# Exploring Country Characteristics that encourage Emissions reduction

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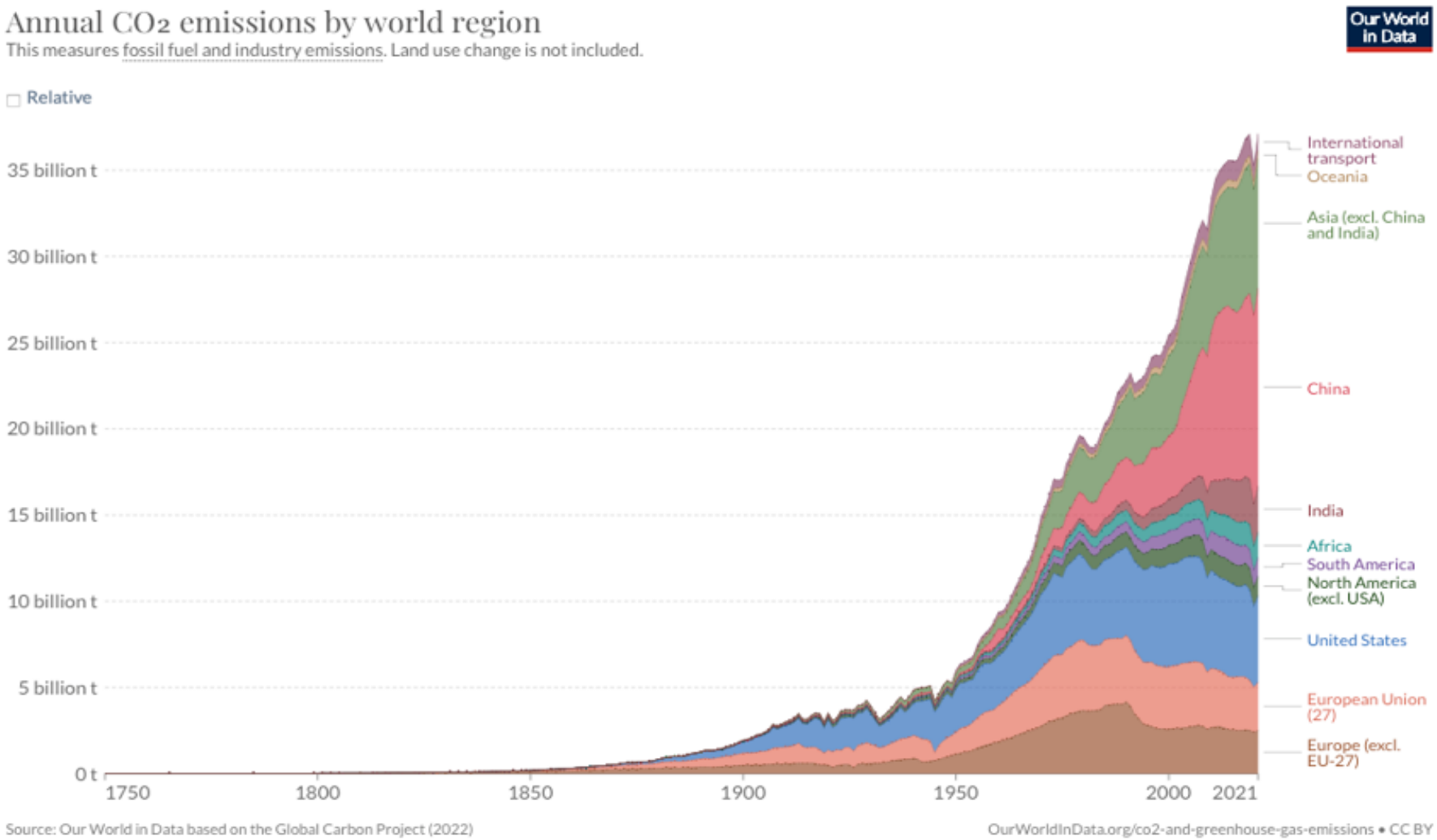
CRETE 2023, Naxos

# Annual CO2 Emissions by Regions



# Climate Change and EU Initiatives

## Climate Change is Real!

- 42% of Global GHG Emissions (1850-2019) occurred between 1990 and 2019
- **3.3–3.6 billion** people in contexts highly vulnerable to Climate Change (IPCC AR6)

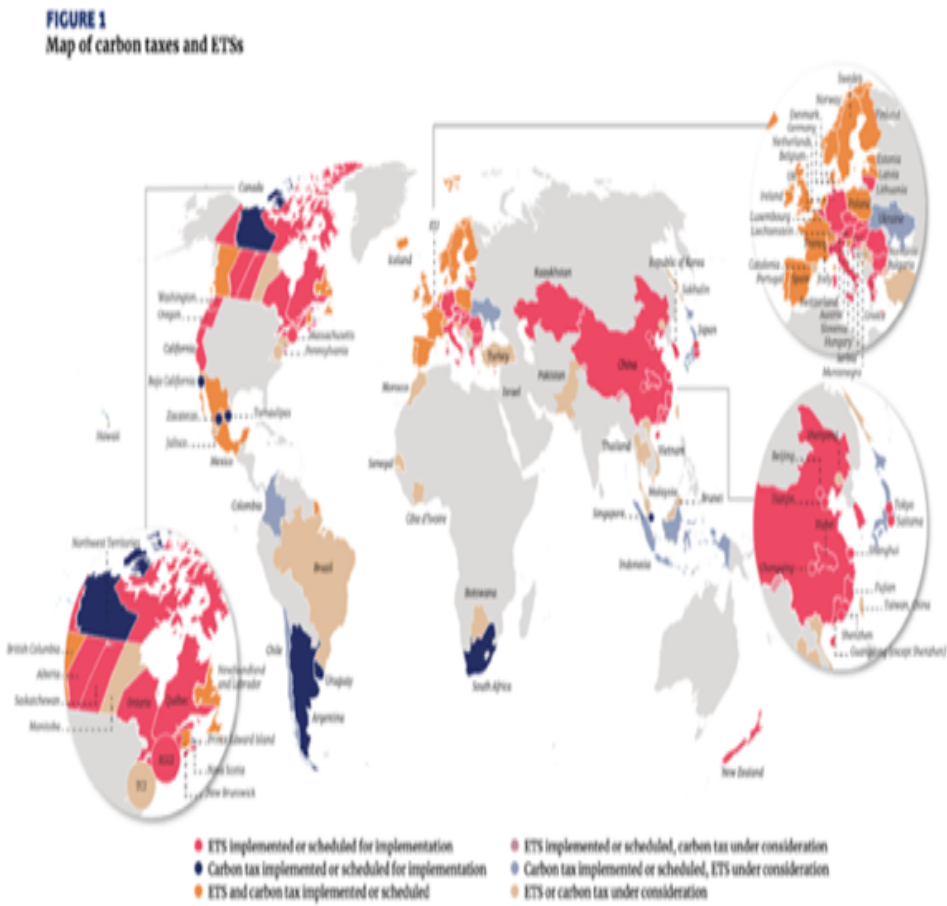
## EU at the forefront of Climate Action

- **Fit-for-55**: ↓ GHG Emissions 55% in 2030 from 1990 levels
- **EU Green Deal (EGD)**: Flagship Initiative for EU leading the Green Transition
- **EU Climate Law**: Enshrines objectives of EGD and FF55
- **EU Missions**: Holistic & Inter-disciplinary Approach to tackle CC

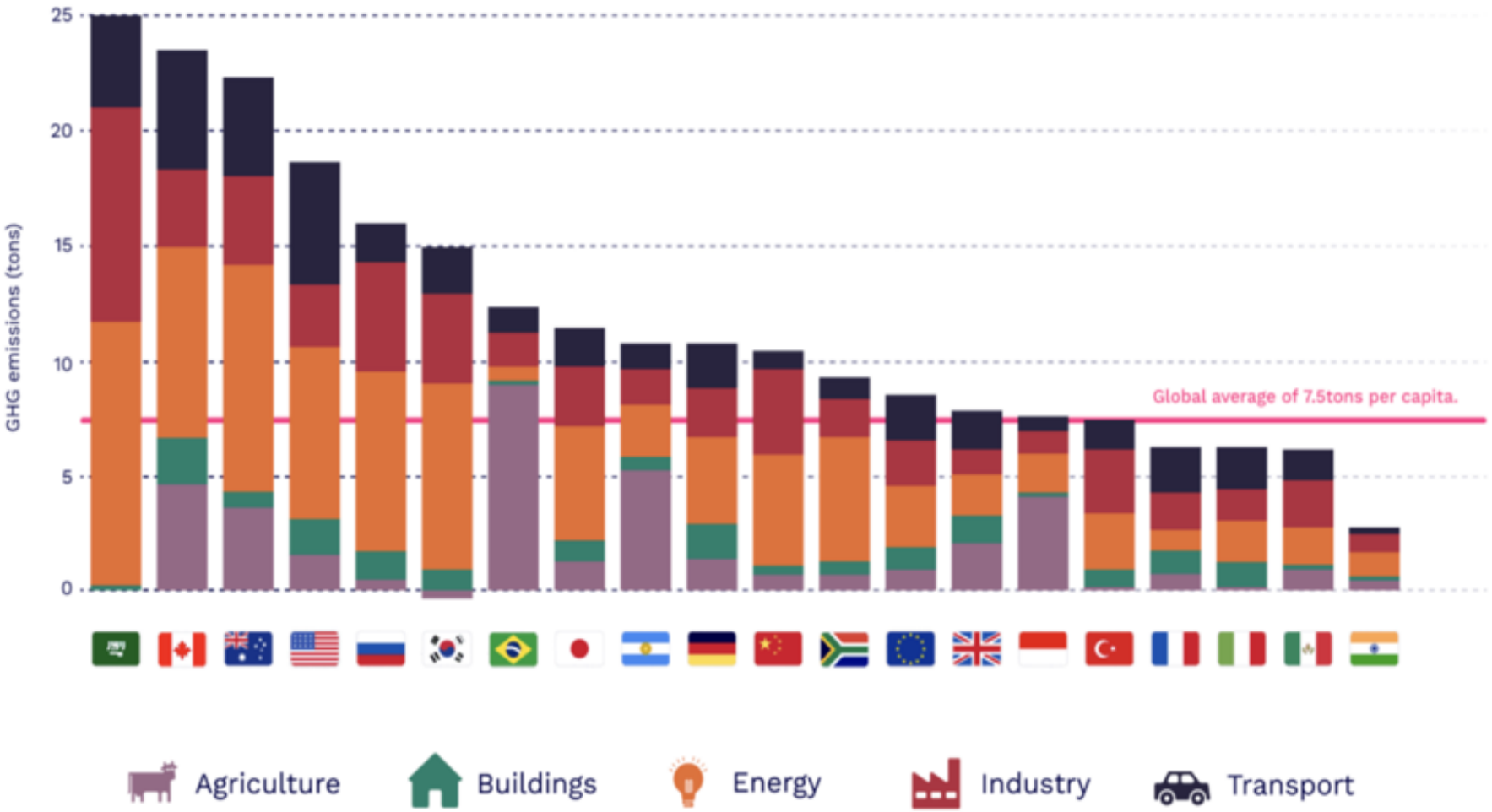
# State and Trends of Carbon Pricing 2022

Currently: 68 Carbon Pricing Instruments (CPIs) in place

37 *Cap and Trade* and 31 Carbon Taxes



# Annual CO2 Emissions for selected countries



# Contribution

Linking **National structural characteristics** with firm emissions reduction process

Informing the discussion of the *Effectiveness* of EU Climate Policies

Combine Firm-level Emissions from **EU-ETS** Sectors with Micro data from **ORBIS** and a rich set of **IMD Structural Competitiveness Indicators**

Underlining the interplay between EU Policy Actions, Key National Enablers and Firm Attributes → Sustainable Transition

# EU - ETS

The **EU Emissions Trading System (ETS)** is a Cap-and-Trade System for Carbon Permits established in 2005

- Phase I: 2005-2007, Phase II: 2008-2012, Phase III: 2013-2020, Phase IV: 2021-2030

Covering more than 11k manufacturing and power plants and about 45% of the EU's GHG emissions in 31 countries

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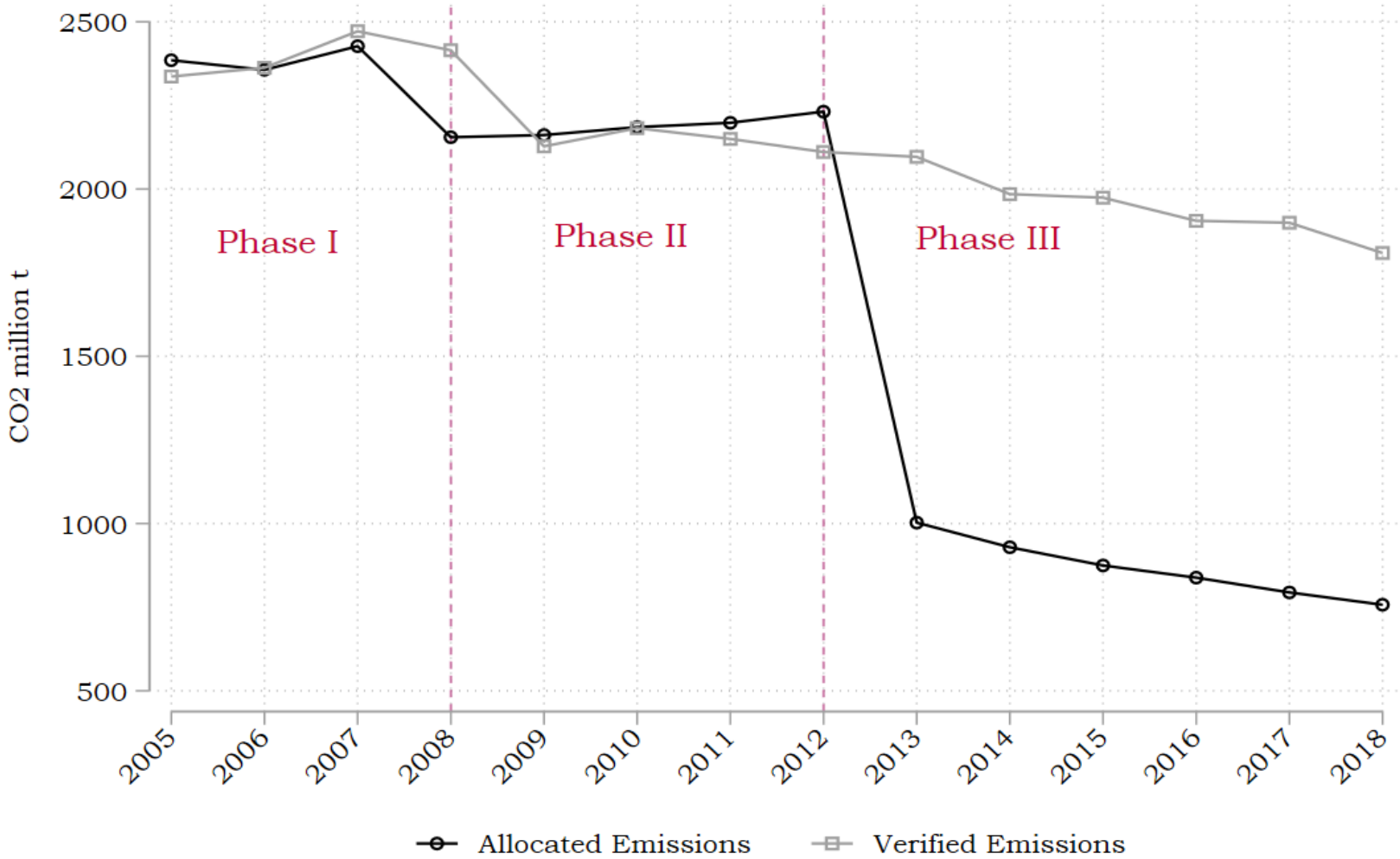
Covering more than 11k manufacturing and power plants and about 45% of the EU's GHG emissions in 31 countries

**2005 → 2022 ↓ of GHG emissions by 38%**
**Phase IV 2030 Target: ↓ 62% vs 2005**

**Premise**: Carbon Price as an **Incentive for Green Innovation**

# ETS GHG Emissions



# EU - ETS (cont.)

Phases I& II failed to promote decoupling from *brown technologies* due to low Carbon Permit Prices

- Grandfathering, ↓ in Economic Activity (GFC) and Technological Lock-in

Recent Progress mostly attributed to *Government and EU support* through Subsidies and public R& D

Phase IV enters with ↑ in Prices and *Sector Coverage*
→ Buildings and Transport

# Carbon Price EU-ETS

# EU - ETS (cont.)

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→ Buildings and Transport

**Carbon Border Adjustment Mechanism (CBAM)**
Import Tariff from Economies with no Carbon Market to avoid *Carbon Leakage* - in effect come 2026

# Literature Review

Institutional environments that foster knowledge accumulation & assimilation pivotal for green innovation (Aghion et al., 2016; Jaffe et al., 2005)

Developing and fostering sound Institutions affects public choice and matters for the enforcement and effectiveness of environmental policies (Halkos & Tzeremes, 2013; Abid, 2017; Lau et al., 2014; Ibrahim & Law, 2016)

Mixed evidence on the effects of the EU ETS on (green) innovation (Hoffman, 2007; Anderson et al., 2010; Borghesi et al., 2015)

- Extra Cost for Firms (Deschenes, 2014; Andreou & Kellard, 2021)

## Research Question

- Testing which **Country Structural characteristics** as associated with firms' emissions controlling for firm and macroeconomic variables
- Combine Emissions data from EU-ETS with ORBIS financial data and Institutional Indicators (WEF, IMD)

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## Empirical Specifications

- **Baseline**: OLS with each Institutional Indicator (t-1) as the RHS variable of interest
- **2-Step GMM**: 2 lags of Institutional Variable as Instruments
- **Robustness**: Common Factors (PCA) to reduce the Institutional Dimensions

# Estimated Model

$$Verified\ Installation_{ijt} = a + a_1 Institution_{jt-1} + a_2 F_{ijkt} + a_3 B_{jt} + a_4 I_k + a_5 P_t + u_{ijt} \quad (1)$$

where

*Verified Installation* is the logarithm of verified emissions of a firm $i$ operating in country $j$, industry $k$ in year $t$ normalized by the number of installations of the firm $i$

*Institution* quantifies each variable of the IMD World Competitiveness (WEF) indicator used of country $j$ in year *t-1*

$F_{ijt}$ : Firm Control Variables table

$B_{jt}$ : Country Control Variables table

$I_k$ : Industry Indicator Variables

$P_t$ : Phase Indicator Variables

# Institutional Indicators

| | |
|---|---|
| | **WEF** |
| Technological readiness | 9th pillar from WEF Global Competitiveness Indicator Report |
| Business sophistication | 11th pillar from WEF Global Competitiveness Indicator Report |
| Innovation capacity | 12th pillar from WEF Global Competitiveness Indicator Report |
| | **IMD** |
| Research legislation | Scientific research legislation: Laws relating to scientific research do encourage innovation |
| Competent | Competent senior managers: Competent senior managers are readily available |
| PPP | Public-private partnerships: Public and private sector ventures are supporting technological development |
| Computers | Number of computers per 1000 people |
| Digital skills | Digital/Technological skills are readily available |
| Skilled labour | Skilled labor is readily available |
| Tech development | Development and application of technology are supported by the legal environment |

# GHG Emissions and Skilled Labor Index

# GHG Emissions and Scientific Legislation Index

# Data and Stylized Facts

Sample: **1104 EU-ETS Firms 2005-2018**

- Removing Industries with $< 1\%$ Representation
- Merging with ORBIS financial data (*bigram* matching)

**Final Sample: 540 EU-ETS Firms 2005-2018** Descriptives

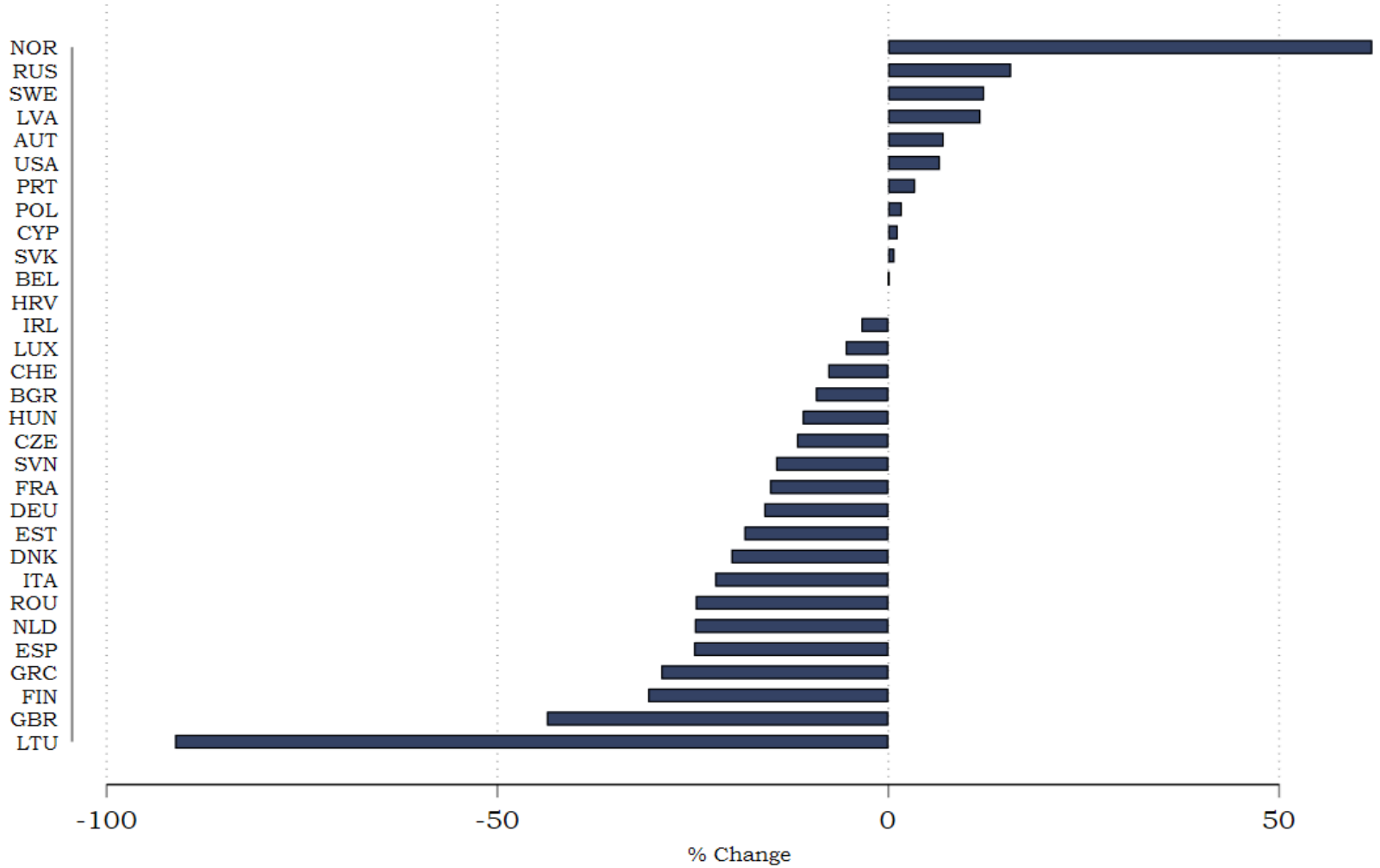
- 31 Origin Countries, 11 ETS covered Industries

Notable ↓ Verified Emissions in Phase III

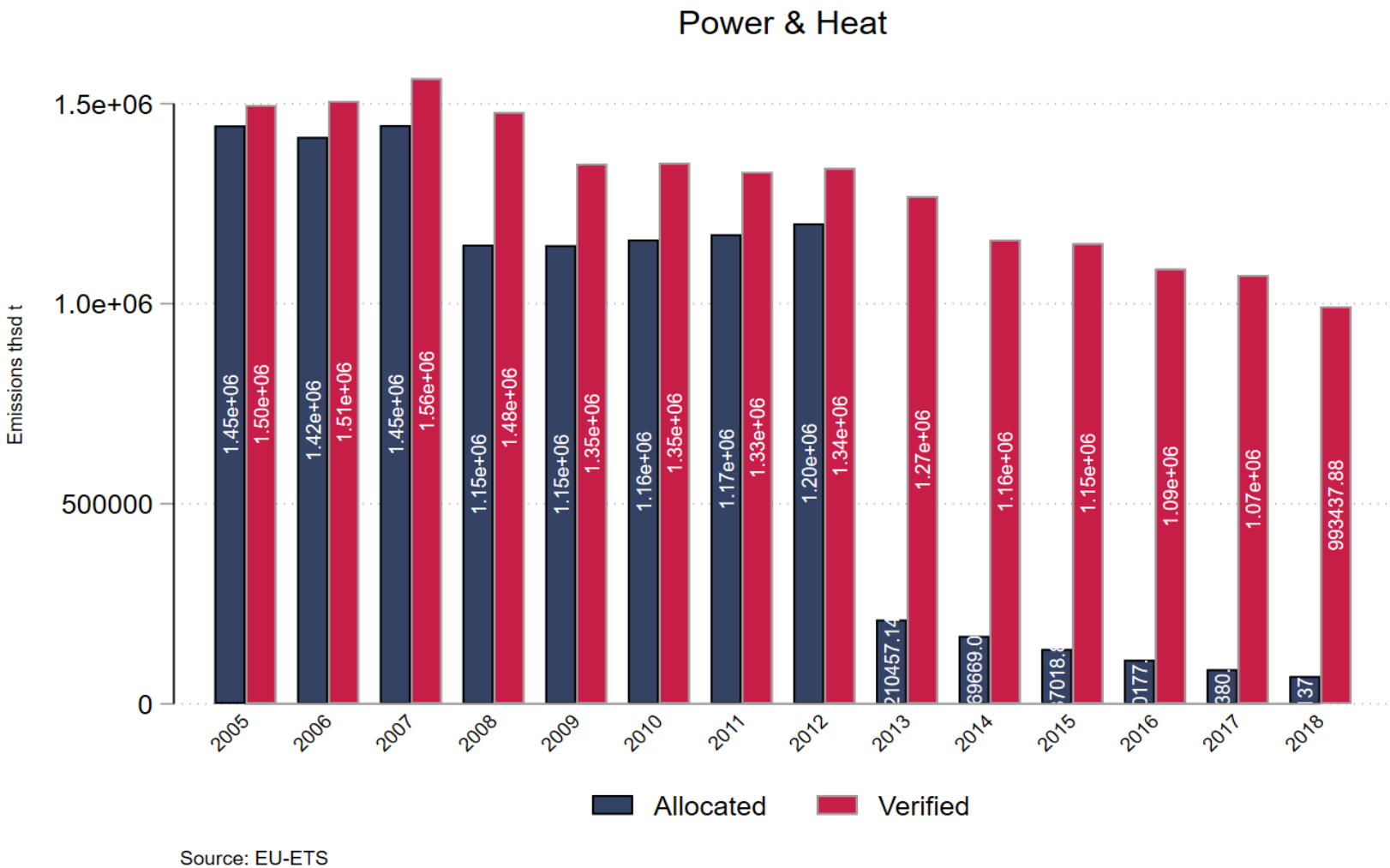
- Steep ↑ of Excess Emissions

**Power & Heat** and **Iron & Steel** → 45 % of total Sample

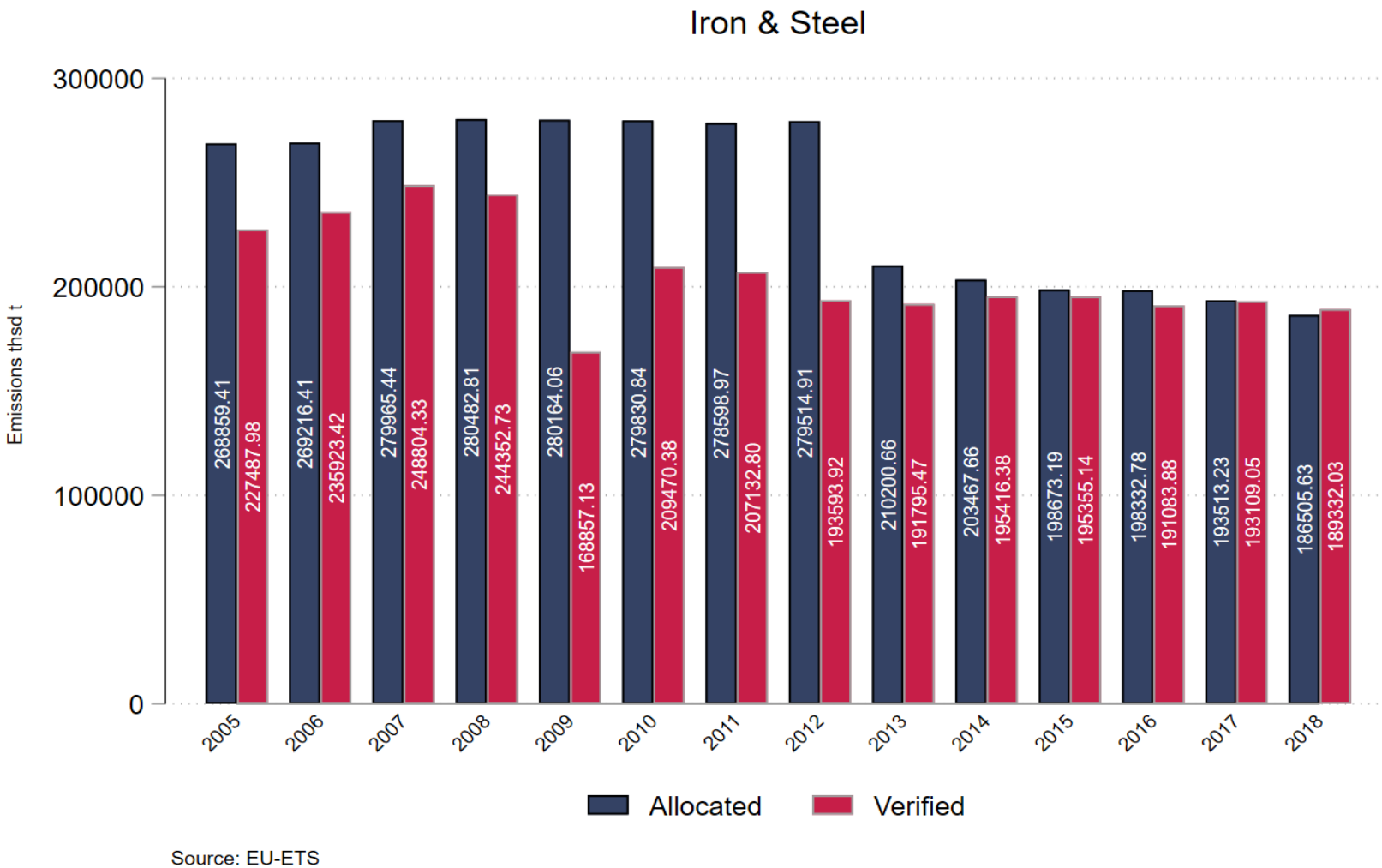
# Change in Verified Emissions by Country 2005-18



# Allocated vs Verified Emissions Power & Heat



# Allocated vs Verified Emissions Iron & Steel



# Baseline Results I

**Dependent Variable: log Verified emissions per Installation**

| VARIABLES | Tech readiness | Business Sophistication | Innovation Capacity | Scientific Legislation | Tech Development |
|---|---|---|---|---|---|
| Institution (t-1) | -0.314*** | -0.529*** | -0.312** | -0.099** | -0.113** |
| | (0.120) | (0.189) | (0.157) | (0.049) | (0.057) |
| Size | 0.296*** | 0.307*** | 0.297*** | 0.301*** | 0.300*** |
| | (0.033) | (0.033) | (0.033) | (0.030) | (0.030) |
| ROE | -0.005* | -0.006* | -0.006* | -0.007** | -0.007** |
| | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) |
| log Intangible Assets | -0.094*** | -0.098*** | -0.096*** | -0.097*** | -0.098*** |
| | (0.019) | (0.019) | (0.020) | (0.017) | (0.017) |
| GFCF % GDP | -0.046** | -0.062*** | -0.046** | -0.043*** | -0.042** |
| | (0.018) | (0.019) | (0.019) | (0.017) | (0.017) |
| Business R&D % GDP | -0.001 | 0.198 | 0.184 | 0.008 | -0.035 |
| | (0.106) | (0.144) | (0.174) | (0.104) | (0.094) |
| **1 SD effect** | **-0.193** | **-0.332** | **-0.278** | **-0.139** | **-0.112** |
| Observations | 1,631 | 1,607 | 1,607 | 1,863 | 1,863 |
| R-squared | 0.227 | 0.232 | 0.229 | 0.226 | 0.226 |
| Industry FE | Yes | Yes | Yes | Yes | Yes |
| Phase FE | Yes | Yes | Yes | Yes | Yes |
| Robust SE | Yes | Yes | Yes | Yes | Yes |

# Baseline Results II

**Dependent Variable: log Verified emissions per Installation**

| VARIABLES | Competent Managers | PPP | Computers per cap | Digital Skills | Skilled Labor |
|---|---|---|---|---|---|
| Institution (t-1) | -0.269*** | -0.144*** | -0.002*** | -0.176*** | -0.258*** |
| | (0.074) | (0.055) | (0.000) | (0.055) | (0.053) |
| Size | 0.304*** | 0.312*** | 0.296*** | 0.295*** | 0.287*** |
| | (0.030) | (0.030) | (0.029) | (0.030) | (0.029) |
| log Intangible Assets | -0.096*** | -0.104*** | -0.094*** | -0.095*** | -0.090*** |
| | (0.017) | (0.018) | (0.017) | (0.017) | (0.017) |
| ROE | -0.007*** | -0.007** | -0.007** | -0.007** | -0.008*** |
| | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) |
| GFCF % GDP | -0.056*** | -0.045** | -0.054*** | -0.049*** | -0.056*** |
| | (0.017) | (0.018) | (0.017) | (0.017) | (0.017) |
| Business R&D % GDP | 0.007 | 0.016 | 0.159 | 0.015 | -0.054 |
| | (0.091) | (0.095) | (0.104) | (0.093) | (0.086) |
| **1 SD effect** | **-0.213** | **-0.141** | **-0.379** | **-0.332** | **-0.214** |
| Observations | 1,863 | 1,817 | 1,864 | 1,863 | 1,863 |
| R-squared | 0.231 | 0.227 | 0.233 | 0.229 | 0.236 |
| Industry FE | Yes | Yes | Yes | Yes | Yes |
| Phase FE | Yes | Yes | Yes | Yes | Yes |
| Robust SE | Yes | Yes | Yes | Yes | Yes |

# Key Takeaways

Institutions supporting **Skills Development, Technological Infrastructure and Innovation** significantly associated with *ceteris paribus* Decrease in Firm-level GHG Emissions

- E.g. 1 SD ↑ of Skilled Labor Indicator →↓ 21.4% Emissions per installation by 21.4%

Control Micro and Macro Variables with Expected Sign and Significance

# Key Takeaways

Institutions supporting **Skills Development, Technological Infrastructure and Innovation** significantly associated with *ceteris paribus* Decrease in Firm-level GHG Emissions

- E.g. 1 SD ↑ of Skilled Labor Indicator →↓ 21.4% Emissions per installation by 21.4%

Control Micro and Macro Variables with Expected Sign and Significance

**Results corroborated** with findings from 2-step GMM Estimations

# 2-step GMM Results I

**Dependent Variable: log Verified emissions per Installation**

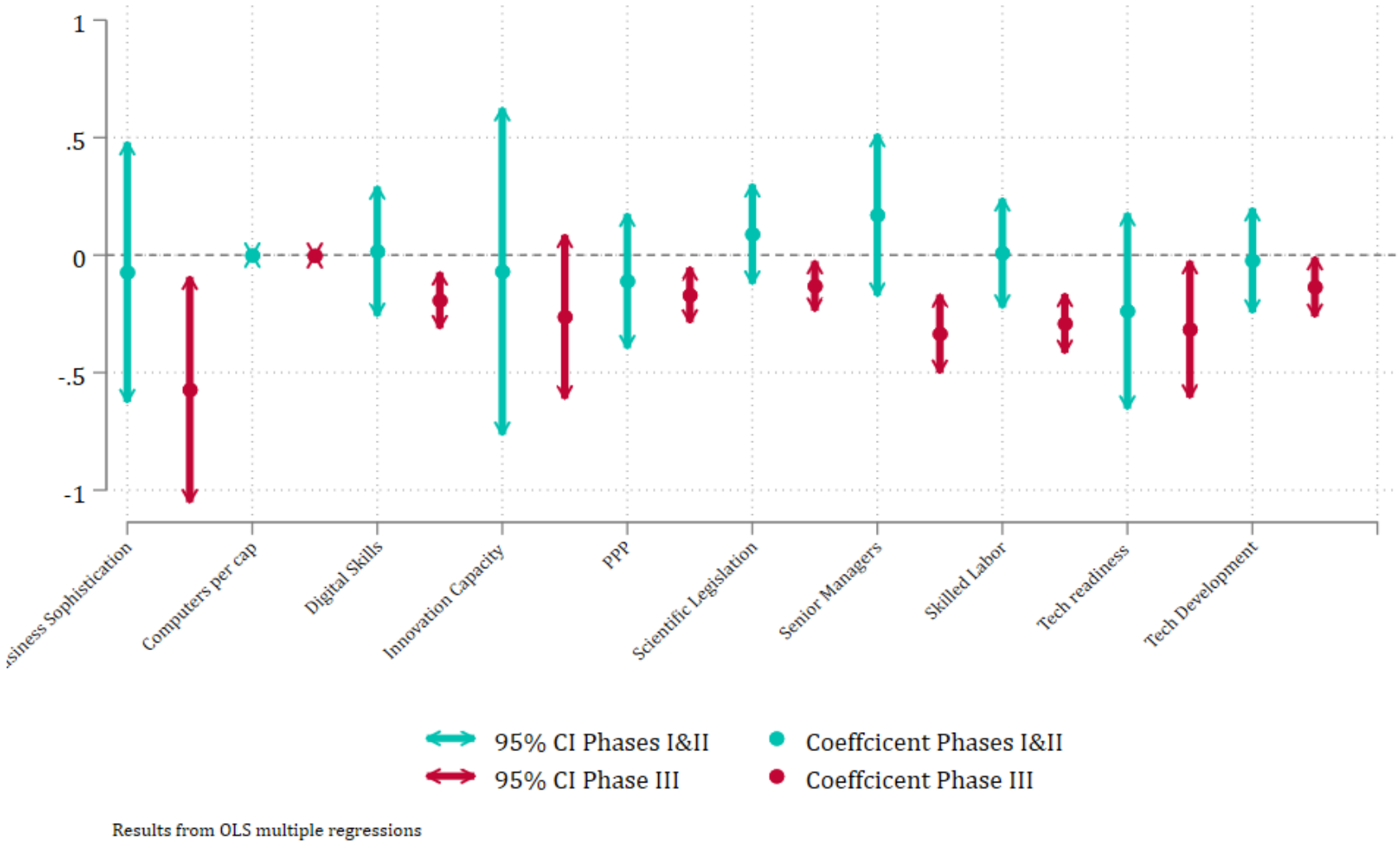
| VARIABLES | Skilled Labor | Competent Managers | PPP | Scientific Legislation | Tech Development |
|---|---|---|---|---|---|
| Institution (t-1) | -0.352*** | -0.538*** | -0.203*** | -0.114* | -0.122* |
| | (0.000) | (0.000) | (0.005) | (0.064) | (0.077) |
| Size | 0.275*** | 0.302*** | 0.305*** | 0.298*** | 0.298*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| log Intangible Assets | -0.083*** | -0.088*** | -0.103*** | -0.098*** | -0.100*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| ROE | -0.008*** | -0.008*** | -0.007** | -0.007** | -0.007*** |
| | (0.004) | (0.005) | (0.016) | (0.012) | (0.010) |
| Cash Flow | -0.000** | -0.000** | -0.000* | -0.000* | -0.000* |
| | (0.038) | (0.031) | (0.060) | (0.074) | (0.065) |
| GFCF % GDP | -0.062*** | -0.063*** | -0.040** | -0.044** | -0.043** |
| | (0.000) | (0.000) | (0.028) | (0.012) | (0.014) |
| Business R&D % GDP | -0.002 | 0.080 | 0.060 | 0.054 | 0.002 |
| | (0.985) | (0.390) | (0.539) | (0.622) | (0.984) |
| **1 SD effect** | **-0.292** | **-0.426** | **-0.198** | **-0.16** | **-0.121** |
| Observations | 1,786 | 1,786 | 1,757 | 1,786 | 1,786 |
| R-squared | 0.235 | 0.229 | 0.227 | 0.228 | 0.228 |
| Phase FE | Yes | Yes | Yes | Yes | Yes |
| Industry FE | Yes | Yes | Yes | Yes | Yes |
| Sargan-Hansen Statistic | 3.174 | 0.702 | 0.589 | 0.0764 | 0.392 |
| Anderson CCStatistic | 389.2 | 295 | 557 | 528 | 613.2 |
| Endogeneity Statitsic | 5.504 | 6.326 | 0.927 | 0.315 | 0.199 |

# 2-step GMM Results II

**Dependent Variable: log Verified emissions per Installation**

| VARIABLES | Tech readiness | Business Sophistication | Innovation Capacity | Computers per cap | Digital Skills |
|---|---|---|---|---|---|
| Institution (t-1) | -0.384*** | -0.606*** | -0.372** | -0.002*** | -0.219*** |
| | (0.005) | (0.003) | (0.034) | (0.000) | (0.000) |
| Size | 0.294*** | 0.315*** | 0.304*** | 0.287*** | 0.288*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| log Intangible Assets | -0.096*** | -0.106*** | -0.103*** | -0.095*** | -0.094*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| ROE | -0.005* | -0.005* | -0.005* | -0.007*** | -0.007*** |
| | (0.099) | (0.092) | (0.097) | (0.009) | (0.009) |
| GFCF % GDP | -0.049*** | -0.064*** | -0.046** | -0.052*** | -0.046*** |
| | (0.009) | (0.001) | (0.017) | (0.003) | (0.007) |
| Business R&D % GDP | 0.060 | 0.249* | 0.251 | 0.172* | 0.050 |
| | (0.581) | (0.095) | (0.178) | (0.096) | (0.590) |
| **1 SD effect** | **-0.236** | **-0.381** | **-0.331** | **-0.379** | **-0.186** |
| Observations | 1,559 | 1,537 | 1,537 | 1,785 | 1,786 |
| R-squared | 0.223 | 0.225 | 0.222 | 0.236 | 0.231 |
| Phase FE | Yes | Yes | Yes | Yes | Yes |
| Industry FE | Yes | Yes | Yes | Yes | Yes |
| Sargan-Hansen Statistic | 0.0346 | 0.0130 | 0.0550 | 12.25 | 2.053 |
| Anderson CCStatistic | 510.4 | 343.1 | 364.1 | 570.9 | 606.6 |
| Endogeneity Statitsic | 4.714 | 0.0544 | 0.151 | 0.755 | 2.542 |

# Institutional Variables Coefficient by Phase




Results from OLS multiple regressions

# Key Takeaways II

Conducive Effect of Institutions on Firm Emission Abatement **Significant only in Phase III**

Pronounced Effect of Institutional Variables in Phase III *(magnitude)*

*Stringency* of Environmental Policies → Incentives for a *vicious cycle* of **Firm Initiative + National Structural Enablers**

- Promising for Phase IV and beyond

# Robustness - Factor Analysis

**38 Institutional Indicators** → **3 Factors** = 85% of total Variation

Principal Component Method - Oblique Rotation

- **Institutional Framework**
  All IMD Variables
- **National Competitiveness**
  All WEF Variables
- **Skills**
  Skilled & digital labor, Financial Skills and Competent Managers

Significantly associated with **Drop in Firm GHG Emissions**

# Caveats

Firm (& Country) Emissions associated with **Local Production** not accounting for *Outsourcing*

Sample Deflation due to ORBIS data availability

Poor performance of *Interaction Effects* for Micro x Macro Variables

Lack of Perfect **Firm-level Innovation** Metric

# Conclusion

Do Sound Institutions that support Innovation Systems positively affect GHG Emission reduction at the firm level ?

- **Yes, they do.**

# Conclusion

Do Sound Institutions that support Innovation Systems positively affect GHG Emission reduction at the firm level ?

- **Yes, they do.**
  - Institutions enhancing Skills, Technological Infrastructure and Innovation Capacity catalyze the effors for Emission Abatement in EU-ETS firms
  - The Effect is stronger when commingled with *Stringent Environmental Policy*
  - Indication that Green Innovation → Green Transformation through **Systemic Efforts at the National and EU level**

# Issues for further inquiry

Incorporate *Global Emissions* based on Ownership data to acccount for **Carbon Leakage**

Investigate the Effect of the **CBAM**

Comparative Study with similar Schemes outside the EU

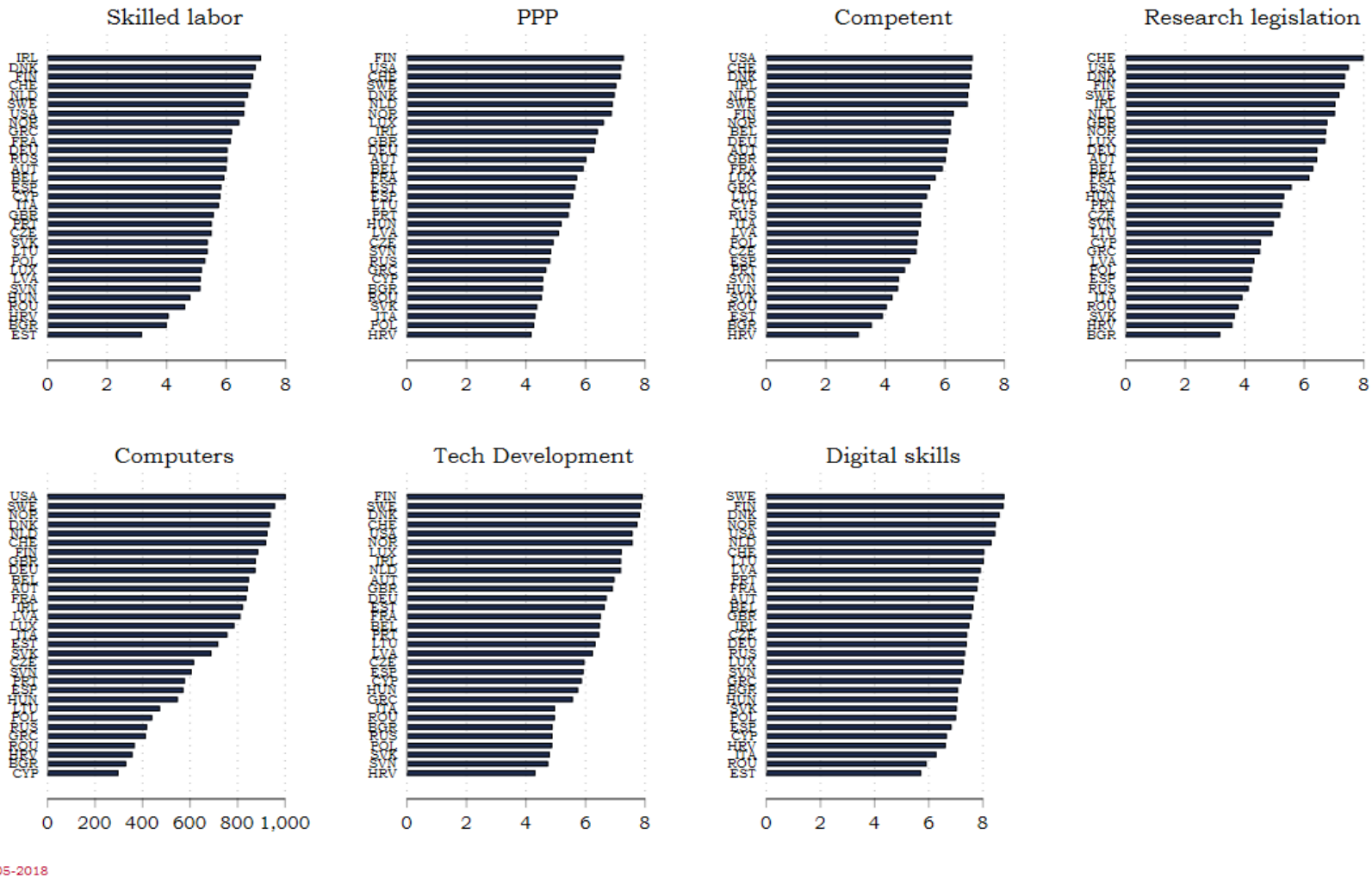
Enrich with Firm Surveys on **ESG performance** (e.g. CDP)

# Descriptive Statistics

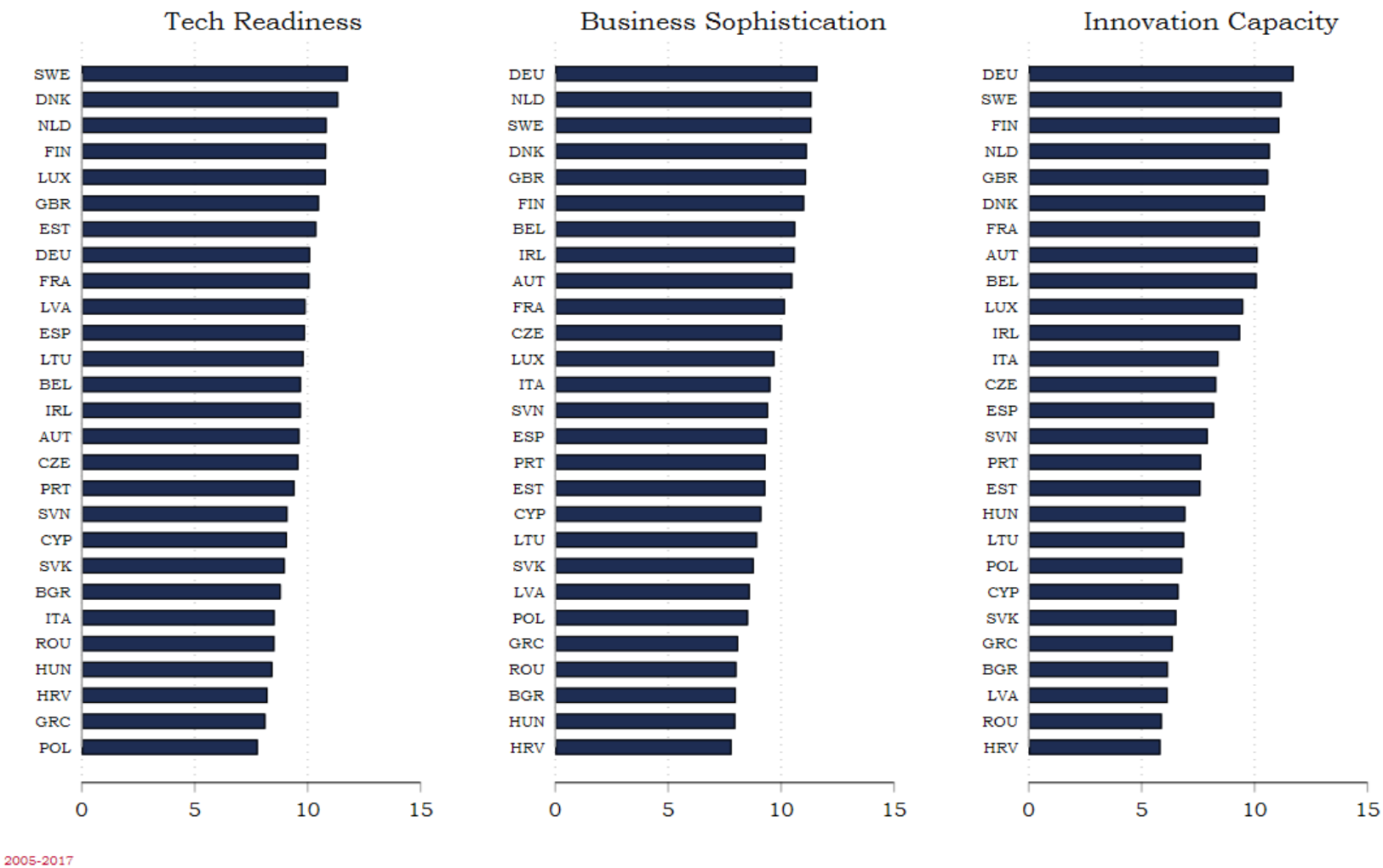
return

| | Obs. | Mean | Median | St.Dev | Min | Max |
|---|---|---|---|---|---|---|
| Allocated | 1,863 | 1,715.37 | 226.27 | 5,538.13 | 0.025 | 75,720.05 |
| Verified | 1,863 | 2,343.80 | 337.042 | 6,393.09 | 0.037 | 72,436.55 |
| Verified Installation | 1,863 | 319.624 | 74.618 | 772.154 | 0.031 | 10,222.78 |
| Size | 1,863 | 20.311 | 20.217 | 2.157 | 14.801 | 26.95 |
| Research legislation | 1,863 | 5.552 | 6.14 | 1.406 | 2.08 | 8.2 |
| Competent | 1,863 | 5.673 | 5.88 | 0.792 | 2.73 | 7.62 |
| PPP | 1,817 | 5.612 | 5.77 | 0.977 | 2.78 | 8.07 |
| Computers | 1,863 | 860.805 | 921.66 | 189.703 | 117.01 | 1087.99 |
| Digital skills | 1,863 | 7.366 | 7.26 | 0.849 | 3.42 | 9.3 |
| Skilled labour | 1,863 | 5.958 | 5.97 | 0.83 | 2.47 | 8.09 |
| Tech development | 1,863 | 6.261 | 6.5 | 0.99 | 3.14 | 8.47 |
| Technological readiness | 1,631 | 5.478 | 5.71 | 0.614 | 3.291 | 6.457 |
| Business sophistication | 1,607 | 4.981 | 5.056 | 0.628 | 3.467 | 6.26 |
| Innovation capacity | 1,607 | 4.544 | 4.832 | 0.89 | 2.913 | 5.787 |

# IMD Indicators



# WEF Indicators



# Control Variables

return

| | |
|---|---|
| **Financial variables (ORBIS)** | |
| Total assets | Total assets in millions |
| Total assets change | Percentage change in total assets between years t and t-1 |
| Intangible | Intangible assets in millions |
| ROE | The ratio of income before interests and taxes to book value of equity |
| Cash flow | Operating income before depreciation divided by beginning of the year net assets. |
| **Macroeconomic variables (Eurostat, OECD, World Bank)** | |
| GDP growth | The country growth in GDP between years t and t-1 |
| Rate | Country short term interest rates (average of commercial banks) |
| GFCF | Gross fixed capital formation as a percentage of GDP |
| Business R&D | Business R&D as a percentage of GDP |
| Liquid liabilities | Ratio of liquid liabilities to GDP |
| Financial development | Sum of private-sector credit and value of all listed stocks, divided by the country's GDP |