Green innovation and income inequality: a complex system analysis

Lorenzo Napolitano[a] Angelica Sbardella[a,b] Davide Consoli[c] Nicolò Barbieri[d] **François Perruchas**[c]

[a]Institute for Complex Systems, National Research Council, Rome (Italy)
[b]Department of Economics and Finance, University of Rome Tor Vergata (Italy)
[c]INGENIO (CSIC-UPV), Valencia (Spain)
[d]Department of Economics and Management, University of Ferrara (Italy)

Geography of Innovation 2020 - January 30th
Stavanger, Norway

Introduction

Motivation

- Green technologies are among the solutions to climate change
- Development of green technologies require a specific set of capabilities, not only linked to welfare (Perruchas et al., 2020)

Main ideas

- Green fitness used to indicate countries' capabilities in developing complex green technologies
- Is inequality a barrier to the development of green innovation capacities?

Previous literature

- **Innovation as a determinant of inequality**: technical change has been skill biased in favour of more skilled workers (Acemoglu, 2002). They enjoy a wage premium that exacerbates inequality (Katz & Murphy, 1992). Innovation stimulates entrepreneurship but also increasing income inequality (Aghion et al., 2018)
- **Inequality as a barrier to innovation**: Middle class consumption generally concerns goods that rely on incremental innovation (Weinhold & Nair-Reichert, 2009, Khan & Sokoloff, 2001).
- Export fitness and income inequality correlate negatively (Hartmann et al., 2017)

Green technological developments

- Green technologies are more complex, novel and impactful than the non-green ones (Barbieri et al., 2019).
- Inequality is less detrimental for innovative activities at the beginning of their life-cycle (Vona & Patriarca, 2011).

Previous literature

Gaps

- Most research on environmental innovation focus on the factors that enable the emergence of new technology
- Scant literature highlights that inequality negatively affects the production of green technologies (Vona & Patriarca, 2011).

Research questions

- Does income inequality affect a country's capacity to generate green innovation ?
- Does the relationship vary by type of green technology ?

Data

Green patents - Identification

- Collected using **Env-Tech (2016)** - Patent classification based on IPC and CPC
- Env-Tech includes a list of climate change adaptation and mitigation technologies, related to:
  - Water, energy, transportation, buildings, waste and env. goods
- Green patent families identified in **PATSTAT 2016a** from 1970 to 2010.

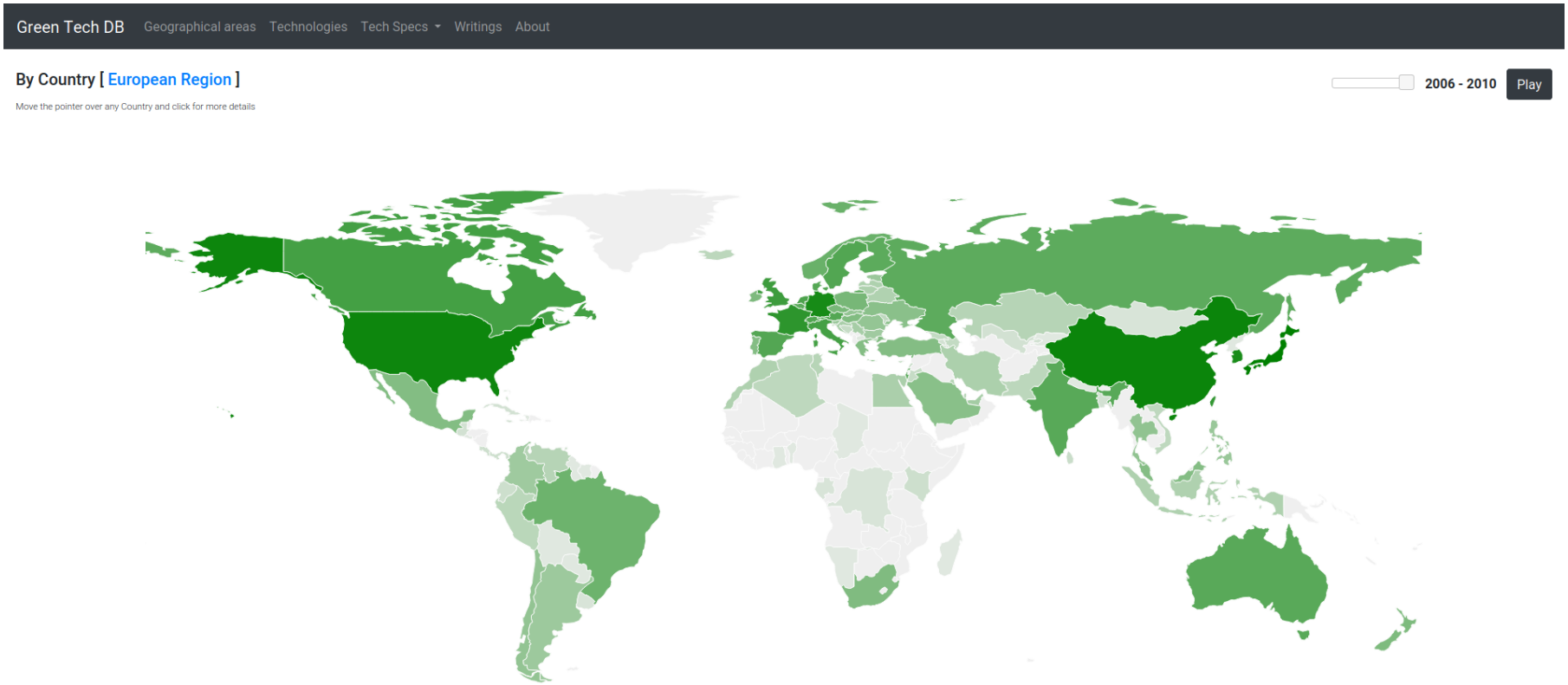
Green patents - Countries identification

- Using inventors' countries
- Enriched with **RISIS Patents** database to fill missing values
- panel of up to 146 countries

Inequality data

- Using World Income Inequality Database (WIID), 5 variables: Gini index and 90:10, 80:20, 70:30 and 60:40 decile ratios

Number of green patent families



GreentechDB - www.greentechdatabase.com

Calculating country fitness & technology complexity

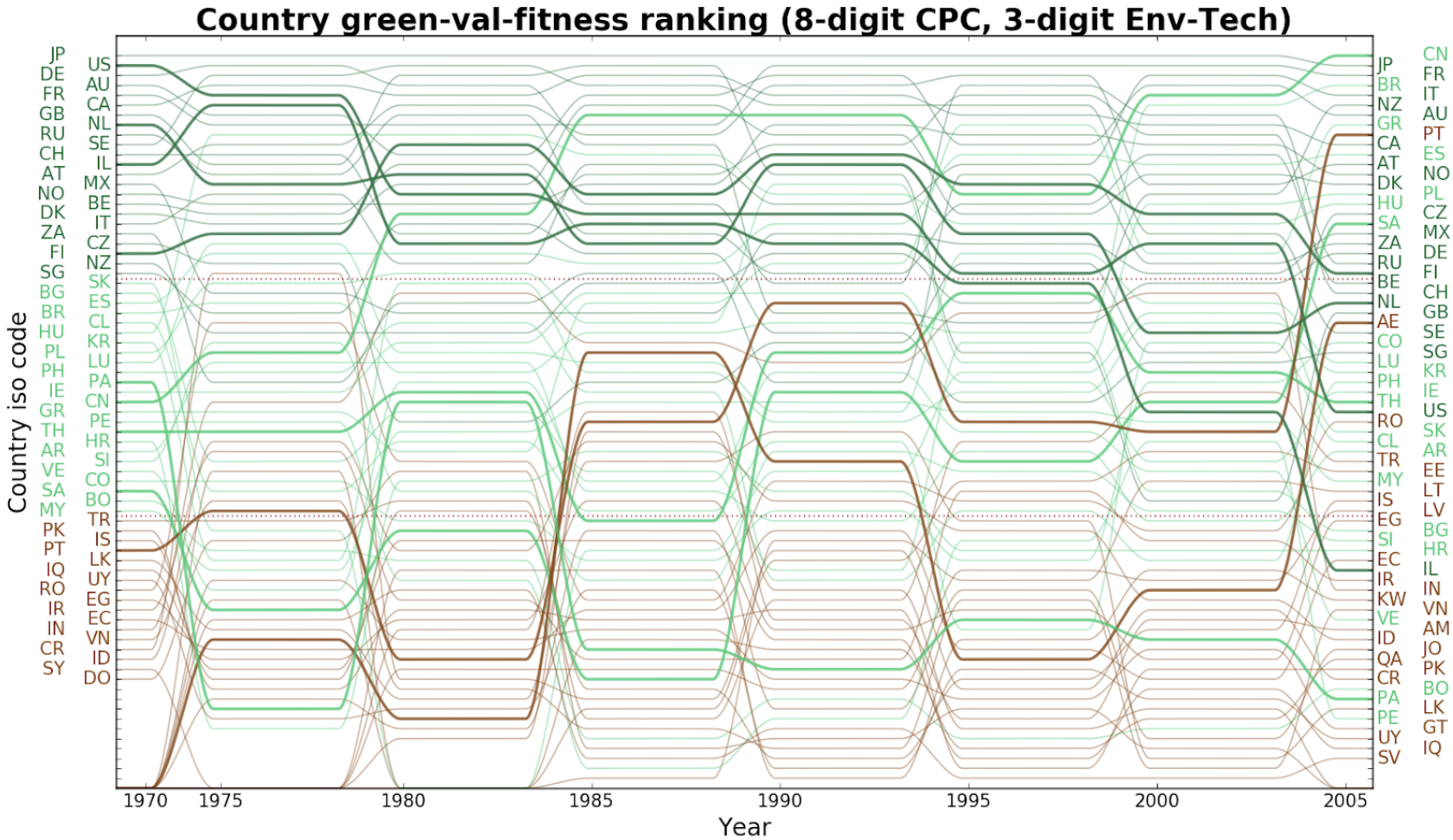
Economic fitness algorithm

- use of country-technology relations over time.
- green fitness of countries is high when countries' portfolio contains complex green technologies
- green technologies complexity is high when they are developed by high fitness countries

Implementation: 4 steps

- bipartite graph of country-technology relations $\rightarrow$ weighted matrix of countries / technologies
- binarization of the weighted matrix based on the Reveal Comparative Advantage (Balassa, 1965)
- recursive Economic Fitness algorithm (Tacchella et al., 2012) to obtain fitness of countries and complexity of technologies
- fitness ranking of countries to avoid the convergence to zero fitness and zero complexity for a subset of countries / technologies (Pugliese et al., 2016).

Green fitness of countries



Parametric approach

- Dependent variable: green fitness ranking of countries
- Independent variable: Income inequality (Gini coef., decile ratios 90:10,80:20,70:30 and 60:40)
- Controls:
  - Pop. density (src. World Bank)
  - GDP per capita (src. World Bank)
  - Schooling (percentage of population with terciary literacy, Barro-Lee)
- Country fixed effects, time dummies
- 5-year time windows (1970-2009)

Parametric regressions results

	(1)	(2)	(3)	(4)	(5)
Log Gini	**-0.593***				
	(0.230)				
90:10		**-0.00502*****			
		(0.000808)			
80:20			**-0.0170***		
			(0.00676)		
70:30				0.0328	
				(0.170)	
60:40					-0.349
					(0.267)
GDP_pc	0.130***	0.125	0.136*	0.130	0.140*
	(0.0255)	(0.0561)	(0.0503)	(0.0573)	(0.0511)
Pop density	-0.00507**	-0.0129**	-0.0117**	-0.0131**	-0.0118**
	(0.00174)	(0.00296)	(0.00259)	(0.00283)	(0.00238)
Schooling	0.00513	0.0146	0.00636	0.0168	0.00602
	(0.0104)	(0.0205)	(0.0154)	(0.0226)	(0.0149)
Time dummies	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes
R-sq	0.117	0.192	0.178	0.185	0.171
Obs	138	110	112	110	112

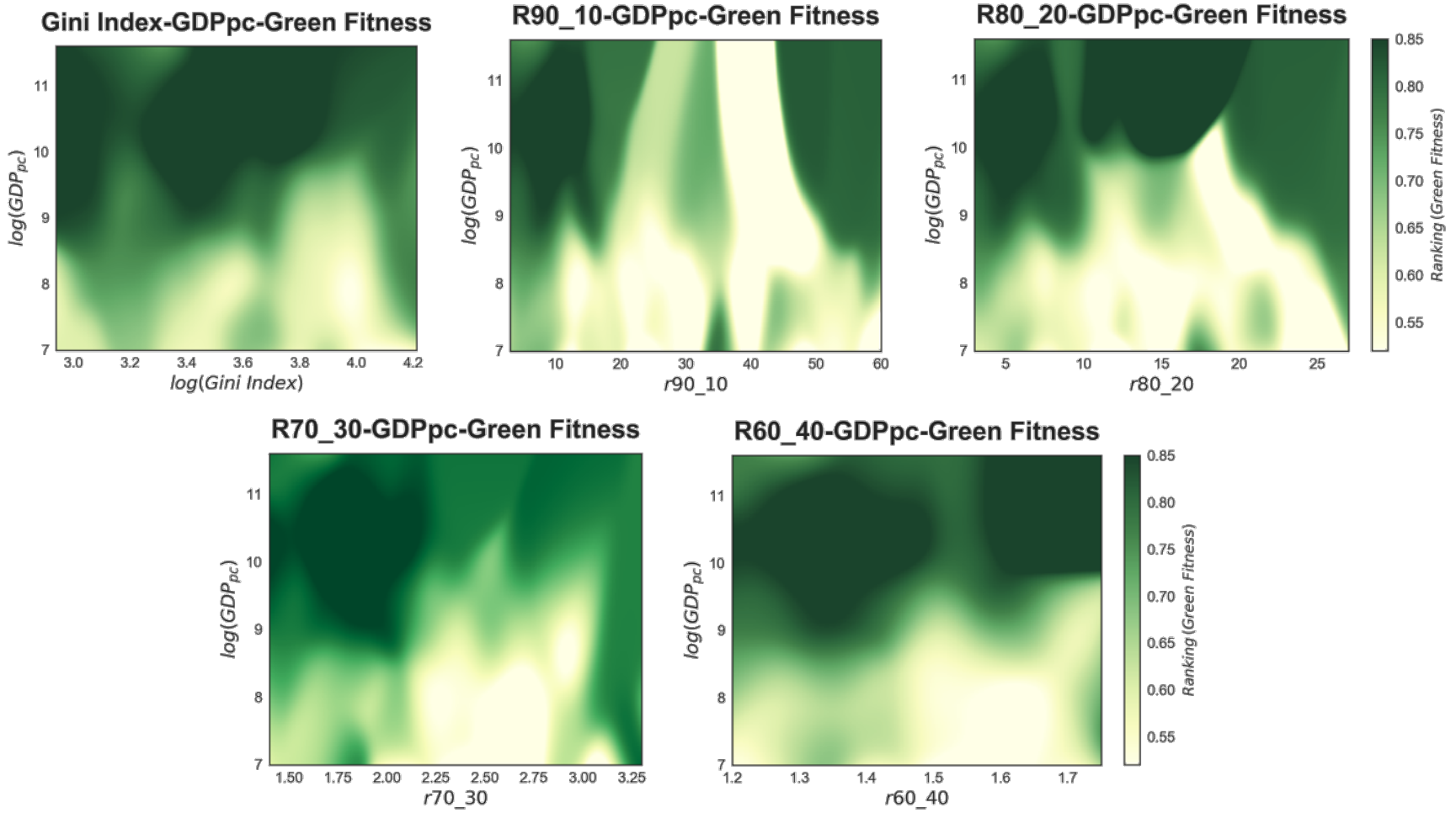
Notes: Dependent variable is mean Green Fitness per country per year. Country fixed effects and time dummies are included in the model. Robust standard errors in parenthesis are clustered by geographical area. * $p < .1$, ** $p < .05$, *** $p < .01$

Parametric regressions results at different levels of technological complexity

	(1) Less complex technologies	(2) More complex technologies
Log Gini	**-0.712****	-0.872
	(0.224)	(0.727)
GDP_pc	-0.0293	-0.312**
	(0.0477)	(0.107)
Pop density	-0.0127***	-0.0154*
	(0.00228)	(0.00580)
Schooling	-0.0489	**0.0783***
	(0.0263)	(0.0343)
Time dummies	Yes	Yes
Country FE	Yes	Yes
R-sq	0.171	0.121
Obs	138	138

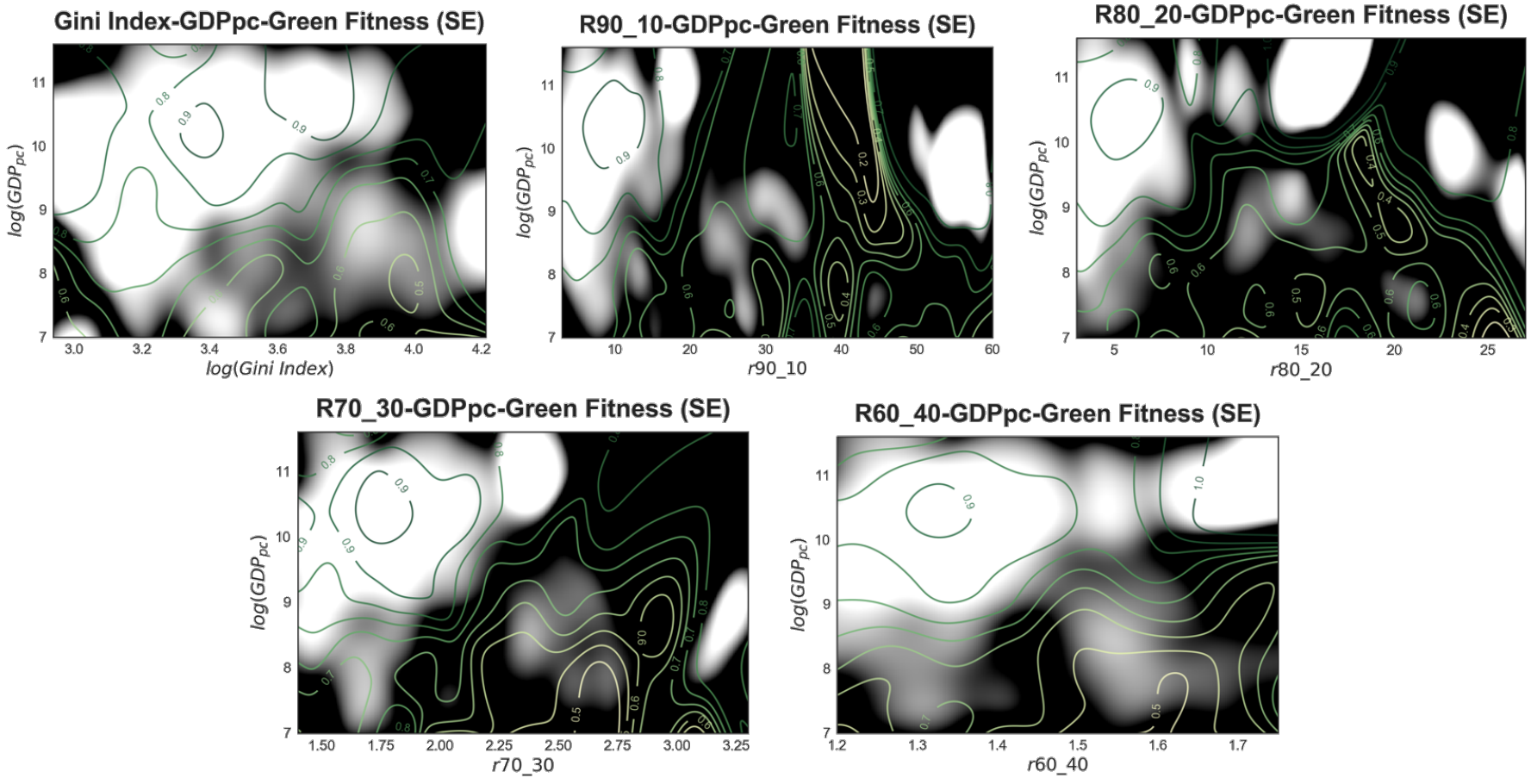
Notes: In Column (1) and (2) the dependent variable is the Green Fitness calculated on technologies at the bottom and top quartile of the complexity distribution. Country fixed effects and time dummies are included in the model. Robust standard errors in parenthesis are clustered by geographical area. * $p < .1$, ** $p < .05$, *** $p < .01$

Non-parametric Nadaraya-Watson kernel estimation



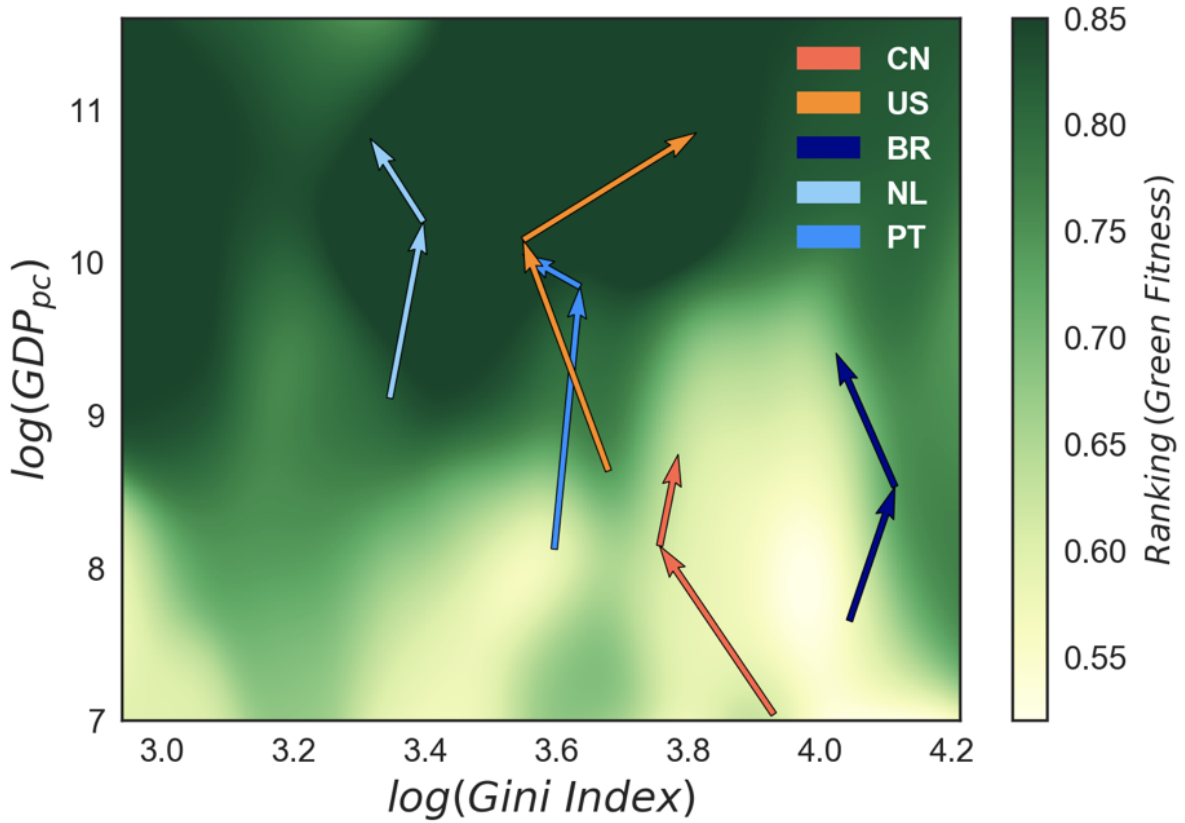
- Relation between **income inequality**, logarithm of **GDP** and the ranking of **green fitness**.
- The colour map represents the expected value of green fitness given the income inequality measure and GDP per capita
- Obtained with a non-parametric Nadaraya-Watson kernel estimation by pooling all countries and years in our database.

Estimation error of the green fitness colour-maps



- In the black and white scale, the standard error of the green fitness ranking mean estimated through a the Nadaraya-Watson regression with Gaussian kernel.
- White $\rightarrow$ standard error of **2% or less**
- Black $\rightarrow$ standard error of **4% or more**.
- Green shades show the iso-lines of the green fitness ranking levels (lowest in light green, highest in dark green)

Gini index colour map with country trajectories



- We superimpose the trajectories of Brazil, China, Portugal, the Netherlands, and the US in the Gini index-GDP per capita plane.
- The arrows represent the initial, middle and final observation of the country in question, and point in the direction of time.

Concluding remarks and further extensions

- **Income inequality** exhibits significant negative correlation with **countries' green innovation capacity**.
- On average, development of **more complex green technological capabilities** is mainly concentrated in countries characterized by a **low levels of inequality**.
- **For high income countries**, **low levels of inequality** are associated with **higher capabilities** in the development of **more complex green technologies**.

- Limitations / Future avenues
  - Patents only measure partially technological development.
  - Region or city-level analysis could draw more specific results.
  - Fitness is a indirect proxy to measure countries' capabilities.
  - Inequality is not only about income distribution.

Thank you

François Perruchas
franperr@ingenio.upv.es

Complexity of green technologies