GREEN INVESTMENT AND PRODUCTIVITY:
MAIN POLICY CHALLENGES

Ettore Gallo (University of Parma)
Cecilia Jona-Lasinio (Luiss Business School)
Benedetta Samoncini (Italian Ministry of Economy and Finance)

Introduction

- **Climate change** is increasingly recognized as a threat to global health and economic prosperity.
  - Achieving the 1.5°C scenario requires significant reductions in greenhouse gas emissions – that would need to be reduced by 45% by 2030 and reach net zero by 2050 – and **a transition to cleaner, renewable energy sources** (e.g., solar, wind, hydro), as well as **energy efficiency** measures, improved **energy storage**, and other low-carbon technologies.
- To do so, quickly scaling up global investment in technologies related to the energy transition is of substantial relevance.
  - **Annual investments in clean technologies** must quadruple to remain on with the 1.5°C scenario outlined in the Paris Agreement (CPI and IRENA 2023).
  - The latest IPCC synthesis report estimates that "investment requirements for 2020 to 2030 in scenarios that limit warming to 2°C or 1.5°C are a factor of three to six greater than current levels, and total mitigation investments [...] would need to increase across all sectors and regions" .

Research goals

- Offer an overview of **green investment** **definitions** and **measurement** approaches.
  - ✓ Provide a measurable definition of green investment, building a database of **18 OECD countries over 2004-2020**.

- Test the effect of scaling up green investment and environmental regulation on **productivity**.
  - ✓ Expected outcomes:
    1. Positive productivity gains from green investment because of **green capital deepening**
    2. Stricter environmental regulations leads to positive productivity returns through innovation (**Porter hypothesis)**

Background literature

- There is not yet a unique definition of what can be included in the boundaries of green investment, most of the studies looked at different categories of expenditures/items potentially considered as green investments.
- Story 1) The relation between green investment, production, productivity, and firms' performances
  - Macro analysis: Few studies. Batini et al. (2022) estimated that multipliers associated with green capital spending on power generation using renewable sources are about 2 to 7 times larger than those associated with 'non-eco-friendly' expenditure
  - Micro analysis: Wide (but not unanimous) consensus about the positive productivity returns of scaling up green investments at the firm level
- Story 2) The relation between environmental regulation and productivity

Porter hypothesis

- Stricter environmental regulation could lead to positive productivity returns through innovation
- We expect that tighter environmental policies might encourage innovations that more than offset the costs associated with complying with regulations, leading to a positive effect on productivity growth (Porter and van der Linde 1995, De Santis et al. 2021).

DEFINING AND MEASURING GREEN INVESTMENT

Defining and measuring green investment

- At present, there are several definitions of green investment without any clear indication from the Official Statistics about what type of assets can be classified as such.
  - ✓ Opinions differ on the extent to which different asset classes can be classified as green as, more generally, there is no clarity around the appropriate metric for 'greenness'.
- Inderst et al. (2012) provide a comprehensive review of concepts and definitions related to green investments examining them in different areas (macroeconomic level, green goods and services, foreign direct investments, patents) and asset classes (stocks, bonds, and alternative investments)
  - ✓ They conclude that it is unlikely that an agreement can be found on an all-encompassing and exact operational definition of what can be classified as green.

Green investment: a definition

- The UN Environment Programme (2011) proposes a broad definition of green investment starting from the concept of ‘green economy’, defined as one that results in improved human well-being and social equity, and that can significantly reduce environmental risks and ecological scarcities.
- Green investment could be defined as the sum of any expenditures in abatement technologies, including (but not limited to) investment in renewable energy and resource efficiency (manufacturing, waste, buildings, transport, and cities), in natural capital (agriculture, fisheries, water resources, forests), and in digital technologies aimed at reducing the carbon intensity of production processes.
    - Over the years, green investment has also been used as an umbrella term including all investments targeting environmental improvements.
    - Often use as interchangeable with concepts like sustainable and responsible investment, socially responsible investment, or environmental, social, and corporate governance (ESG) investment.

Green investment through macroeconomic lenses

- Eyraud et al. (2013) provide a measurable definition of green investment at the macroeconomic level
- Green investments are those needed for reducing greenhouse gas and air pollutant emissions without significantly reducing the production and consumption of non-energy goods.
- They identify three main investment components for being classified as green:

  a. **Low-emission energy supply**, which refers to investment that involves shifting energy supply from fossil fuels to less polluting alternatives;

  b. **Energy efficiency**, that includes technologies reducing the amount of energy required to provide goods and services;

  c. **Carbon sequestration**, that involves halting ongoing deforestation, reforesting, and sequestering more carbon in soils through new agricultural practices.

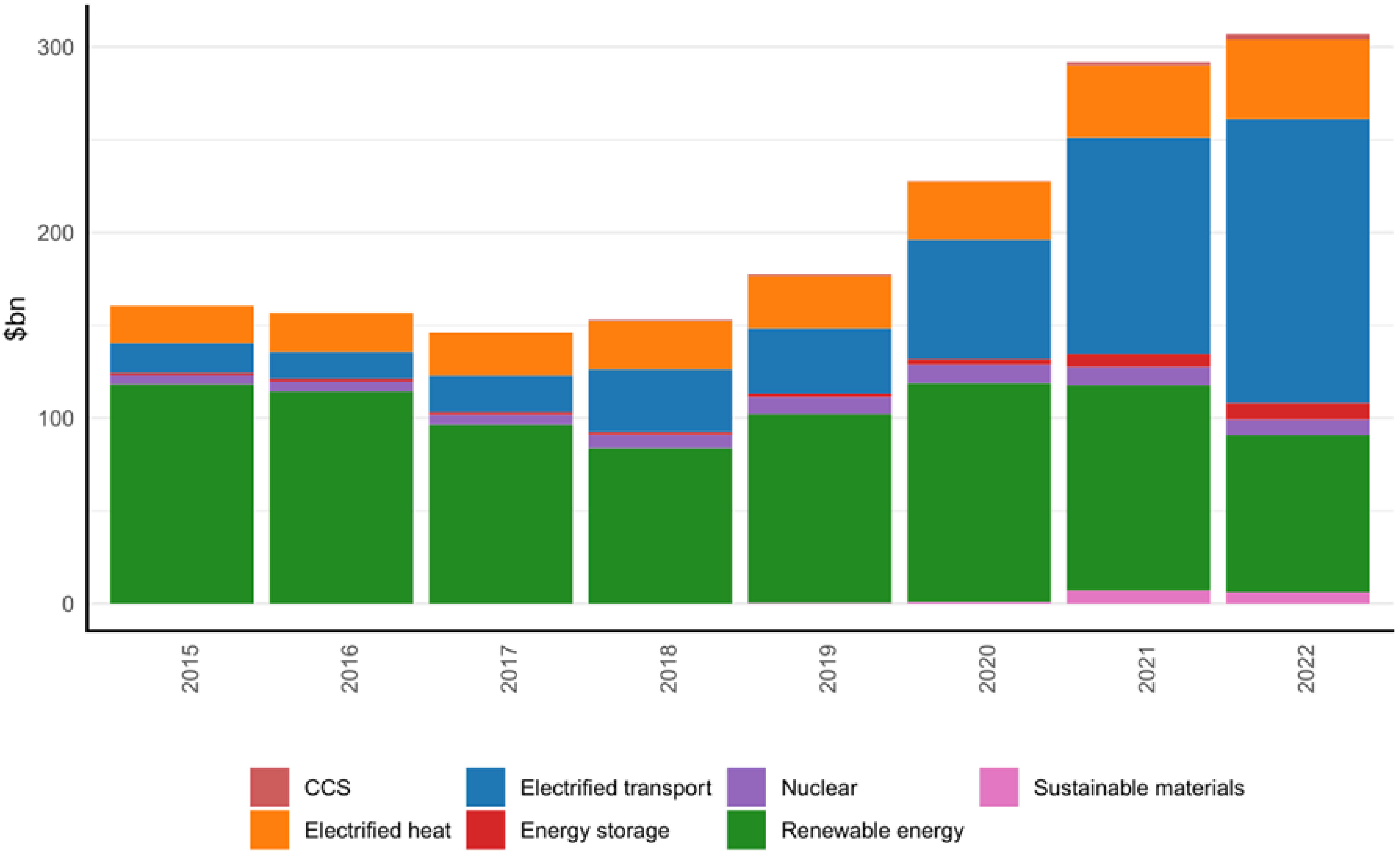
Macroeconomic measurement of green investment

Definition	Indicator	Source
Green investment (Eyraud et al., 2013)	Financial investment in renewables	BloombergNEF
	Energy efficiency investments	BloombergNEF
	Corporate and government R&D	BloombergNEF
Climate change mitigation investment (EIB, 2023)	Investment in energy efficiency - estimates	IEA
	Total investment in renewable energy	IEA
	Transport investments (rail and inland waterways)	OECD ITF
	Gross fixed capital formation (GFCF) in forestry	Eurostat and BEA
	R&D investment in low-carbon technologies	JRC-SETIS, IEA, IMF, OECD
Green spending (Batini et al., 2022)	IEA estimates of capital spending on power generation using renewable energy	IEA
	Overnight construction cost - clean non-renewable energy (nuclear energy)	OECD's Nuclear Energy Agency, IAEA
Climate investment (CPI, 2022; CPI and IRENA, 2023)	Annual investments in renewable energy	CPI, IEA, BloombergNEF

Capturing green investment

- Data on green investment are taken from BloombergNEF, providing an indicator of energy transition expenditures covering investment in the following areas:
  - ✓ **Renewable energy**: wind (on- and offshore), solar (large- and small-scale), biofuels, biomass & waste, marine, geothermal and small hydro;
  - ✓ **Energy storage:** stationary storage projects (large- and small- scale), excluding pumped hydro, compressed air and hydrogen. The majority are battery projects;
  - ✓ **Nuclear power**: reactors under construction and major refurbishments;
  - ✓ **Hydrogen**: hydrogen electrolyzer projects, thermochemical hydrogen production, pipelines and underground storage;
  - ✓ **Carbon capture and storage (CCS):** large- and small-scale commercial CCS projects, dedicated transport and storage;
  - ✓ **Electrified transport:** sales of electric cars, commercial vehicles and buses, as well as home and public charging investments. Hydrogen fuel cell vehicles and refuelling stations are also included in this category;
  - ✓ **Electrified heat:** residential heat pump investments;
  - ✓ **Sustainable materials**: circular economy (recycling) and bioplastics.

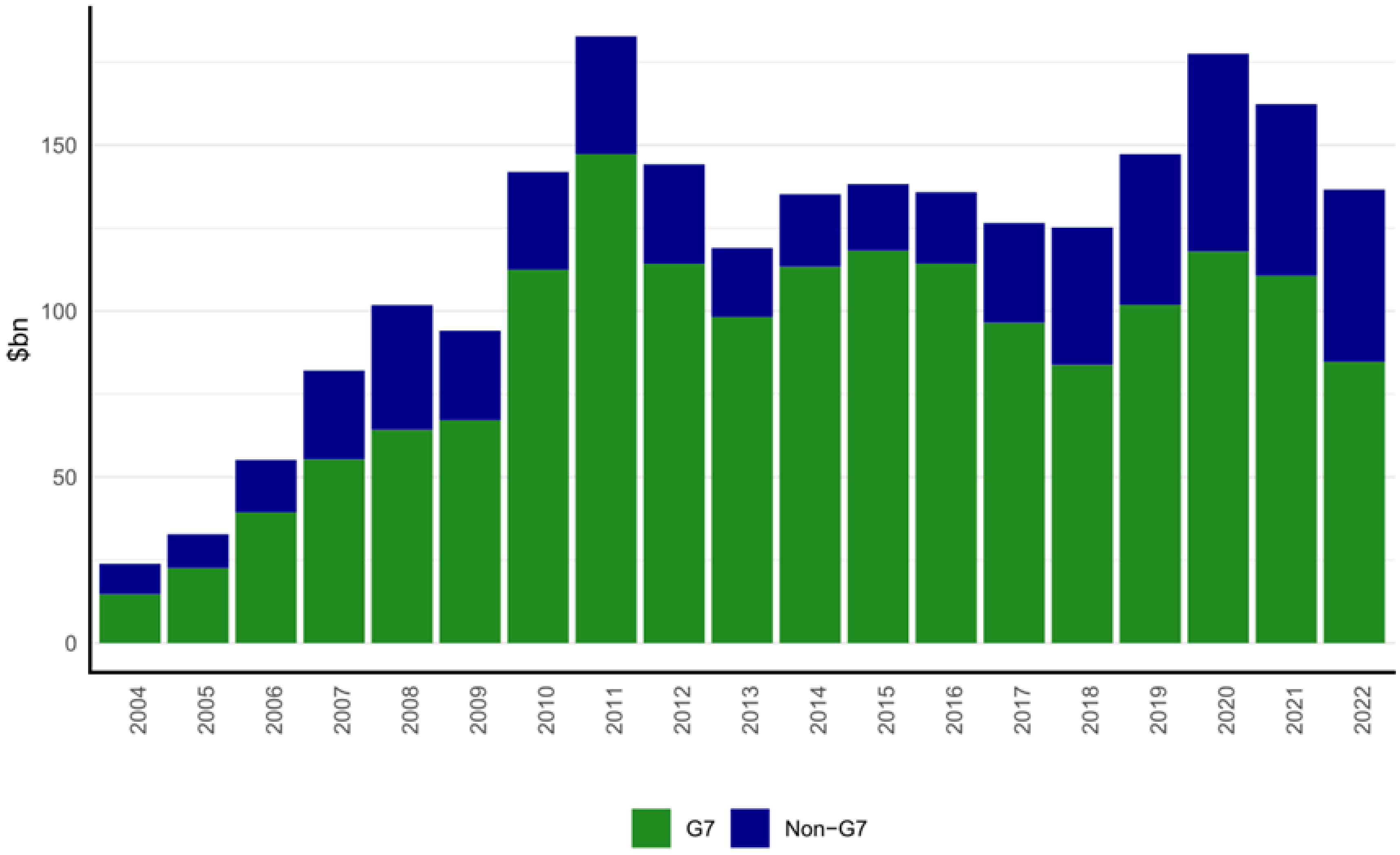
Green investment, 2015-2022, total, G7 countries



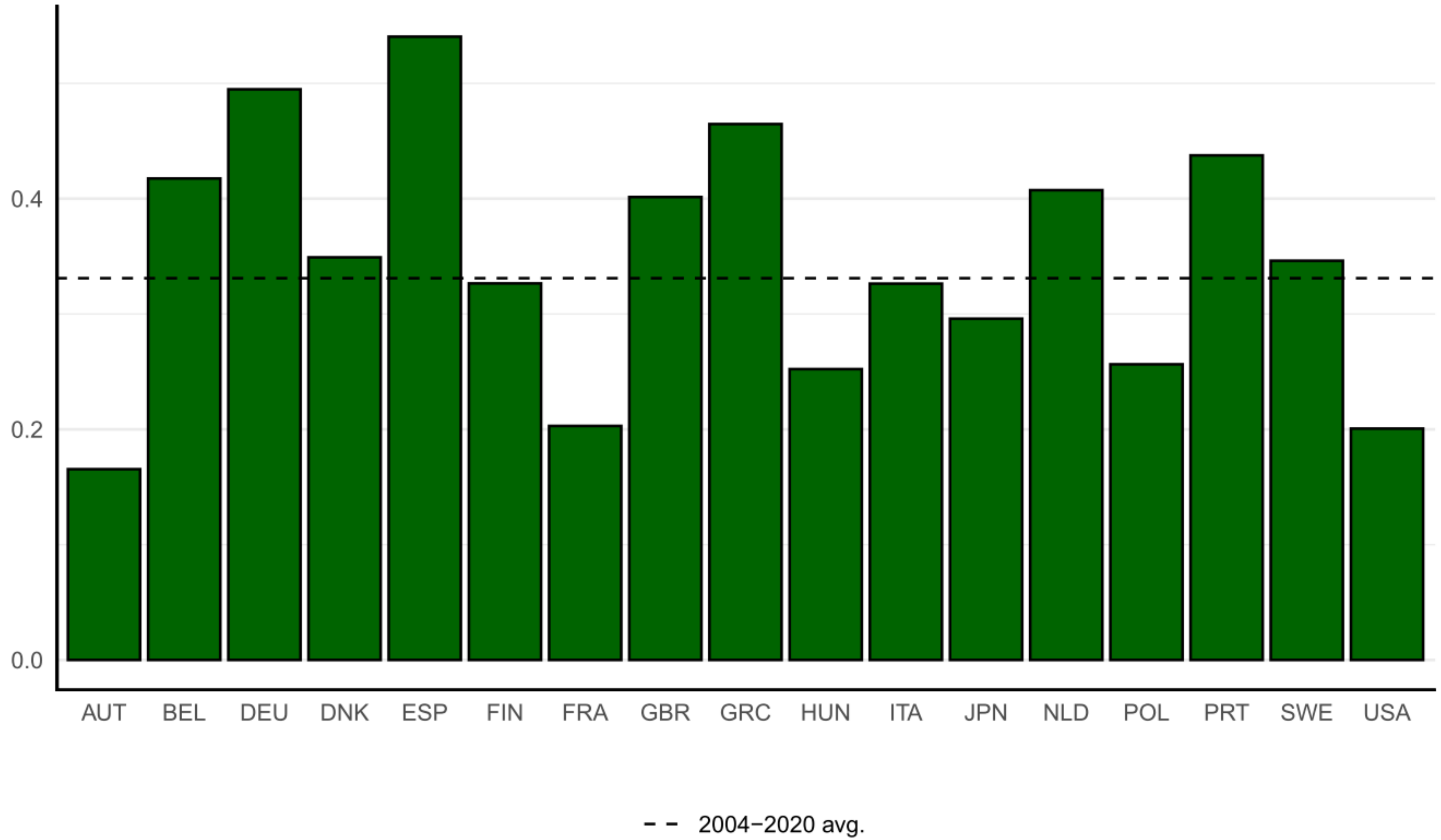
Caveat:

- Data on green investment by area are available at annual frequency only after 2015
- The empirical analysis focuses more specifically on **renewable green investment** because of better data availability (2004-2023, annual)

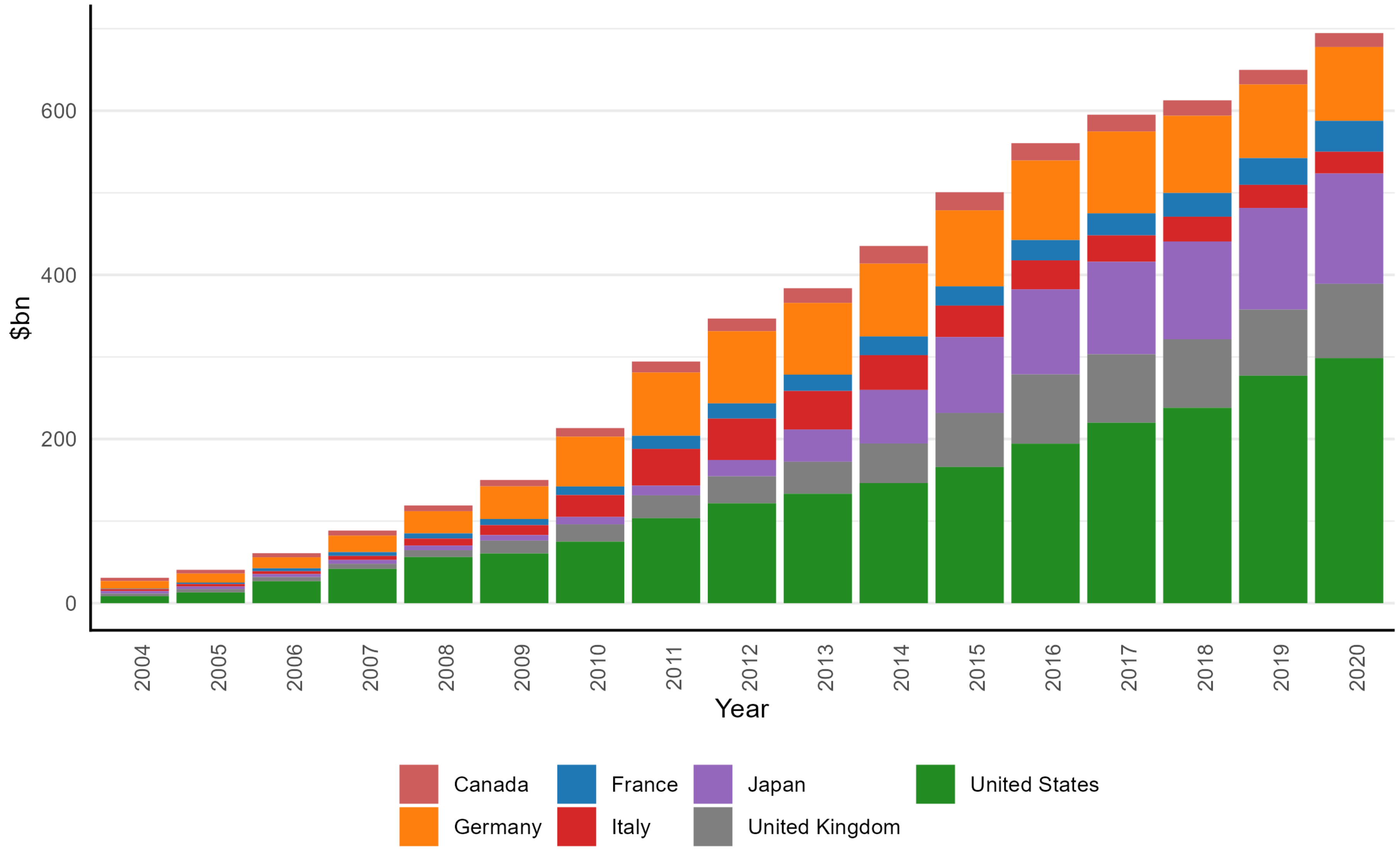
Renewable green investment, 2004-2022



Renewable green investment (per Gross Value Added), by country, 2004-2020 averages

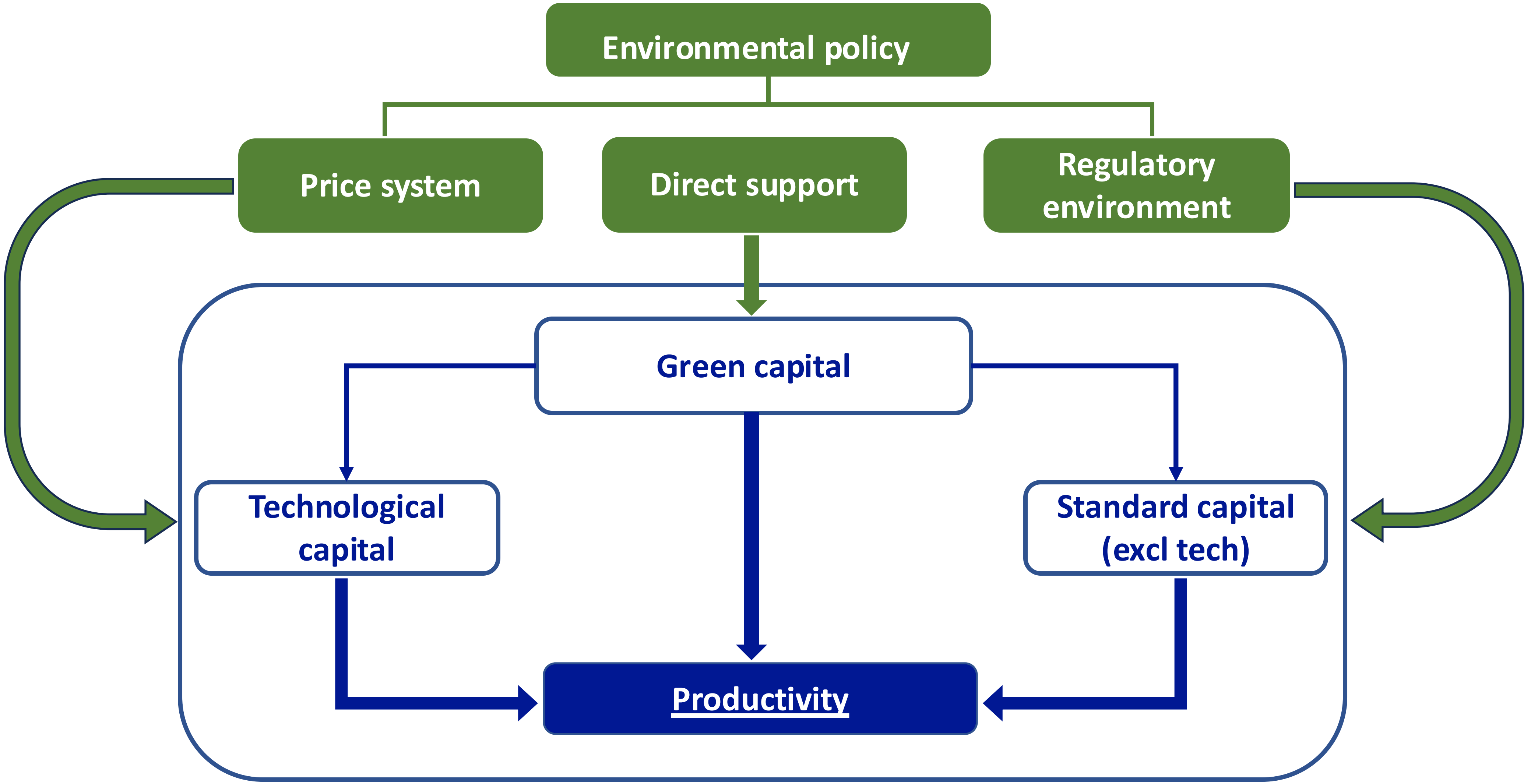


Renewable green capital in G7 countries, 2004-2020



GREEN INVESTMENT, PRODUCTIVITY, AND ENVIRONMENTAL POLICY STRINGENCY

Conceptual framework



Construction of the dataset

- The dataset used in this paper covers 18 OECD countries for the period 2004-2020.
- It encompasses annual data on:
  - Green investment
  - Green capital
  - Capital formation
  - Hours worked
  - Labor productivity
  - Stringency of environmental policies
- The database includes the following countries:
  Austria, Belgium, Germany, Denmark, Greece, Spain, Finland, France, Hungary, Italy, Japan, Netherlands, Poland, Portugal, Sweden, United Kingdom, United States

Other data sources: productivity, labor and capital inputs

- The renewable green investment data from BloombergNEF are then integrated with input and output variables from the EUKLEMS & INTANProd providing data for productivity analysis.
- The database consists of two modules: statistical and analytical.
- We resort to the statistical module containing all the key variables for industry-level productivity accounting gathered directly from the national accounts of individual countries.
  - We collect data on Gross Value Added (GVA) and hours worked to compute a labor productivity indicator as GVA per hour worked.
  - We use the capital accounts in the statistical module to retrieve data capital stocks by asset for OECD member countries – including few OECD members not part of the European Union (namely, United Kingdom, United States, and Japan).
  - Data are expressed in real terms – at 2015 prices – and then standardized by hours worked.

Data description

Variable	Description	Source
y	Labor productivity – GDP per hour worked	EUKLEMS & INTANProd
k	Capital intensity – Capital per hour worked	EUKLEMS & INTANProd
k_{green}	Renewable green capital per hour worked	BloombergNEF, EUKLEMS & INTANProd
$green_{int}$	Green skills intensity	Bontadini et al. (2024)
EPS	Environmental policy stringency index - total	OECD
EPS_{MKT}	Environmental policy stringency index - market policies	OECD
EPS_{NMKT}	Environmental policy stringency index - non-market policies	OECD
$TECHSUP$	Environmental policy stringency index - technology support	OECD

Summary statistics

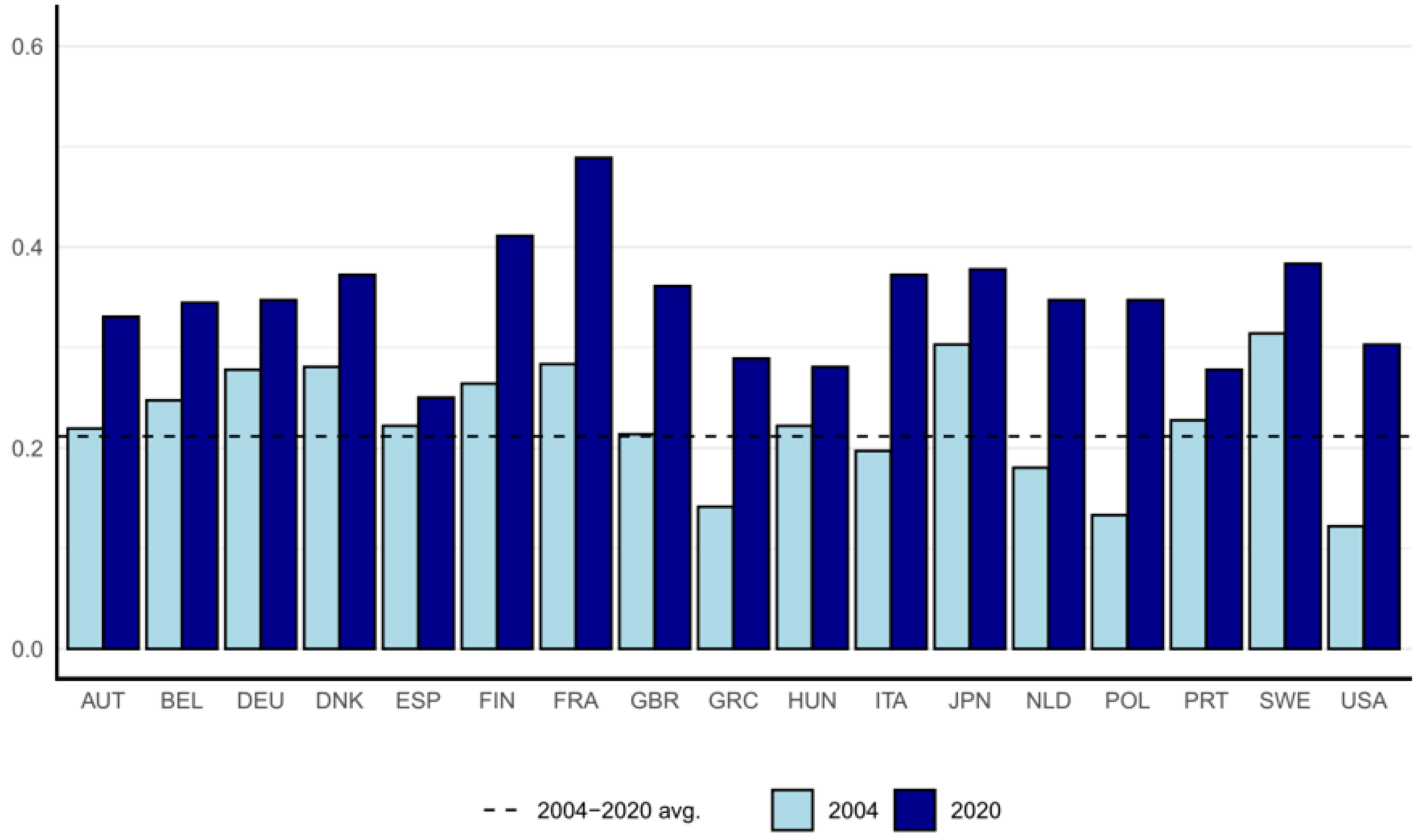
Variable	Obs	Mean	Std. Dev.	Min	Max
$\Delta\ln(y)$	271	0.008	0.018	-0.079	0.064
$\Delta\ln(k_t)$	271	0.01	0.029	-0.102	0.119
$\Delta\ln(k_{green,t})$	287	0.207	0.375	-0.154	4.371
$green_{int}$	135	0.024	0.003	0.02	0.033
EPS	306	0.304	0.061	0.122	0.489
EPS_{MKT}	306	0.161	0.094	0.017	0.417
EPS_{NMKT}	306	0.506	0.068	0.2	0.6
$TECHSUP$	306	0.246	0.122	0	0.6

Source: authors' elaboration on OECD.Stat, EUKLEMS & INTANProd

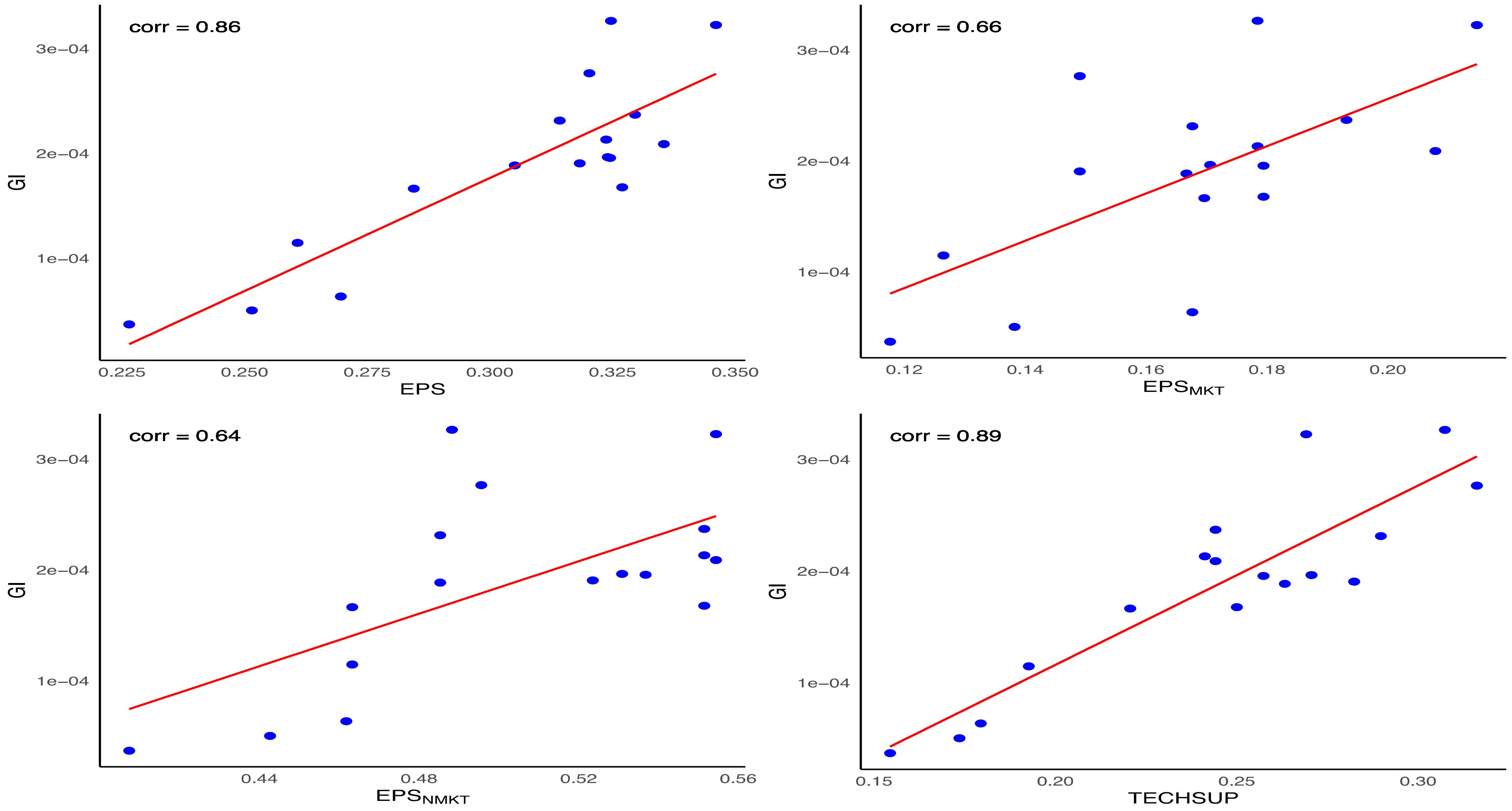
Environmental Policy Stringency

- The OECD Environmental Policy Stringency Index (EPS) is a country-specific and internationally comparable measure of the stringency of environmental policy, developed for the OECD countries by on the basis of the taxonomy of . The index was recently updated by .
- The level of stringency in environmental regulation refers to how much polluting or environmentally detrimental behavior is penalized, either explicitly or implicitly.
- The aggregate EPS index consists of three equally-weighted sub-indices, ranging between **0** (not stringent) and **0.6** (highest stringency) and measuring the stringency of:
  - **Market based policies**, such as taxes, permits, trading schemes, and certificates;
  - **Non-market based policies**, such as those that mandate emission limits and performance standards;
  - **Technology Support policies**, encompassing those policies that support innovation in clean technologies and their adoption, e.g. R&D support, feed-in tariffs, auctions.

Economic policy stringency by country, total index, 2004-2020



Renewable green investment and environmental policy stringency, averages by time, 2004-2020



Model specification

We econometrically test this relationship in a production function model augmented with green investment and EPS

The general specification of the model is as follows:

$$\Delta y_{i,t} = \beta_0 + \sum_{c=1}^{C} \beta_C \Delta x_{i,t}^{C} + \sum_{d=1}^{D} \beta_D x_{i,t}^{D} + \sum_{e=1}^{E} \beta_E X_{i,t}^{E} + \gamma_t + \eta_i + \epsilon_{i,t}$$

where i = country and t = time. $x_{i,t}^{C}$ is the vector of covariates (in log differences), $x_{i,t}^{D}$ is the vector of covariates in levels, $X_{i,t}$ are the control variables (when applicable, intangible assets), η_i represents the country-specific fixed effects and γ_t captures the time-specific fixed effects.

Regression results

Variables	(1) GLS	(2) GMM	(3) GLS	(4) GMM	(5) GLS	(6) GLS	(7) GLS	(8) GLS	(9) GLS
$\Delta \ln(k)$	0.422***	0.353***	0.414***	0.418***	0.412***	0.416***	0.419***	0.409***	0.481***
	(0.0387)	(0.128)	(0.0379)	(0.121)	(0.0381)	(0.0378)	(0.0377)	(0.0401)	(0.0573)
$\Delta \ln(k_{Green})$			0.00773***	0.00971*	0.00774***	0.00731***	0.00764***	0.00763***	0.0192***
			(0.00214)	(0.00511)	(0.00214)	(0.00216)	(0.00213)	(0.00217)	(0.00524)
$\ln(EPS)$					0.00467				
					(0.00800)				
$\ln(EPS_{MKT})$						-0.00416			
						(0.00331)			
$\ln(EPS_{NMKT})$							0.0169**		0.0304**
							(0.00840)		(0.0127)
$\ln(TECHSUP)$								2.45e-05	
								(0.00203)	
$\ln green_{int} \times \ln(k_{Green})$									0.0987***
									(0.0356)
Observations	271	238	271	238	271	271	271	268	112

Note: Annual data; Standard errors in parentheses;
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Empirical findings (so far)

- Our findings show that, albeit small, scaling up **renewable green capital** has a positive and significant effect on productivity growth
  - Difference between estimation results using different methods suggest that k_{green} might be affected by a downward endogeneity bias.
- The results suggest that strengthening environmental regulation does not hamper productivity growth.
  - **Market policies**, e.g. carbon taxes and trading schemes, could lead to productivity effects that, however, are not statistically significant.
  - At the same time, **non-market policies** – such as emission limits – appear to be the most effective in fostering innovation in our sample.
  - Last, the stringency associated with **technology support measures** has a positive but not significant impact on productivity growth.
    - ✓ However, one might notice that the sub-index groups together two sets of policies which have arguably different effects (Becker 2015), i.e. public R&D expenditures on low-carbon energy technology and renewable energy support measures.
- When interacted with renewable green capital, **green skill intensity** has a positive and statistically significant impact on productivity

POLICY DISCUSSION

Policy discussion 1/2

- It’s important to look at how to **further improve green investment measurements** to provide data and instruments that allow a better policy evaluation of the **green transition** and better define **environmental mitigation strategies**

- The empirical analysis conducted suggests some potential **policy issues** that might be worth further developing:

    - an increase in **renewable green capital** leads to positive and significant effects on **productivity growth**;

    - there **may not necessarily be a trade-off** between climate change mitigation objectives and economic growth;

    - potential **synergies** may exist between the two goals: governments may decide to pursue climate change mitigation objectives and spur productivity growth at the same time.

Policy discussion 2/2

The results of our analysis suggest a deeper exploration of the following preliminary findings:

- **more stringent environmental regulatory measures** may have a **potential positive role** to play: stricter regulation does not necessarily constrain productivity growth and might even stimulate innovation thus favoring adaptation

- we found that **non-market policies** appear to be the most effective in **fostering innovation and likely productivity**;

- policymakers should also consider the potential positive role of **green technology support measures**.

Overall, scaling public investment alone is not enough: to fulfill climate ambitions, policymakers has a role to play also in **mobilizing private capital** and creating favorable conditions for private investment (*Deleidi et al., 2020*).

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