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Comparing Renewable Energy Policies in EU, US and China: A Bayesian DSGE Model

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Goals of the paper

- Analyze the impact of renewable energy sources (RES) development policies and strategies in the European Union (EU), the United States (US) and China.

- Evaluate the occurrence of grid parity between RES and fossil fuels in the three economies .

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Background

- How to improve design subsidy regimes that guarantee a proper RES development is a crucial and controversial issue.
- On the supply side, both organizational innovations and improvement of technological capabilities by research and development activities are determinant for the RES learning process (Horbach et al., 2012; Koseoglu et al., 2013).
- On the demand side, mechanisms such as subsidies are seen as key remove deployment barriers (Stokes, 2013).

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Background

- Different regions of the world use a wide range of instruments, the most diffused of which is some form of the feed-in tariffs mechanism.

Currently, RES in the energy mix for electricity generation account for :

- 23.2% in the EU → 27% policy target by 2030
- 13.1% in the US → 21% policy target by 2030
- 15% in China → 30% policy target by 2030

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The model

- We build a micro-founded dynamic stochastic general equilibrium (DSGE) model, explicitly focusing on the energy and environmental sectors.

Structure:

- one final consumer good;
- three intermediate goods, i.e., energy, fossil fuels and RES;
- the Government that subsidizes the RES production through the fiscal revenues collected from environmental tax.

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The model
The firms

- Final output, Y_t, is produced using inputs of labor, N_t^{fg}, private capital, K_{t-1}^{fg}, and energy services, E_t (A_t^{fg} is total factor productivity):

$$Y_t = A_t^{fg}\left(N_t^{fg}\right)^{\alpha}(E_t)^{\gamma}\left(K_{t-1}^{fg}\right)^{1-\alpha-\gamma}$$

- Energy services, E_t, is:

$$E_t = \left(\eta(ER)_t^{-\varepsilon} + (1-\eta)(EF)_t^{-\varepsilon}\right)^{-\frac{1}{\varepsilon}}$$

with fossil fuels, $(EF)_t$, RES, $(ER)_t$, $\varepsilon = \frac{1-\sigma}{\sigma}$, σ is the elasticity of substitution between RES and fossil fuels.

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The model
The firms

- The fossil fuels sector $(EF)_t$ employs private capital, K_{t-1}^{ef}, labor, N_t^{ef}, the stock of fossil fuel S_{t-1}, the total factor productivity A_t^{ef} :

$$(EF)_t = A_t^{ef}\left(N_t^{ef}\right)^{\theta}(S_{t-1})^{\varsigma}\left(K_{t-1}^{ef}\right)^{1-\theta-\varsigma}$$

- The RES sector depends on private capital, K_{t-1}^{er}, labor, N_t^{er} , the total factor productivity A_t^{er}:

$$(ER)_t = A_t^{er}(N_t^{er})^{\iota}(K_{t-1}^{er})^{1-\iota}$$

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The model

The households and the government

- Households' preferences depend on private consumption C_t, labor services, N_t that are allocated to final output production N_t^{fg}, fossil fuel sector N_t^{ef} and RES sector N_t^{er} :

$$E_0 \Sigma_{t=0}^{\infty} \rho^t U_t\left(C_t, N_t^{fg}, N_t^{ef}, N_t^{er}\right)$$

- For government's budget constraint, tax revenues on fossil fuels are equal to the entire amount of the subsidy:

$$\tau(EF)_t = \mu_t(ER)_t$$

- Then, optimal conditions that characterize decentralized equilibrium of firms and households is calculated.

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Model estimation

Method

- The model parameters have been calibrated on each country annual data from 1980 to 2012
- The inferential procedure adopted for the parameters' estimation, the simulation of the time series for the variables and their dynamic responses in the presence of stochastic shocks are based on the Monte Carlo Markow Chains (MCMC) methods

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Model estimation

- The dynamic response of the main variables to stochastic shocks on TFPs and taste shifter are represented by impulse response functions (IRFs) for each country

- For all of the IRFs, the size of the standard deviations of the stochastic shocks and the variables' responses relate to the posterior-average of the IRFs for each draw of the MCMC algorithm, together with 95% credible intervals

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Simulation results

- A positive technology shock to final output (Figures 1b, 2b, 3b) generates an increase in production and consumption through a positive shift of final goods' supply curves (Figures 1a, 2a, 3a) and productive factors' demand curves in all three economies.
- In all countries, an increase in TFP generates different growth paths of energy demand (Figures 1c, 2c, 3c) and of both fossil fuel (Figures 1h, 2h, 3h) and RES prices (figures 1i, 2i, 3i).
- This induces different quantities responses: in the EU and China, the response of final output has almost the same shock size, whereas in the US, final output increases more than final output TFP.

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Simulation results

EU Impulse Response Functions for a Positive TFP Shocks on Final Output Sector

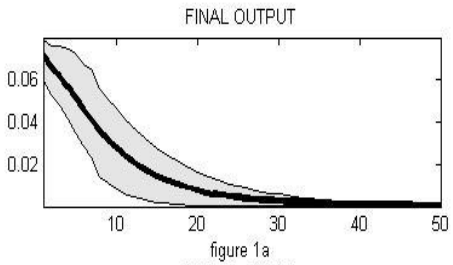

figure 1a

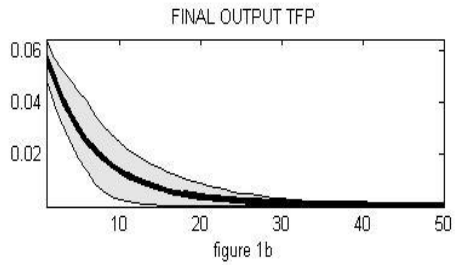

figure 1b

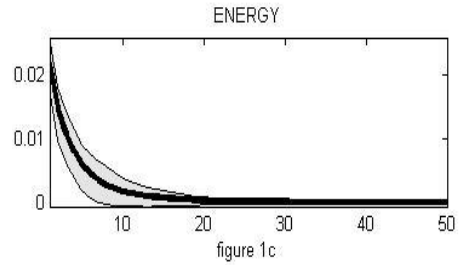

figure 1c

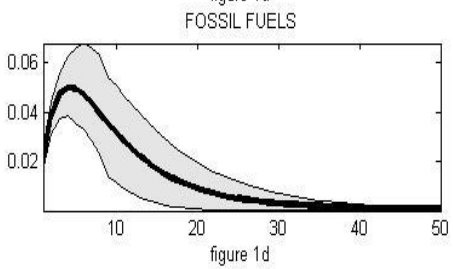

figure 1d

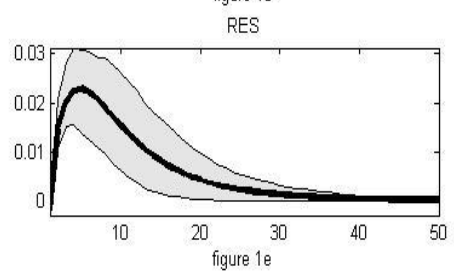

figure 1e

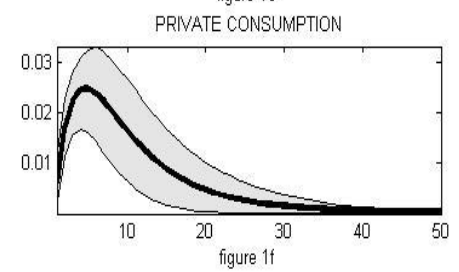

figure 1f

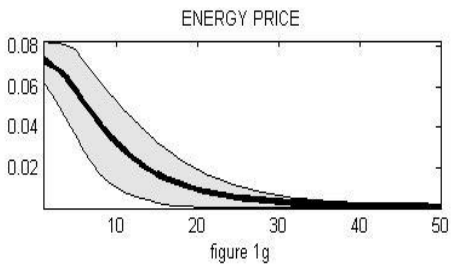

figure 1g

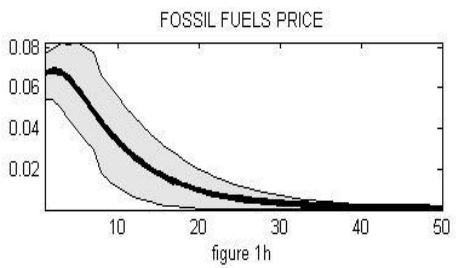

figure 1h

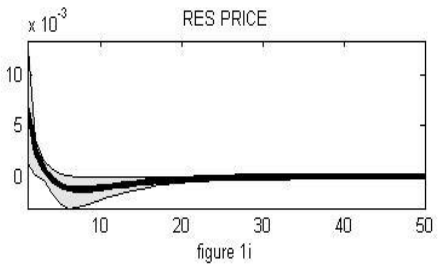

figure 1i

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Simulation results

US Impulse Response Functions for a Positive TFP Shocks on Final Output Sector

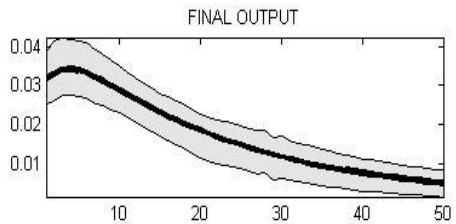

figure 2a

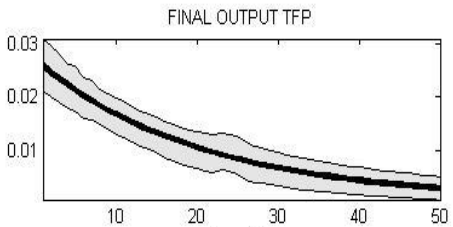

figure 2b

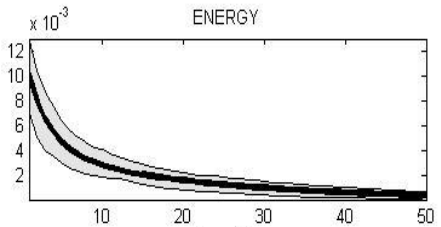

figure 2c

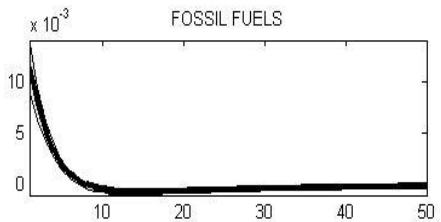

figure 2d

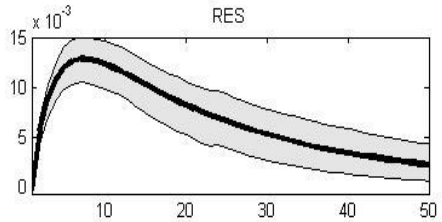

figure 2e

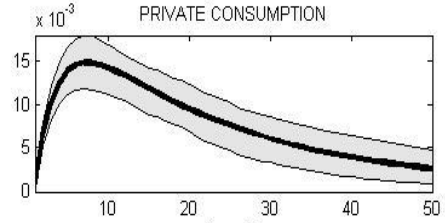

figure 2f

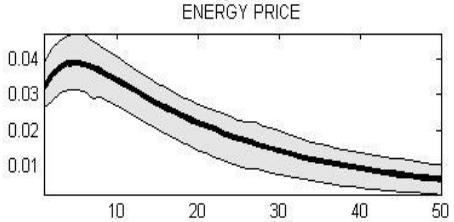

figure 2g

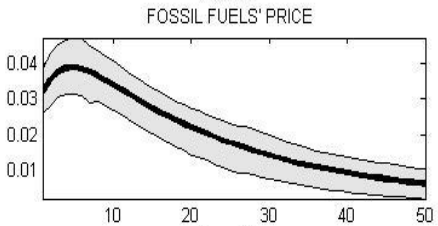

figure 2h

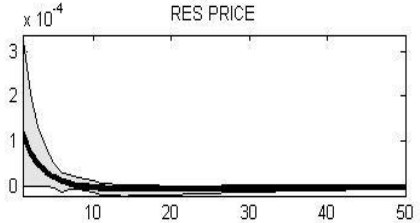

figure 2i

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Simulation results

China Impulse Response Functions for a Positive TFP Shocks on Final Output Sector

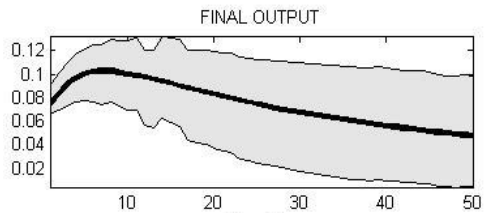

figure 3a

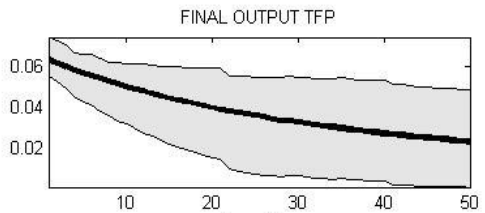

figure 3b

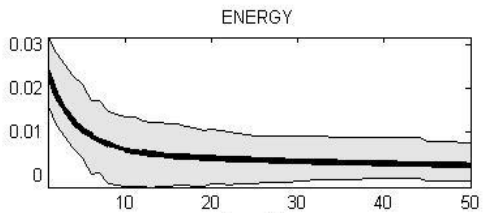

figure 3c

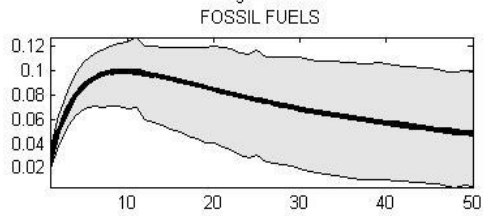

figure 3d

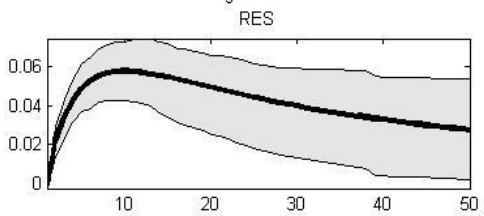

figure 3e

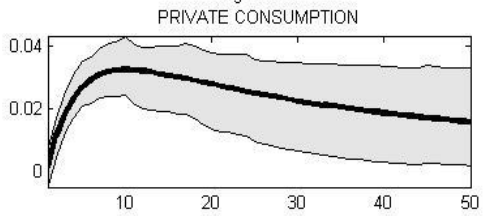

figure 3f

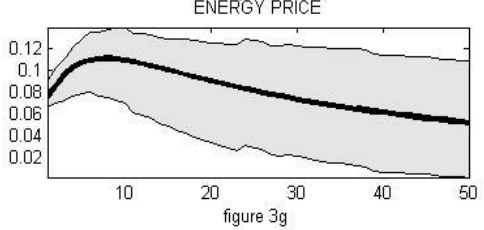

figure 3g

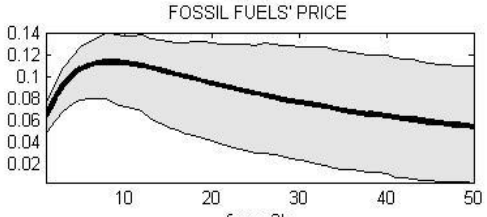

figure 3h

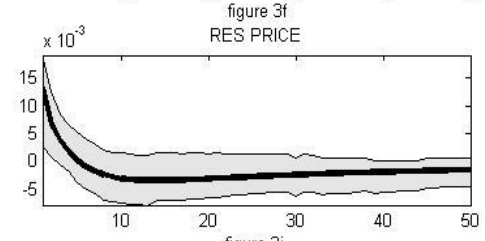

figure 3i

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Simulation results

- Then, we analyze the price dynamics of RES and fossil fuels, with a 95% confidence interval, in order to estimate the grid parity.
- The huge variability of the RES price is linked to the high standard deviation of the exogenous shifts of TFP in the RES sector.
- The achievement of grid parity is endogenously determined.
- The grid parity is achieved earlier in the EU, then in China and lastly in the US.

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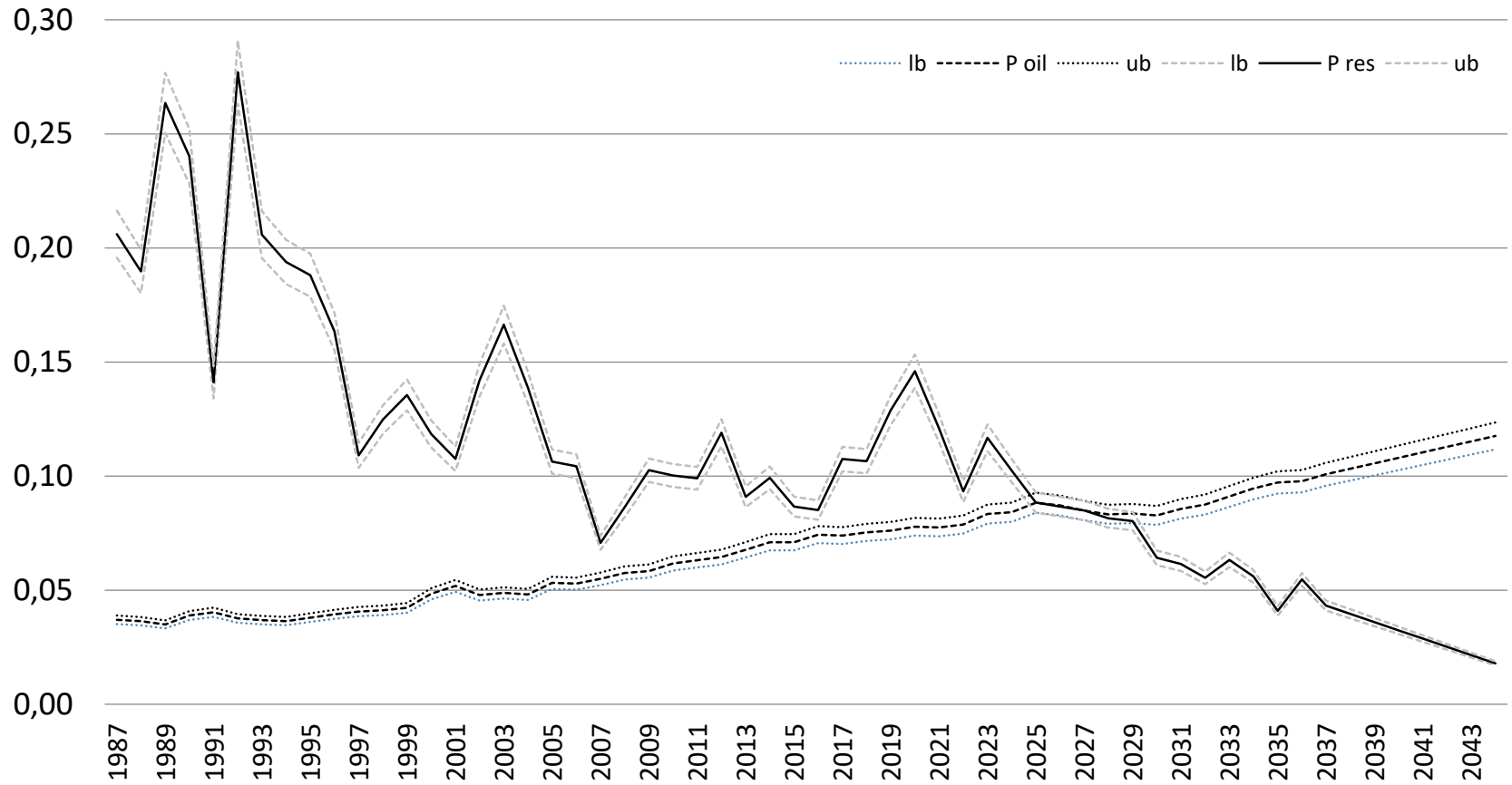
Simulation results

EU Grid Parity Trends (prices are expressed in euro/Kwh)



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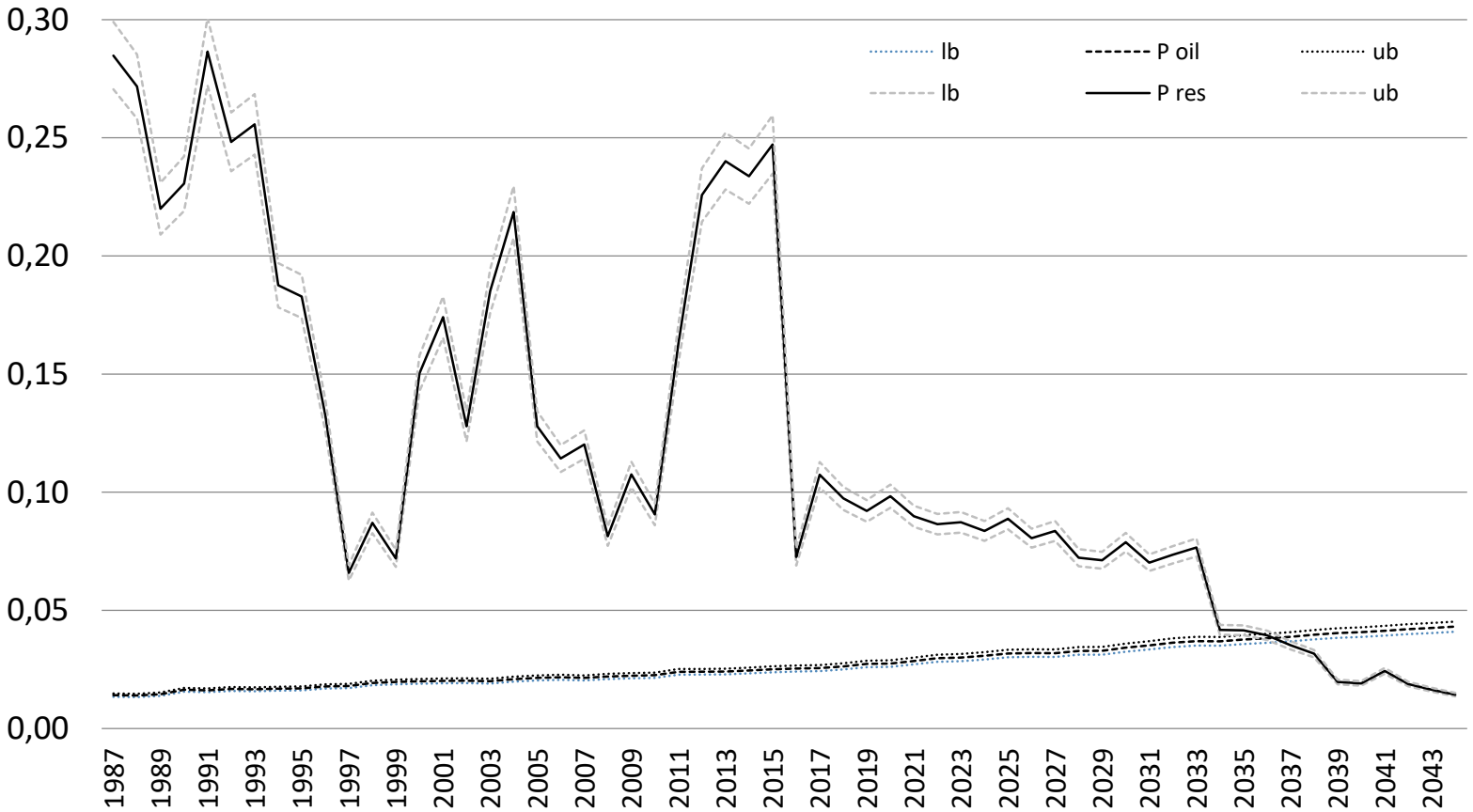
Simulation results

US Grid Parity Trends (prices are expressed in euro/Kwh)



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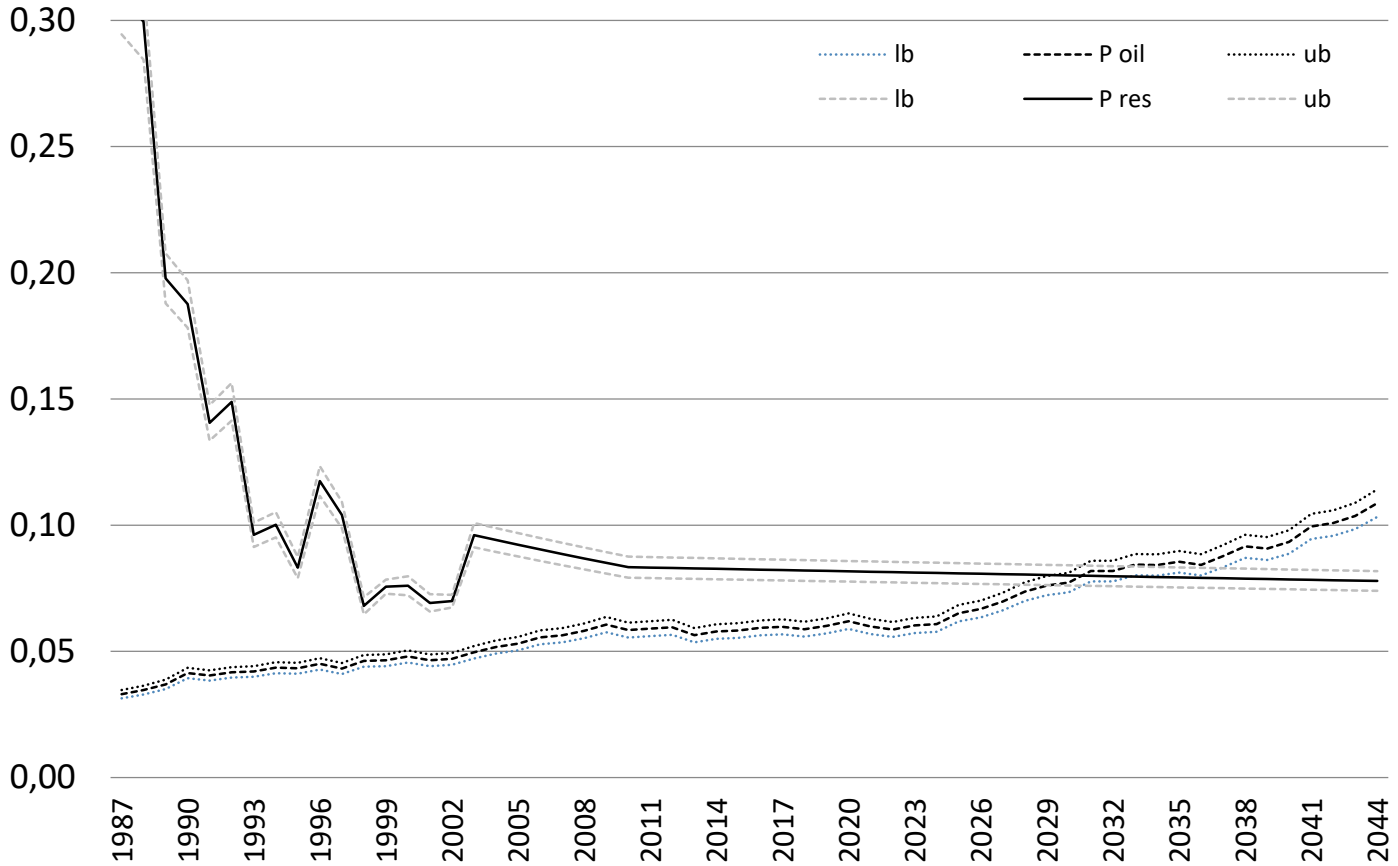
Simulation results

China Grid Parity Trends (prices are expressed in euro/Kwh)



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Simulation results

- To appraise if our model fits real world we have performed several test using main moments and the full distributions.

Moments and Distributions Tests [(a)] -Year 1987-2015 (Obs. = 28)

Test		oil	oil CHN	oil US	oil EU
	mean	0.0243	0.0258	0.0232	0.0248
	t-test	---	t = -1.1930	t = 0.7461	t = -0.9634
			P = 0.2429 [(b)]	P = 0.4618 [(b)]	P = 0.3436 [(b)]
	st. dev.	0.0118	0.0097	0.0095	0.0121
	F-test	---	f = 1.4918	f = 1.5549	f = 0.9501
			Prob = 0.2959 [(c)]	Prob = 0.2489 [(c)]	Prob = 0.8932 [(c)]
	Kolmogorov-Smirnov test	---	K-S = 0.3103	K-S = 0.1724	K-S = 0.2759
			P-value = 0.079*	P-value = 0.703 [(d)]	P-value = 0.154 [(d)]

(a) Simulated regional oil prices do not include regional taxes (euro/kWh), (b) We do not find a statistically significant difference in the means, (c) We do not find a statistically significant difference in the variances ratio, (d) We cannot reject that series do not have the same distribution function, * Significant at 10%; ** significant at 5%; *** significant at 1%.

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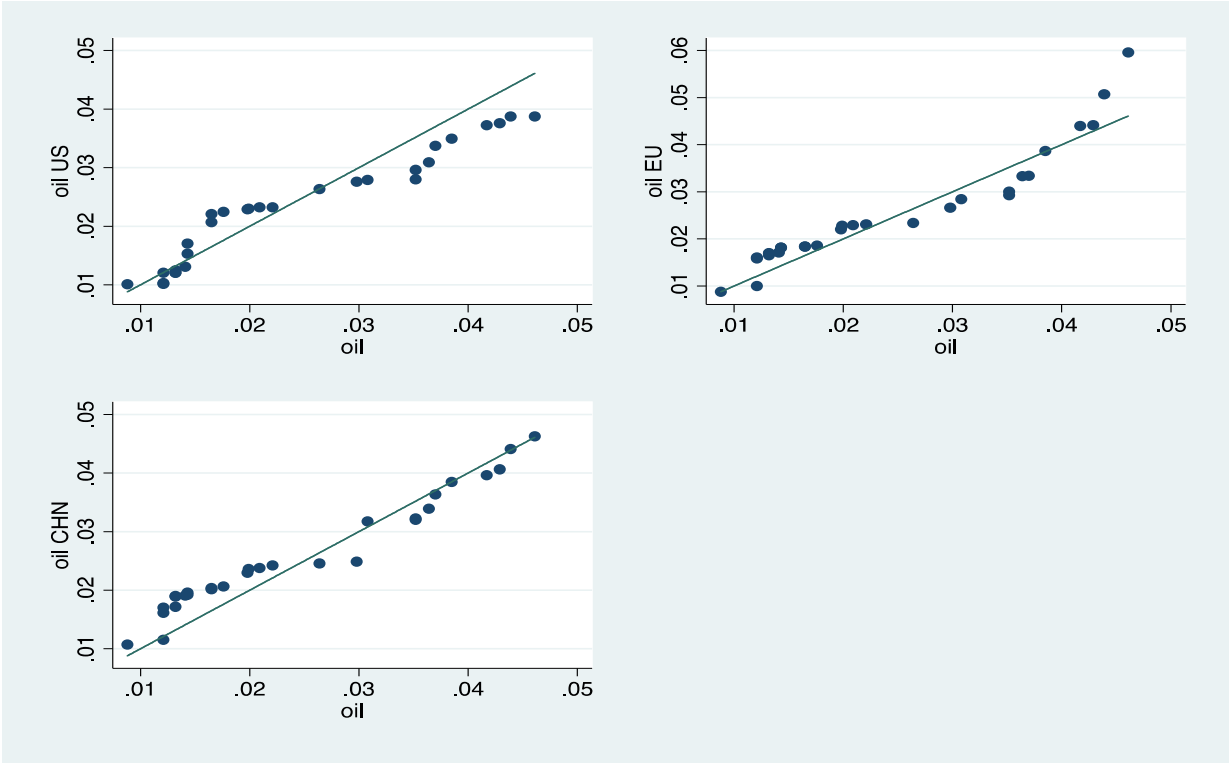
Simulation results

- We have paired plotted quantiles of simulated series *vs.* actual data finding that they are very similar

Quantile – Quantile plot; Simulated Series *vs.* Actual Data



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Conclusions

- The estimation results over the period 1995-2012 reveal that assuming an understanding that a carbon tax is required, monetary subsidy to RES producers have different effects for RES long-run development.
- A final output TFP shock generates a much stronger effect on the production in the US, where the share of energy is higher, than in China and the EU.
- A shock in RES, instead, produces a higher RES growth in the EU than in the US and China, confirming the validity of the favorable policy attitude towards RES in the EU.
- There is a noticeable anticipation of achieving grid parity in more flexible economies.
- Future applications of the model could include its implementation on a full world model, where trade and financial interactions among countries are better modeled, including developing countries.

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