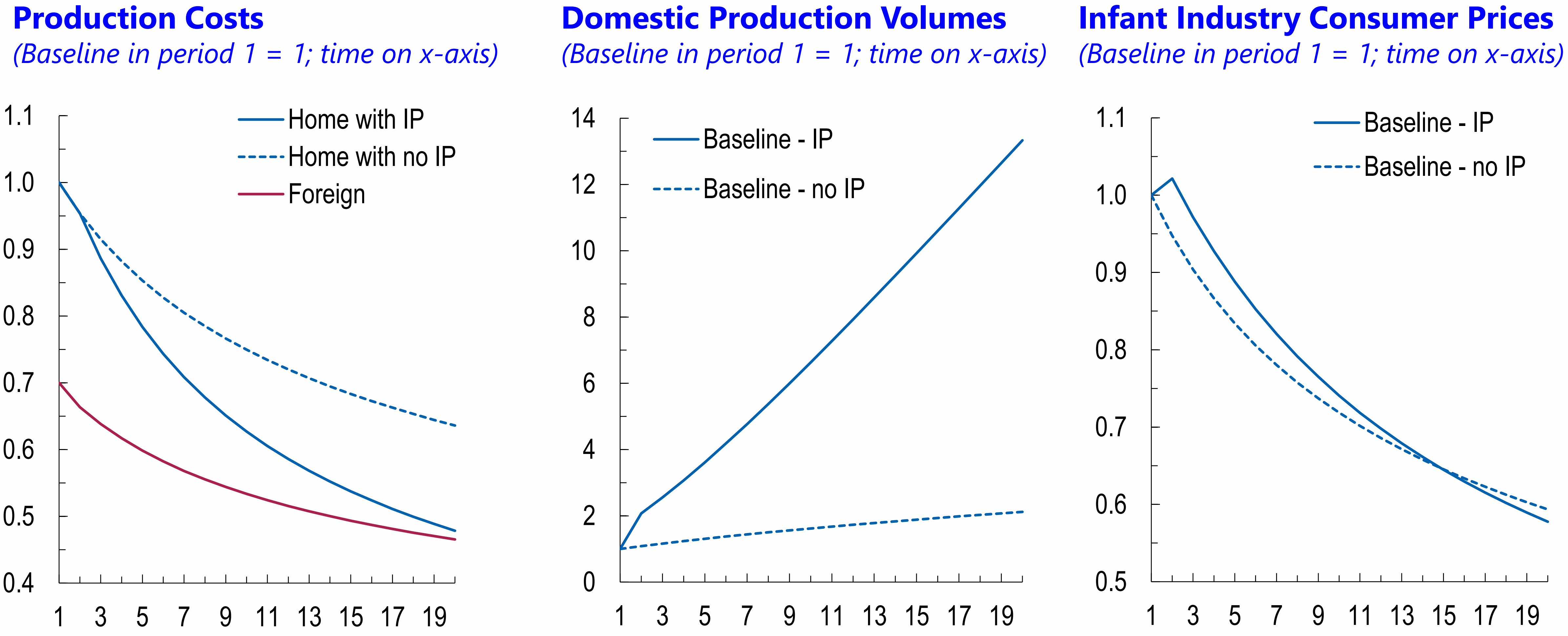
$$I_t + T_t = V_t + p_t' X_t$$

**Online Annex Table 3.3.1. Model Calibration**

| | Home | Foreign |
|---|---|---|
| | (1) | (2) |
| Initial Cost | 1.0 | 0.7 |
| Initial Experience | 2.0 | 10.0 |
| Baseline Learning Rate (Percent) | 19.0 | 19.0 |
| Trade Elasticity | 5.0 | 5.0 |
| Demand Elasticity | 2.0 | 2.0 |

Source: IMF staff compilation.

# Effects on production costs & volumes, consumption, and trade
## Infant industry protection model



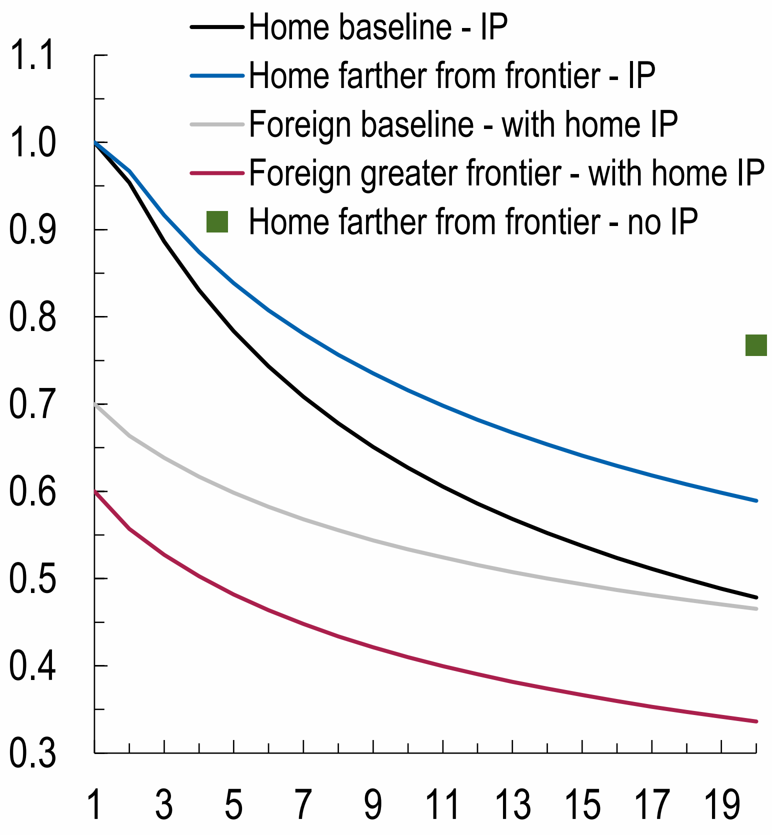

Source: IMF staff calculations.
Note: Period 1 simulates model outcomes for one period assuming no IPs. Thus, period 1 outcomes are identical across both scenarios. IP scenario assumes that home economy imposes trade protections and production subsidies (12 percent production subsidy and 10 percent tariff) in period 2 and onward. The "no IP" scenario assumes that no Ips are in place from period 1 onward. The learning rate is 19 percent. Normalizations in period 1 are as follows: production costs, production volumes, and consumer prices are each normalized to 1. IP = industrial policy.



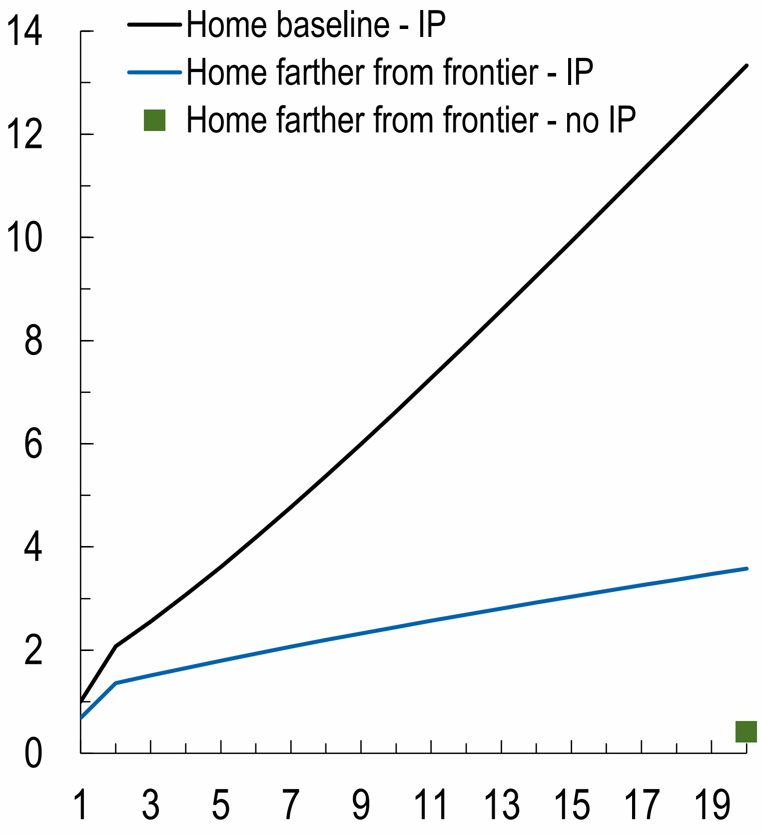
Back

# Intertemporal trade-offs depend on distance from frontier
## Infant industry protection model

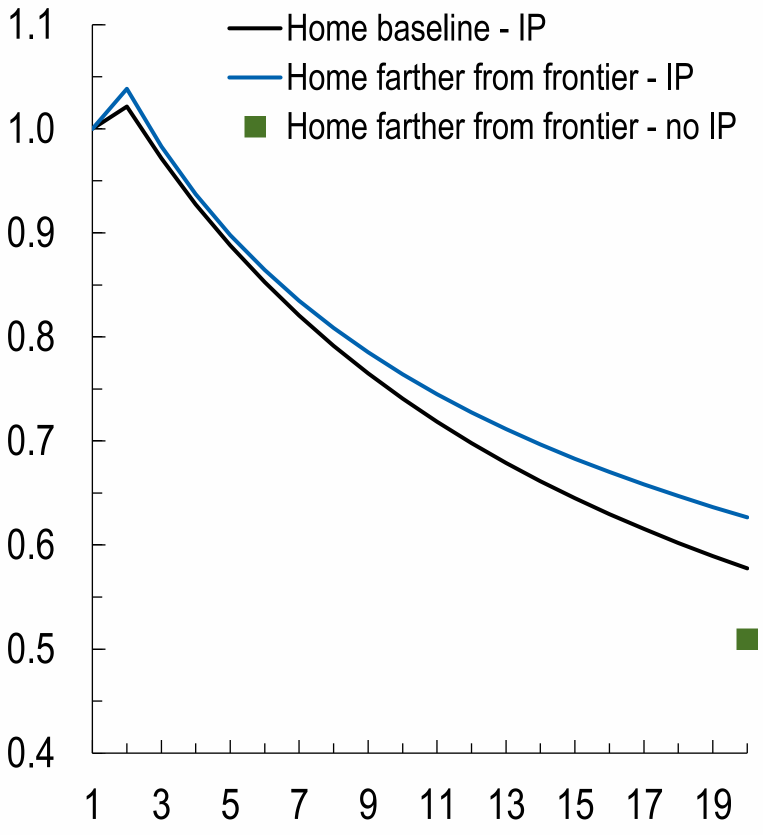
### Production Costs
*(Baseline in period 1 = 1; time on x-axis)*




### Domestic Production Volumes
*(Baseline in period 1 = 1; time on x-axis)*



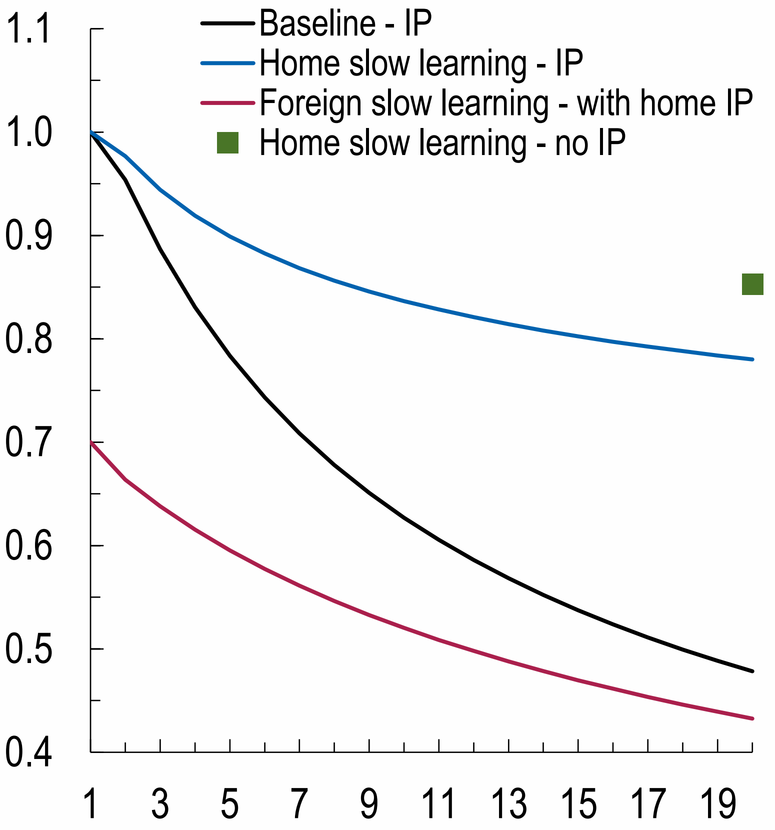

### Consumer Prices
*(Baseline in period 1 = 1; time on x-axis)*



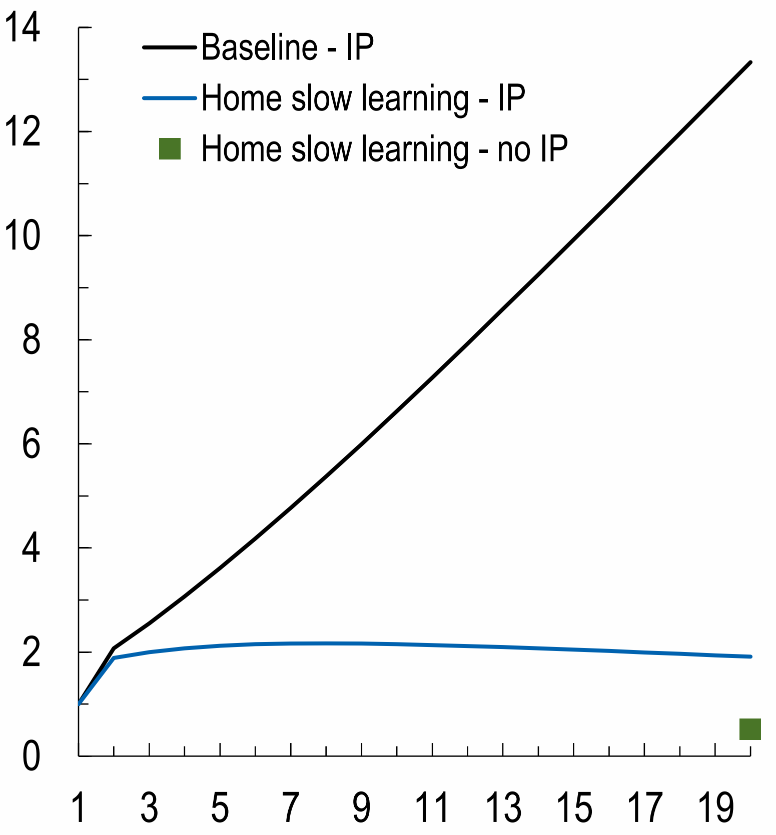

Source: IMF staff calculations.
Note: For all panels, t = 1 features no industrial policy (IP) and IP is introduced at t = 2. Charts compare home economy outcomes under IP (12 percent production subsidy and 10 percent tariff) when foreign country has a 40 percent cost advantage to outcomes under baseline where the foreign country has a 30 percent cost advantage for production costs (panel 1), domestic production (panel 2), and consumer prices (panel 3). Diamonds indicate home country outcomes in period 20 in scenario with a greater foreign cost advantage in the absence of IP, that is, with 0 percent subsidy and 0 percent tariff.

# Intertemporal trade-offs depend on learning rate
## Infant industry protection model

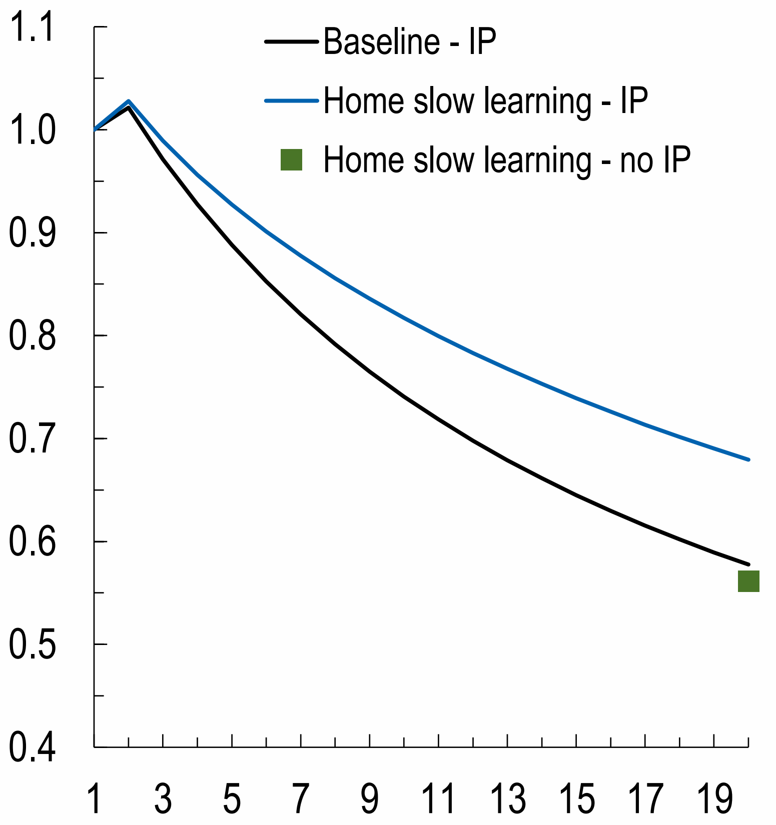
### Production Costs
*(Baseline in period 1 = 1; time on x-axis)*




### Domestic Production Volumes
*(Baseline in period 1 = 1; time on x-axis)*



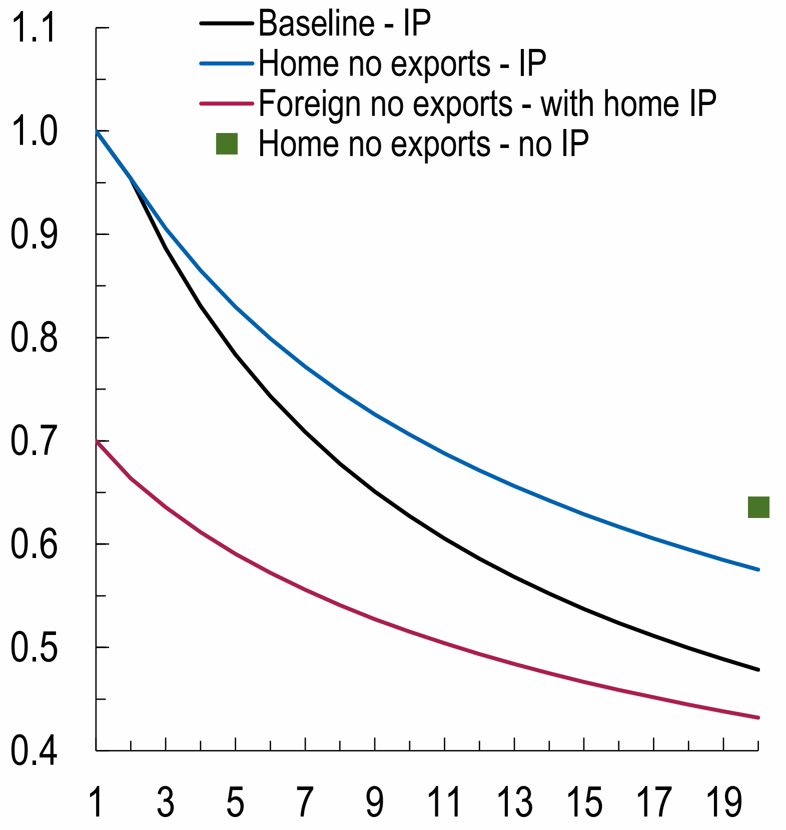

### Consumer Prices
*(Baseline in period 1 = 1; time on x-axis)*



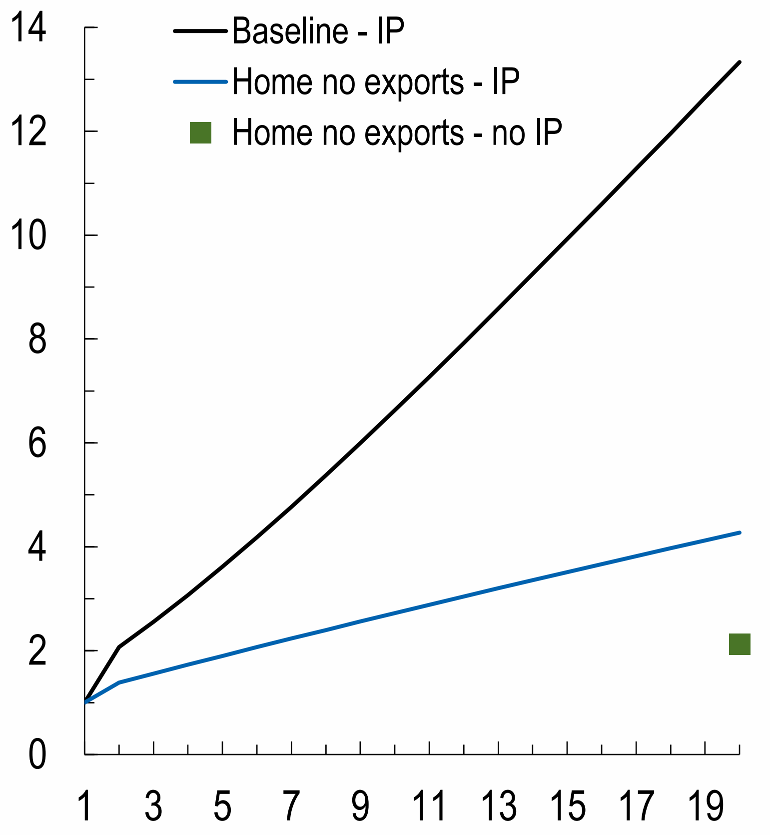

Source: IMF staff calculations.
Note: For all panels, t = 1 features no industrial policy (IP) and IP is introduced at t = 2. Charts compare home economy outcomes under IP (12 percent production subsidy and 10 percent tariff) when the home country has a 9.5 percent learning rate to baseline where the home country has a 19 percent learning rate. Outcomes considered are production costs (panel 1), domestic production (panel 2), and consumer prices (panel 3). Diamonds indicate home country outcomes in period 20 in the slow domestic learning rate scenario in the absence of IP, that is, with 0 percent subsidy and 0 percent tariff.

# Intertemporal trade-offs depend on market size
## Infant industry protection model

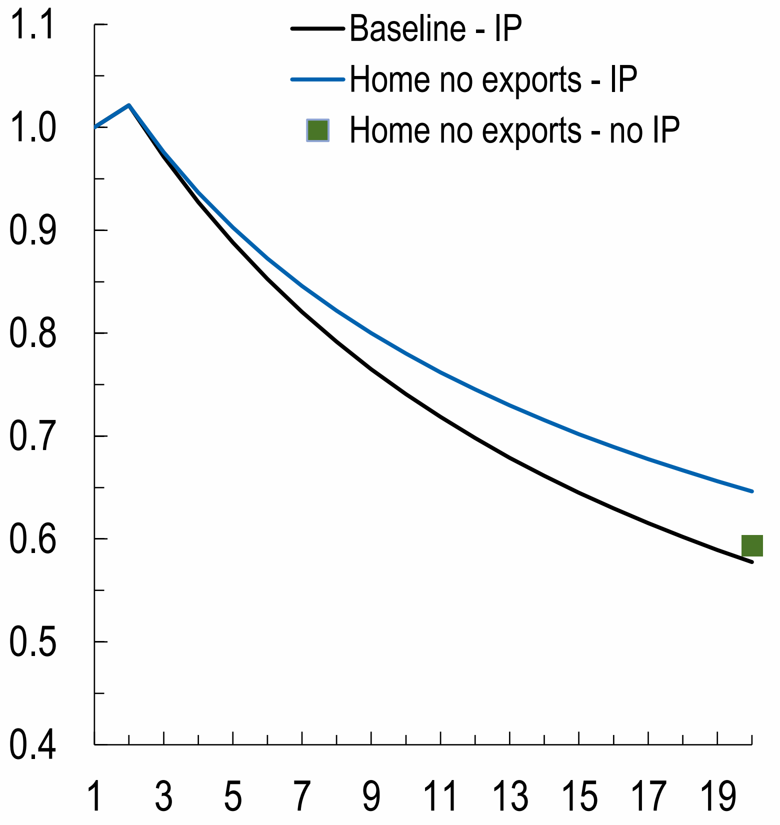
### Production Costs
*(Baseline in period 1 = 1; time on x-axis)*




### Domestic Production Volumes
*(Baseline in period 1 = 1; time on x-axis)*




### Consumer Prices
*(Baseline in period 1 = 1; time on x-axis)*




Source: IMF staff calculations.

Note: For all panels, t = 1 features no industrial policy (IP) and IP is introduced at t = 2. Charts compare home economy outcomes under IP (12 percent production subsidy and 10 percent tariff) when the home country has no access to export markets to a baseline simulation where the home country has access to export markets. Outcomes considered are production costs (panel 1), domestic production (panel 2), and consumer prices (panel 3). Diamonds indicate outcomes in period 20 in the scenario with no exports by the home country in the absence of IP, that is, with 0 percent subsidy and 0 percent tariff.

# Quantitative 4-country Learning-by-Doing Model
## Set up

- Consumers have quasilinear preferences with a CES aggregator over varieties of the high-tech good:

$$u^i(x_{i.1}, x_{i,2}, x_{i,3}, x_{i,4}, V) = V + a^{\frac{1}{\sigma}} \frac{\sigma}{\sigma - 1} C_1^{\frac{\sigma-1}{\sigma}}$$

$$C_i = \left( \alpha_1^{\frac{1}{\varepsilon}} (x_{i,1})^{\frac{\varepsilon-1}{\varepsilon}} + \alpha_2^{\frac{1}{\varepsilon}} (x_{i,2})^{\frac{\varepsilon-1}{\varepsilon}} + \alpha_3^{\frac{1}{\varepsilon}} (x_{i,3})^{\frac{\varepsilon-1}{\varepsilon}} + \alpha_4^{\frac{1}{\varepsilon}} (x_{i,4})^{\frac{\varepsilon-1}{\varepsilon}} \right)^{\frac{\varepsilon}{\varepsilon-1}}$$

- Country-level learning-by-doing ($\beta$) based on accumulated experience determine production costs

$$c_{i,t}(Q_{i,t}^{hist}) = k_i {Q_{i,t}^{hist}}^{-\beta} \text{ where } Q_{i,t}^{hist} = \sum_{s=0}^{t-1} Q_{i.s} \text{ for given } Q_{i,0}^{hist}$$

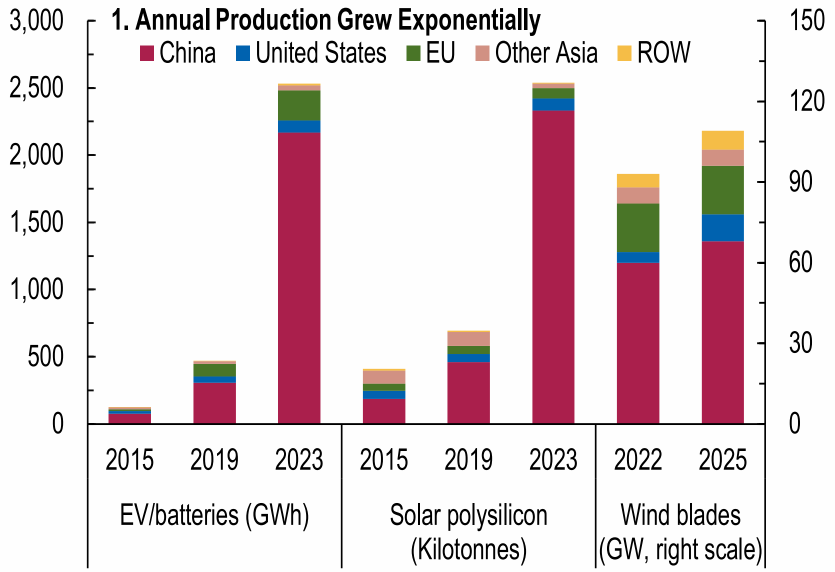
- Each period, total production must satisfy $Q_{i.t} = \sum_z x_{z,i,t}$

- Perfect competition

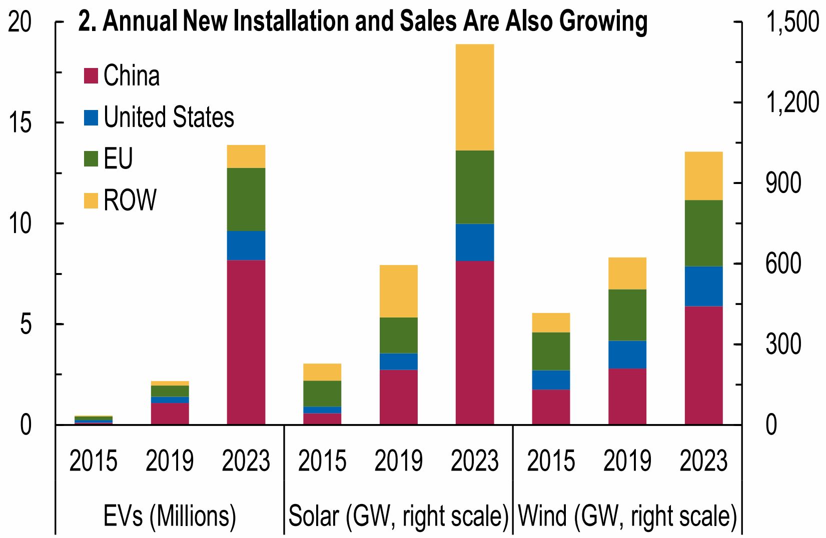
$$p_{i,j,t} = c_{j,t} (1 + \tau_i)(1 - \theta_j)$$

# China's advantage in clean tech manufacturing

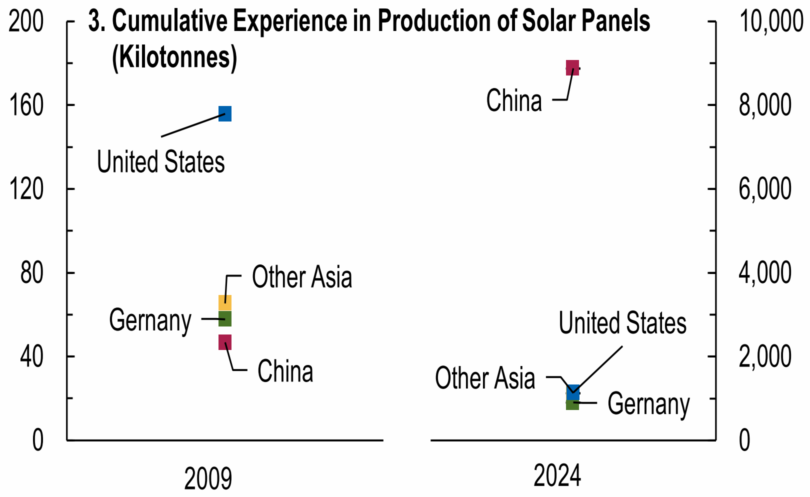
## Annual production of clean tech




## Annual installation of clean tech




## Cumulative experience




Sources: Bloomberg New Energy Finance; International Renewable Energy Agency; and IMF staff calculations.
Note: In Panel 1, for solar polysilicon, EU only contains Germany. For EV/batteries, the blue bars represent North America. In panel 2, for solar and wind, EU includes EU countries and United Kingdom. Panel 3 shows the cumulative solar production 2004–2009; and 2004–2024. EVs = electric vehicles; EU = European Union; ROW = rest of the world.


Back

# Stylized Learning-by-doing Model
## Calibration

**Online Annex Table 3.4.1. Renewable Energy Parameters**

| | Renewables | | | | |
|---|---|---|---|---|---|
| | China | European Union | Rest of the World | United States | Sources |
| | (1) | (2) | (3) | (4) | (5) |
| Initial Cost (USD/kW) | 238 | 503 | 503 | 480 | IEA; IRENA 2023 |
| Domestic Market Size (2023) | 293 | 65 | 73 | 31 | IRENA 2023 |
| Learning Rate (Percent) | 21 | 21 | 21 | 21 | IRENA 2023 |

Sources: International Energy Agency (IEA); International Renewable Energy Agency (IRENA) 2023; and IMF staff compilation.

**Online Annex Table 3.4.2. Electric Vehicle Parameters**

| | Electric Vehicles | | | | |
|---|---|---|---|---|---|
| | China | European Union | Rest of the World | United States | Source |
| | (1) | (2) | (3) | (4) | (5) |
| Initial Cost (USD/kWh) | 94.0 | 139.0 | 139.0 | 123.0 | BNEF 2024 |
| Domestic Market Size (Million vehicles, 2023) | 9.9 | 2.9 | 2.1 | 1.8 | BNEF 2024 |
| Learning Rate (Percent) | 18.0 | 18.0 | 18.0 | 18.0 | Barwick and others 2024; BNEF 2024 |

Sources: Barwick and others 2024; Bloomberg New Energy Finance (BNEF) 2024; and IMF staff compilation.

# Stylized Learning-by-doing Model
## Tariffs in each scenario

**Online Annex Table 3.4.3. Bilateral Import Tariff Rates**

*(Percent)*

| Importing Regions \ Exporting Regions | | Electric Vehicles | | | | Renewables | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | China | EU | ROW | US | China | EU | ROW | US |
| | | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Baseline | China | — | 15.0 | 15.0 | 15.0 | — | 1.6 | 1.6 | 1.6 |
| | EU | 30.7 | — | 10.0 | 10.0 | 16.7 | — | 16.7 | 16.7 |
| | ROW | 16.0 | 16.0 | — | 16.0 | 3.9 | 3.9 | — | 3.9 |
| | US | 50.0 | 2.3 | 2.3 | — | 39.6 | 38.3 | 38.3 | — |
| No IP | China | — | 0.0 | 0.0 | 0.0 | — | 0.0 | 0.0 | 0.0 |
| | EU | 0.0 | — | 0.0 | 0.0 | 0.0 | — | 0.0 | 0.0 |
| | ROW | 0.0 | 0.0 | — | 0.0 | 0.0 | 0.0 | — | 0.0 |
| | US | 0.0 | 0.0 | 0.0 | — | 0.0 | 0.0 | 0.0 | — |
| Reshoring | China | — | 15.0 | 15.0 | 15.0 | — | 1.6 | 1.6 | 1.6 |
| | EU | 30.7 | — | 10.0 | 10.0 | 16.7 | — | 16.7 | 16.7 |
| | ROW | 16.0 | 16.0 | — | 16.0 | 3.9 | 3.9 | — | 3.9 |
| | US | 50.0 | 2.3 | 2.3 | — | 39.6 | 38.3 | 38.3 | — |

Sources: International Trade Centre (ITC), Market Access Map; and IMF staff calculations.

Note: Tariffs are based on product-level tariffs from the ITC Market Access Map for latest year available (2022 for most countries and 2021 in some instances). Data retrieved on December 19th, 2024. These tariffs are supplemented with country-specific information that capture deviations and updates relative to 2022 Market Access Map tariff rates. Based on end products listed in Rosenow and Mealy (2024), renewables are identified as HS6 codes 854140 (solar) and HS6 codes 841290, 850300, and 730820 (wind). EVs and EV batteries are identified as HS6 codes 850710, 850619, 850780, 870390, 870290. Aggregations across products and across countries are computed as simple averages. EU = European Union; ROW = rest of the world; US = United States; IP = industrial policy.

# Stylized Learning-by-doing Model
## Subsidies in each scenario

**Online Annex Table 3.4.4. Subsidy Rates**

*(Percent)*

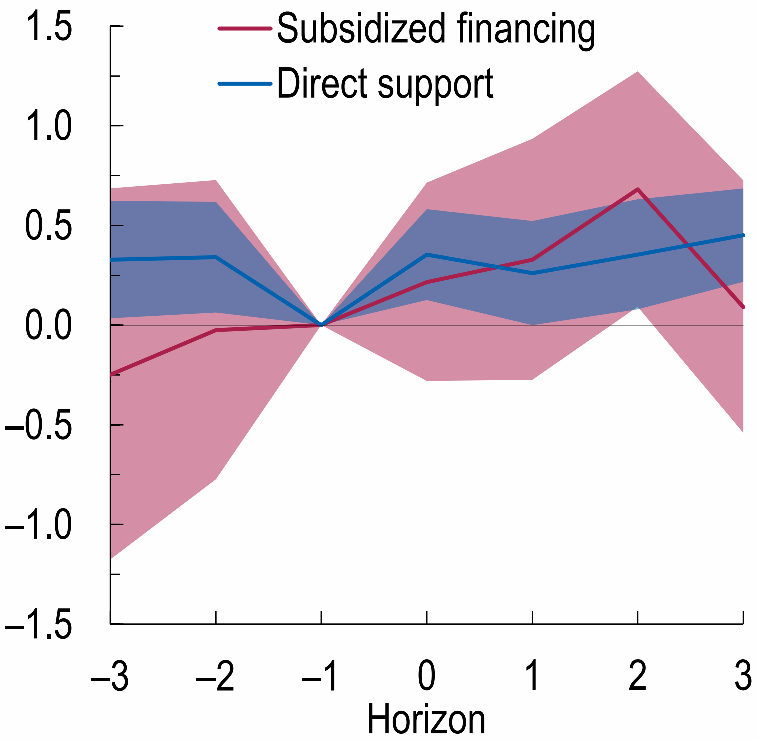
| | Producing Region | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Electric Vehicles | | | | Renewables | | | |
| | China | European Union | Rest of the World | United States | China | European Union | Rest of the World | United States |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Baseline | 1.2 | 0.3 | 0.0 | 1.5 | 1.2 | 0.3 | 0.0 | 1.5 |
| No IP | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Reshoring | 1.2 | 15.0 | 0.0 | 15.0 | 1.2 | 30.0 | 0.0 | 30.0 |

Sources: Global Trade Alert; New Industrial Policy Observatory; and IMF staff calculations.

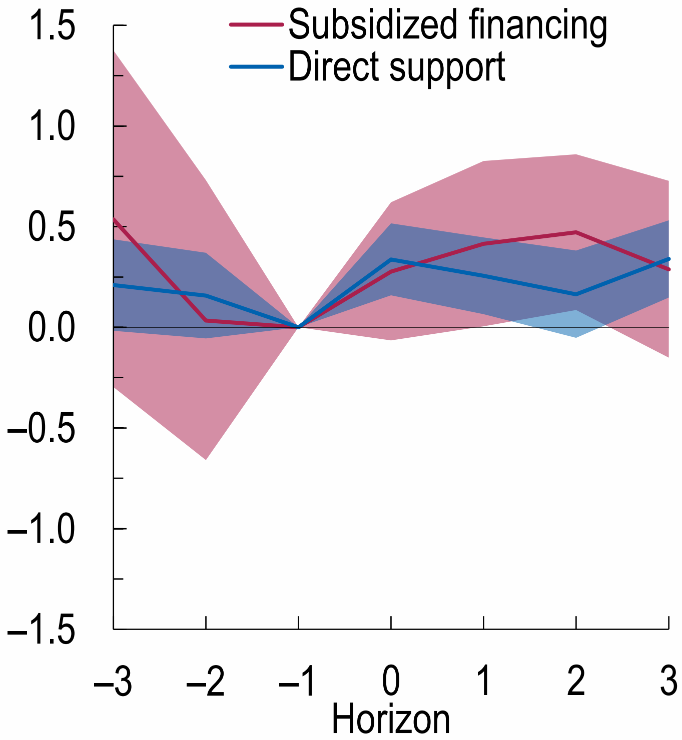
Note: Baseline subsidy rates are computed from NIPO and GTA following the methodology in Rotunno and others (forthcoming). Subsidy rates for EVs and renewables are set equal to the NIPO-GTA implied subsidy rate on "electrical equipment" sector. IP = industrial policy.

# Direct support is linked to improved value added, productivity and allocative efficiency of targeted sectors

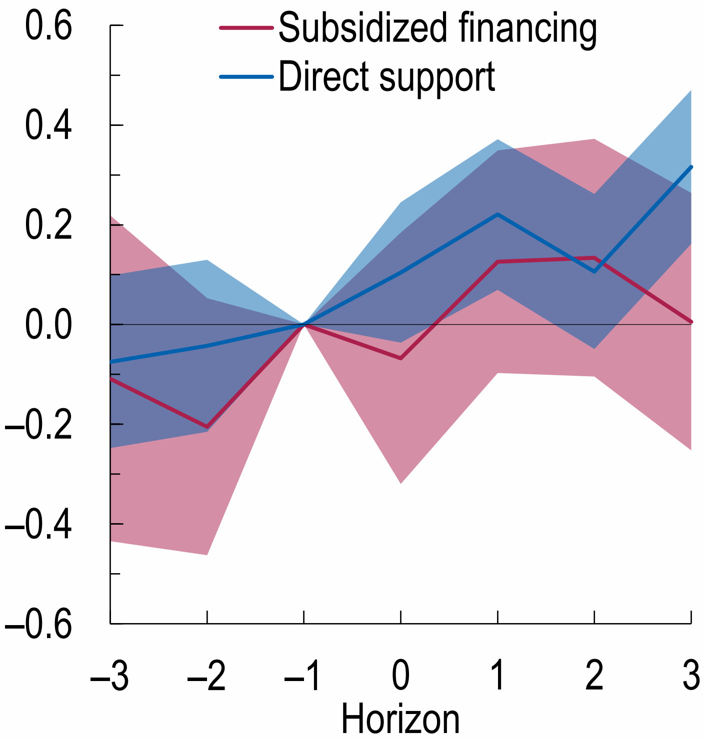
## IPs and Sector Value Added
*(Percent)*




## IPs and Sector Productivity
*(Percent)*




## IPs and Allocative Efficiency
*(Percent)*



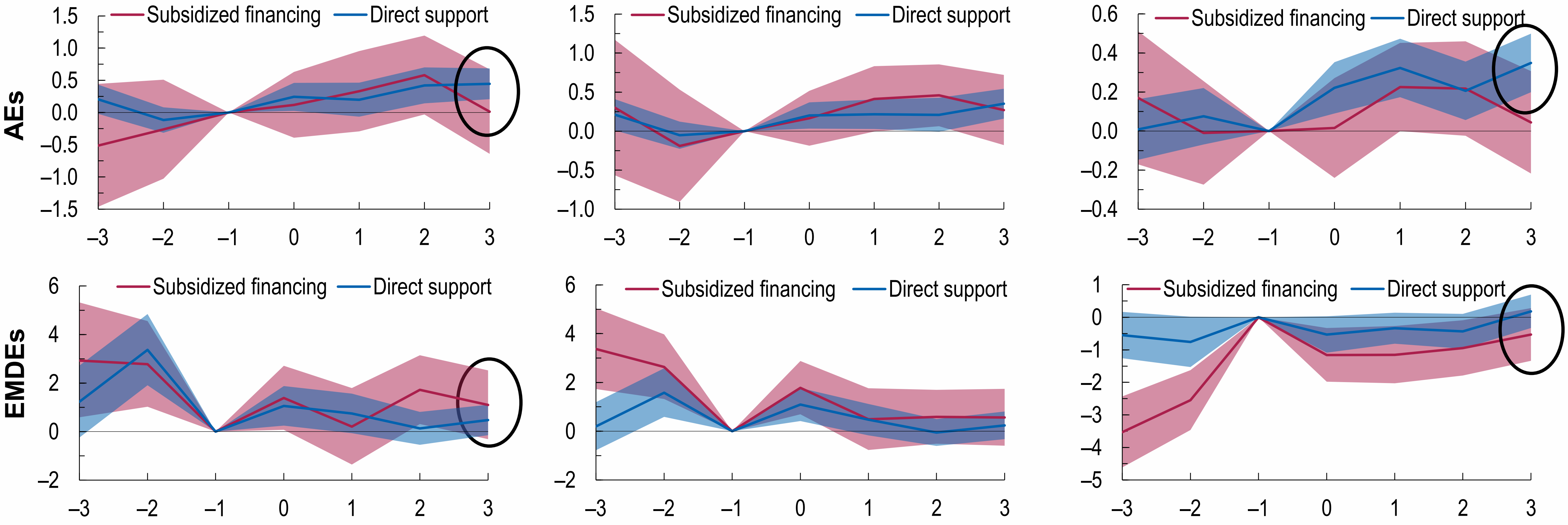

Sources: Global Trade Alert; Juhász and others 2022, 2025; Orbis; and IMF staff calculations.
Note: The figure estimates the impact of industrial policies (IPs) using the local projection method. The dependent variables are the log difference in sectoral value added, TFP, or allocative efficiency over the specified horizon. The key independent variables are the change in the number of subsidized financing and direct support IPs targeting that sector. All specifications control for one lag of dependent and independent variables and include country-sector, country-year, and sector-year fixed effects. Shaded areas represent 90 percent confidence intervals. TFP = total factor productivity.

# Direct support is linked to higher medium-term VA and allocative efficiency in AEs but not in EMDEs

**IPs and Sector Value Added**
*(Percent; horizon on x-axes)*

**IPs and Sector Productivity**
*(Percent; horizon on x-axes)*

**IPs and Allocative Efficiency**
*(Percent; horizon on x-axes)*



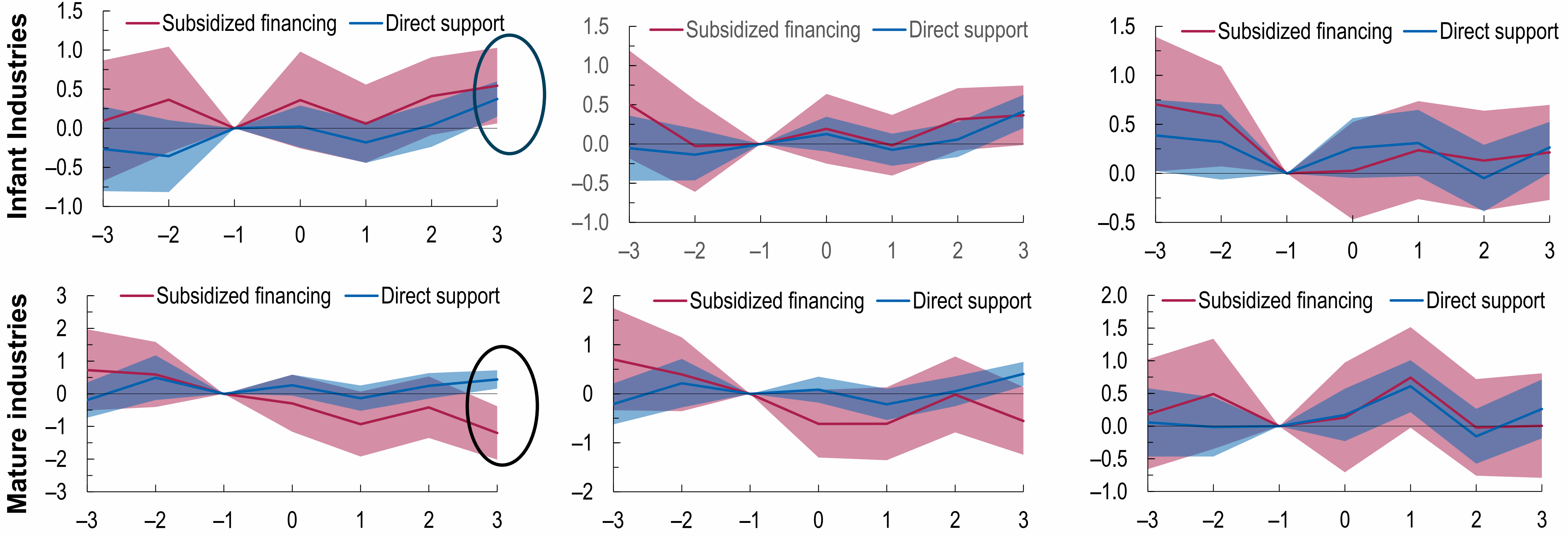

Sources: BvD Orbis; Global Trade Alert; Juhasz and others (2023); and IMF staff calculations.
Note: The figure estimates the impact of IPs using the local projection method. The dependent variables are the log difference in sectoral value added, TFP, and allocative efficiency over the specified horizon. The key independent variables are the change in the number of subsidized financing and direct support IPs targeting that sector interacted with a dummy indicating whether each country is an Advanced Economy or an Emerging Market and Developing Economy. All specifications control for one lag of dependent and independent variables and include country-sector, country-year and sector-year fixed effects. Shaded areas represent 90 percent confidence intervals.

# Subsidized financing is linked to higher value added of infant industries but lower value added of mature industries

## IPs and Sector Value Added
*(Percent; horizon on x-axes)*

## IPs and Sector Productivity
*(Percent; horizon on x-axes)*

## IPs and Allocative Efficiency
*(Percent; horizon on x-axes)*



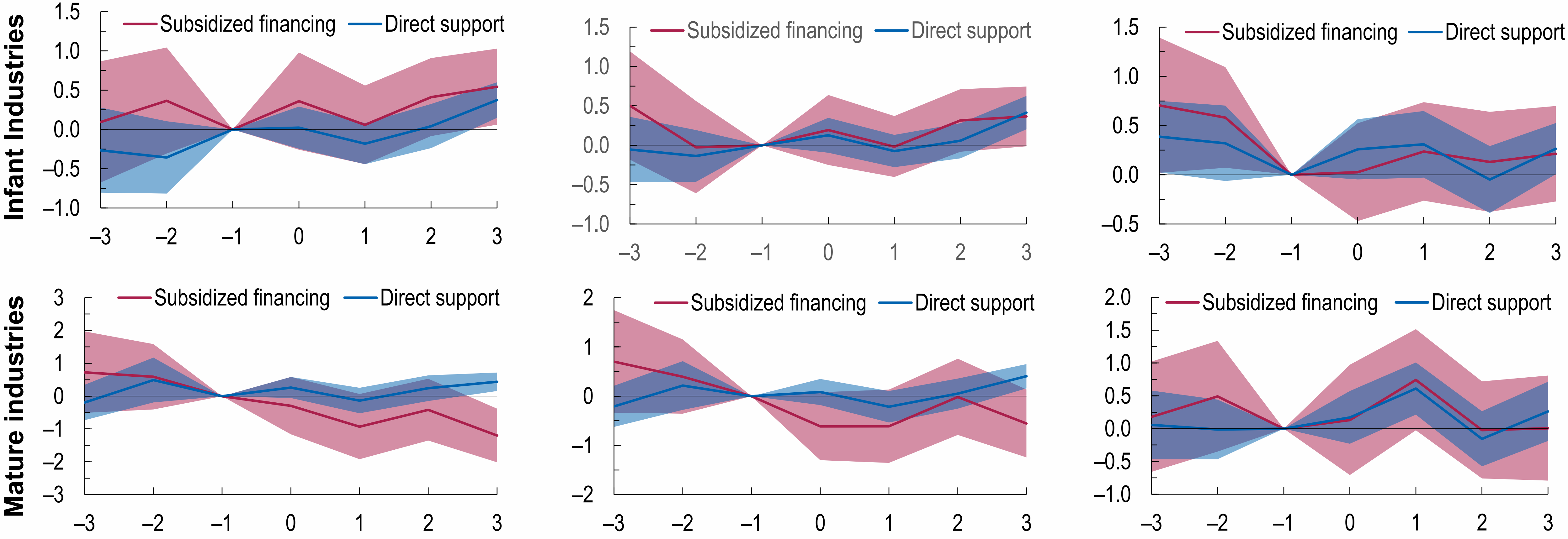

Sources: BvD Orbis; Global Trade Alert; Juhasz and others (2023); and IMF staff calculations.
Note: The figure estimates the impact of IPs using the local projection method. The dependent variables are the log difference in sectoral value added, TFP, and allocative efficiency. The key independent variables are the change in the number of subsidized financing and direct support IPs targeting that sector interacted with a dummy indicating whether each industry is infant or mature. In each country, infant industries are industries with above-average share of young and leveraged firms, and above-average distance to the world productivity frontier. All specifications control for one lag of dependent and independent variables and include country-sector, country-year and sector-year fixed effects. Shaded areas are 90 percent confidence intervals.

# Subsidized financing is linked to higher value added of infant industries but lower value added of mature industries

## IPs and Sector Value Added
*(Percent; horizon on x-axes)*

## IPs and Sector Productivity
*(Percent; horizon on x-axes)*

## IPs and Allocative Efficiency
*(Percent; horizon on x-axes)*




Sources: BvD Orbis; Global Trade Alert; Juhasz and others (2023); and IMF staff calculations.

Note: The figure estimates the impact of IPs using the local projection method. The dependent variables are the log difference in sectoral value added, TFP, and allocative efficiency. The key independent variables are the change in the number of subsidized financing and direct support IPs targeting that sector interacted with a dummy indicating whether each industry is infant or mature. In each country, infant industries are industries with above-average share of young and leveraged firms, and above-average distance to the world productivity frontier. All specifications control for one lag of dependent and independent variables and include country-sector, country-year and sector-year fixed effects. Shaded areas are 90 percent confidence intervals.