Green Technologies, Environmental Policy and Regional Growth

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Outline

Background

- Green technologies are at the core of endeavors to achieve sustainable growth, one of the aims of, e.g., the European Green Deal (European Commission, 2019)
  - They contribute to increase environmental productivity (e.g. Popp, 2010)
  - They might as well increase economic productivity (e.g. Xepapadeas and de Zeeuw, 1999)
  - Green technologies as source of win-win opportunities
- **RQ: What is the impact of green technology development on labor productivity of European regions?**
- Firm level evidence: lower returns compared to other innovation (Marin and Lotti, 2017) or positive effects only for specific types of green technologies (resource-saving) (Ghisetti and Rennings, 2014; Rexhäuser and Rammer, 2014; Van Leeuwen and Mohnen, 2017)
- Sector level evidence: positive, albeit small returns (Stucki and Woerter, 2019); potential U-shaped relationship (Soltmann et al., 2015; Stucki and Woerter, 2019)

- We aim to estimate a logarithmized aggregate production function for each European region r and year t

$$y_{rt} = \sigma_g k_{g,rt} + \sigma_p k_{p,rt} + \sigma_k k_{k,rt} + v_{rt}, \tag{2.1}$$

with

$$v_{rt} = \psi_r + e_{rt}, \tag{2.2}$$

where

- y_{rt}: Labor productivity
- $k_{k,rt}$: Physical capital input
- $k_{g,rt}$: Green knowledge stock
- $k_{p,rt}$: Non-green knowledge stock
- ψ_r: Region-specific, year-invariant effect

Data and Sample

- Panel dimension: $R = 158$ European NUTS-2 regions over the period $1980 - 2018$ ($T = 39$) from twelve countries (eleven EU-15 plus Norway)
- We utilize the following data for the respective variables...
  - y_{rt}: Gross value added by employment (ARDECO)
  - $k_{k,rt}$: Gross fixed capital formation by employment (ARDECO)
  - $k_{g,rt}$: Based on Y02 patents (RegPat 2021) per employment
  - $k_{p,rt}$: Based on total patents (RegPat 2021) per employment

- Heterogeneous coefficients between regions
- Time series properties of the variables of the production function
- Lagged feedback and dynamic adjustment processes
- Convergence rates of estimators given the time series and cross-section dimensions
- **Cross-sectional dependence**
  - e_{rt} might contain cross-sectional dependence (CSD) because of omitted sources of between-region spillovers
  - Recent studies stress the importance to account for CSD (e.g. common shocks, knowledge spillovers) when estimating returns to knowledge (Ertur and Musolesi, 2017; Mitze et al., 2016; Eberhardt et al., 2013)

Estimation Technique

- General approach: we use different methods to make sure that the results are not driven by assumptions on the data generation process (e.g. Eberhardt and Teal, 2011; Eberhardt et al., 2013)
- Based on the CSD tests, we choose the common correlated effects estimator (CCE) (Pesaran, 2006) as a priori preferred method
  - In essence, cross-sectional averages of dependent and independent variables are used to approximate the common factors
  - We utilize the pooled version as our main estimator (CCEP)
- Additionally: two-way fixed effects (2FE), first difference (FD)

Results I: Main Estimates

	POLS	FE	POLS	2FE	FD	CCEP
Investment	0.471***	0.292***	0.476***	0.277***	0.110***	0.085***
	(0.0094)	(0.0255)	(0.0097)	(0.0274)	(0.0119)	0.0183
Green knowledge stock	0.014***	0.022***	0.0004	-0.001	0.004*	-0.001
	(0.0027)	(0.0055)	(0.0032)	(0.0074)	(0.0025)	0.0052
Non-green knowledge stock	0.039***	0.060***	0.047***	0.037***	0.026***	0.046***
	(0.0031)	(0.0081)	(0.0033)	(0.0134)	(0.0052)	0.0158
Year dummies	No	No	Yes	Yes	Yes	No
Observations	6162	6162	6162	6162	6004	6162
Regions	158	158	158	158	158	158

*Note: Asterisks indicate significance at ***1%; **5%; *10%.*

Results II: Regional heterogeneity

	Mean Group		Interaction		
	MG	CCEMG	2FE	FD	CCEP
Investment	0.169***	0.109***	0.280***	0.110***	0.0837***
	(0.0177)	(0.0128)	(0.0274)	(0.0119)	(0.0184)
Green knowledge stock	-0.0179*	0.00196	-0.0159	0.00318	-0.0128*
	(0.0071)	(0.00815)	(0.0116)	(0.00322)	(0.00606)
Non-green knowledge stock	0.0352*	0.0459**	0.0743***	0.0368***	0.0504
	(0.0159)	(0.0145)	(0.0193)	(0.00716)	(0.0293)
Green * Industry			0.0900**	0.00490	0.0570*
			(0.0340)	(0.00796)	(0.0258)
Non-green * Industry			-0.172**	-0.0503*	-0.0228
			(0.0628)	(0.0211)	(0.139)
Year dummies	Demeaned	No	Yes	Yes	No
Observations	6162	6162	6162	6004	6162
Regions	158	158	158	158	158

*Note: Asterisks indicate significance at ***1%; **5%; *10%.*

Main Results: Summary

- We find a significant productivity effect by non-green innovation, while there are no private returns to green innovation
- Generally robust for different computation of knowledge and capital stocks, quality-weighted knowledge stocks, and weak exogeneity
- We find the regional economic structure to moderate the productivity effects of green and non-green
  - We find no evidence for distinct effects within individual sectors

Results III: Technology heterogeneity

	Buildings		Energy efficiency		Renewables	
	FD	CCEP	FD	CCEP	FD	CCEP
Investment	0.107***	0.0901***	0.113***	0.0888***	0.103***	0.0913***
	(0.0127)	(0.0160)	(0.0130)	(0.0159)	(0.0114)	(0.0353)
Green	0.00341	0.00568*	0.00382*	0.00579	0.000433	-0.0007
	(0.00188)	(0.0032)	(0.00194)	(0.0036)	(0.00154)	(0.0036)
Non-green	0.0313***	0.0540**	0.0293***	0.0432**	0.0326***	0.0626**
	(0.00562)	(0.0269)	(0.00528)	(0.0174)	(0.00558)	(0.0294)
Year dummies	Yes	No	Yes	No	Yes	No
Observations	5814	5967	5890	6045	5890	6045
Regions	153	153	155	155	155	155

*Note: Asterisks indicate significance at ***1%; **5%; *10%.*

Results IV: Critical mass in knowledge - Interactions

	Complementarity		Green		Non-green	
	FD	CCEP	FD	CCEP	FD	CCEP
Investment	0.110***	0.103***	0.110***	0.105***	0.111***	0.109***
	(0.012)	(0.022)	(0.012)	(0.021)	(0.012)	(0.021)
Green knowledge stock	0.006	0.003	0.023*	0.035	0.001	-0.004
	(0.003)	(0.018)	(0.010)	(0.025)	(0.002)	(0.011)
Non-green knowledge stock	0.027***	0.014	0.025***	0.014	0.050***	0.108**
	(0.005)	(0.028)	(0.005)	(0.014)	(0.010)	(0.037)
Non-green * Green	0.0003	0.00004				
	(0.0004)	(0.0057)				
Green * Green			0.0014*	0.0028		
			(0.0007)	(0.0025)		
Non-green * Non-green					0.0025*	0.010*
					(0.0011)	(0.005)
Year dummies	Yes	No	Yes	No	Yes	No
Observations	6004	6162	6004	6162	6004	6162
Regions	158	158	158	158	158	158

*Note: Asterisks indicate significance at ***1%; **5%; *10%.*

Results V: Critical mass in knowledge - Thresholds

Threshold variable Regime dependent variable	Green	Green Non-green	Both	Both	Non-green Green	Non-green
Investment	0.2663*** (0.0058)	0.2649*** (0.0058)	0.2639*** (0.0058)	0.2686*** (0.0057)	0.2755*** (0.0058)	0.2674*** (0.0058)
Green knowledge stock		0.0066*** (0.0022)				-0.0025 (0.0021)
Green knowledge stock (below threshold)	0.0046** (0.0022)		0.0061*** (0.0022)	-0.0026 (0.0021)	-0.0011 (0.0021)	
Green knowledge stock (above threshold)	0.0139*** (0.0025)		0.0102*** (0.0026)	-0.0109*** (0.0027)	-0.0281*** (0.0038)	
Non-green knowledge stock	0.0463*** (0.0030)				0.0391*** (0.0030)	
Non-green knowledge stock (below threshold)		0.0400*** (0.0030)	0.0429*** (0.0032)	0.0467*** (0.0030)		0.0446*** 0.0030
Non-green knowledge stock (above threshold)		0.0567*** (0.0034)	0.0533*** (0.0036)	0.1045*** (0.0059)		0.1004*** (0.0056)
Threshold value	-4.9972	-4.8207	-4.8207	-0.7806	0.9645	0.0593
Threshold p-value	0.0000	0.0100	0.0000	0.0100	0.0800	0.0033
Threshold percentile	25%	25%	25%	50%	95%	75%
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6162	6162	6162	6162	6162	6162
Regions	158	158	158	158	158	158

*Asterisks indicate significance at ***1%; **5%; *10%. Fixed-effects panel threshold regression implemented with xthreg in STATA.*

Summary and Concluding Remarks

- We find a significant productivity effect by non-green innovation, while there are no private returns to green innovation
- We find on average more industrialized regions to potentially profit distinctly from green innovation
  - We find no distinct returns within the industry sector
  - We find some evidence that the green technology profile might be important
  - We find some evidence towards critical mass phenomena, i.e. that an existent knowledge base moderates productivity gains
    - Both green and non-green profit from a larger own knowledge base
    - A knowledge complementarity seems to be a one-sided relation, i.e. non-green profits from a green knowledge base but not the other way around

Thank you!

If you have any further questions or suggestions, please feel free to contact me via
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