Do Environmental and Energy Expenditures Pay Off?

Evidence on Firm-Level Productivity in Romania

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Acknowledgment & Disclaimer: This presentation draws on a preliminary working paper based on 2020–2023 National Institute of Statistics (NIS, Romania) Structural Business Survey (SBS) data. Findings are provisional and subject to further revision. All conclusions and interpretations drawn from the data represent the sole view of the author.

Presentation overview

Introduction: motivation and context

- **The growing role of environmental management:** environmental practices have shifted from simple compliance to a **core strategic factor** for long-term firm stability and cost management (Barney, 1991; Porter and van der Linde, 1995).

- **Global macroeconomic shocks (2020-2023):**
  - **COVID-19 pandemic**: a temporary drop in energy demand that opened a window for "green recovery" funding through NextGenerationEU.
  - **2022 energy crisis**: accelerated the shift toward energy security and the REPowerEU strategy.

- **The Romanian context:**
  - entry into **phase 4 of the EU ETS (2021)** with stricter carbon emission regulations (Marcu et al., 2025).
  - a persistent **productivity gap**, with many firms still operating below the EU average (OECD, 2026).

Introduction: research objective and contributions

Core research question:

To what extent do environmental management (adoption vs. scale) and energy intensity shape firm-level productivity during a period of global disturbances?

- **Main contributions of the study:**
  - **Separating the margins**: distinguishing the effect of starting green activities (**adoption**) versus the financial intensity of those activities (**scale**).
  - **Crisis context**: examining Romanian firms during the overlapping COVID-19 and Energy crises (2020-2023).
  - **Structural estimation**: applying the **Levinsohn-Petrin** technique to retrieve robust measures of Total Factor Productivity (TFP).

Theoretical framework: foundational paradigms

- **Porter Hypothesis (PH):** proposes that environmental awareness triggers **innovation offsets**. These efficiency gains can compensate for compliance costs and enhance firm competitiveness (Porter and van der Linde, 1995).

- **Resource-Based View (RBV):** views green management as a **strategic internal asset**. Leveraging these unique capabilities allows firms to optimize resources and gain a sustained competitive advantage (Barney, 1991).

- **Neoclassical View (the opposite):** the "cost-only" paradigm where environmental spending is a **"cost burden"**. It argues that these expenditures divert finite resources away from core production, hampering TFP (Palmer et al., 1995).

Research focus: we evaluate how the **adoption** (extensive margin) and **expenditure scale** (intensive margin) align with these competing perspectives.

Data: sources and sample

- **Primary source:** micro-level data from **NIS** and **SBS**.
- **Sample scope:** a large-scale panel comprising **137,256 firm-year observations** for the 2020-2023 period.
- **Environmental and energy indicators:**
  - **Adoption (EnvExt)**: extensive margin (participation).
  - **Expenditure scale (EnvInt)**: intensive margin (conditional intensity).
  - **Energy intensity (EnerInt)**: ratio of energy spending to total output.
- **Firm controls and robustness variables:**
  - **Baseline**: firm size (employees).
  - **Additional controls**: export orientation, net investments, and innovation (IT investments).
  - **Strategic assets**: human capital (wages), intangible assets, and technological modernization (machinery).

Methodology: identification strategy

Stage 1: Structural TFP estimation

- We apply the **Levinsohn and Petrin (2003)** semi-parametric approach to retrieve robust firm-level productivity.
- This method uses intermediate materials to proxy for unobserved productivity shocks, effectively correcting for **simultaneity bias**.

$$\ln Y_{it} = \alpha \ln K_{it} + \beta \ln L_{it} + \gamma \ln M_{it} + \underbrace{\ln A_{it}}_{TFP} + u_{it}$$

Stage 2: Empirical modeling

- We employ a **two-way Fixed Effects (FE)** estimator to control for firm-level heterogeneity and systematic macroeconomic shocks.
- This model accounts for common disturbances such as the COVID-19 pandemic and the energy crisis.

$$TFP_{it} = \theta_1 EnvExt_{it} + \theta_2 EnvInt_{it} + \pi EnerInt_{it} + \zeta Z_{it} + \lambda_i + \phi_t + e_{it}$$

Results: TFP estimation and dynamics

- **Production function elasticities (LP method):**
  - **Labor** explains the largest share of output variation (0.550), followed by **materials** (0.246) and **capital** (0.168).
  - All coefficients are positive and highly significant at the 1% level.
- **Returns to scale (CRS):**
  - The sum of elasticities is approximately **0.96**.
  - Statistical tests (Wald test, p=0.69) confirm that firms operate under **constant returns to scale**.
- **Productivity distribution and evolution:**
  - Most firms exhibit a TFP average between **3.0 and 3.5**, with a right-skewed distribution indicating high-performance leaders.
  - A **sharp transitory decrease in TFP occurred in 2022**, reflecting the impact of inflation and the energy crisis.

Main Results: environmental and energy spending model

- **Extensive margin (adoption):** the positive effect of green adoption supports the **weak PH** and **RBV**, suggesting that participation signals strategic efficiency and superior management.
- **Intensive margin (scale):** the negative impact of expenditure scale reinforces the neoclassical **"cost burden"** view, where high financial intensity diverts resources from core production activities.
- **Energy dependence:** the positive and highly significant effect of energy intensity reflects a **structural technological dependence** within the current capital configuration.
- **Aggregation bias:** standard models mask the benefits of adoption because they fail to separate the initial decision to "go green" from the subsequent financial weight of the expenditures.

Results: marginal effects and robustness

- **Total marginal effects by percentile:** the impact of environmental efforts is highly sensitive to spending intensity:
  - **Low intensity (p25)**: the total effect on TFP is statistically insignificant.
  - **Medium to high intensity (median & p75)**: a significant "productivity penalty" emerges, increasing from roughly -2.5% to -4.1% as the financial scale of green efforts grows.

- **Extended FE:** baseline findings remain remarkably stable when accounting for idiosyncratic sector-specific and regional shocks through **Year** $\times$ **Industry** and **Year** $\times$ **Region** interaction FE.

- **Internal capabilities (RBV covariates):** results are robust to the inclusion of additional productivity drivers, including:
  - **Digital and tech**: IT investments and machinery modernization.
  - **Strategic assets**: human capital (wages), intangible assets, and export orientation.

- **Simultaneity and lags:** re-estimation using **one-year lagged variables** filters out immediate shocks and addresses potential reverse causality. Past adoption continues to drive current efficiency, confirming the persistence of the identified effects.

Sensitivity: industry structural characteristics

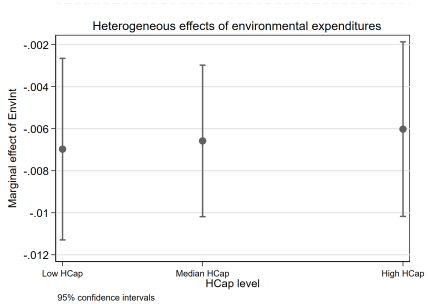
- **High transition exposure:** positive productivity effects of green adoption (EnvExt) are significant **only** in carbon-intensive and EU ETS-related sectors.
  - This validates the **weak PH**: regulatory pressure acts as a catalyst for firms to overcome organizational inertia.
- **Cost burden persistence:** the expenditure scale (EnvInt) remains a negative driver across all sub-samples, with the heaviest penalties observed in regulated industries.
- **Energy resilience:** in energy-intensive sectors, efficiency is a valuable capability (**RBV**) for mitigating price shocks, though structural dependence remains high.
- **Key insight:** the "win-win" outcome is not universal; it is concentrated in sectors where the strategic benefits of adoption outweigh high compliance costs.

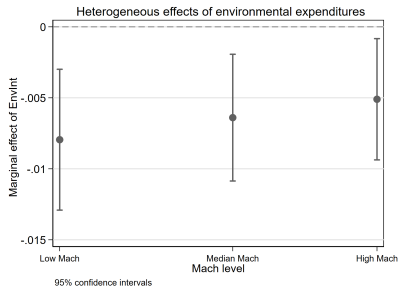
Sensitivity: moderating role of internal capabilities

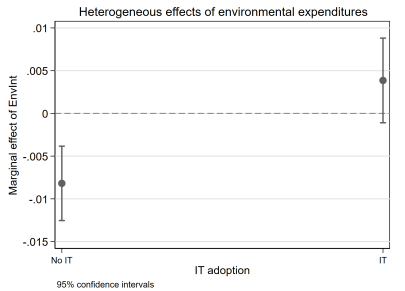
- **Human capital (HCap):** labor quality alone is **insufficient** to trigger innovation offsets. The productivity penalty persists even at high wage levels, as confidence intervals do not cross the zero axis.
- **Tech modernization (Mach):** modern physical assets significantly **attenuate** the negative impact, facilitating the restructuring of the capital stock required for cleaner production.
- **Digital transformation (IT):** the most robust moderator. IT investment **fully neutralizes** the cost burden; for digitally mature firms, the impact on TFP becomes statistically insignificant (CI crosses zero).

Conclusion: these results validate a **conditional PH**. Efficiency gains from environmental efforts are not automatic but depend heavily on the firm's internal resource base (**RBV**).

Average Marginal Effects (AME)







Concluding remarks and theoretical reconciliation

- **The "sign reversal" phenomenon:**
  - **Adoption (EnvExt)**: a strategic asset that enhances efficiency, supporting the **weak PH** and **RBV** perspectives.
  - **Scale (EnvInt)**: a financial "cost burden" that diverts resources, aligning with the neoclassical view.
- **Structural energy dependence:** the positive link between energy intensity and productivity highlights that output growth remains tied to energy consumption, indicating a current lack of decoupling in the technological framework.
- **Strategic implications:** environmental protection "pays off" at the extensive margin (adoption signals management quality), but the intensive margin (spending scale) poses a significant short-term efficiency challenge.
- **Towards a conditional PH:** a "win-win" outcome is not automatic but contingent on internal resources; digital capabilities (IT) and modernization (Mach) are essential for neutralizing green compliance costs.

Policy implications and research limitations

Policy recommendations

- **Tailored regulations**: rules should not be uniform; they must account for sector-specific costs to avoid unfair productivity penalties.
- **Twin transition**: prioritize funds (e.g. NextGenerationEU) for projects that integrate both digital and green transitions.
- **Resource efficiency**: focus on process innovation to effectively decouple growth from energy shocks.
- **Digital support**: subsidizing IT investment is the most effective path to neutralizing the "green cost burden".

Limitations and future paths

- **Time window**: the 2020-2023 period may capture transitory crisis shocks rather than long-term equilibrium.
- **Data granularity**: future research should refine human capital metrics and deeper sectoral splits.
- **Long-term dynamics**: track if "innovation offsets" materialize more fully beyond the immediate learning-by-doing phase.

Thank you for your attention!

Questions and comments are welcome.

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