
# *Policy choice, timing and stringency and the direction of innovation*


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2D4D Disruptive Digitalization for Decarbonization

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# Outline

- The paper in a nutshell
- Motivation
- Competing models of the direction of technical change
- Econometric implementation and data
- Empirical results
- Simulation and discussion

# The paper in a nutshell

# In a nutshell

What: We test whether and how the effectiveness of environmental policy instruments in promoting a radical technology depends on the level of existing “competencies”-i.e. the knowledge stocks

How: We develop three alternative models and choose the one that best fits the data

Results: Competencies mediate policy effectiveness in a non-linear way, giving rise to different policy effectiveness regimes.

Relevance: the effectiveness of a given policy instrument depends on the level of competences, the timing of policy choice and policy stringency

→ **If you choose the wrong policy instrument, or time it wrongly, innovation benefits related with policies will not accrue**

# Motivation

# Motivation

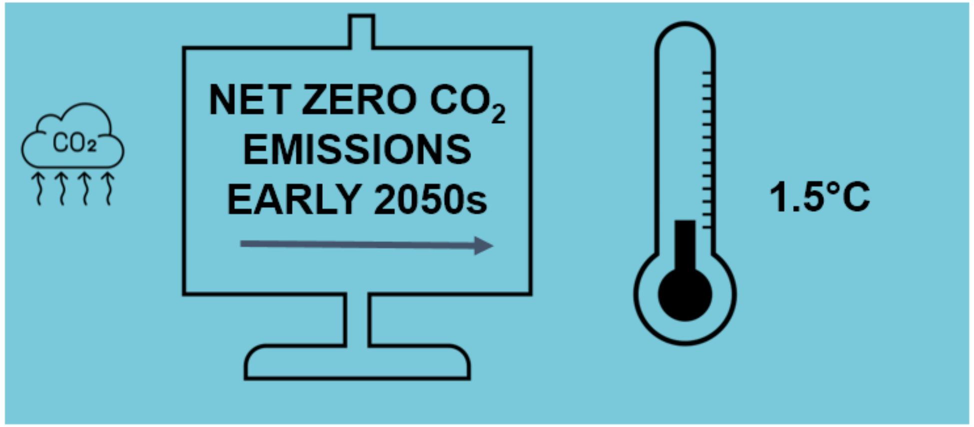
The idea is not new: appropriate policy choice is contingent on the stage of technological development of a country

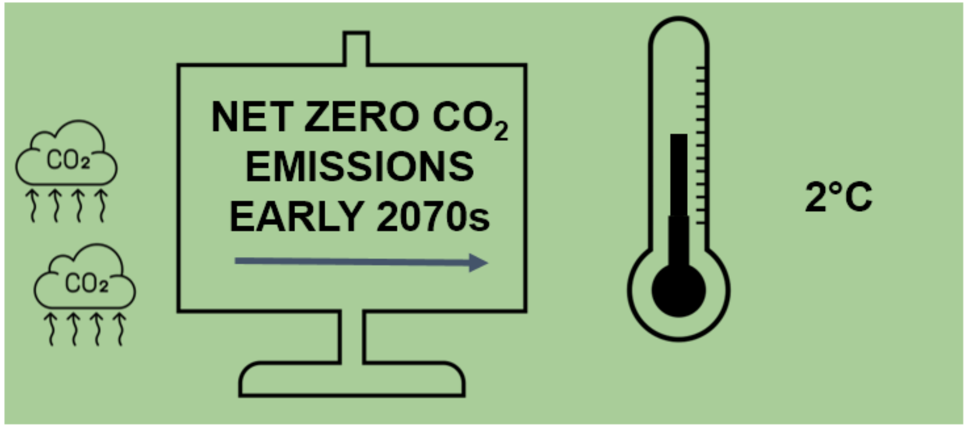
- Rodrick (2005) on appropriate growth strategy
- Rich literature explores poverty traps and multiple equilibria as a function of policies affecting accumulation of physical or human capital and technologies)
- In Acemoglu et al. (2006) the choice of the appropriate policy depends on the distance to the technological frontier

But we give it a twist: Policy effectiveness in promoting innovation, and directing it towards a radical innovation rather than an incremental one, is not independent from the relative specialization of a country in these two technological domains. Furthermore, there is not reason to exclude that the mediating role of specialization is non linear.

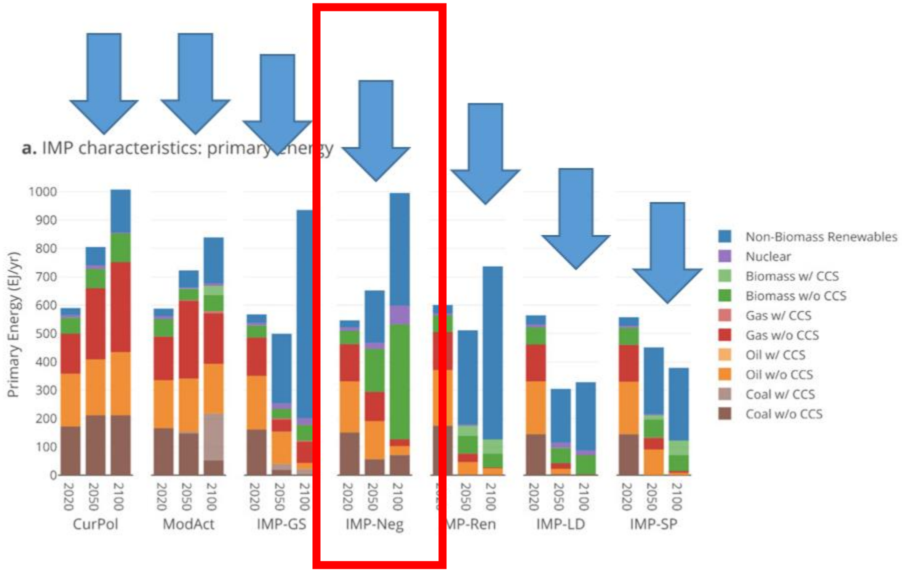
*Why giving it a twist? BECAUSE WE NEED TO PROMOTE RENEWABLE ENERGY INNOVATION*

# Motivation




*(based on IPCC-assessed scenarios)*



# Competing models of the direction of technical change

# Theoretical framework

1st building block: Knowledge production function

$$k = AK^{\beta_K} \mathbf{C}^{\mathbf{B_C}} e^{\mathbf{B_P} \times \mathbf{P} + \upsilon}$$

2nd building block: Heterogeneity in research domains

$$k_d = A_d K_d^{\beta_{K_d}} K_{-d}^{\beta_{K_{-d}}} \mathbf{C}^{\mathbf{B_{d,C}}} e^{\mathbf{B_{d,P}} \times \mathbf{P} + \upsilon_d}$$

In the context of radical and incremental energy technologies:

$$\begin{cases} k_g & = A_g K_g^{\beta_{K_g}} K_{-g}^{\beta_{K_{-g}}} \mathbf{C}^{\mathbf{B_{g,C}}} e^{\mathbf{B_{g,P}} \times \mathbf{P} + \upsilon_g} \\ k_f & = A_f K_f^{\beta_{K_f}} K_{-f}^{\beta_{K_{-f}}} \mathbf{C}^{\mathbf{B_{f,C}}} e^{\mathbf{B_{f,P}} \times \mathbf{P} + \upsilon_f} \end{cases}$$

# Three alternative models

$$rk = k_g / k_f$$

$$\mathbf{B_P} = \mathbf{B_{g,P}} - \mathbf{B_{f,P}}$$

$$K_{-g} \simeq K_{-f} \simeq K_{-(g+f)}$$

$$K_{-(g+f)} = K - K_g - K_f$$

$$\beta_{K_f} = \beta_{K_g} + \beta_{K_{f'}}$$

$$\beta_{K_f} > \beta_{K_g} \text{ (resp. } \beta_{K_f} < \beta_{K_g})$$

## Linear

$$\ln rk = \ln rA + \beta_{K_g} \ln rK - \beta_{Kf'} \ln K_f + \beta_{K_{-(g+f)}} \ln K_{-(g+f)} + \mathbf{B_C} \ln \mathbf{C} + \mathbf{B_P P} + \epsilon.$$

## Interaction

$$\begin{aligned} \ln rk &= \ln rA + \beta_{K_g} \ln rK + \mathbf{B_P P} + \mathbf{B_{K_g,P}} (\ln rK \times \mathbf{P}) \\ &- \beta_{Kf'} \ln K_f + \beta_{K_{-(g+f)}} \ln K_{-(g+f)} + \mathbf{B_C} \ln \mathbf{C} + \epsilon. \end{aligned}$$

$$\partial \ln rk / \partial \ln \mathbf{P} = \mathbf{B_P} + \mathbf{B_{K_g,P}} \times \ln rK$$

## Threshold

$$\begin{aligned} \ln rk = \ln rA + \beta_{K_g} \ln rK + \mathbf{B_{1P} P} \times \mathbf{I_1}(\gamma_1, \gamma_2) + \mathbf{B_{2P} P} \times \mathbf{I_2}(\gamma_1, \gamma_2) + \mathbf{B_{3P} P} \times \mathbf{I_3}(\gamma_1, \gamma_2) \\ - \beta_{Kf'} \ln K_f + \beta_{K_{-(g+f)}} \ln K_{-(g+f)} + \mathbf{B_C} \ln \mathbf{C} + \epsilon, \end{aligned}$$

# Two demand-pull policy instruments

Command-and-control: Impose limits on the level of pollution of requirements

- Limits on emissions
- Green certificates

Market-based: impose an implicit or explicit price on emissions

- Carbon-tax
- Emission trading scheme

Latter preferred by economic theory on efficiency grounds (static vs dynamic)

But: no strong empirical evidence, criticism by social scientists

→ WE SPLIT THE POLICY VECTOR IN TWO

# Econometric implementation and data

# Econometric implementation

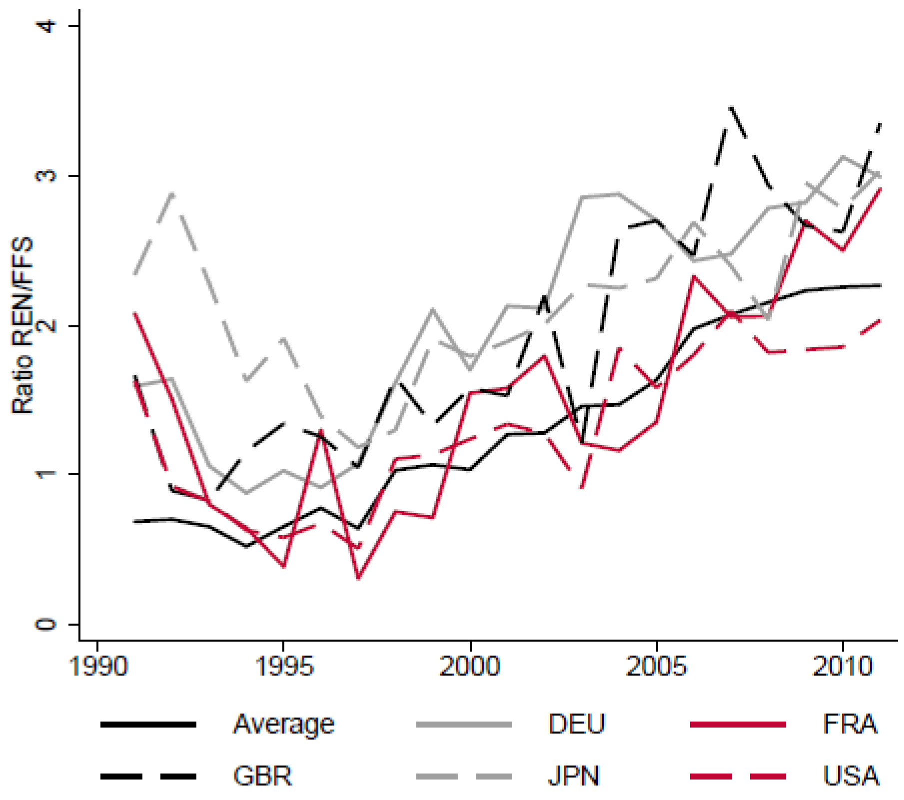
Challenges, which we address in the analysis:

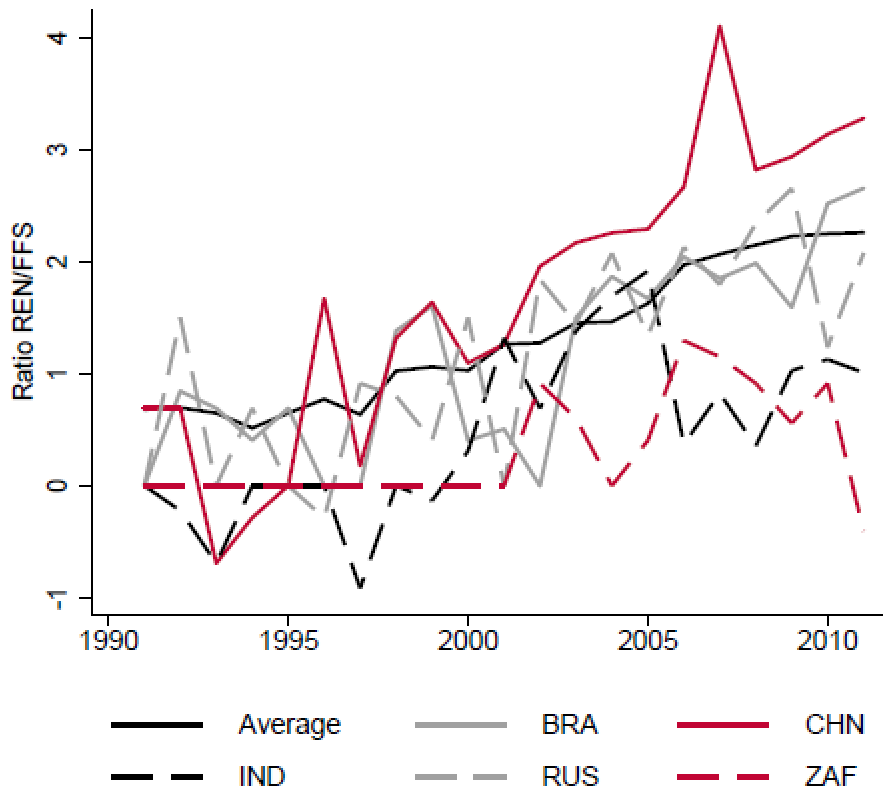
1. (a) Accounting for unobserved heterogeneity in the context of slowly changing policy variables and (b) endogeneity of the policy variables: *control function and IV*
2. Implementing an empirical strategy to search for thresholds effects: *Hansen's threshold method*
3. Developing a model selection procedure to compare the performance of different models: *R-squared, Vuong's 2LR statistics on overlapping models, Akaike information criterion (AIC) with a correction for small samples (AICC)*

# Data

- Econometric analysis: balanced panel of 33 countries, 1990-2015
- Innovation: Patent data from PATSTAT, using classification in renewable and efficient fossil as standard in the field
- Threshold variable: ratio of K stocks (perpetual inventory method)
- Policy indexes: EPS index for MB and C&C (instrumented via a shift-share approach) IV approach to account for endogeneity
  - Reverse causality: policy response depends positively on present and future competence of the country (↑)
  - Measurement error in the policy variables (↓ )
  - Omitted variable bias (fossil subsidies) (↓ )
- Standard controls in the literature (el. consumption p/c, el. imp. & exp. shares, human capital index, GDP, pop)

# Descriptives



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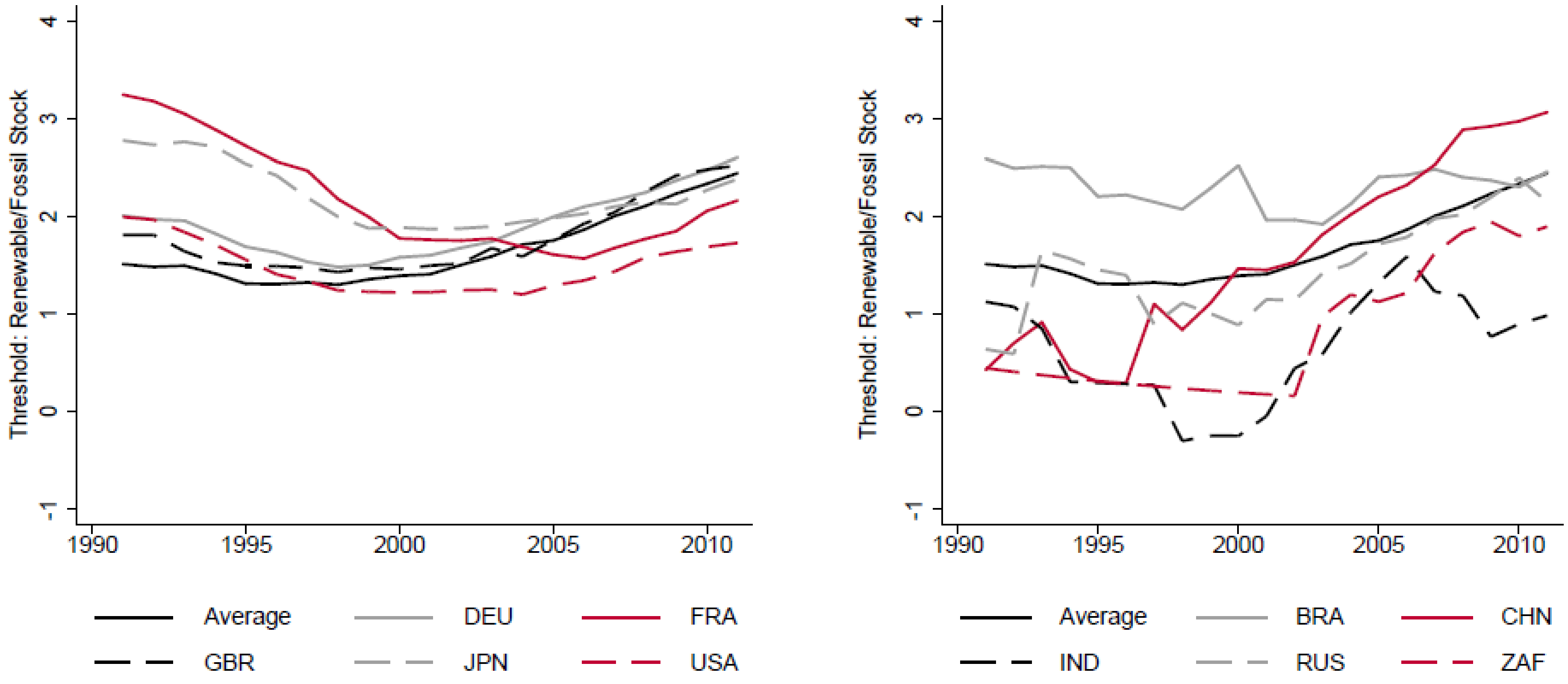

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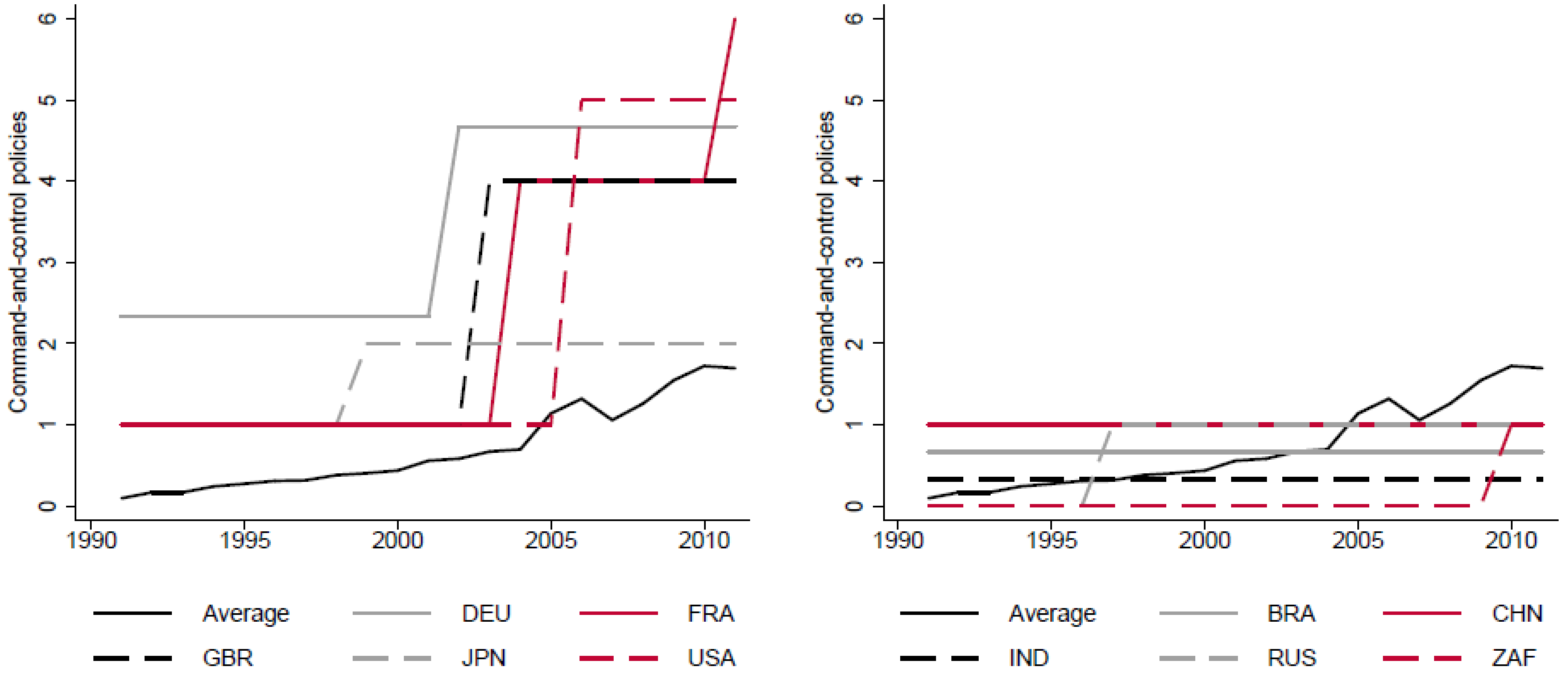

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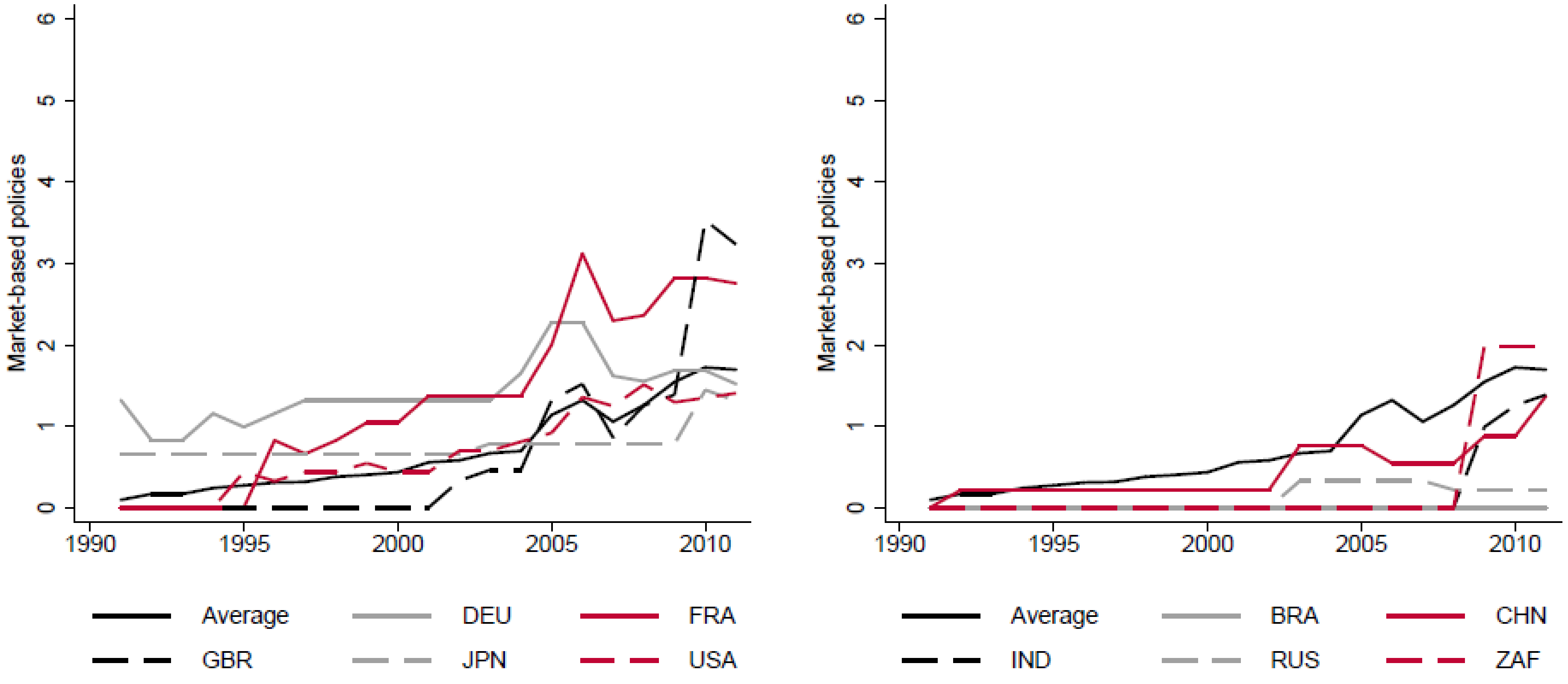


# Empirical results

# Results

Two discontinuities

→ three regimes (47th,89th)

MB instrument effective only in strengthening current specialization, consolidate comparative advantage

*Third regimes*: top 11 percent

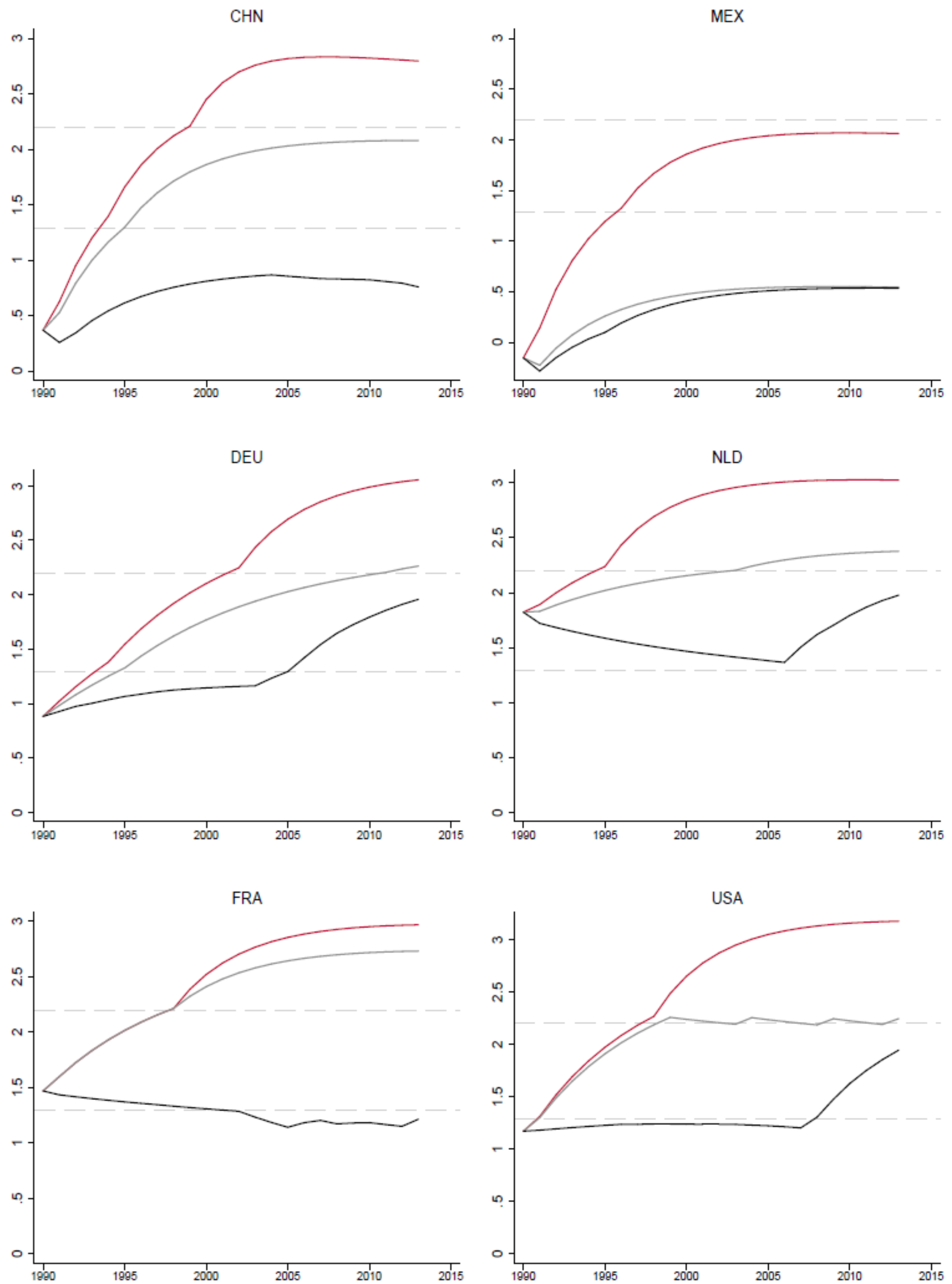
| | Linear 1$P$ Eq.(4) (1) | Linear 2$P$ Eq.(4) (2) | Interaction Eq.(5) (3) |
|---|---|---|---|
| $\ln rK_{g/f,t-1}$ | 0.400*** (0.122) | 0.411*** (0.116) | 0.225** (0.114) |
| $\ln K_{f,t-1}$ | 0.003 (0.164) | -0.046 (0.120) | -0.061 (0.118) |
| $\ln K_{-(f+g),t-1}$ | 0.144 (0.111) | 0.139 (0.095) | 0.172* (0.092) |
| $ALL$ policies | 0.158 (1.999) | | |
| $MB$ policies | | 0.129 (0.391) | -1.408* (0.735) |
| $MB \times \ln rK_{g/f,t-1}$ | | | 0.837* (0.492) |
| $CC$ policies | | 1.161** (0.510) | 0.816 (0.645) |
| $CC \times \ln rK_{g/f,t-1}$ | | | 0.202 (0.353) |
| $F$-stat IV $ALL$ | 70.51 | | |
| $F$-stat IV $MB$ | | 45.73 | 45.73 |
| $F$-stat IV $CC$ | | 65.94 | 65.94 |

| | Threshold Eq.(7) (4) |
|---|---|
| $\ln rK_{g/f,t-1}$ | 0.258** (0.108) |
| $\ln K_{f,t-1}$ | -0.080 (0.125) |
| $\ln K_{-(f+g),t-1}$ | 0.176* (0.095) |
| $MB \times \mathbf{I}(\ln rK_{g/f,t-1} \leq \hat{\gamma}_1^r)$ | -0.692 (0.576) |
| $MB \times \mathbf{I}(\hat{\gamma}_1^r < \ln rK_{g/f,t-1} \leq \hat{\gamma}_2)$ | -0.021 (0.506) |
| $MB \times \mathbf{I}(\ln rK_{g/f,t-1} > \hat{\gamma}_2)$ | 1.680* (0.947) |
| $CC \times \mathbf{I}(\ln rK_{g/f,t-1} \leq \hat{\gamma}_1^r)$ | 1.130** (0.499) |
| $CC \times \mathbf{I}(\hat{\gamma}_1^r < \ln rK_{g/f,t-1} \leq \hat{\gamma}_2)$ | 1.371** (0.628) |
| $CC \times \mathbf{I}(\ln rK_{g/f,t-1} > \hat{\gamma}_2)$ | 0.609 (0.789) |
| $F$-stat IV $ALL$ | |
| $F$-stat IV $MB$ | 45.73 |
| $F$-stat IV $CC$ | 65.94 |

# Simulation

# Simulation

- BLACK: reproduces observed
- GREY: if policies had been introduced with observed stringency but correct timing
- RED: if policies had been introduced with maximum stringency AND correct timing



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# *Thank you.*

**Elena Verdolini**

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# Results

| | $\hat{\gamma}_1^r$ | $\hat{\gamma}_2$ | $\hat{\gamma}_3$ |
|---|---|---|---|
| Threshold percentile | 47 | 89 | 32 |
| Threshold value for $\ln rK_{g/f,t-1}$ | 1.292 | 2.198 | 1.033 |
| 95 % CI for $\ln rK_{g/f,t-1}$ | [0.929, 1.336] | [2.161,NA] | [.457, 1.154] |
| 90 % CI for $\ln rK_{g/f,t-1}$ | [1.219, 1.336] | [2.147,NA] | [.491, 1.120] |
| F-statistics | 25.260 | 21.430 | 10.140 |
| P-value | 0.001 | 0.010 | 0.126 |

# Results

Table A1: First Stage Tobit Regressions

| | (1) *ALL* | (2) *MB* | (3) *CC* |
|---|---|---|---|
| Pre-sample mean | 0.061*** | 0.086*** | 0.057** |
| | (0.018) | (0.025) | (0.023) |
| $\ln rK_{g/f,t-1}$ | 0.013 | 0.147*** | -0.041*** |
| | (0.011) | (0.019) | (0.016) |
| $\ln K_{f,t-1}$ | 0.033** | 0.158*** | -0.022 |
| | (0.013) | (0.025) | (0.018) |
| $\ln K_{-(g+f),t-1}$ | -0.023** | -0.129*** | 0.024* |
| | (0.010) | (0.019) | (0.014) |
| $IV_{ALL}$ | 0.880*** | | |
| | (0.070) | | |
| $IV_{MB}$ | | 1.441*** | 0.063 |
| | | (0.175) | (0.140) |
| $IV_{CC}$ | | -0.230** | 0.912*** |
| | | (0.109) | (0.078) |
| Control variables | Yes | Yes | Yes |
| Observations | 759 | 759 | 759 |
| Observations left censored | 85 | 280 | 132 |
| Observations right censored | 0 | 1 | 8 |
| $F$-stat IV | 70.51 | 45.73 | 65.94 |