Forward-looking energy elasticity parameters and optimised structure of nested CES production function

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Outline

- “Bottom-Up”, “Top-Down”, and Hybrid models
- Motivation
- Energy substitution and nested CES
- Historical vs. forward-looking parameters
- Estimating energy substitution elasticities on “Bottom-Up” models
- Conclusions and Results

“Bottom-Up”, “Top-Down”, and Hybrid models

- “Bottom-Up” energy models:
  - Technology explicit
  - Linear, cost minimizing, partial equilibrium
  - TIMES / MARKAL / OSeMOSYS
- “Top-Down” economic models:
  - Bird-eye view on an economy
  - Simplified technological options (CES, …)
  - CGE models, IO-models, ...
- Hybrid models:
  - Some combination of “BU” and “TD”
    - Soft link, Hard link (see Böhringer and Rutherford 2006, 2008)

Motivation

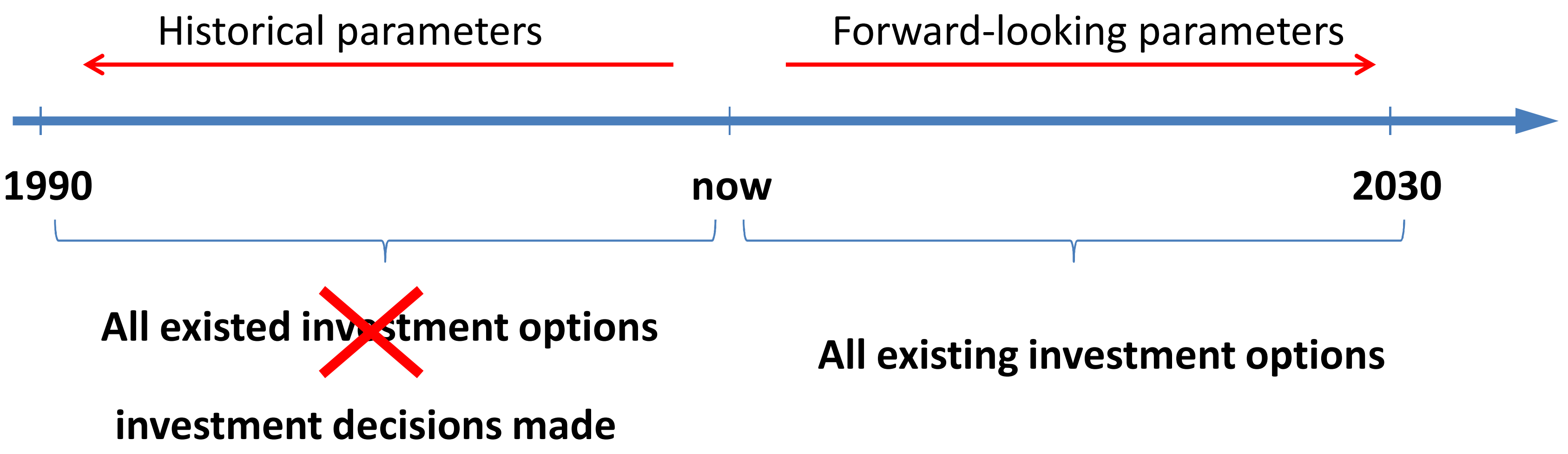
- Elasticities are crucial for CGE analysis.
  - Energy elasticities are crucial for climate, environmental, energy policy analysis.

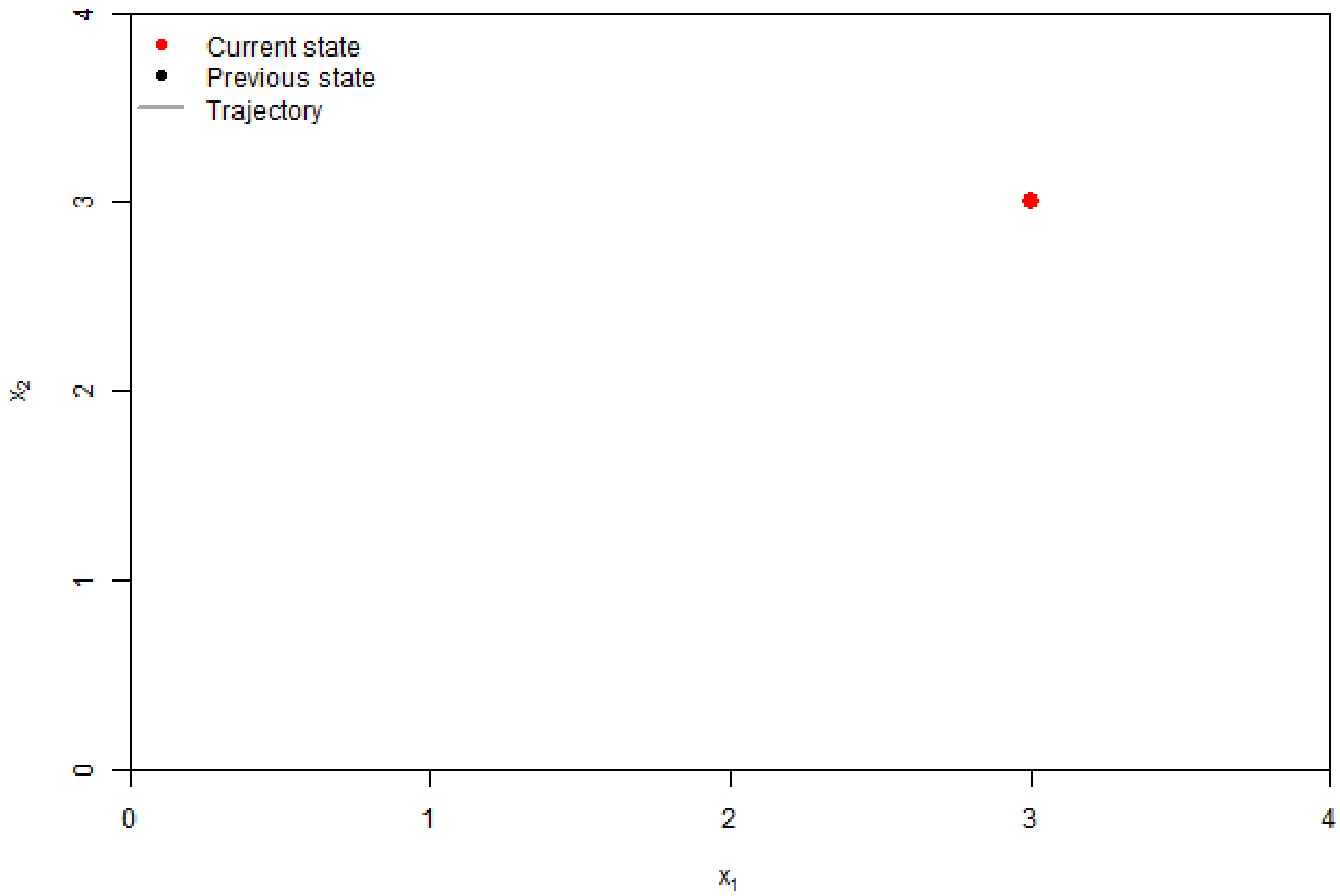
- “Top-Down” and “Bottom-Up” energy models often show polar conclusions of the same policy analysis.
  - Hybrid modeling is preferred.

Where the CES-parameters we use in "Top-Down" come from?

- Econometric estimates on historical data
  - Past investment decision does not have information on all existed and especially currently available technological options.
- "Coffee-table" elasticities
  - Experts' opinions on technological substitution between fuels (verified by "reasonable" model results).
- Calibration to MACC
  - Simplified, usually for capital-energy nest only.

Historical vs. forward-looking parameters





Current state
Previous state
Trajectory
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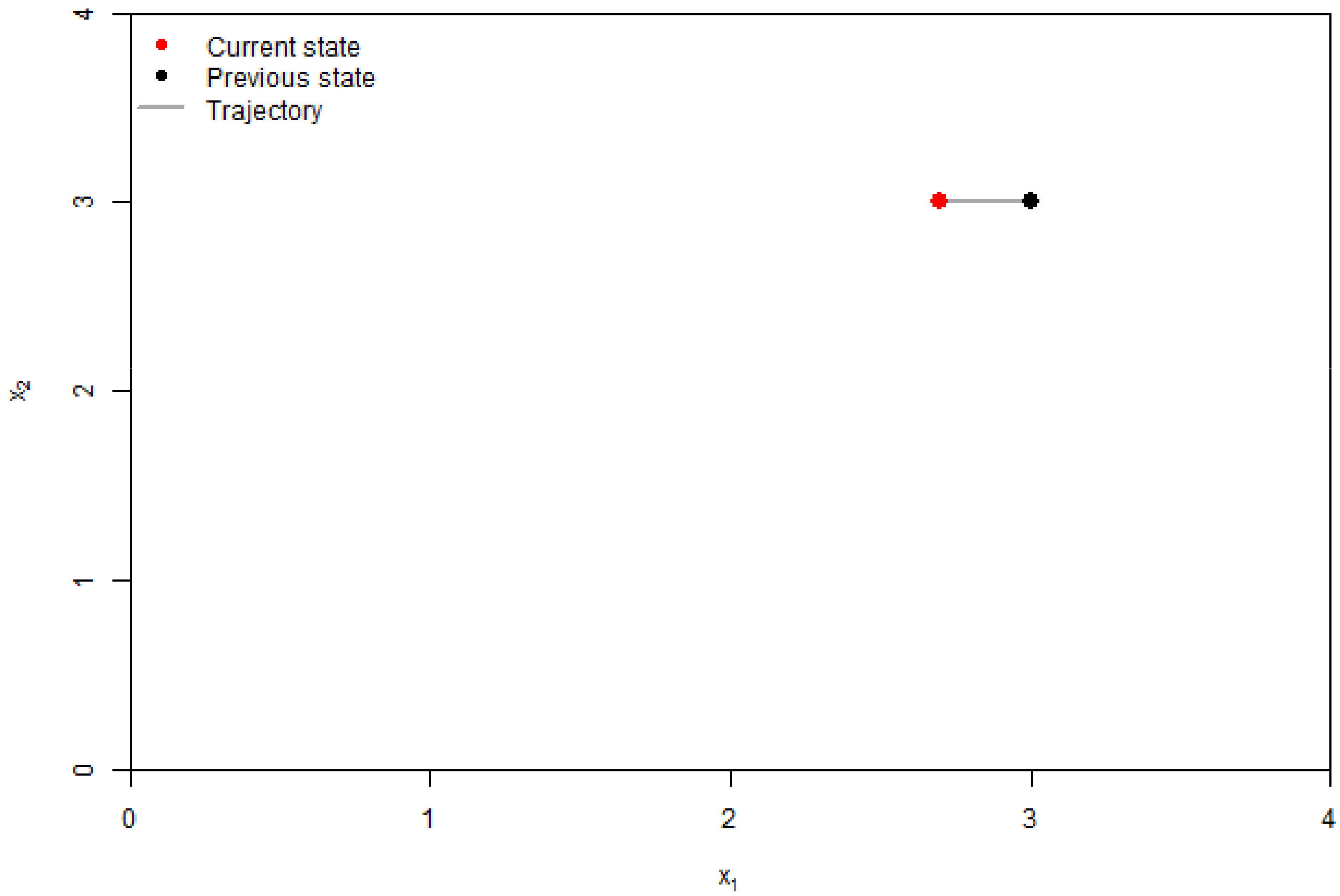
2
3
4
x_1
x_2



Current state
Previous state
Trajectory
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x_1
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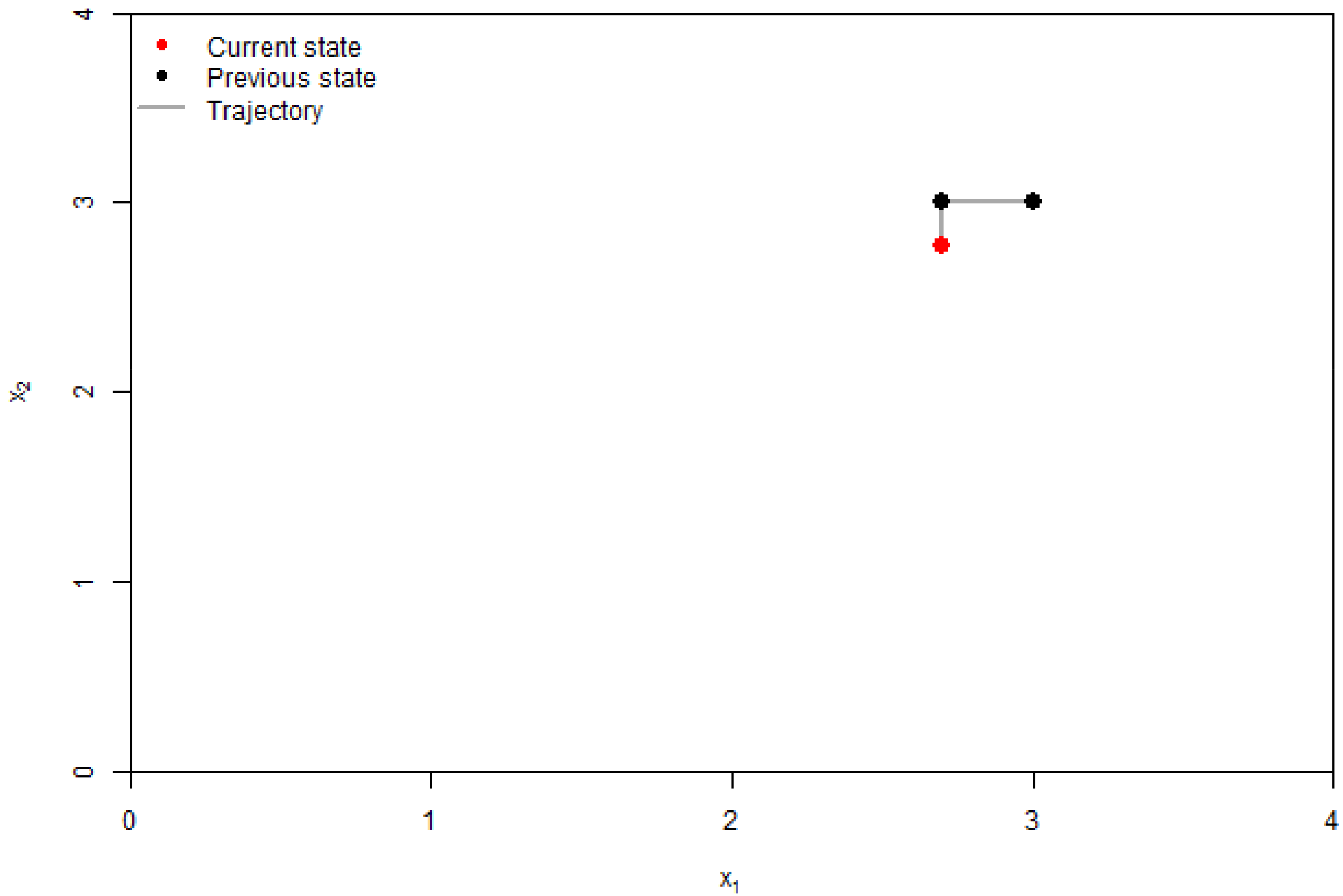

Current state
Previous state
Trajectory
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x_1
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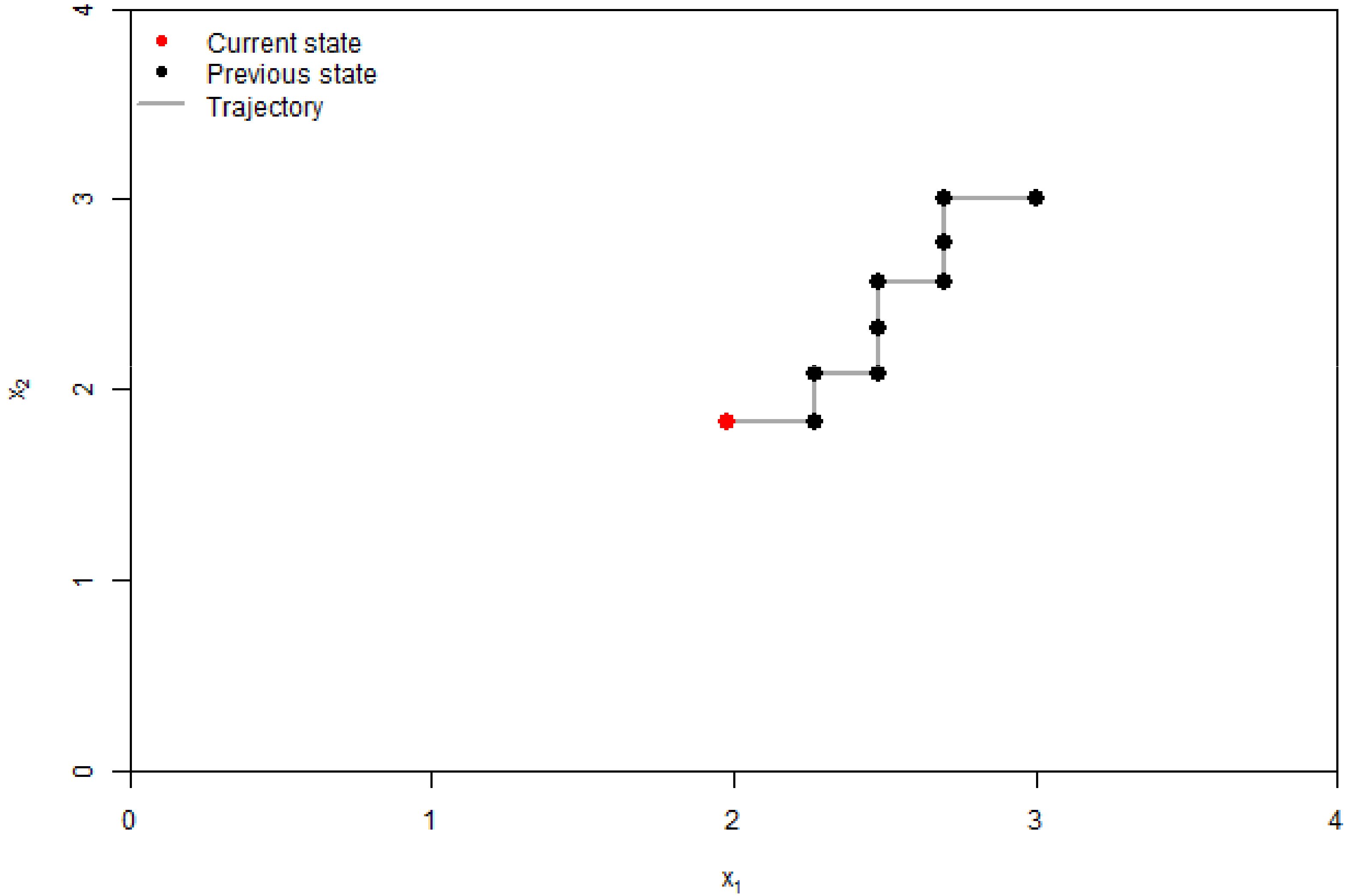
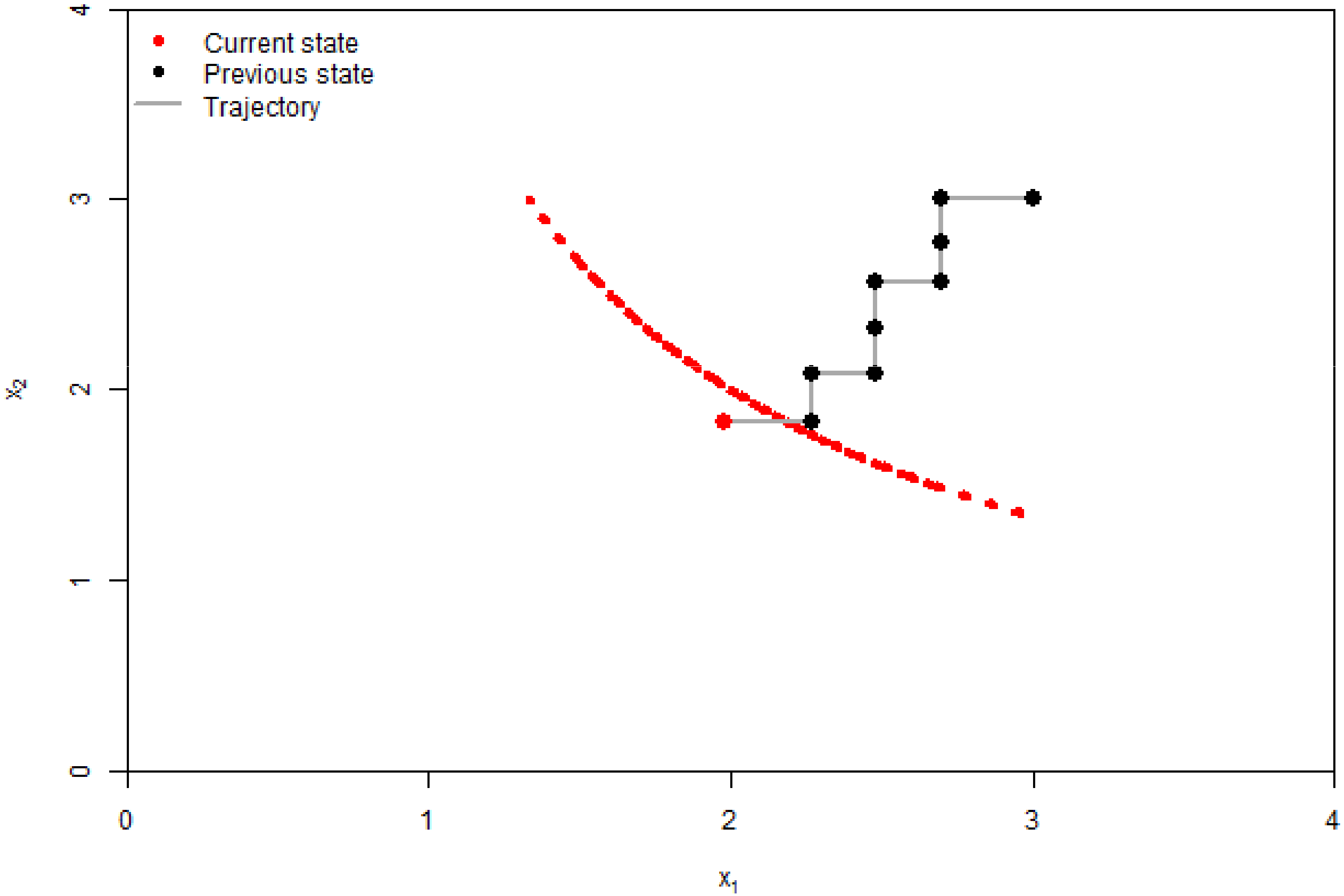


Current state
Previous state
Trajectory
x2
x1
0
1
2
3
4


Current state
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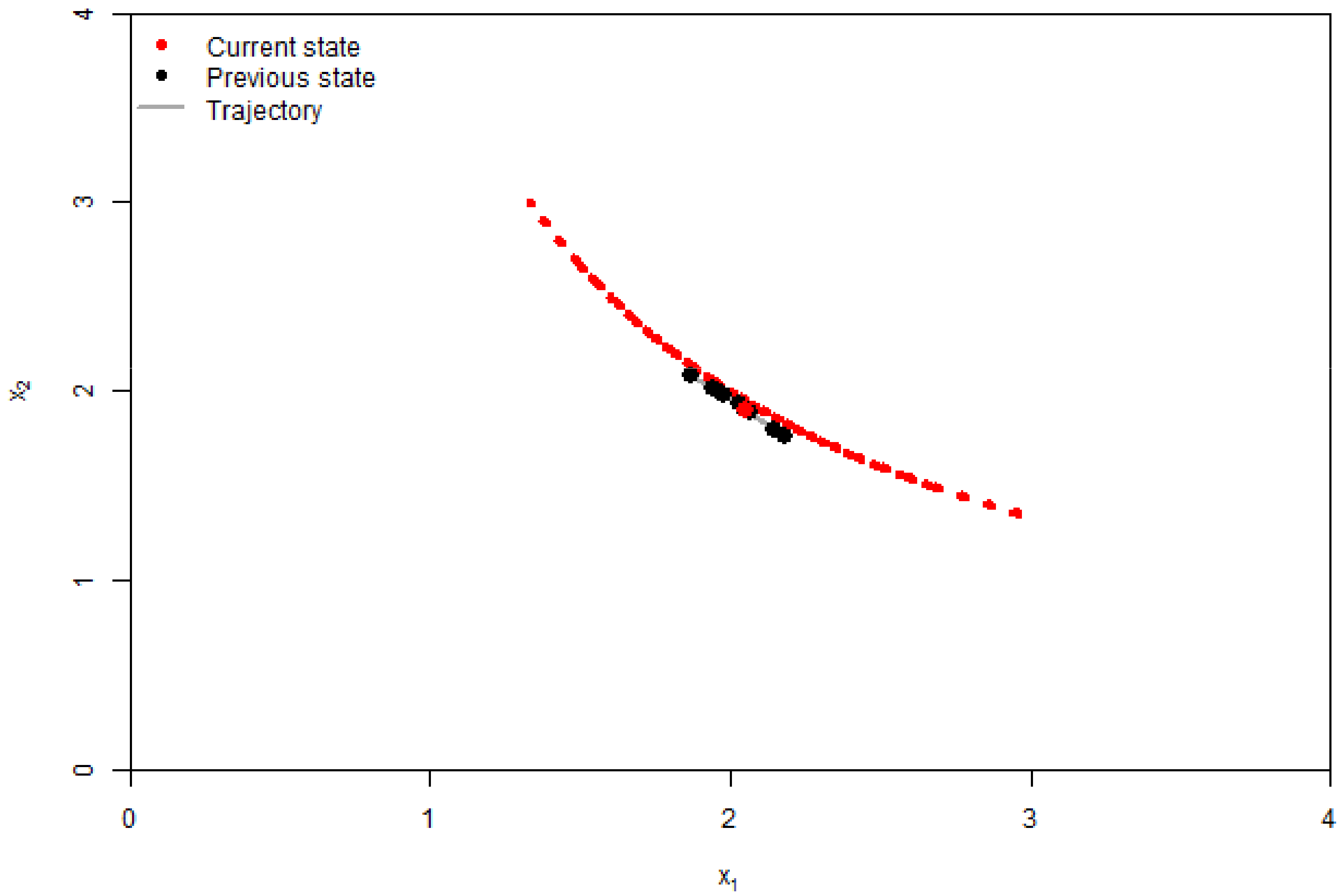
Current state
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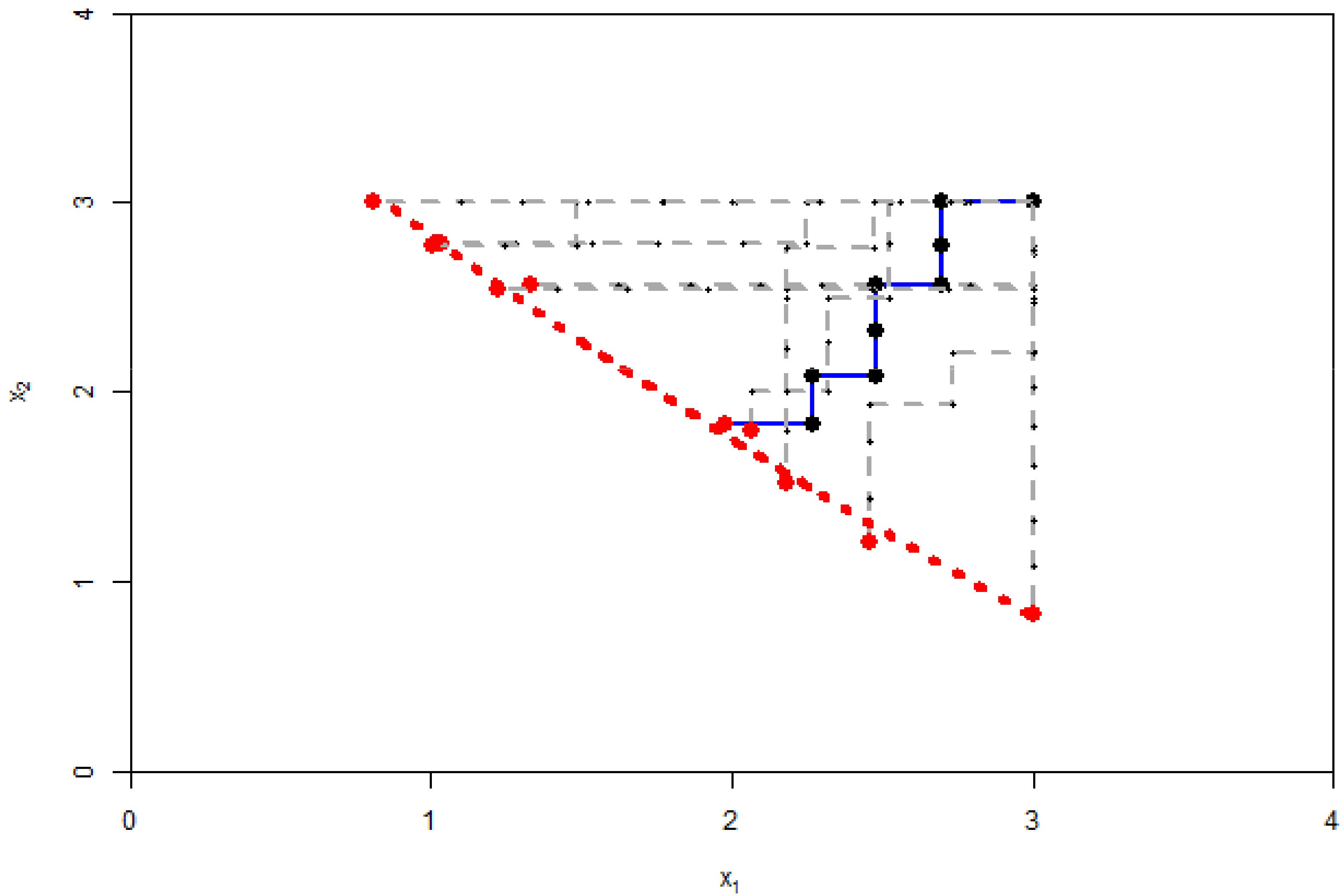
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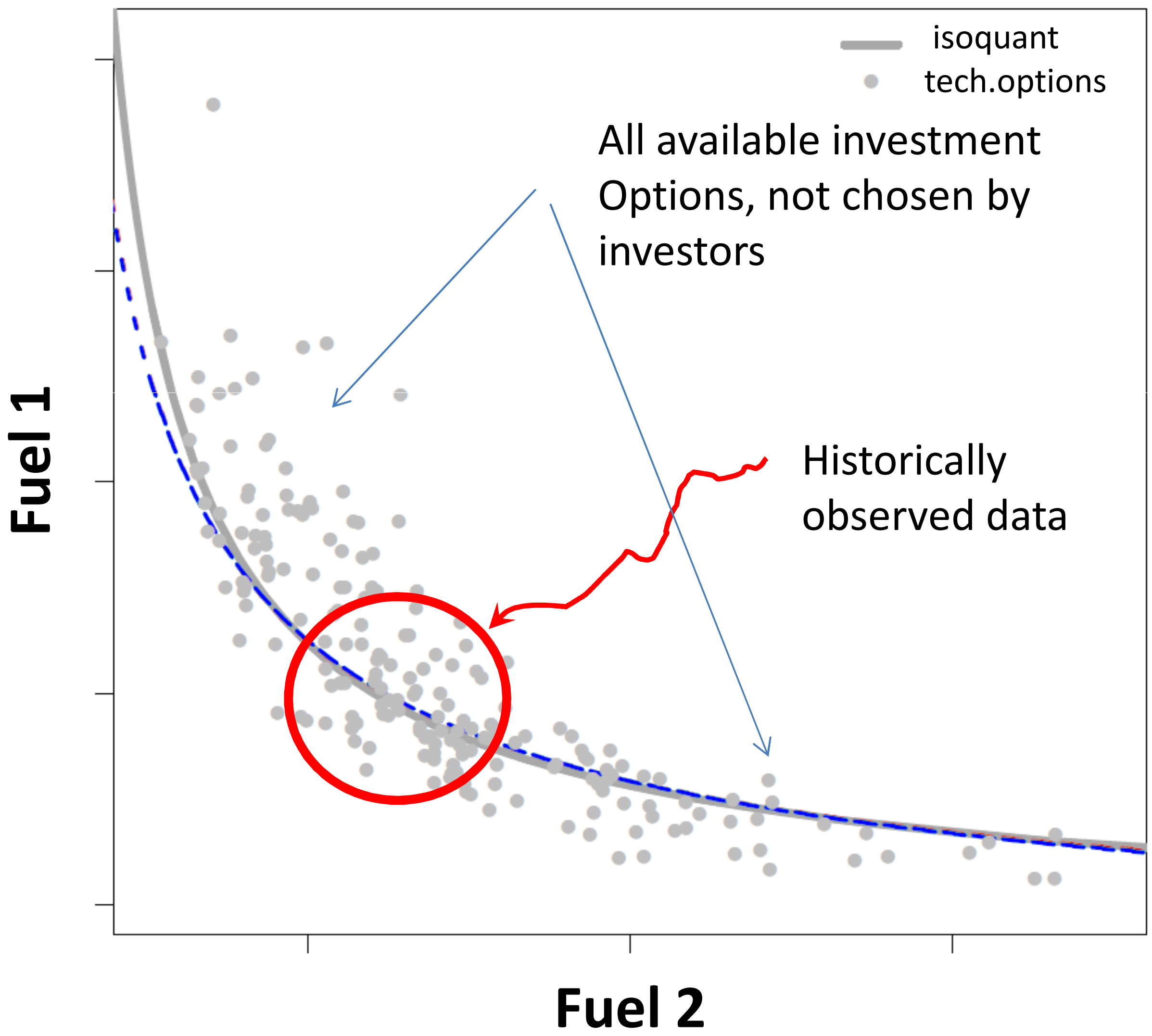
x_1
x_2

Technological options vs. actual investment decisions



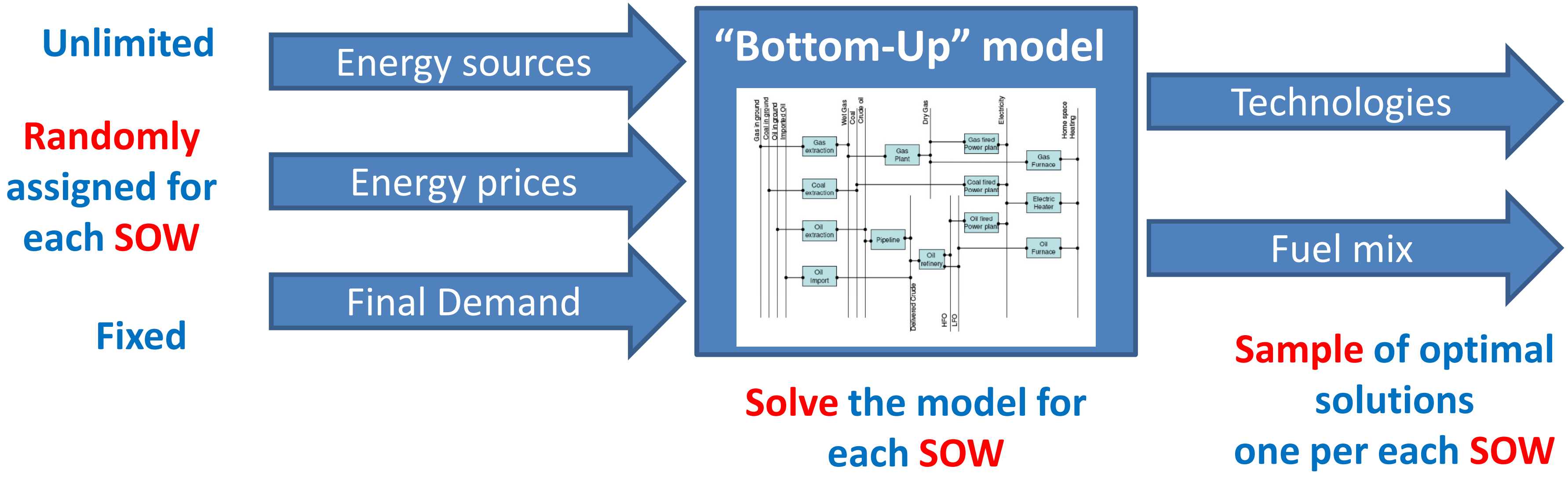
Proposed methodology:

- Estimate CES-parameters based on “Bottom-Up” energy model.

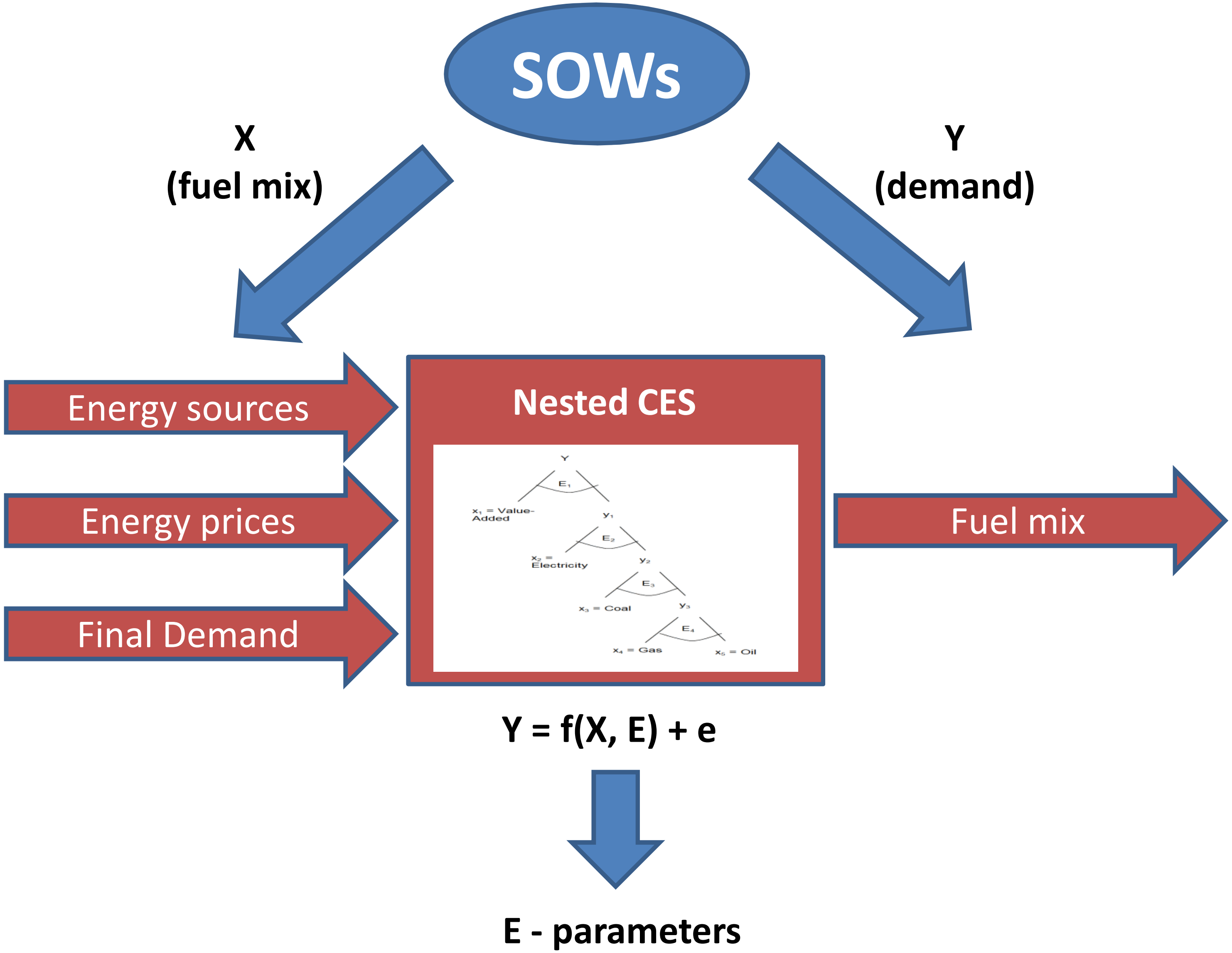
- Steps:
  - Simulate “all possible” states of the world (SOW) using “Bottom-Up” model
  - Use the data to estimate CES parameters

Step 1: Simulation of SOWs (sample of BU optimal solutions)

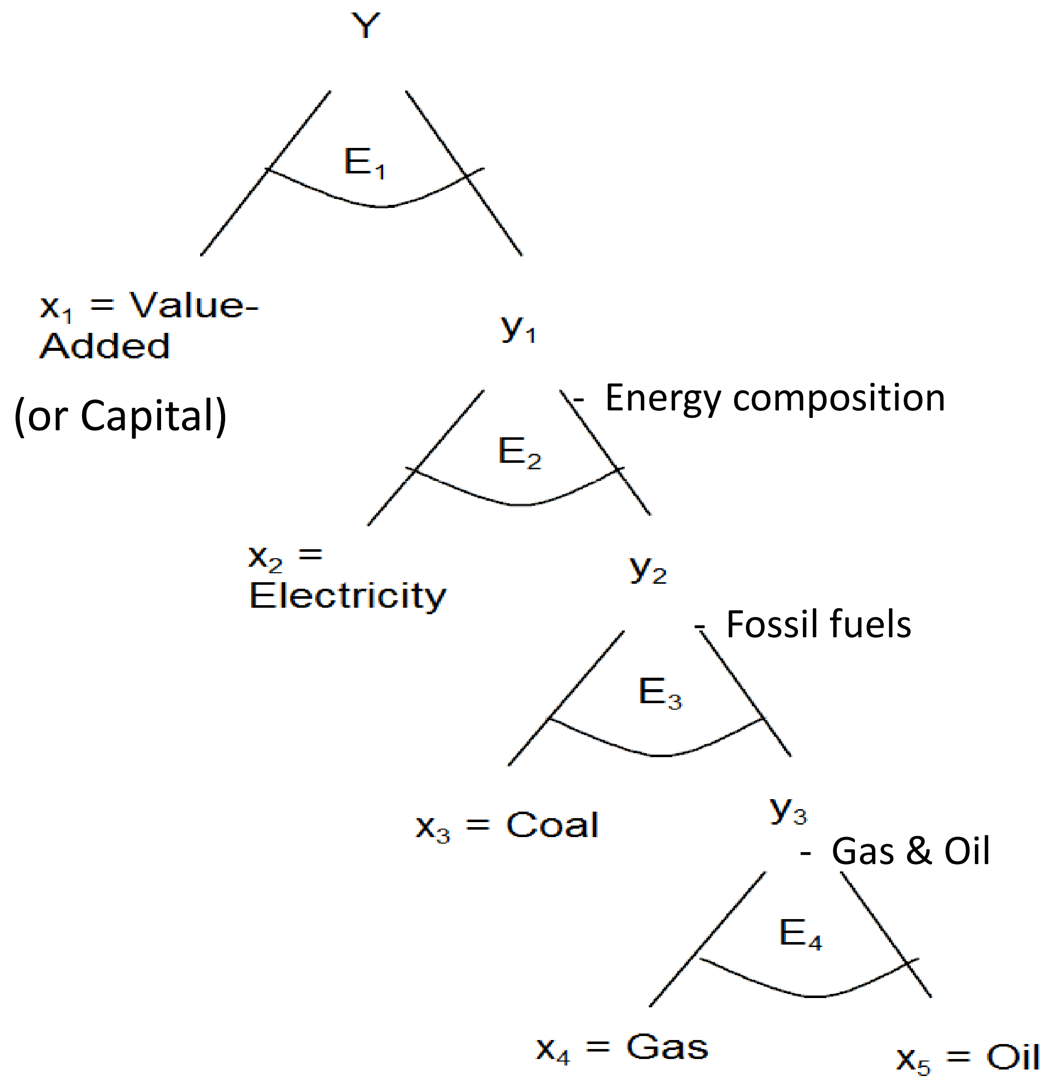
- Exogenous input to “Bottom-Up” model (from now to the end of planning period, f.i. 2010-2050):
  - Energy prices
  - Final demand
  - Available energy sources



Step 2: Econometrically estimate CES



Top-Down: Nested CES production function

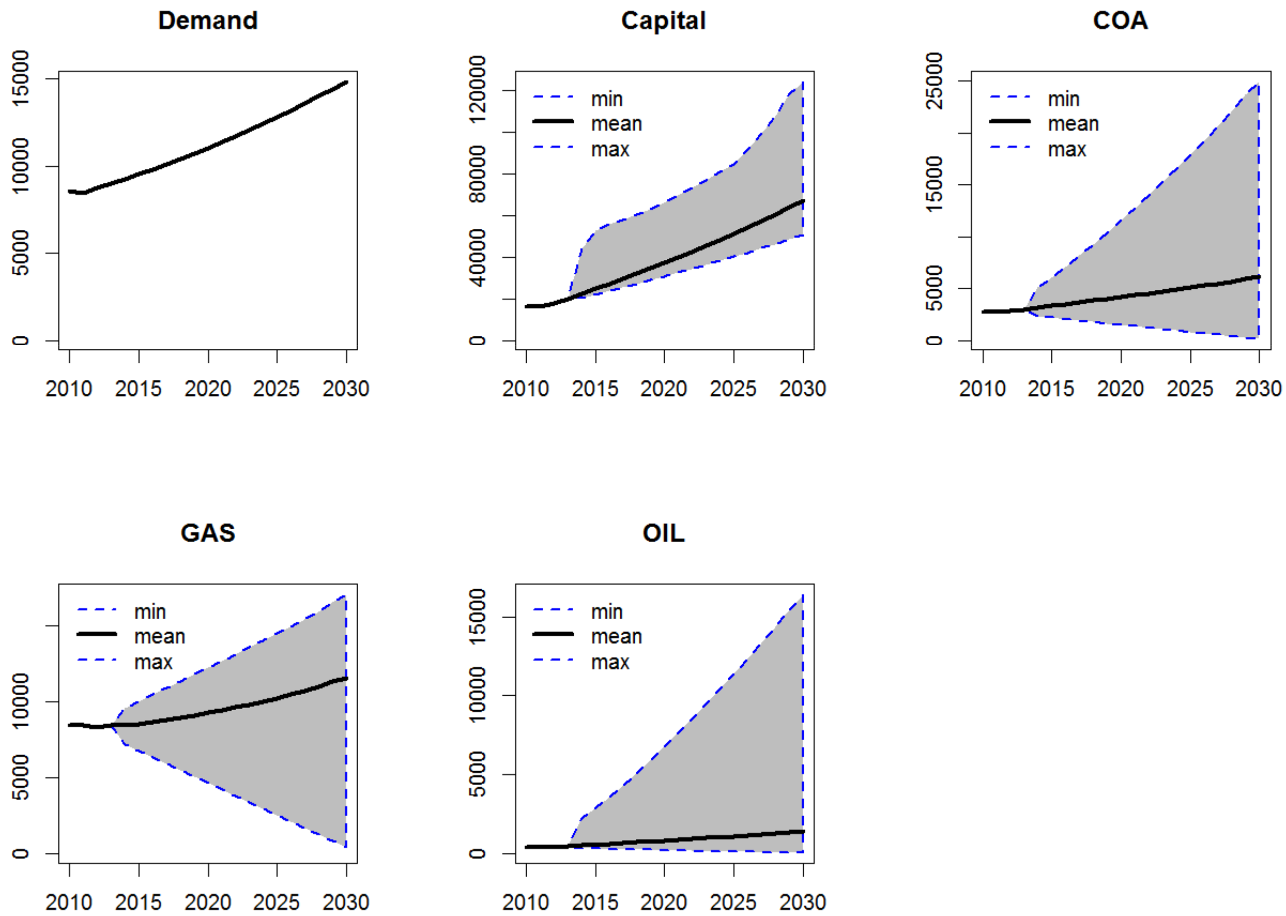


Econometric problem:

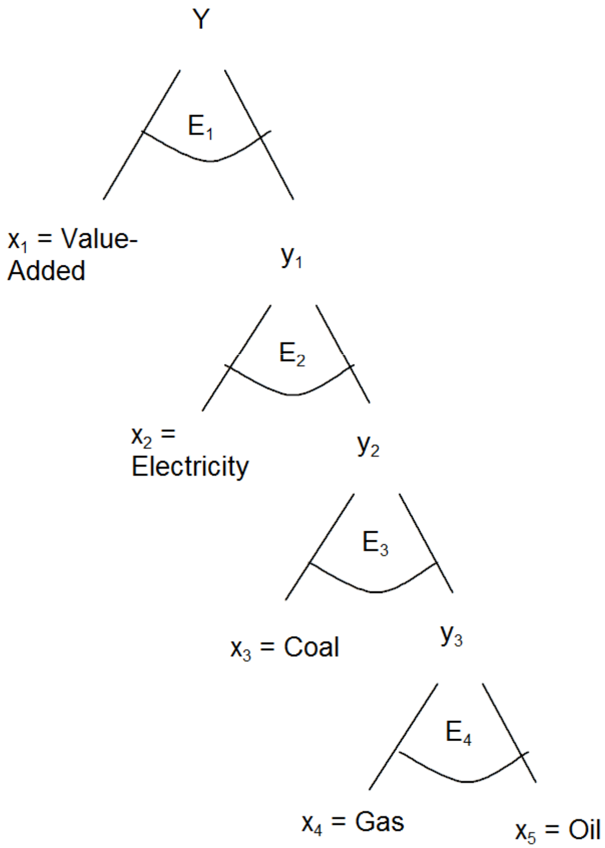
- Estimation of nested CES is not straightforward
- Nonlinear methods required
- We applied Bayesian econometrics to estimate 4-level nested CES function
- Equations for each level of CES (nest):

$$\log y = \log ad - \frac{1}{\rho} \cdot \log\left(d \cdot x_1^{-\rho} + (1-d) \cdot \left(d_2 \cdot x_2^{-\rho_2} + \cdots\right)^{\rho/\rho_2}\right) + \varepsilon$$

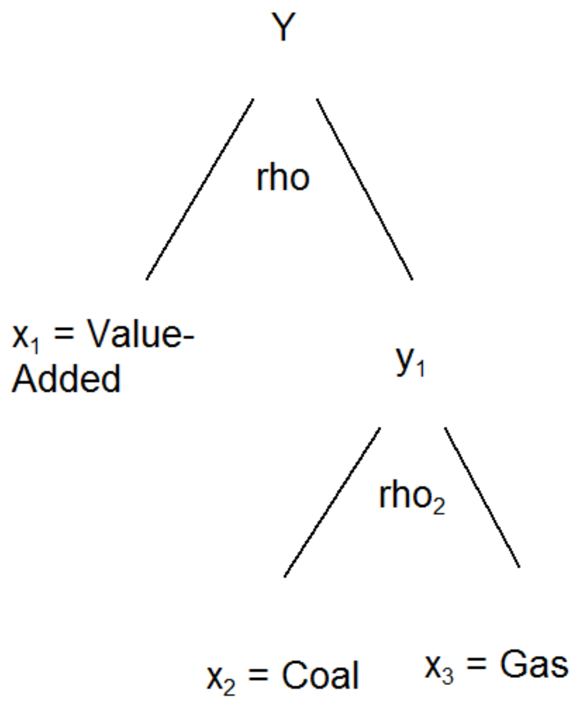
Results: Ranges of fuels variation for Power Sector



Use more suitable structure

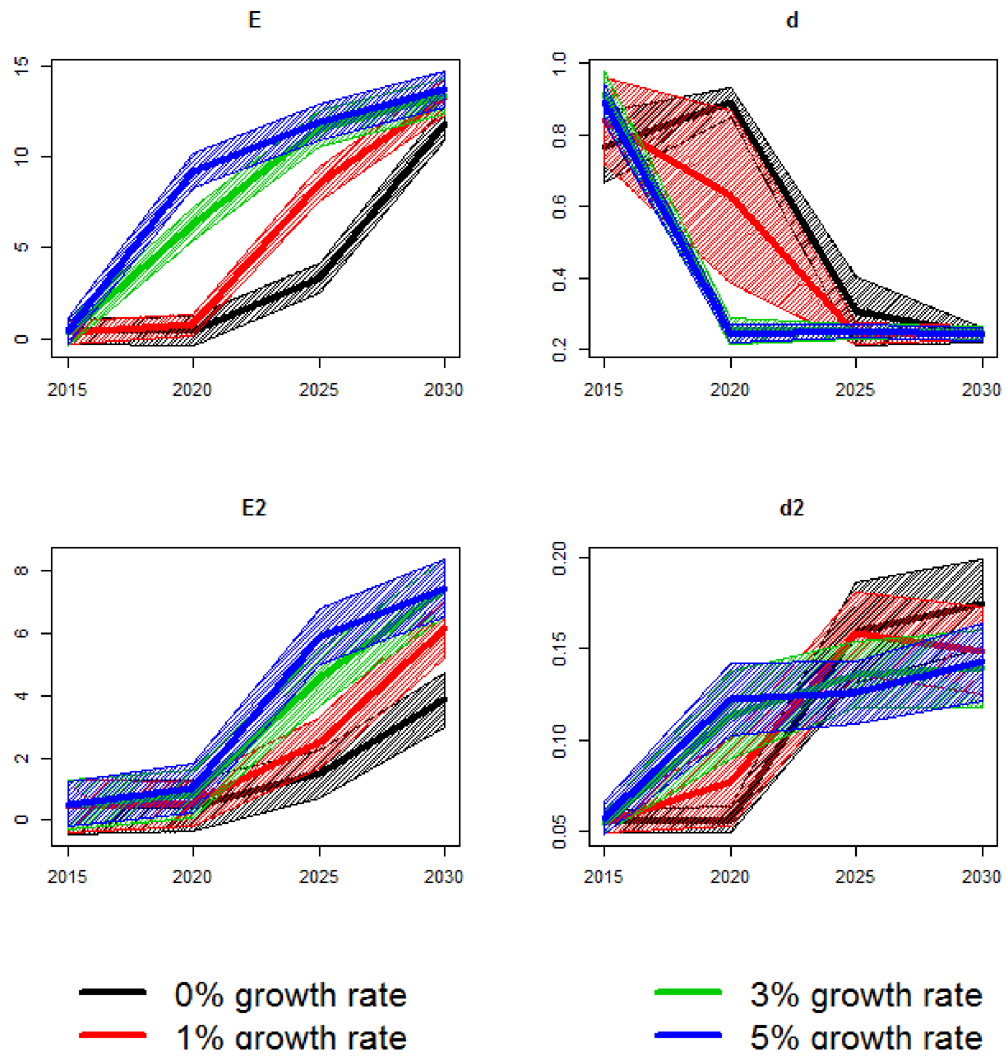


General

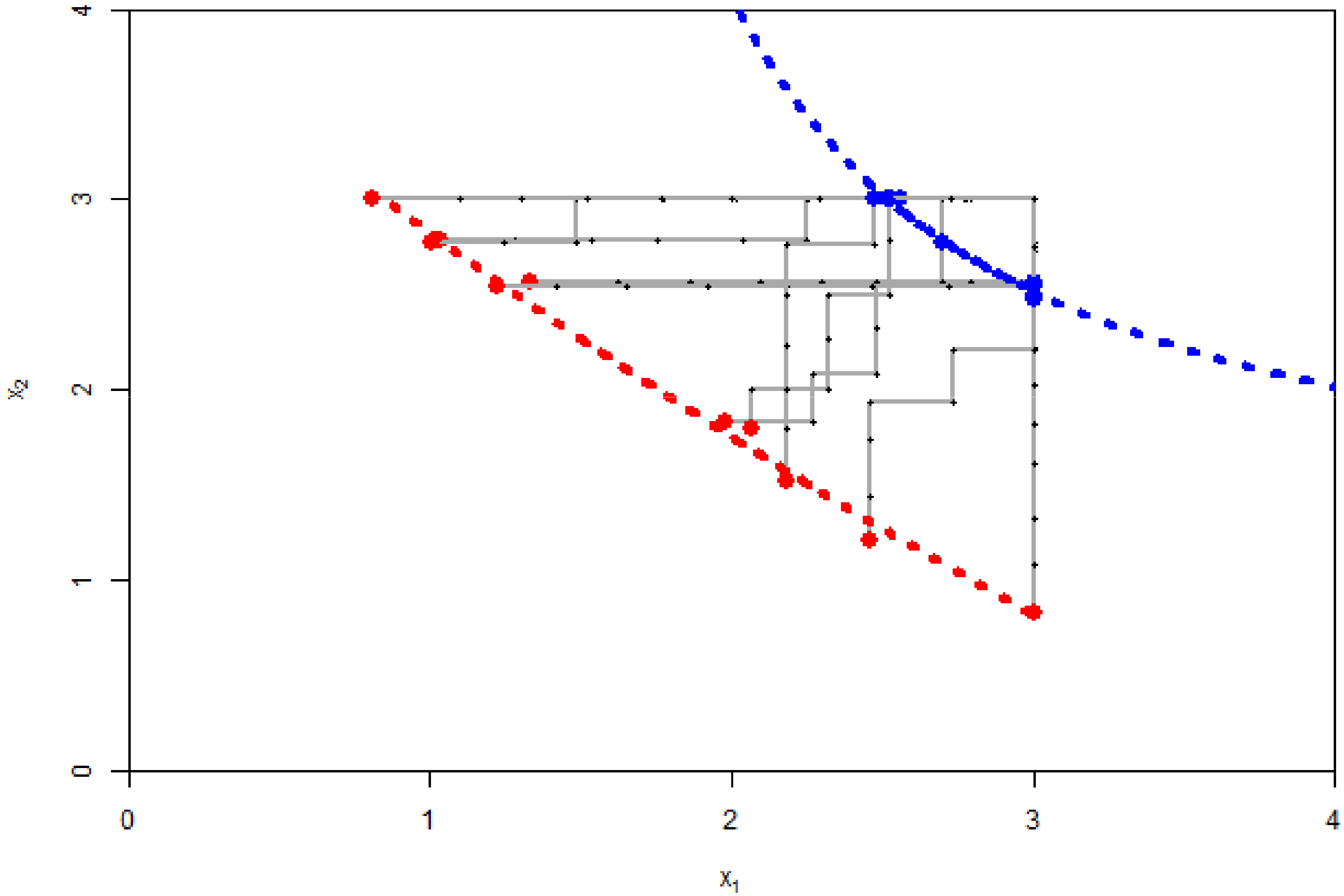


Electricity

Results: Power Sector



- Elasticity growth with time
- Elasticity growth with growth rate
- d – share parameter dramatically change



0
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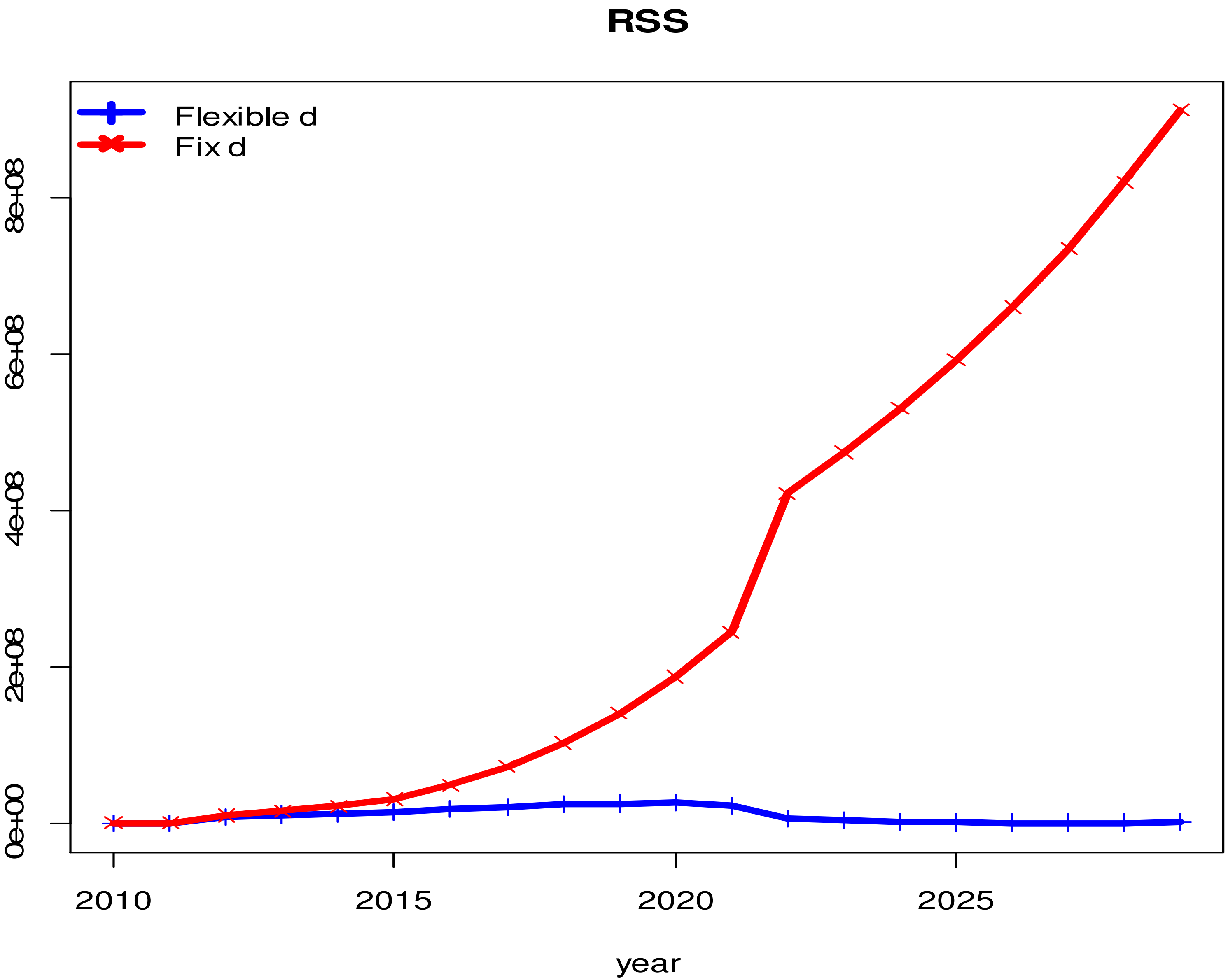
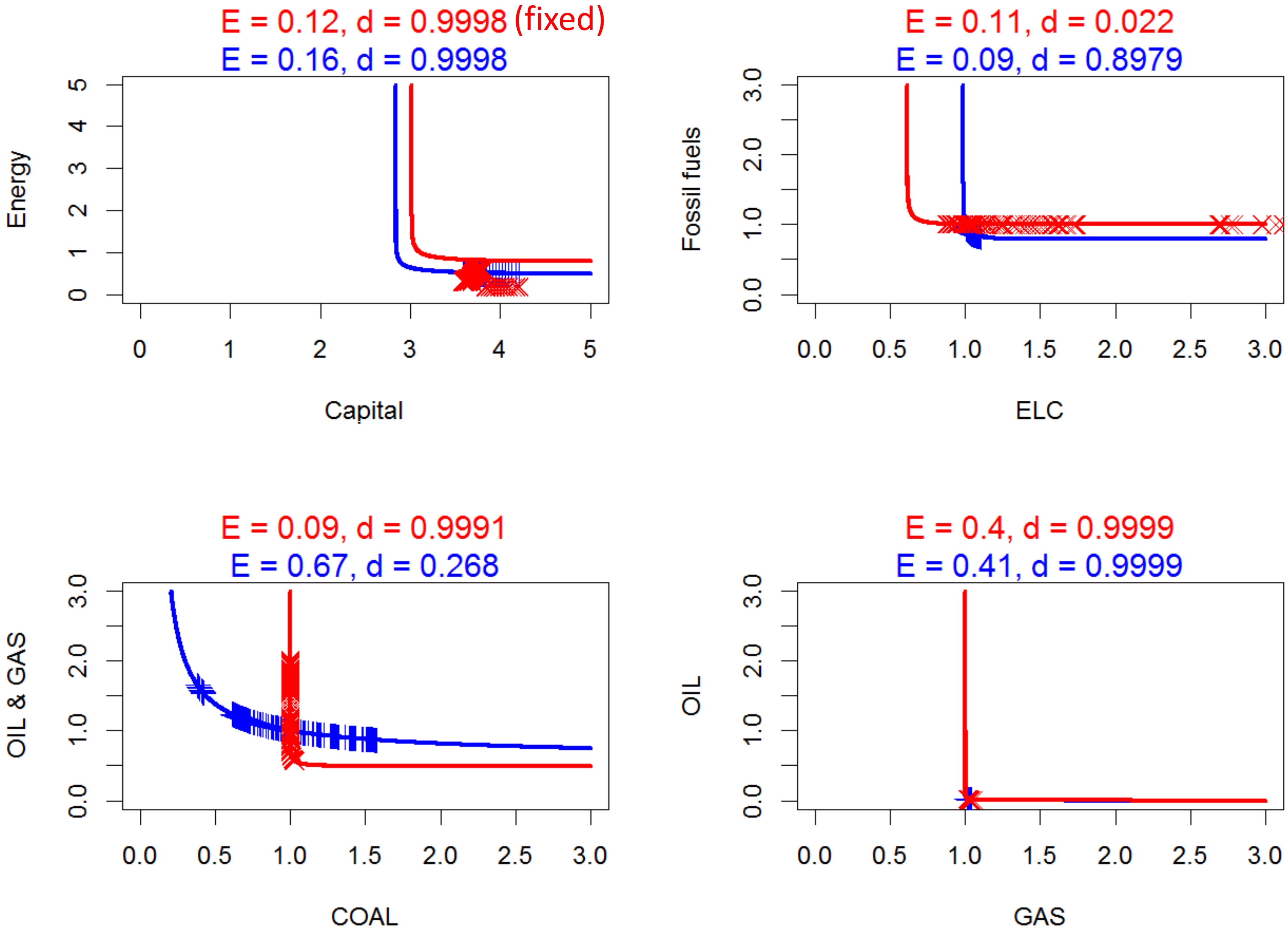
x_1
x_2

Quality of CES fit



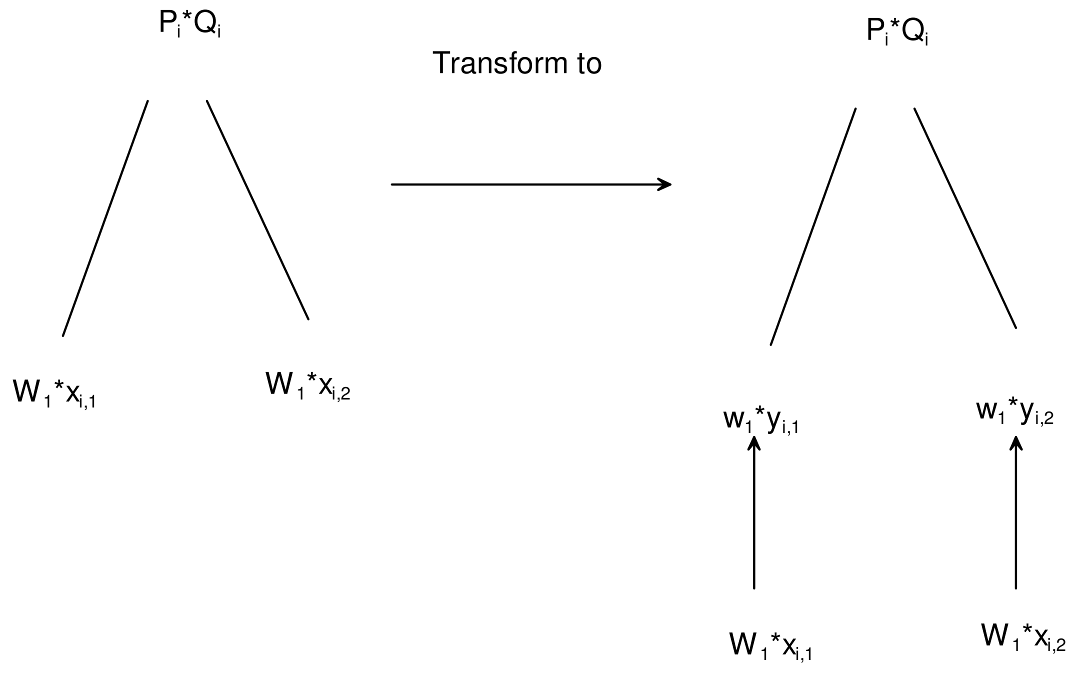
Results: four-level CES function: **2030**



Use correct shock

- Usually change ad – productivity factor
- Have to ad, d, E, …

Method



Some conclusions (1/4)

- Connection between “BU” and “TD” models can be (potentially) done by calibration of nested CES parameters on data simulated with “BU” models.
- There are two options how to connect the two models:
  - Exogenous shift: Let “BU” model predict technological shift and use it as a shock for CGE model.
  - Endogenous: let CGE model predict technological shift. However, in the current experiment we have not received good estimates for CES with fixed share parameter (d).

Some conclusions (2/4)

- Assumption of **higher economic growth** should result in **higher elasticity of substitution** (or share parameter shift). Currently existing capacities limit an opportunity for a technological maneuver in the short and medium run periods. However expansion of production assumes investments in new capacities.

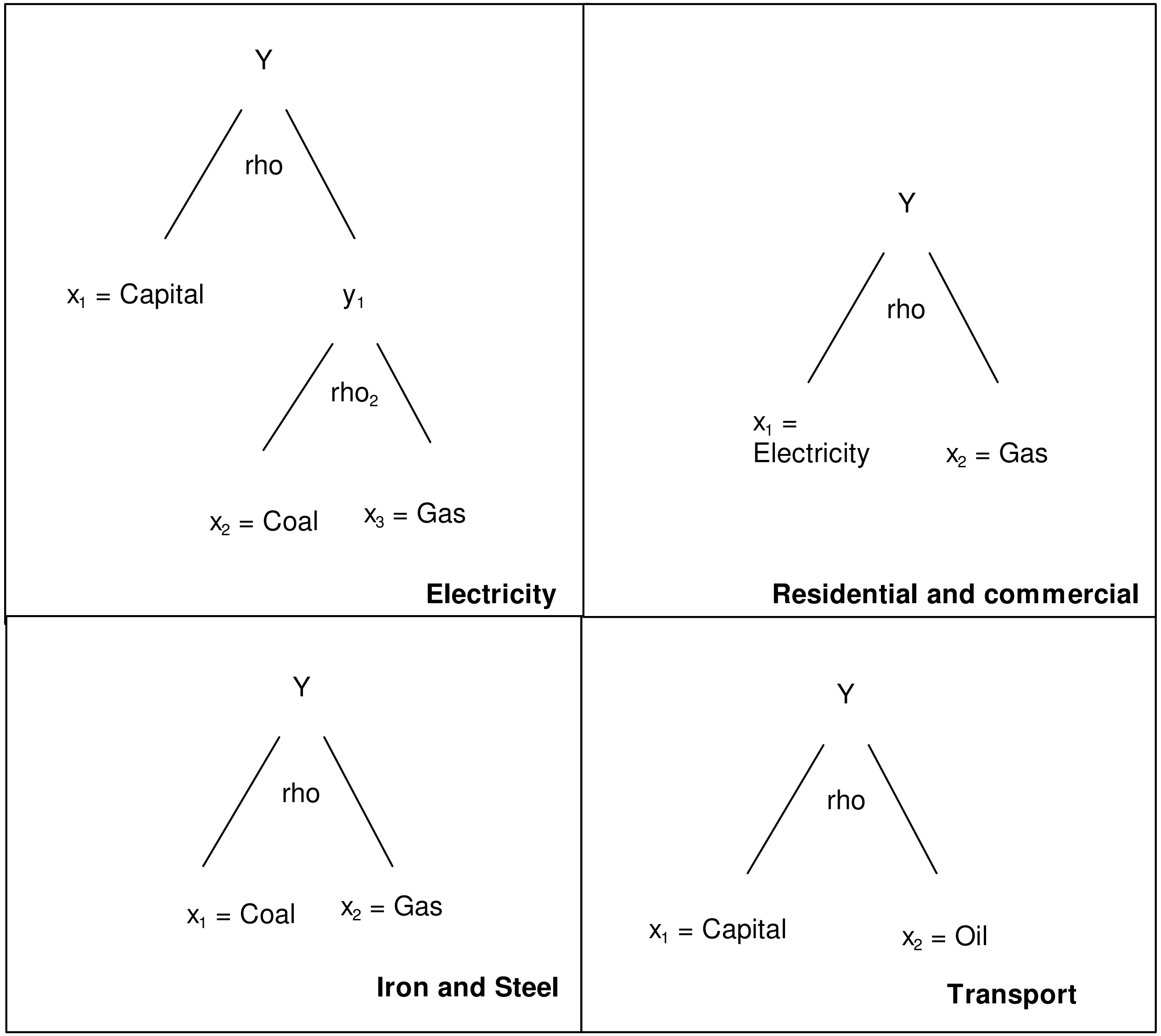
Some conclusions (3/4)

- Elasticity parameters, technological shift (ad), and share parameters (d) depend on **horizon of planning** (experiment). Longer horizon of planning usually lead to higher potential of switching between fuels and technologies, i.e. elasticity parameters are higher.

Some conclusions (4/4)

- CGE model structure have to adjusted for adequate implement technological shift

Optimal nested CES production function for different sector for Russia.



Thank you for your attention!

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Estimation results of CES functions for Iron and Steel

Parameter	Growth	Value	2015	2020	2025	2030
ad	0%	mean	0.05	0.06	0.06	0.07
		sd	0.00	0.00	0.00	0.00
E		mean	2.36	1.89	1.84	1.72
		sd	0.98	0.97	0.96	0.95
d		mean	0.38	0.37	0.36	0.35
		sd	0.00	0.00	0.01	0.01
ad	1%	mean	0.05	0.06	0.06	0.06
		sd	0.00	0.00	0.00	0.00
E		mean	2.68	2.79	3.45	3.66
		sd	0.98	0.97	0.96	0.95
d		mean	0.38	0.37	0.36	0.36
		sd	0.00	0.00	0.00	0.01
ad	3%	mean	0.05	0.05	0.05	0.05
		sd	0.00	0.00	0.00	0.00
E		mean	3.30	4.70	5.82	5.26
		sd	0.98	0.97	0.96	0.95
d		mean	0.37	0.37	0.37	0.37
		sd	0.00	0.00	0.00	0.01
ad	5%	mean	0.05	0.05	0.05	0.05
		sd	0.00	0.00	0.00	0.00
E		mean	3.95	5.90	6.41	8.64
		sd	0.98	0.96	0.96	0.96
d		mean	0.37	0.37	0.37	0.38
		sd	0.00	0.00	0.00	0.00

Estimation results of two-level CES functions for Electricity

Parameter	Growth	Value	2015	2020	2025	2030
ad	3%	mean	0.53	0.78	0.68	0.64
		sd	0.04	0.04	0.02	0.03
E		mean	0.32	6.28	11.57	13.33
		sd	0.73	0.91	0.97	0.97
d		mean	0.92	0.25	0.25	0.25
		sd	0.06	0.04	0.02	0.02
E2		mean	0.49	0.82	4.57	7.42
		sd	0.79	0.76	0.89	0.94
d2		mean	0.05	0.11	0.14	0.14
		sd	0.01	0.02	0.02	0.02
ad	5%	mean	0.51	0.75	0.65	0.62
		sd	0.03	0.04	0.02	0.03
E		mean	0.38	9.21	11.92	13.74
		sd	0.73	0.95	0.97	0.98
d		mean	0.89	0.24	0.25	0.24
		sd	0.05	0.02	0.02	0.02
E2		mean	0.52	1.02	5.88	6.85
		sd	0.71	0.79	0.91	0.93
d2		mean	0.06	0.12	0.13	0.14
		sd	0.01	0.02	0.02	0.02

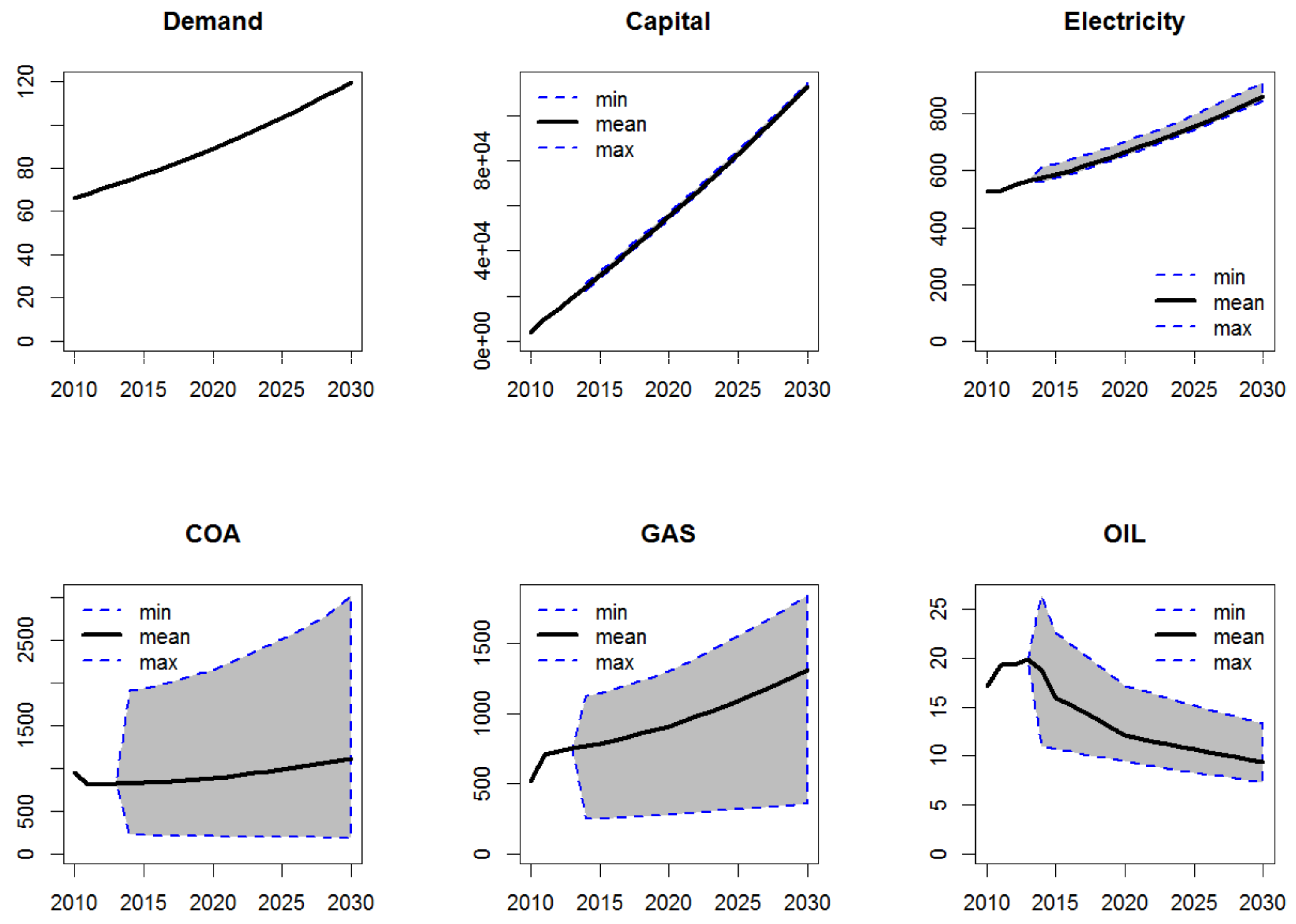
Estimation results of CES functions for Transport

Parameter	Growth	Value	2015	2020	2025	2030
ad	3%	mean	0.03	0.01	0.01	0.01
		sd	0.00	0.00	0.00	0.00
E		mean	1.83	3.20	10.55	13.59
		sd	0.93	0.87	0.96	0.98
d		mean	0.15	0.38	0.14	0.10
		sd	0.04	0.18	0.03	0.01
ad	5%	mean	0.03	0.01	0.01	0.01
		sd	0.01	0.00	0.00	0.00
E		mean	1.91	4.03	7.17	13.60
		sd	0.91	0.86	0.96	0.98
d		mean	0.15	0.33	0.18	0.10
		sd	0.05	0.20	0.03	0.02

Estimation results of CES functions for Residential and Commercial

Parameter	Growth	Value	2015	2020	2025	2030
ad	3%	mean	1.07	1.16	1.24	1.31
		sd	0.02	0.02	0.02	0.02
E		mean	1.10	1.47	1.43	1.55
		sd	0.60	0.66	0.64	0.67
d		mean	0.91	0.92	0.92	0.92
		sd	0.03	0.03	0.03	0.03
ad	5%	mean	1.09	1.20	1.28	1.34
		sd	0.02	0.02	0.02	0.03
E		mean	1.20	1.49	1.50	1.62
		sd	0.62	0.64	0.66	0.67
d		mean	0.91	0.92	0.92	0.92
		sd	0.03	0.03	0.03	0.03

Results: Ranges of fuels variation for Iron and Steel



Results: Iron and Steel