Future investments of renewable energy technologies at volatile raw material- and energy prices - an econometric assessment

RE-Shaping
Shaping an effective and efficient
European renewable energy market

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Content

- Motivation and background information
- Methodology: Theoretical approach
- Analyses and results … the case of onshore wind and Photovoltaic
- Conclusions

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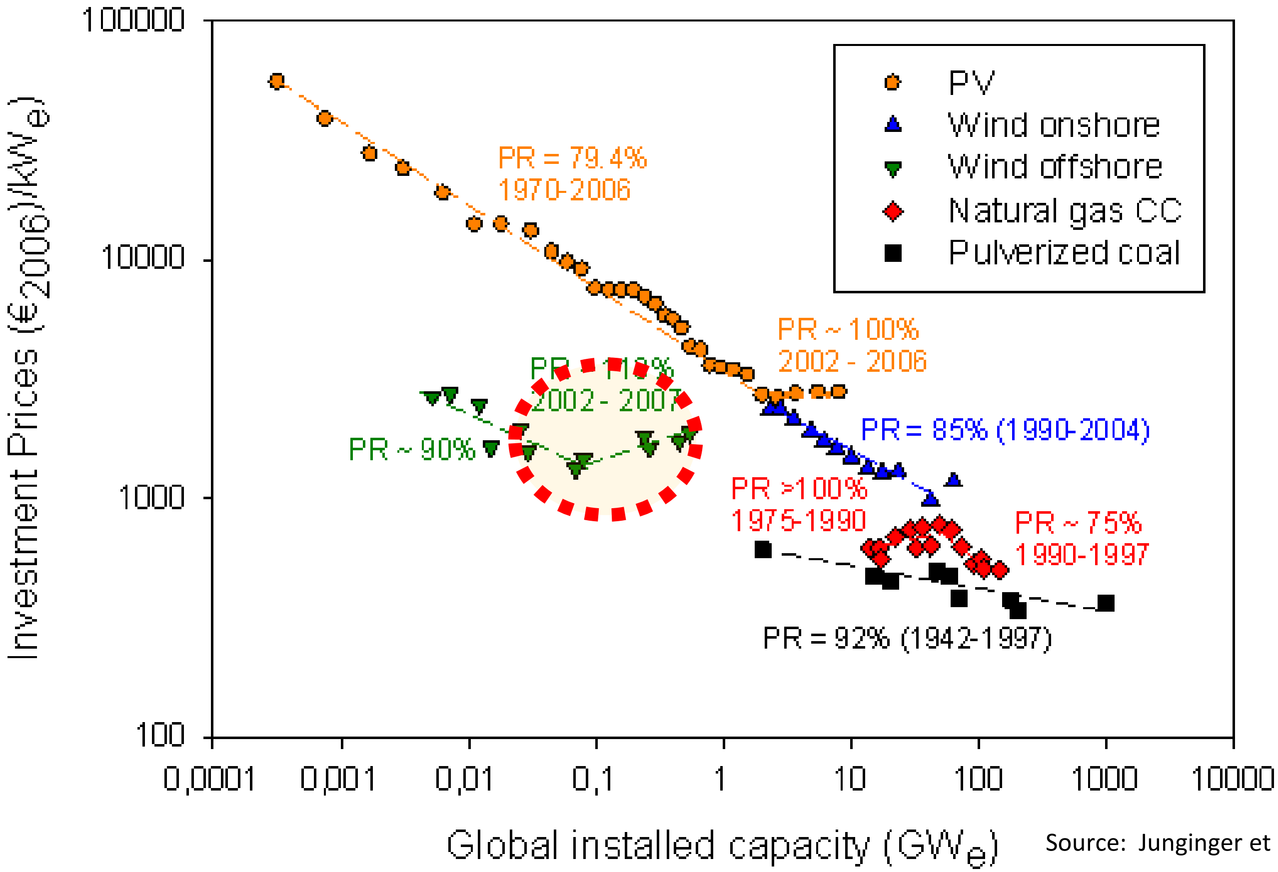
Technological learning … the old "fairy tale"?

- *Observed historic cost development for various energy technologies and identified progress ratios*

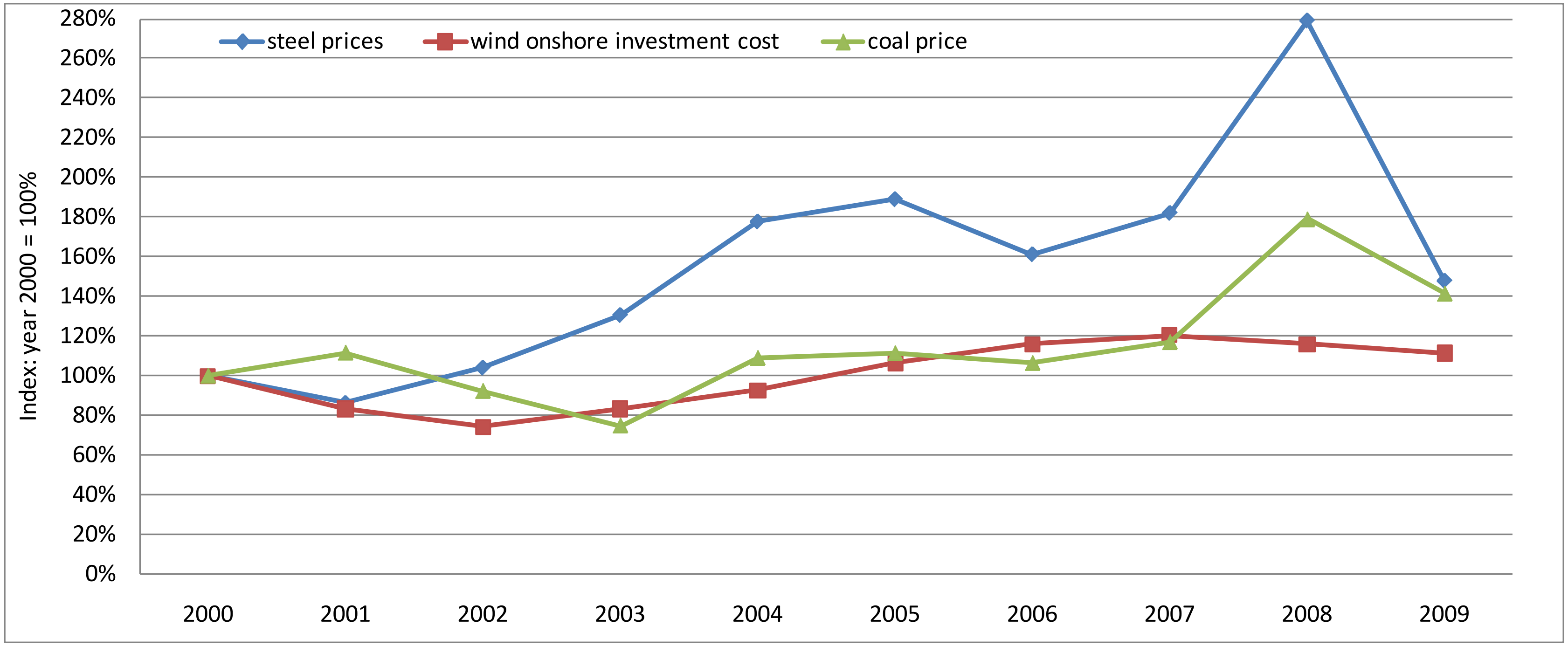
→ "Negative learning" in 2002-2007 ?!?



Source: Junginger et al. (2010)

Historic development of capital cost for wind onshore

- *Correlation between steel prices and capital cost for wind onshore: 0.66*
- *Correlation between steel- and coal prices: 0.74*



Source: Wind onshore capital cost … (EWEA, 2010), steel price … (Steel Business Briefing), and coal price … (European Commission)

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Method of approach

$$c(x_t) = \prod_{CP} (\alpha + \vec{\beta} * CP_t + \vec{u}_t) \cdot \left(\frac{x_t}{x_0} \right)^{-b}$$

$$LR = 1 - 2^{-b}$$

$$PR = 1 - LR$$

α ... Constant factor

$\vec{\beta}$ ... Coefficient vector

$\vec{u}_t$ ... Residual vector

$c(x_t)$ ... investment capital of RES technology

CP_t ... commodity price

x_t ... cumulated production of technology

Practical Implementation:

- Identification of the impact of **energy prices on raw material prices**
- Derivation of raw material prices based on regression
  → in the past, and in the future ...
- Data adjustment (correction for technological learning effect) for conducting a **regression analysis of capital cost** for RE technologies
- **Quantitative** assessment of the **future development of capital cost** (for RE technologies)

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Impact of energy prices on commodity prices

- Regression analysis based on data for the period **1999 to 2009 in the EU**
- Impact off energy prices on commodity prices rather represent their **production cost** due to neglecting other (market) drivers

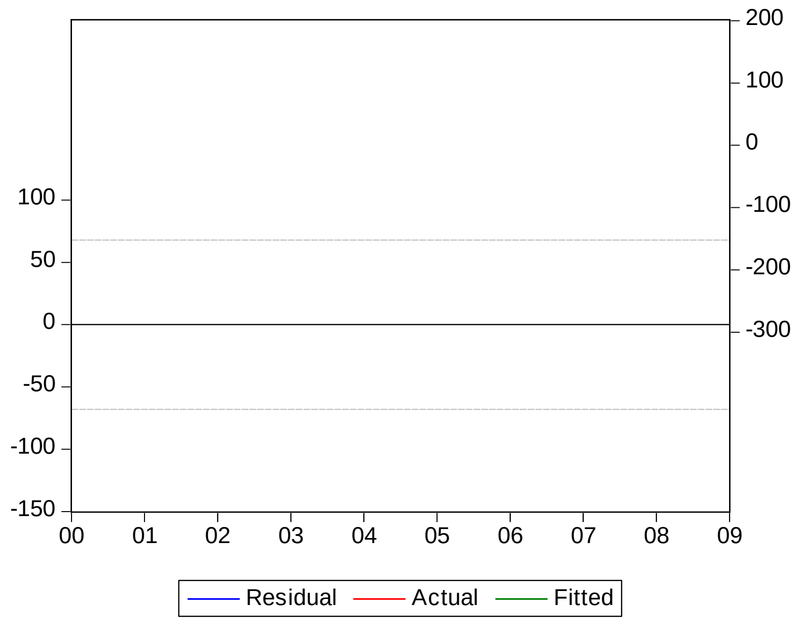
Equation: REG_DIFF Workfile: STEEL_ANNUAL_2009::...

View | Proc | Object | Print | Name | Freeze | Estimate | Forecast | Stats | Resids

Dependent Variable: DIFFSTEEL
Method: Least Squares
Date: 09/29/11 Time: 12:38
Sample (adjusted): 2000 2009
Included observations: 10 after adjustments
White Heteroskedasticity-Consistent Standard Errors & Covariance

	Coefficient	Std. Error	t-Statistic	Prob.
C	18.46943	20.44624	0.903317	0.3964
DIFFCOAL	2.493618	0.815295	3.058548	0.0184
DIFFCOAL(-1)	-4.475420	1.130665	-3.958219	0.0055

R-squared	0.700218	Mean dependent var	6.500000
Adjusted R-squared	0.614566	S.D. dependent var	109.4961
S.E. of regression	67.97885	Akaike info criterion	11.51960
Sum squared resid	32347.86	Schwarz criterion	11.61037
Log likelihood	-54.59798	Hannan-Quinn criter.	11.42001
F-statistic	8.175137	Durbin-Watson stat	2.870768
Prob(F-statistic)	0.014751		



Source: Own calculations

- Annual change in steel price depend on annual energy price change plus the change in the previous year (long term contracts). Strong decreasing coal/coke prices might stimulate the actual steel production -> creating a high supply (surpluses) - > reduces demand in next year -> reduces steel price in next year

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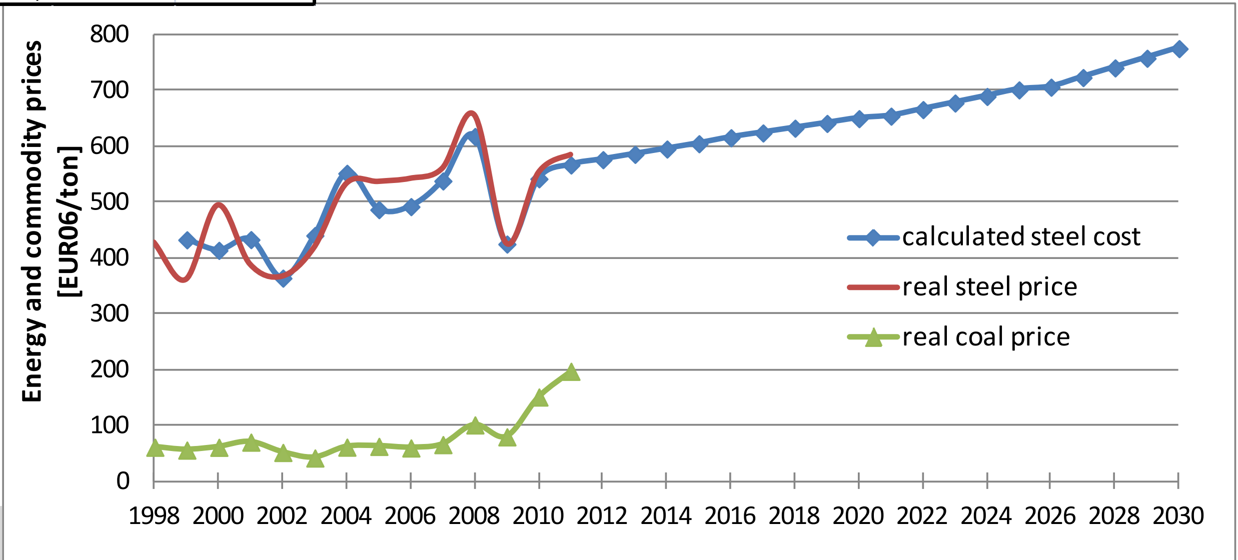
Impact of energy prices on commodity prices

Statistic overview		
Unit root:	Augumented Dickey-Fuller Test	
	H0...time series has a unit root	
	DIFFCOAL	rejects H0 with 97% probability within 5% significance intervall
	DIFFSTEEL	rejects H0 with 98.15% probability within 5% significance intervall
Normality:	Jarque-Bera Test	
	H0...regression is normal distributed	
	JB=0.585	Accept H0 with 74.6% probability
Serial Correlation:	Durbin Watson (1st order) - DW:2.87 -> undefined	
	Breusch-Godfrey serial correlation test	
	H0...no serial correlation	
	$N*R^2$=6.885	$chi^2(7,0.95)$=14.067 => H0 accepted
Homoskedastic:	Breusch-Pagan-Godfrey test	
	H0...homoskedastic	
	$N*R^2$=0.215	$chi^2(2,0.95)$=5.991 => H0 accepted

Based on unit root test, the first difference of time series has been taken into account here.

Source: Own calculations

Future forecast strongly depends on exogenous energy price assumptions



Results - calculated capital cost for wind onshore

- **Steel prices show a significant impact on onshore wind investments** but do not allow to follow in (full) detail the actual observations…

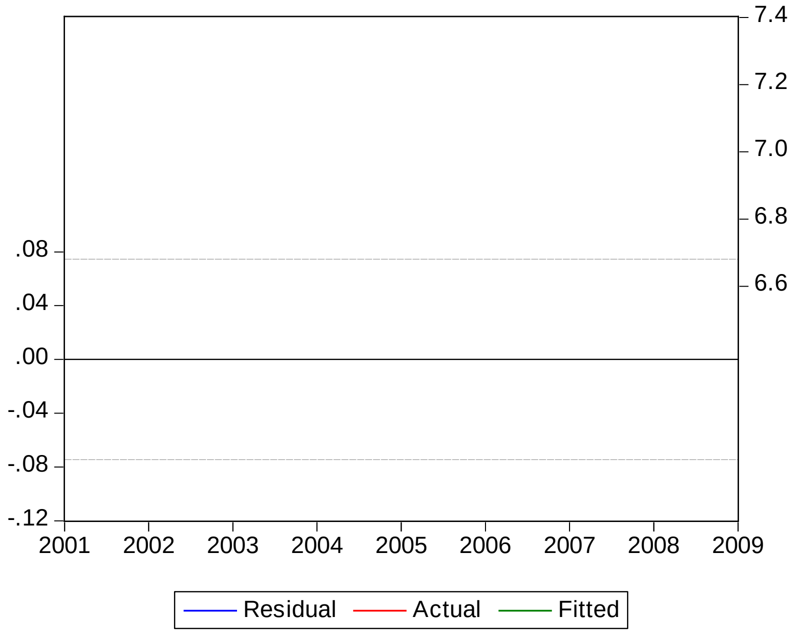
Equation: REG_STEEL_LAGSTEEL_LOG   Workfile: REG…

View | Proc | Object | Print | Name | Freeze | Estimate | Forecast | Stats | Resids

Dependent Variable: LOG_INV_EWEA
Method: Least Squares
Date: 08/25/11   Time: 12:00
Sample (adjusted): 2001 2009
Included observations: 9 after adjustments
White Heteroskedasticity-Consistent Standard Errors & Covariance

	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.359379	0.966299	-0.371913	0.7227
LOG_STEEL	0.556760	0.155566	3.578923	0.0117
LOG_STEEL(-1)	0.642003	0.144951	4.429112	0.0044

R-squared	0.902361	Mean dependent var	7.060191
Adjusted R-squared	0.869815	S.D. dependent var	0.206668
S.E. of regression	0.074568	Akaike info criterion	-2.093005
Sum squared resid	0.033362	Schwarz criterion	-2.027263
Log likelihood	12.41852	Hannan-Quinn criter.	-2.234875
F-statistic	27.72544	Durbin-Watson stat	1.993183
Prob(F-statistic)	0.000931		



Source: Own calculations

- Wind onshore investments are depending on actual as well as previous steel prices whereas both are influencing wind onshore investments directly. This might be a result of the steadily growing demand on onshore wind turbines.

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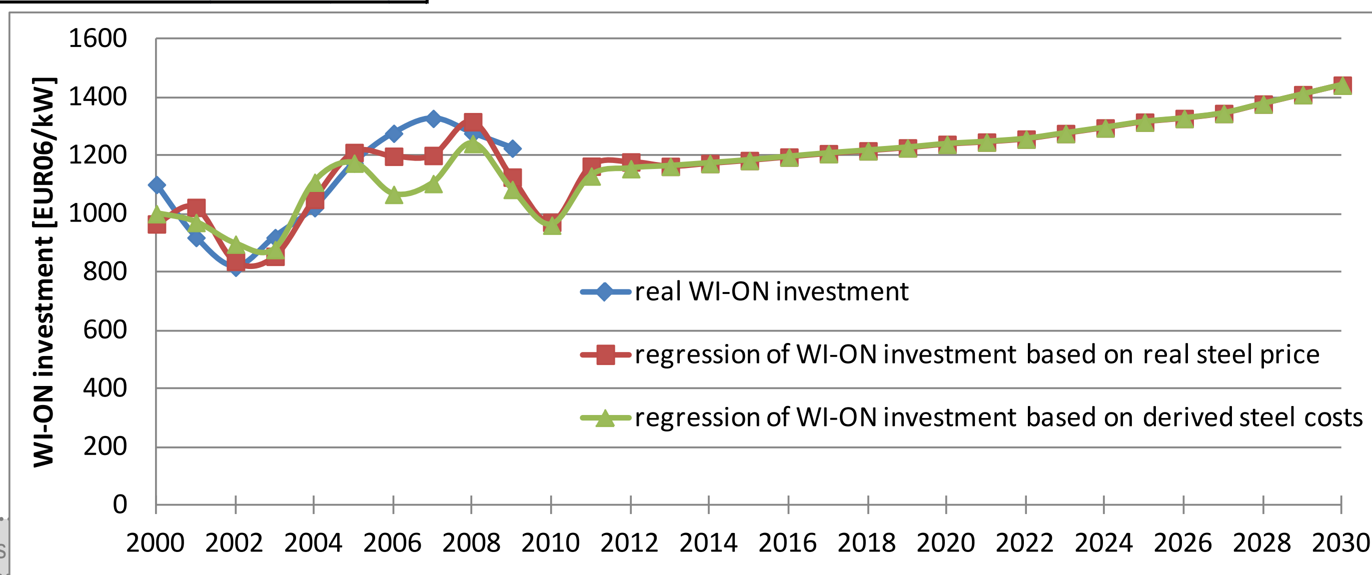
Results - calculated capital cost for wind onshore

Statistic overview			
Unit root:	Dickey-Fuller Test		
	H0...time series has a unit root		
	LOG_STEEL	rejects H0 within 10% significance intervall	
	LOG_INV_EWEA	rejects H0 within 5% significance intervall	
Normality:	Jarque-Bera Test		
	H0...regression is normal distributed		
	JB=0.658	Accept H0 with 71.9% probability	
Serial Correlation:	Durbin Watson (1st order) - DW:1.99-> no autocorrelation of 1st order		
	Breusch-Godfrey serial correlation test		
	H0...no serial correlation		
	$N*R^2=8.13$	$chi^2(7,0.95)=14.067$	=> H0 accepted
Homoskedastic:	Breusch-Pagan-Godfrey test		
	H0...homoskedastic		
	$N*R^2=0.833$	$chi^2(2,0.95)=5.991$	=> H0 accepted

Dickey-Fuller and Augmented Dickey Fuller are conflicting – but all other test indicate no unit root!

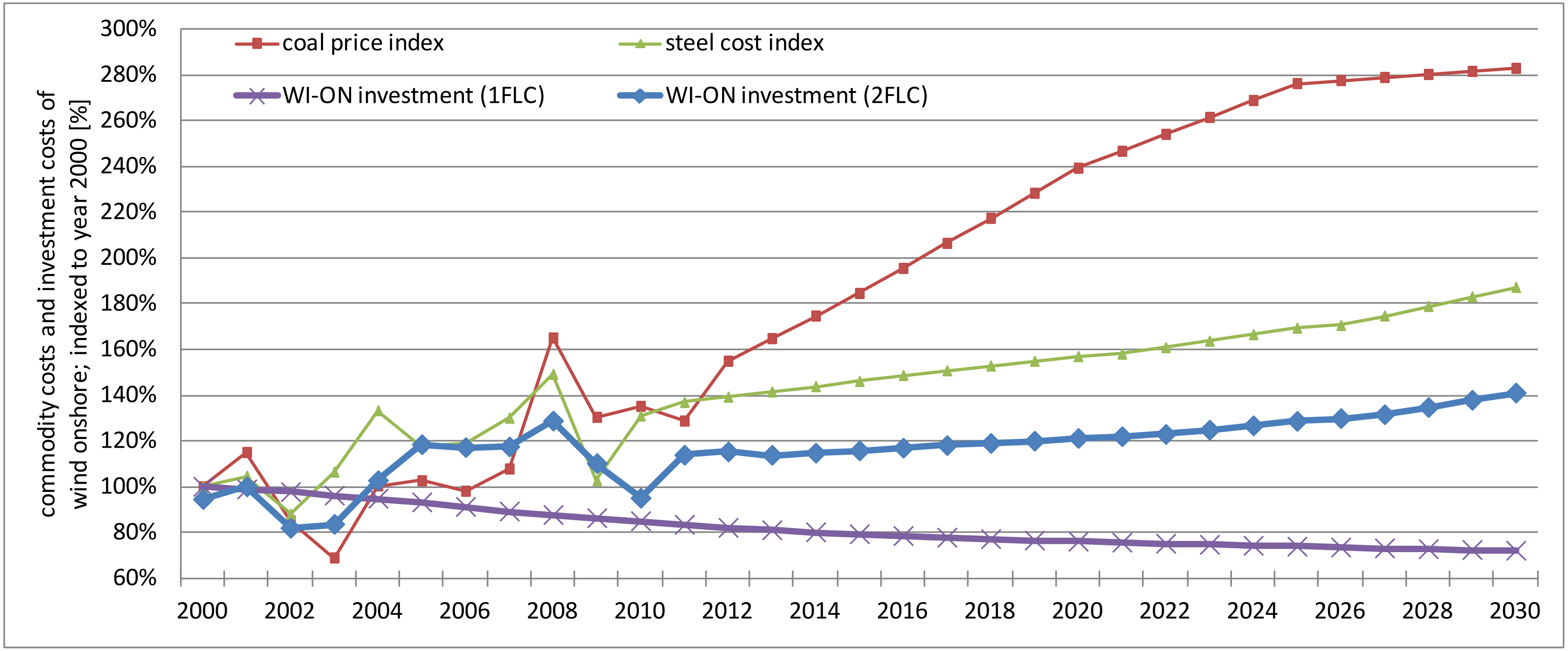
Source: Own calculations

Derived steel costs only show the minimal impact of commodities on Wind onshore investments



Results - expected future cost reduction w/o consideration of energy/raw material prices

- Correlation between energy prices and capital cost for wind onshore
- Comparison of default modelling approach (1-factor-learning-curve (1FLC)) and improved approach (considering the impact of raw material prices) (2FLC)
  → **„effective“ learning rate reduced – turns even negative here!**



Source: own calculations

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Results - impact of the new approach

- **Volatile character** of capital cost for energy technologies in the near past can be explained – future **forecasts depend on energy price** assumptions!
- **Novel technologies show a stronger impact of (real) learning** compared to raw material (or energy) prices, while **for mature technologies it appears to be the other way round.**

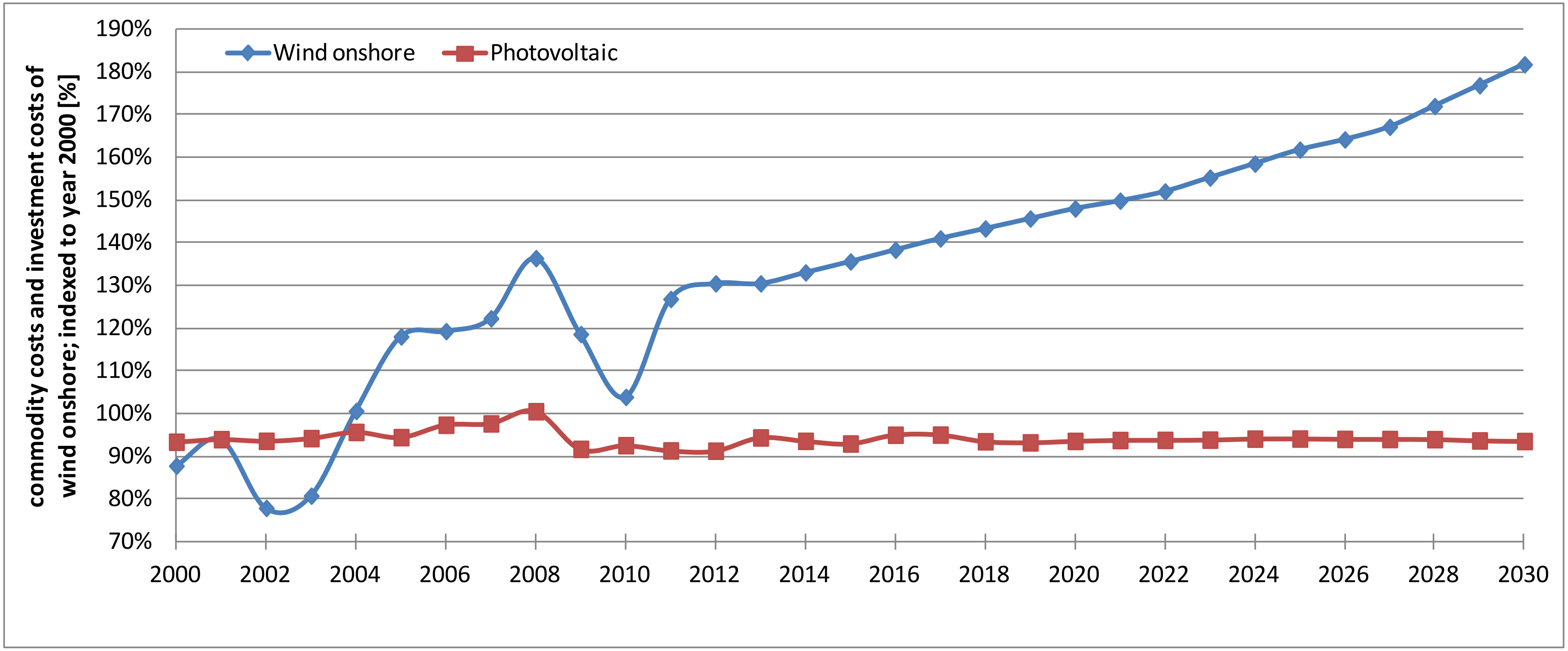

Figure: New versus traditional approach
[% - share of default (old) approximation]

Source: own calculations

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Conclusion

- **Raw material prices** are **dominated** by the **energy price development**, **BUT** also **market situations** as overcapacities, etc **impact raw material prices**
- **Long term contracts of energy, lag** the relation between **energy prices** and **commodity prices (costs)**
- **Raw material / commodity prices depend** on **various parameter** → **consideration** of solely the impact of **energy prices** indicates the **"minimal impact" on the cost for RE technologies**
- Manufacturing processes of RES technologies are constantly developing, but **companies improve their processes only by time -> time lags in the relation of commodity prices and technology investments**
- **The "multi-factor" learning approach appears a suitable complementary** (to traditional modelling techniques for technological change) for energy models **to allow an improved estimation of future cost changes**
- Due to **limited data availability** some **additional information** is required in order to **improve the statistical significance** of the econometric analyses
- **Long term projections are very uncertain**, based on limited historic data

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Thank you for your attention!

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