Measuring Green Capital Flows: A new database of cleantech manufacturing investment, determinants, and impacts

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September 22, 2026

Abstract

Foreign Direct Investment can help investors reap efficiency gains and access markets, and help recipient nations integrate into global value chains, absorb technology, and grow their economies. This paper creates a Cleantech Manufacturing Foreign Direct Investment Database (CMFDI) to measure and map the trends in clean technology investment in the world economy since 2000. With these data, we statistically examine the determinants and impacts of such flows in recipient countries. We find a major surge in CMFDI since 2017. Until 2017, CMFDI accounted for roughly 2 percent of all FDI flows, but it jumped tenfold to 20 percent from 2017 to 2025. Moreover, while CMFDI in 2017 was largely concentrated in advanced economies, emerging markets and developing countries now receive roughly half of all CMFDI. Strikingly, after 2017, China leaps from a net recipient of CMFDI to the largest source of CMFDI in the world economy. Our econometric analyses show that the determinants of CMFDI are a large and growing economy, high levels of 'transition minerals', and domestic manufacturing capacity. Domestic conditions, including high labor costs and saturated home markets, determine if firms will invest abroad. Finally, with some exceptions, we find that CMFDI helps host countries further integrate into green value chains and diffuse clean technology in host economies.

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1 Introduction

Countries are increasingly turning to clean technologies such as solar, wind, batteries, and electric vehicles (EVs) to address converging economic, energy security, and climate challenges. On the economic front, the energy transition offers a new suite of products and technologies for which first-mover benefits remain to be reaped, particularly through export and income growth. At the same time, these technologies provide a pathway to greater energy sovereignty by reducing dependence on fossil fuel imports and exposure to external energy supply shocks. With rising geopolitical tensions and the consolidation of regional spheres of influence, such vulnerabilities are no longer confined to developing economies. Moreover, green investment can bolster political coalitions comprising manufacturers, suppliers, and workers to support the energy transition. This amplifies opportunities for green industrial policy to effectively link climate and development and, in turn, entrench global climate action.

These overlapping motivations have intensified competition among countries to both attract and seek foreign direct investment (FDI) in clean technology value chains. From the investors' perspective, FDI offers a cost-effective alternative to exporting under uncertain tariff environments and helps investors locate production close to target markets. For destination countries, FDI can enable domestic production capacity growth and accelerate clean-technology deployment. In the short term, investment may leverage cost advantages or resource abundance to generate export revenues. In the medium term, FDI can expand access to and support the diffusion of clean technologies within destination economies. In the long term, well-managed FDI—supported by destination-country industrial policy instruments—can facilitate deeper technology transfer from foreign incumbents, fostering domestic manufacturing capabilities, innovation ecosystems, and ultimately more competitive markets. These green development and growth of manufacturing capabilities further contribute to emerging political coalitions that lobby for ambitious green industrial policy and economic development.

We contribute to this growing area of research by compiling an original Cleantech Manufacturing FDI (CMFDI) dataset of firm-level manufacturing plants from 2000–2025, covering greenfield investments in solar, wind, battery, and EVs. We compiled the dataset by initially scouting projects using Financial Times's fDi Intelligence, followed by media scraping, further data sourcing using AI agents, and rigorous human verification (see the methodological appendix, data-compilation section). The dataset enables an initial mapping of cleantech manufacturing investment patterns, highlighting their geographical and sectoral composition, as well as their evolution over time. Second, we examine the determinants of global CMFDI flows using a push-and-pull framework. Finally, we analyze the impact of CMFDI on host country economic activity such as export performance and deployment. The initial mapping of flows indicates a significant surge in CMFDI starting in 2017, with EV and battery projects leading the drive and peaking in 2023. China stands out as the single largest investor, with outbound investments greater than the combined total of advanced countries in our sample. The analysis finds that CMFDI tends to follow market-seeking logics, where firms from high-labor-cost-burdened, saturated host-country markets seek new consumer bases abroad. Host-country transition mineral abundance and established manufacturing capabilities also pull these investment projects. Moreover we find modest effects for export increases for EVs, batteries, and solar panels and deployment increases in solar energy alone. Taken together, the results identify a clear economic rationale for FDI outflows and several pathways for emerging economies to reap mutually beneficial gains, but they point to modest economic benefits due to limitations in the analysis window, especially in the EV and battery sectors.

2 The Landscape of CMFDI

The CMFDI space, visualized in Figure 1, remained somewhat inert until 2017 (Figure 1, panel a), with the majority of flows into wind power investments from select advanced economy investors such as Denmark, Germany, and France. Additionally, CMFDI destinations maintained a low but sustained inflow of CMFDI (see Appendix Figure A3), with both investment and its destinations largely concentrated among advanced economies. Solar overtook wind around 2013 in both project count and investment amount (see Appendix Figure A1). This parallels China's rise: China entered solar in 2003 as a destination for first-mover Japanese solar investments, before emerging as an investor in the same technology a decade later. China subsequently launched an overseas investment surge that made it the leading global investor within five years.

China's growth further parallels a marked shift in the share (percent of CMFDI in total FDI) and composition of investment destinations after 2017 (Figure 1, panel b). An intense first wave of investment after 2017 focuses on emerging markets, including Hungary, Morocco, Thailand, Indonesia, Malaysia, and Slovakia, which were infrequent recipients of CMFDI before 2017. These investments are mainly driven by battery and EV projects, which overtook the short-lived solar investment wave. After 2022, a second wave of emerging market destinations attracts high shares of solar and EV investment, including Oman, Ethiopia, Turkey, and India. Although countries such as the US and Germany attract more capital in absolute value than these emerging destinations, these high shares suggest an appetite, either investor- or destination-driven, for emerging clean technology industries in these economies.

China's shift from a net destination to a major net investor exemplifies a dynamic transition in this current era of transition (Figure 2). China is the most dynamic actor in this space, moving from a tiny dot on the very edge of the y-axis to the middle in a decade, and eventually becoming both the largest recipient and source of CMFDI. Yet,

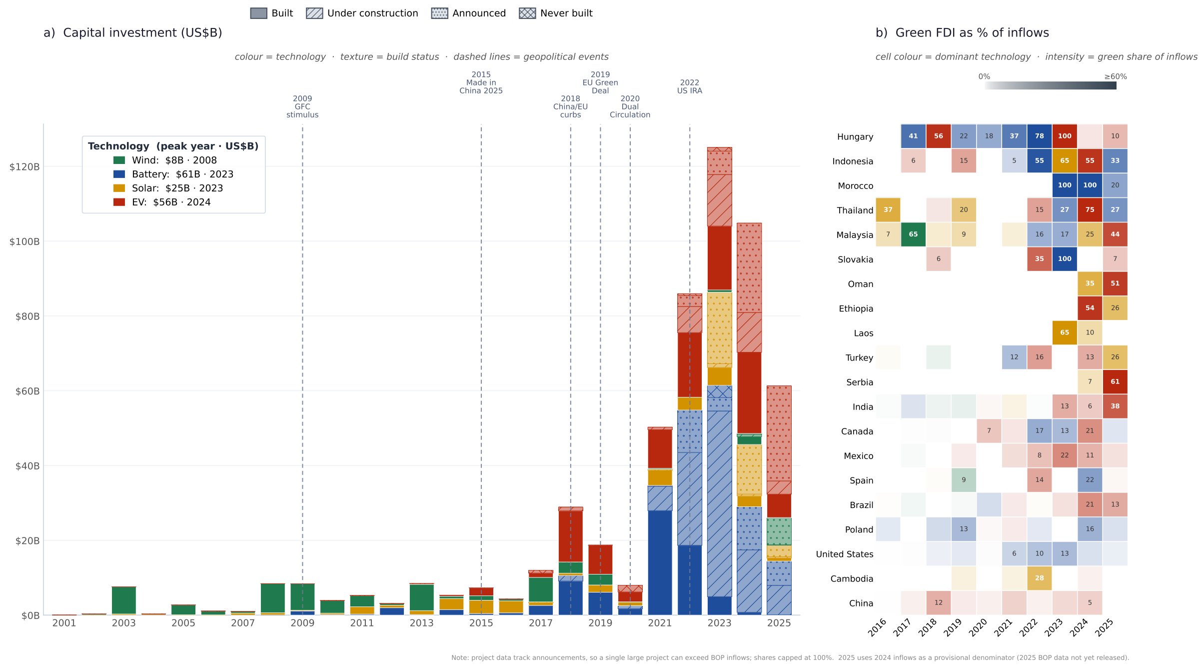


Figure 1: The Evolution of Clean Technology FDI

China is not alone in this type of transformation. Vietnam seems to be following a similar trajectory, although at a slower pace and smaller scale. India too has dislodged itself from the y-axis by steadily increasing outbound investment. Japan and Korea are close behind China in net outbound investment, though they too have moved up as destinations for inbound investment. While Germany has remained a net investor, only growing modestly in capital invested, the US seems to have changed trajectory post-2021, now standing out as a major capital-attracting destination. Finally, a group of countries, including Indonesia, Brazil, Thailand, and Hungary, are pure destinations and have only grown to attract more capital over the years. In sum, the landscape for foreign direct investment has shifted meaningfully over the last two decades, with new destination markets emerging and China moving from a net destination to the largest investor in clean technology manufacturing.

Figure 2: Disclosed capital stock of clean technology manufacturing FDI

3 The Pull and Push Framework

Having established these general patterns of CMFDI, we next detail our use of the push-and-pull framework to examine its drivers (Fernandez-Arias, 1996; Li et al., 2020, 2022). Push factors refer to source-country-specific conditions that motivate investors to expand production abroad, while pull factors refer to destination-country-specific conditions that attract investors. We complement this framework with Dunning's motivations approach (Dunning, 1980, 1988, 2000), which provides a structured typology of drivers. The Dunning approach applies to both push and pull perspectives, and the subsequent analysis characterizes FDI determinants from the investor's motivational perspective.

Dunning identifies four broad motivations: resource seeking, market seeking, efficiency seeking, and strategic asset seeking investment. First, resource wealth attracts investors, for example, transition minerals used in battery production. We measure transition mineral abundance using an aggregated ore revealed comparative advantage (RCA) measure. As a pull driver (PUD), a higher ore RCA is expected to attract FDI, while as a push driver (PSD), a lower ore RCA would drive investors abroad to secure mineral supply chains.

Market-seeking investors look to expand the customer base abroad by locating closer to target markets. Here, direct measures of market size, such as GDP, GDP growth, and the current installed capacity of renewable technologies, signal potential for expansion as a PUD, while the same variables may act as a deterrent on the push side (Carr et al., 2001; Beise, 2004; Blonigen and Piger, 2014). An oversaturated domestic market will drive investors outwards, for example, with high-renewable installation economies in Western

Europe now investing abroad (Steffen et al., 2018). The market-seeking variables also include a PUD that captures the trade and investment treaty network—a proxy for a country acting as an export platform to access a third market (Ekholm et al., 2007).

Efficiency-seeking investment is typically motivated by cost savings and is measured by unit labor costs (ULCs), where lower labor costs act as a PUD. Conversely, as a PSD, higher ULCs may also drive investors outward (Helpman, 1984; Carr et al., 2001; Dellis et al., 2017; Islam and Beloucif, 2023). We also include a set of PUDs that capture the host-country clean-technology industrial base, such as manufacturing value added, technology-specific final goods, downstream, and midstream RCA. We expect high industrial base compatibility to attract FDI. Higher final-good RCA as PSD may also drive investors to outsource less technology-intensive production (Qiang et al., 2021; Imbruno et al., 2024).

The final motivation is strategic asset seeking, measured by a joint-venture likelihood variable that enters the analysis only as a PUD and is expected to attract FDI, since working with local partners can facilitate better and faster understanding of the host country's business environment and consumer base by reducing information discovery costs. Conversely, this variable could also deter some investors.

4 Results

The main estimation uses a Poisson Pseudo-Maximum Likelihood (PPML) regression model where the dependent variable is the count/capital amount of FDI projects aggregated at the destination-year level for the pull-side regressions and the investor-year level for the push-side regression. We also apply a Mundlak decomposition that identifies whether between-country variation or within-country variation in a variable pulls inbound FDI or pushes outbound FDI to and from a country (see the methodological appendix for details).

The results show that investing firms are motivated by large and growing markets, an established manufacturing base, and abundant transition minerals. Furthermore, a large market and mineral abundance attract more joint ventures. To elaborate, larger economies attract more projects and even more capital (∼117% and ∼176% more than the average economy), while growing economies also attract more projects (∼25% more) to a lesser extent. Investors looking to expand their customer base invest in economies with rising installed capacity over time, signaling potential for market growth. However, countries with above-average installed capacity seem to receive fewer projects (∼30% fewer), potentially reflecting the negative effect of market saturation. A larger manufacturing base than that of an average destination is also a PUD (∼29% more projects and ∼96% more capital). Resource-seeking investors are attracted to countries that export mineral ores and tend to invest more in them (∼23% more projects and ∼42% more

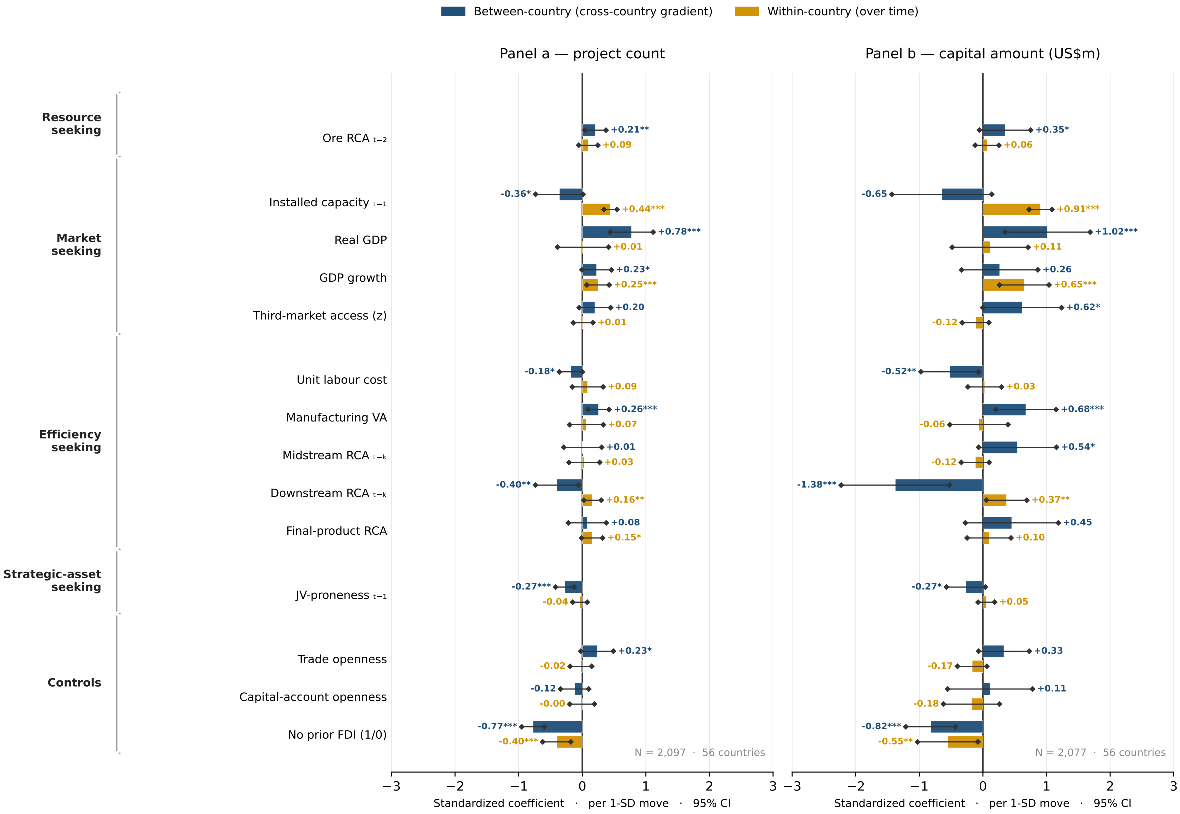


Figure 4: Pull determinants of CMFDI

capital than the average host). The capability breakdown of the industrial base shows a contradictory result where higher downstream RCA between countries does not appear to be a point of attraction, though higher midstream and final-good RCA is. It is worth noting that joint venture proneness appears to also contradict expectations. However, when interacted with economy size and mineral abundance, they point to attracting more capital (Appendix Table A13). This result has implications for technology transfer, as countries may be able to leverage market size and resource abundance not only to attract projects but also to negotiate technology transfer clauses. Overall, the pull-side results show that investors are most motivated by the size of the potential customer base, while mineral abundance, above-average manufacturing capacity, and cheaper labor also play a role.

From the push-side regression results, three results stand out and align with our pull-side findings. First, the investors appear to be pushed out of their home countries by high labor costs, though they do not necessarily invest in the lowest labor-cost host countries. An investor country whose unit labor cost (ULC) is one standard deviation above the mean is associated with ∼150% more outbound projects than a country with an average ULC. Second, higher installed capacity at home pushes investors to invest in more projects and capital abroad, with a one-standard-deviation rise in home installed

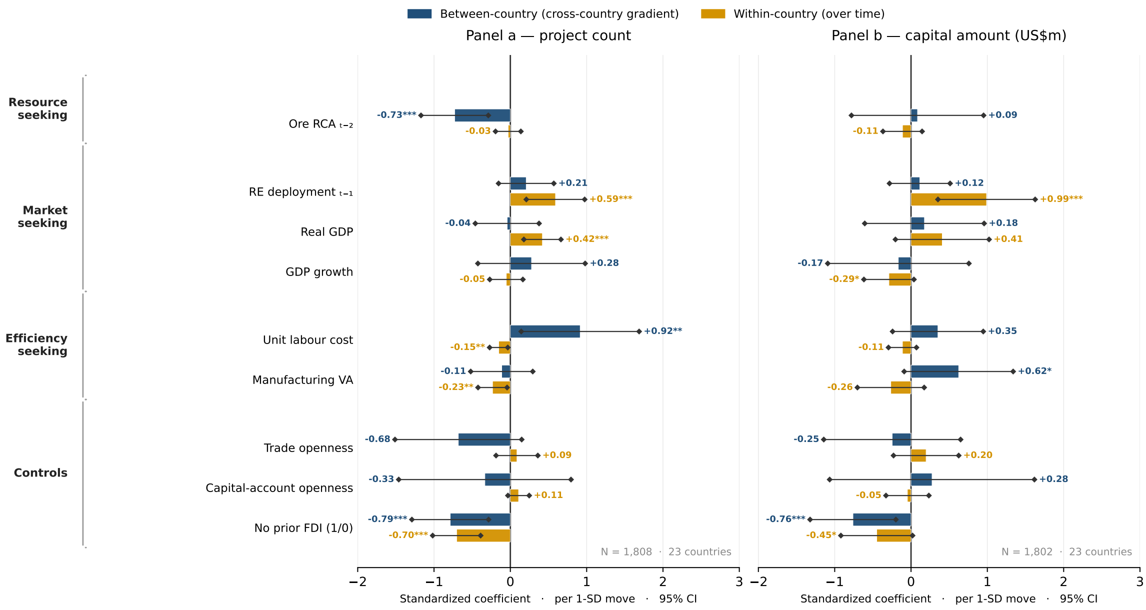


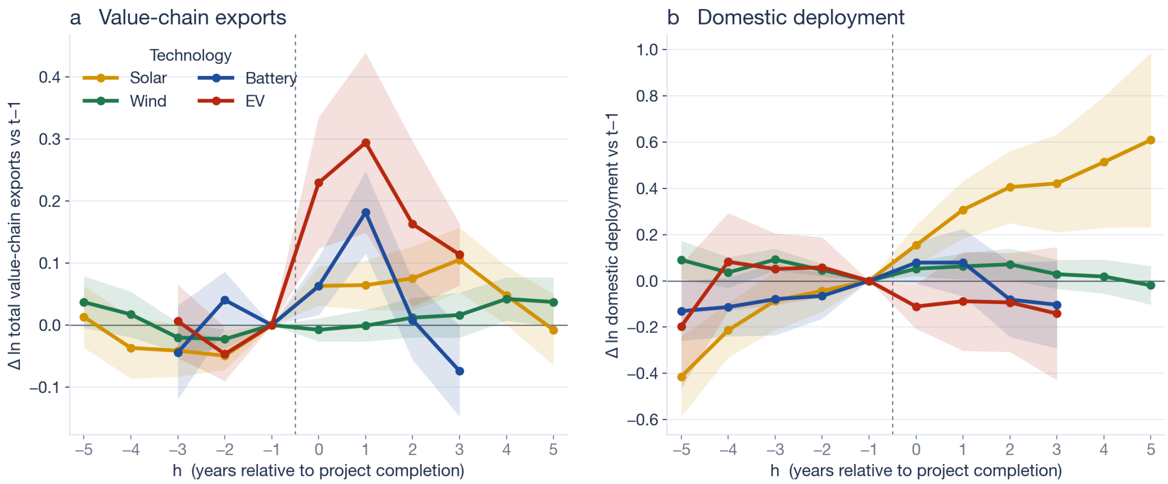
Figure 5: Push determinants of CMFDI

capacity over time associated with ∼81% more projects and ∼169% more capital, complementing the market-seeking motive shown in the pull results. Third, an investor whose final-good RCA is one standard deviation above the mean records ∼62% more outbound FDI projects and ∼91% more capital (see Appendix Table A6). High final-good export competitiveness may push firms to outsource simpler tasks, while focusing on more technology- and capital-intensive activities at home. The technology-wise breakdown of the push-and-pull framework (Appendix Tables A8 and A9) further reinforces the pooled headline results.

We complement these results with an analysis focused on trade regulation, since a well-established literature shows that higher tariffs trigger investors to locate FDI to circumvent tariffs (Horstmann and Markusen, 1992; Markusen and Venables, 1998; Blonigen, 2002). Some have hypothesized that Chinese clean technology FDI follows a similar pattern (Montti, 2025). We address this question systematically, and find that only about 12 percent of all Chinese FDI projects since 2009 have been located in a country with an FTA with the US, while there has been a high preference for countries with EU market access (see Appendix Table A11, panel b). Most Chinese FDI projects are directed at Vietnam, Indonesia, Thailand, Malaysia, Brazil, Hungary, Turkey, and India, none of which have FTAs with the US. Yet, when we include an interaction term in the regression, the EU access coefficient becomes consistently negative, while the US coefficient, which remains negative until 2022, turns positive but remains insignificant (see Appendix Table A11, panels c and d). However, countries with US FTAs — chiefly Mexico, Morocco, South Korea, and Oman — are associated with more Chinese projects and capital post-2022 than in other periods (see Appendix Table A12, panels a and b). These results show that

Chinese projects are only somewhat motivated by tariff-circumvention aimed at the US, while investments to the EU are mainly direct market-seeking.

Having established the relationship between CMFDI and investor motivations, we now examine destination-country impacts. Our outcomes of interest are export generation and technology deployment in the host-country economy. These variables track the short-, medium-, and long-term outcomes postulated at the beginning of this paper. We adopt a local projections event-study framework that captures the temporal dynamics from CMFDI project completion to the realization of economic and structural outcomes. Given data limitations, the EV and battery aspects of the following analysis should be considered suggestive.



Solar/Wind h −5…+5 (HS02 exports / IRENA capacity); Battery/EV exports capped h −3…+3 (HS17 credible window). Panel b: Solar to PV capacity, Wind to wind capacity, EV to EV sales, Battery to EV sales (batteries deploy in EVs — a proxy, not a direct battery-deployment outcome). Country + year FE, country-clustered SEs.

Figure 6: Impulse-response analysis of CMFDI: impact on export performance and deployment

The results in Figure 6 may be interpreted as an increase in the relevant indicator—change in exports of the entire value chain or deployment in GWs, and sales—compared to the same indicator in the year before an FDI project was completed. Therefore, EV value chains appear to increase by ∼25% in the year an EV FDI project was completed, continue to increase to around 30% a year later, and hover around 10% three years after completion. Battery value chain exports behave similarly, peaking at 20% in the first year. Solar exports increase steadily, peaking at 10% by year 3, while wind investments have minimal effect. Per the breakdown of the value chain components (see Appendix Figure A6), these increases are driven by final product exports for solar, while midstream and downstream components drive EV, and upstream and downstream components drive battery action. Moreover, FDI project completion does not correspond to increased component imports for most technologies (see Appendix Figure A7). This evidence points towards increased domestic production rather than pass-through.

Looking at domestic deployment (installed capacity for solar/wind; unit sales for EVs), solar performance stands out as well. FDI project completion is associated with a steady increase in solar GWs added to the energy mix, peaking at around a 60% increase five years after project completion compared to the year before completion. None of the other technologies show significant deployment after FDI project completion, which, for EVs and batteries, combined with strong export figures, may indicate export-oriented FDI. For wind, it appears to be a case of import substitution, where, with the establishment of these manufacturing plants, parts that were imported in the past are now being produced domestically (Appendix Figure A8). Notably, the solar deployment line trended upward even before FDI was introduced (the pre-trends enter the figure from below the x-axis). This suggests that solar FDI projects were attracted to countries already deploying a certain level of solar energy and continued to boost deployment, aligning with the market-seeking motivation identified above. Overall, solar FDI projects appear to drive export performance and reinforce existing domestic deployment trajectories in host countries.

5 Conclusion

The scale and composition of green FDI is undergoing a transformation. CMFDI as a share of total FDI has grown tenfold in the last 20 years and now comprises 20 percent of all FDI flows. Before 2017, most CMFDI occurred within advanced economies, yet China has leaped from a net destination of CMFDI to the largest CMFDI investor, while emerging markets and developing countries attract more than half of all global CMFDI. Several important drivers explain this trend, including large and growing markets, industrial capacity, and the location of transition minerals in host countries. Finally, the spread of CMFDI also appears to positively affect entry into green value chains in EVs, batteries, and solar, as well as solar deployment at the host-country level. Impacts may, to some extent, be conditional upon the specific features of each technology. For example, solar is modular and easily shippable, so production does not need to co-locate with demand to the same extent as wind manufacturing. Our findings underscore how the intersection of economic and technical features produces patterns of green technology investment.

From a policy perspective, the experience of China's evolution from a net destination to the largest CMFDI provider suggests that it may be possible to use CMFDI to build strong domestic industries that can go global (Lewis, 2013; Gallagher, 2014; Jia-Zheng and Binda, 2024). From a political perspective, this domestic capacity building can pave the way for green manufacturing coalitions that link climate ambition to developmental goals. Our analysis shows that Vietnam, to some extent, echoes China's evolution. Furthermore, our results show that countries can exploit location-specific advantages such as their transition minerals or large markets to not only attract FDI but to use joint ventures that ensure that technology transfer and backward linkages occur.

This data and subsequent analysis have important implications for future research and policy. This database will be made accessible as a public good, so other analysts can answer further research questions at the intersection of energy transition and sustainable development. Further research is needed on additional determinants of these FDI flows, as well as their impacts. On the latter, these data make possible analyses of the impacts of CMFDI on forward and backward linkages to host economies, on the balance of payments, local employment, patents and innovation, and beyond.

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Table 1: Variable definitions and sources

Variable	Measurement	Transform	Lag	Source	Coverage/notes
Dependent variables					
Project count	No. of greenfield LCT projects (country×tech×year; zeros kept)	count (PPML)	–	Author compilation	Baseline count margin.
Capital amount	Announced capex, US$m (no announced capex = NaN, not 0)	level (PPML)	–	Author compilation	Intensive (capital) margin.
Explanatory variables — main pull/push specifications					
Ore RCA	Balassa RCA in ore exports	log	$t-2$	CEPII BACI (HS02)	Resource seeking (both sides).
Installed capacity	Solar/wind = deployed GW; battery/EV = EV sales	log1p	$t-1$	Ember + IEA Global EV Data 2024	Pull market seeking; battery proxied by EV sales in the main spec.
RE deployment	Home renewable capacity, GW	log1p	$t-1$	Ember	Push market seeking; aggregate installed renewables.
Real GDP	Real GDP	log	contemp.	WDI (constant-2015 US$)	Market seeking (both sides).
GDP growth	Real GDP growth, trailing 5-yr MA	level	contemp. (MA)	WDI	Market seeking (both sides).
Third-market access (TIP)	z-scored betweenness in the UNCTAD trade-treaty network	z-score	contemp.	UNCTAD TIP (author)	Pull only; EU members inherit the EU hub.
Unit labour cost	Manufacturing wage ÷ industry value-added-per-worker	log	contemp.	ILOSTAT (wages); WB + BEA/FRED (productivity)	Efficiency seeking (both sides). US VA-per-worker backfilled: WB national accounts 2000–21, BEA/FRED chained 2022–24 (WB ends 2021).

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Variable	Measurement	Transform	Lag	Source	Coverage/notes
Manufacturing VA	Manufacturing value added, % of GDP	log	contemp.	WDI (NV.IND.MANF.ZS); US 2022–24 BEA/FRED	Efficiency seeking (both sides). US 2022–24 backfilled from FRED VAPGDPMA (WB series ends 2021).
Midstream RCA	Value-chain RCA, midstream segment	log	$t-4$ s/w, $t-1$ bat/EV	NZIPL	Pull efficiency seeking; graded lag for the short HS17 series.
Downstream RCA	Value-chain RCA, downstream segment	log	$t-4$ s/w, $t-1$ bat/EV	NZIPL	Pull efficiency seeking.
Final-product RCA	Value-chain RCA, final-product segment	log	pull: $t-4$ s/w, $t-1$ bat/EV; push: $t-1$	CEPII BACI	Pull efficiency seeking; push = capabilities (robustness).
JV-proneness	EB-shrunk cumulative JV share of prior projects	per 10pp	$t-1$	Author compilation	Pull strategic-asset seeking.
Trade openness	Trade (exports + imports) as % of GDP	level	contemp.	WDI	Control.
Capital-account openness	Chinn-Ito index, $[0, 1]$	level	contemp.	Chinn-Ito	Control.
No prior FDI (1/0)	1 if the unit never received an LCT project through $t-1$	0/1	$t-1$	Author compilation	Extensive-margin control / stratifier.
Additional variables — extension exhibits					
Chinese-investor share	Prior-year inbound LCT FDI from Chinese investors	per 10pp	$t-1$	Author compilation	IRA/CBAM-break and entry exhibits.
US-market access (US FTA)	1 if US market access via an FTA	0/1	contemp.	CEPII Gravity	Regime / circumvention / IRA exhibits.
EU-market access (EU FTA)	1 if EU member or covered by an EU FTA/customs union	0/1	contemp.	CEPII Gravity	Regime / circumvention / IRA exhibits.
Chemicals RCA	Material-family supply-chain RCA, tech-conditional	log	$t-2$	NZIPL	Supply-chain robustness exhibit.

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Variable	Measurement	Transform	Lag	Source	Coverage/notes
Electronics RCA	Material-family supply-chain RCA, tech-conditional	log	$t-2$	NZIPL	Supply-chain robustness exhibit.
Industrial-materials RCA	Material-family supply-chain RCA, tech-conditional	log	$t-2$	NZIPL	Supply-chain robustness exhibit.
Machinery RCA	Material-family supply-chain RCA, tech-conditional	log	$t-2$	NZIPL	Supply-chain robustness exhibit.
Metals RCA	Material-family supply-chain RCA, tech-conditional	log	$t-2$	NZIPL	Supply-chain robustness exhibit.

Notes. Variables, transforms, and lags are those used in the R14 estimation round. Unit labour cost and manufacturing VA carry US backfills for 2022–24 (see the respective rows). Taiwan, the UAE, Hong Kong, Norway, and Israel are excluded for want of consistent macro/wage controls (14 of 816 projects). log1p = log(1+x); RCA = Balassa revealed comparative advantage.

Figure Appendix

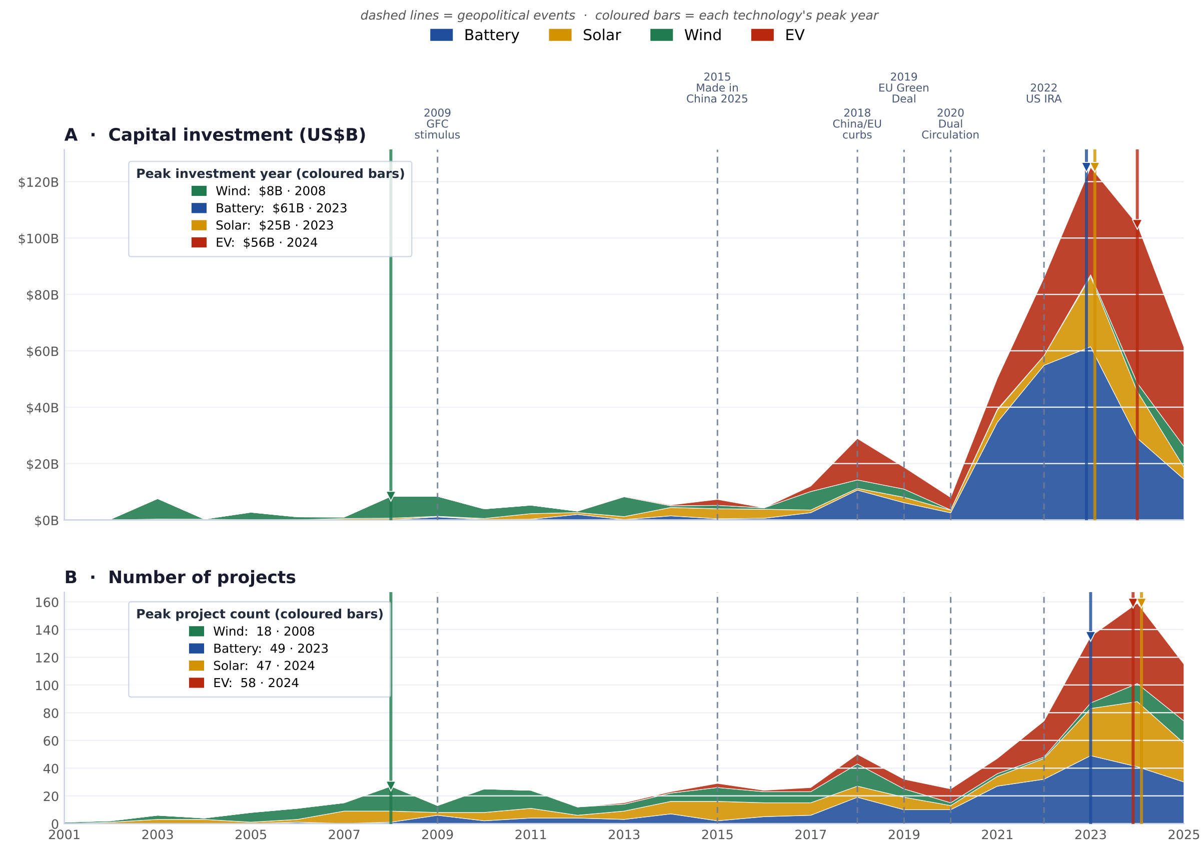


Figure A1: CMFDI over time, by technology

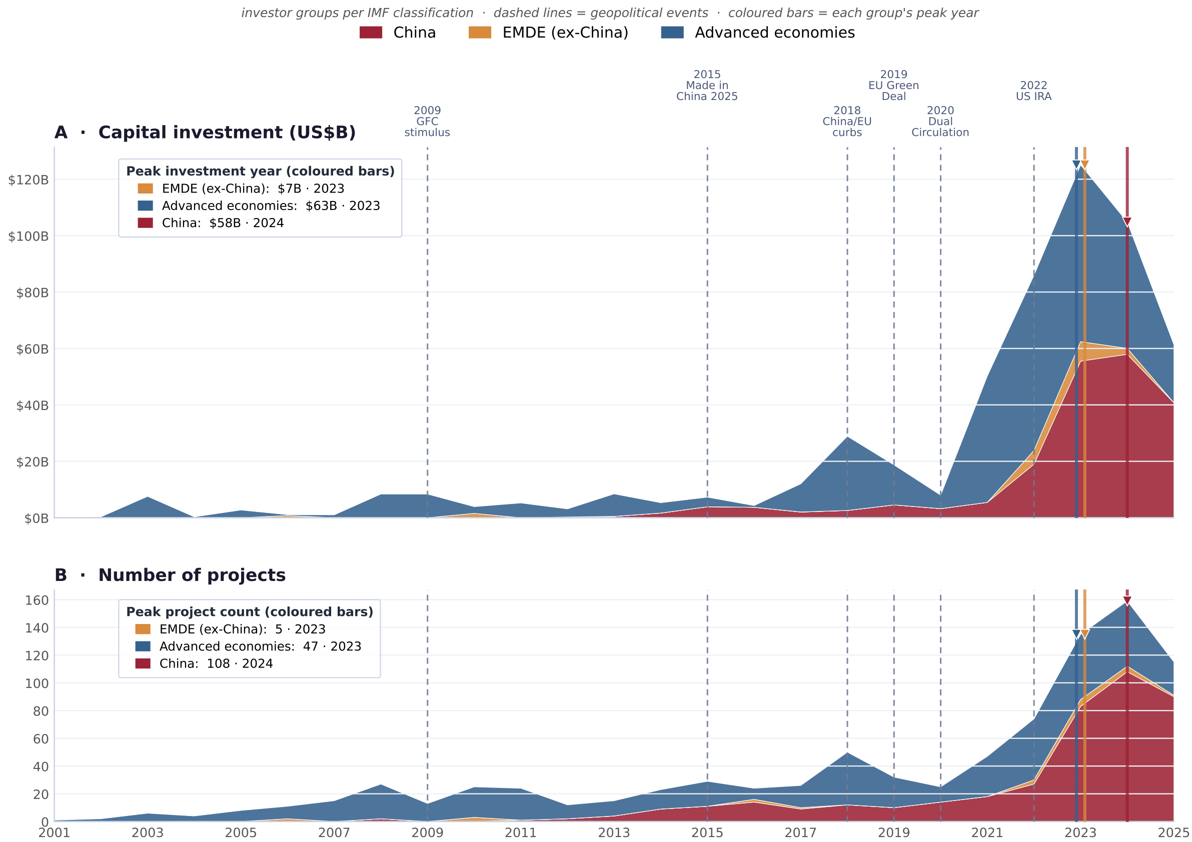


Figure A2: CMFDI over time, by investor group

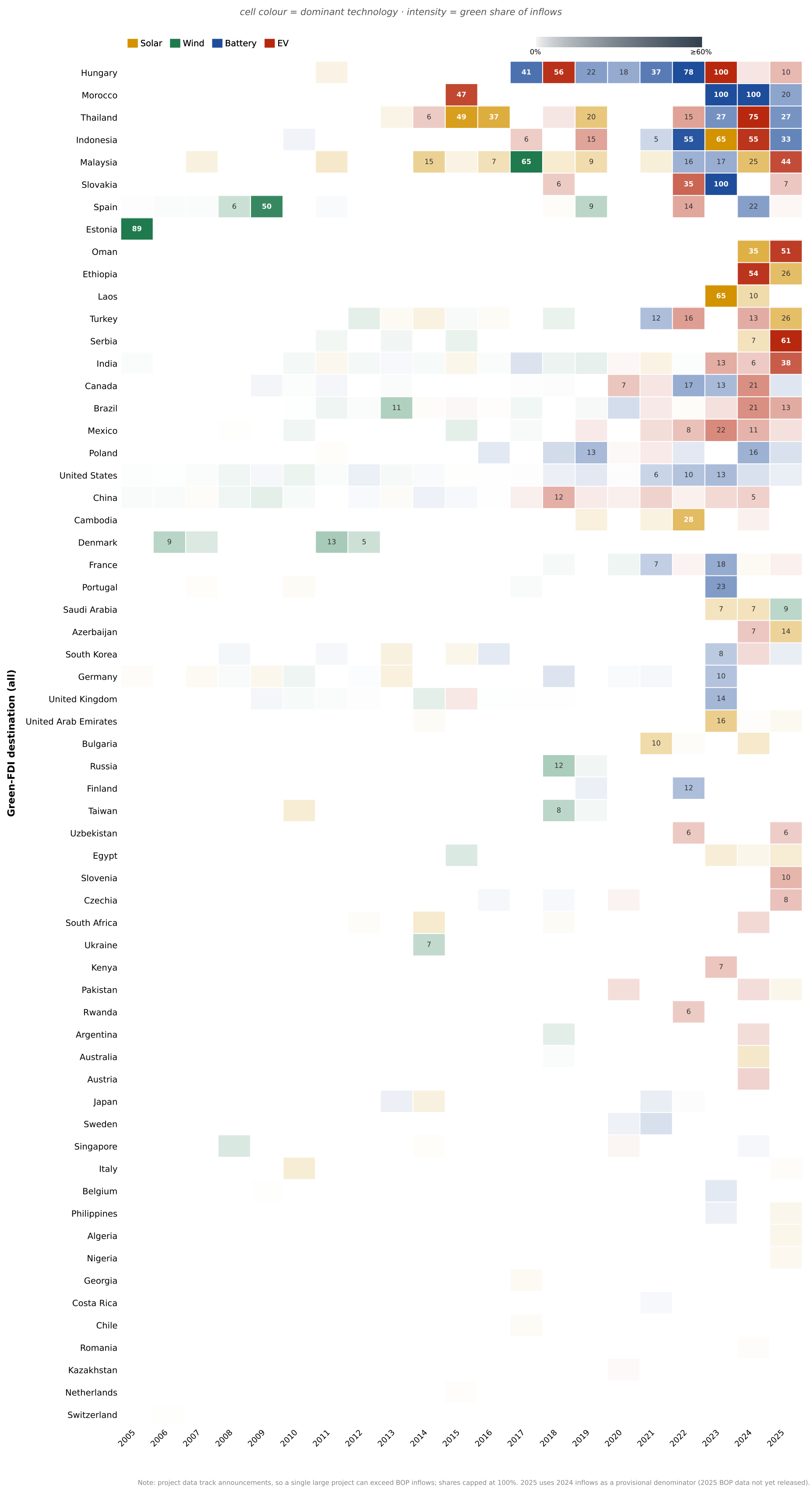


Figure A3: CMFDI as a percentage of total FDI inflows — all destinations

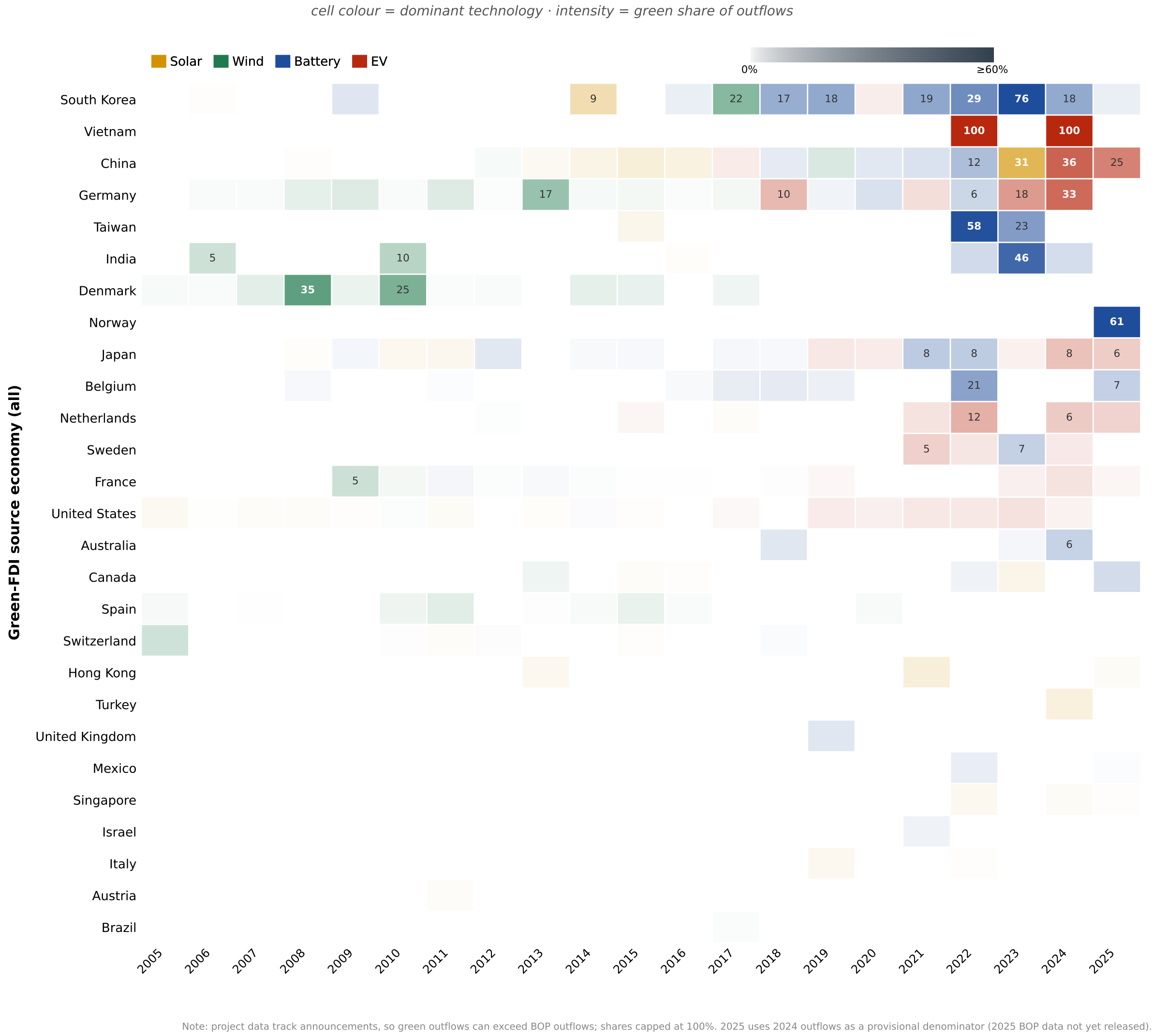


Figure A4: CMFDI as a percentage of total FDI outflows — all investors

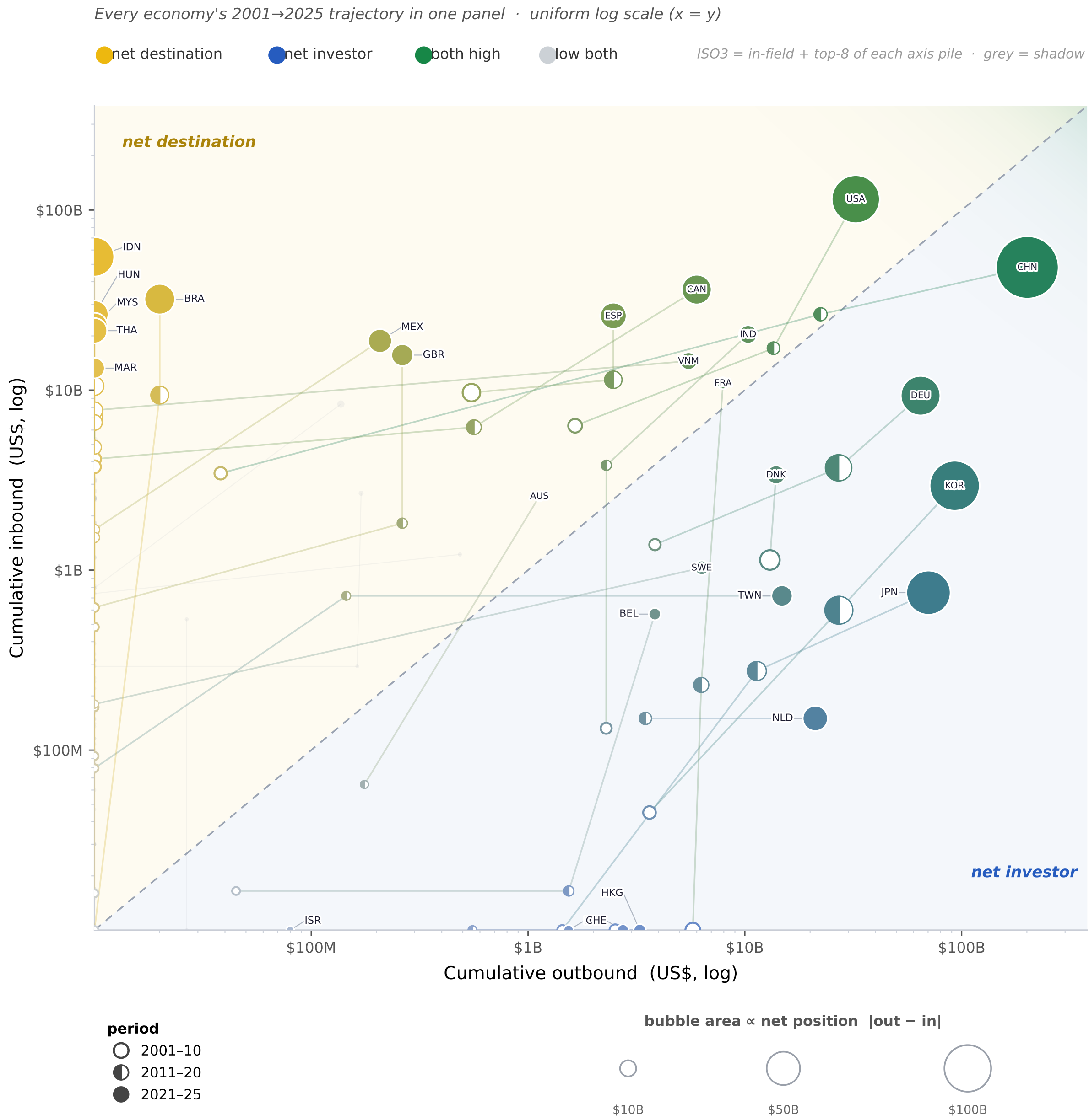


Figure A5: Cumulative disclosed capital stock of cleantech manufacturing FDI (all countries)

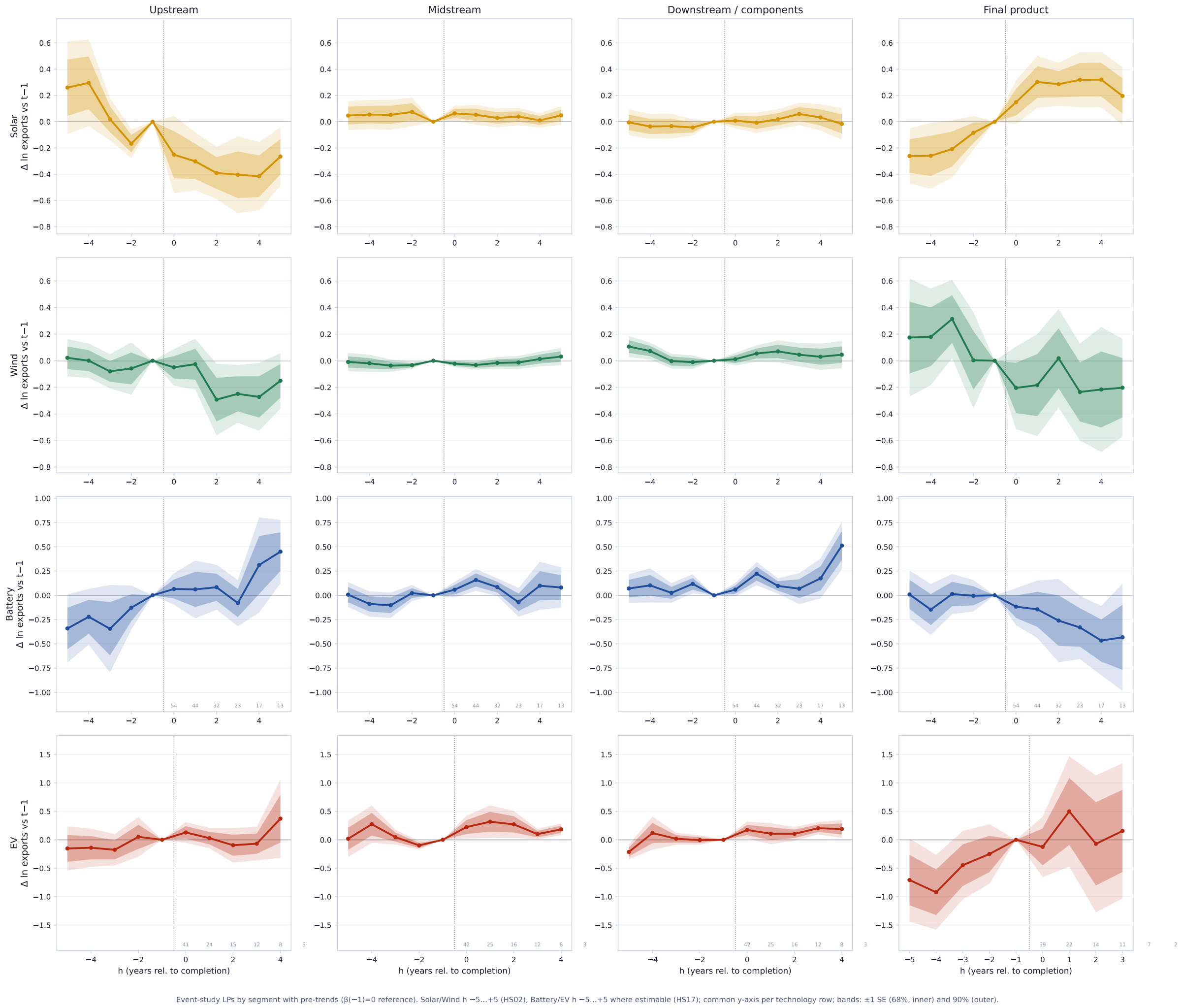
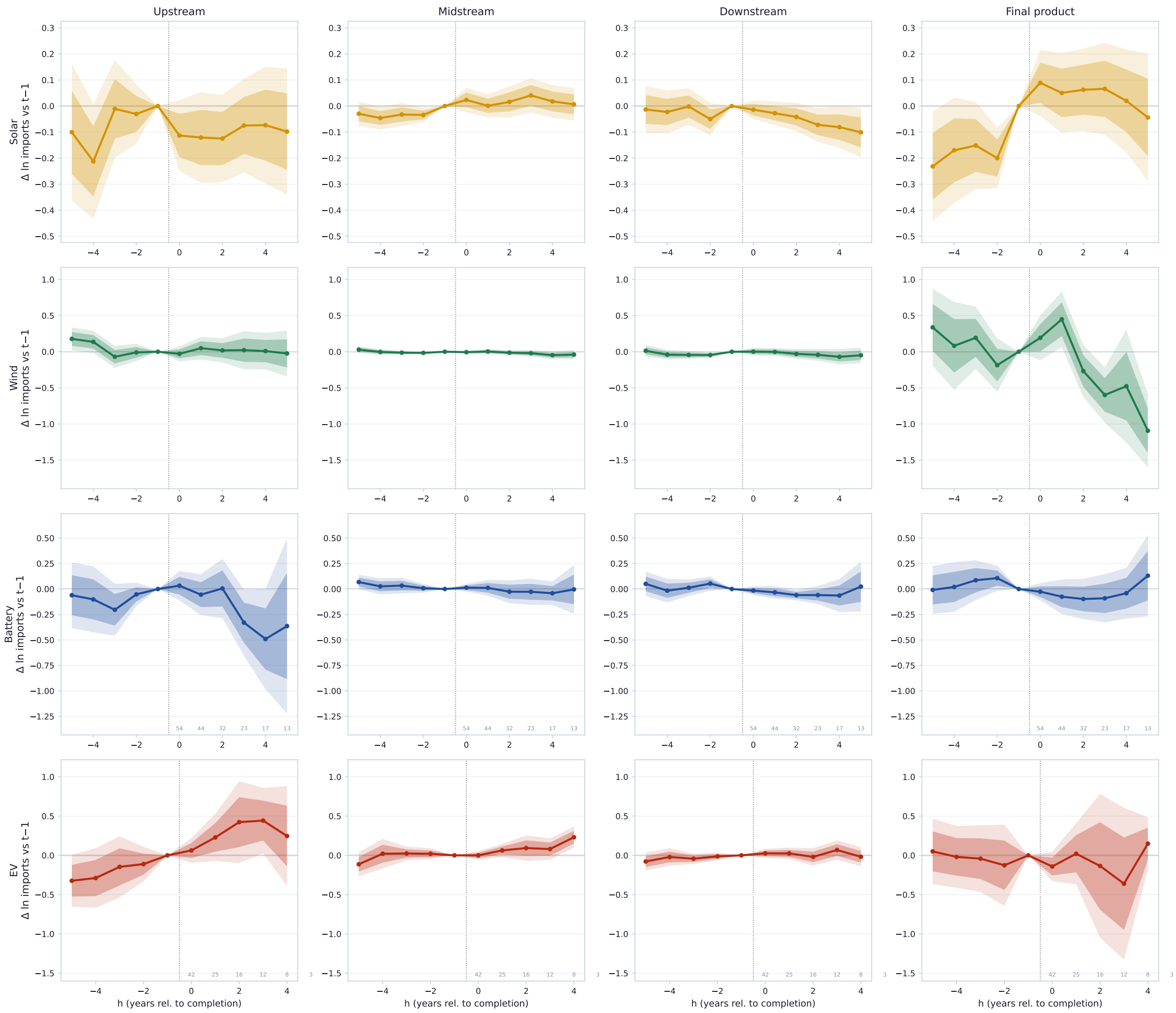
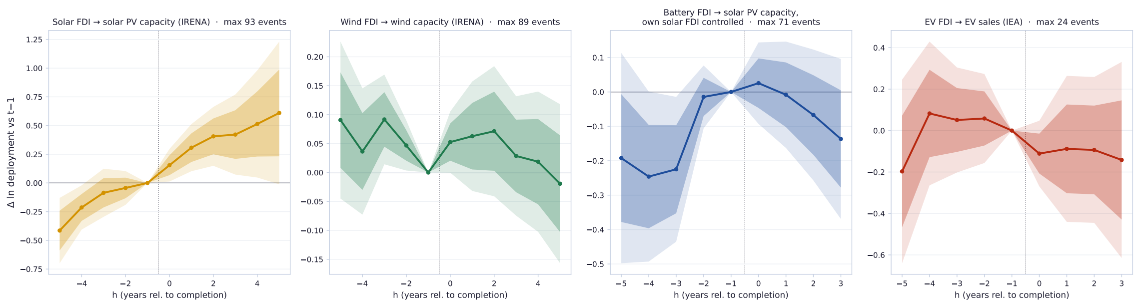


Figure A6: IRF analysis of CMFDI and impact on export performance (standardized y-axis)



Event-study LPs: FDI completion → value-chain IMPORTS with pre-trends (β(−1)=0 reference). Solar/Wind h −5…+5 (HS02), Battery/EV h −5…+5 where ≥8 events (HS17); common y-axis per technology row; bands: ±1 SE (68%, inner) and 90% (outer).

Figure A7: IRF analysis of CMFDI and impact on import dependence (standardized y-axis)



Event-study LPs: FDI completion → domestic deployment with pre-trends (β(−1)=0 reference). Solar/Wind h −5…+5, EV/Battery h −5…+3 where ≥8 events; battery deployment PROXIED by host solar PV capacity (grid storage co-deploys with solar); panel-specific y-axes; bands: ±1 SE (68%, inner) and 90% (outer).

Figure A8: IRF analysis of CT-FDI project completion and deployment