Trading wind power closer to real-time and other multi-market questions.

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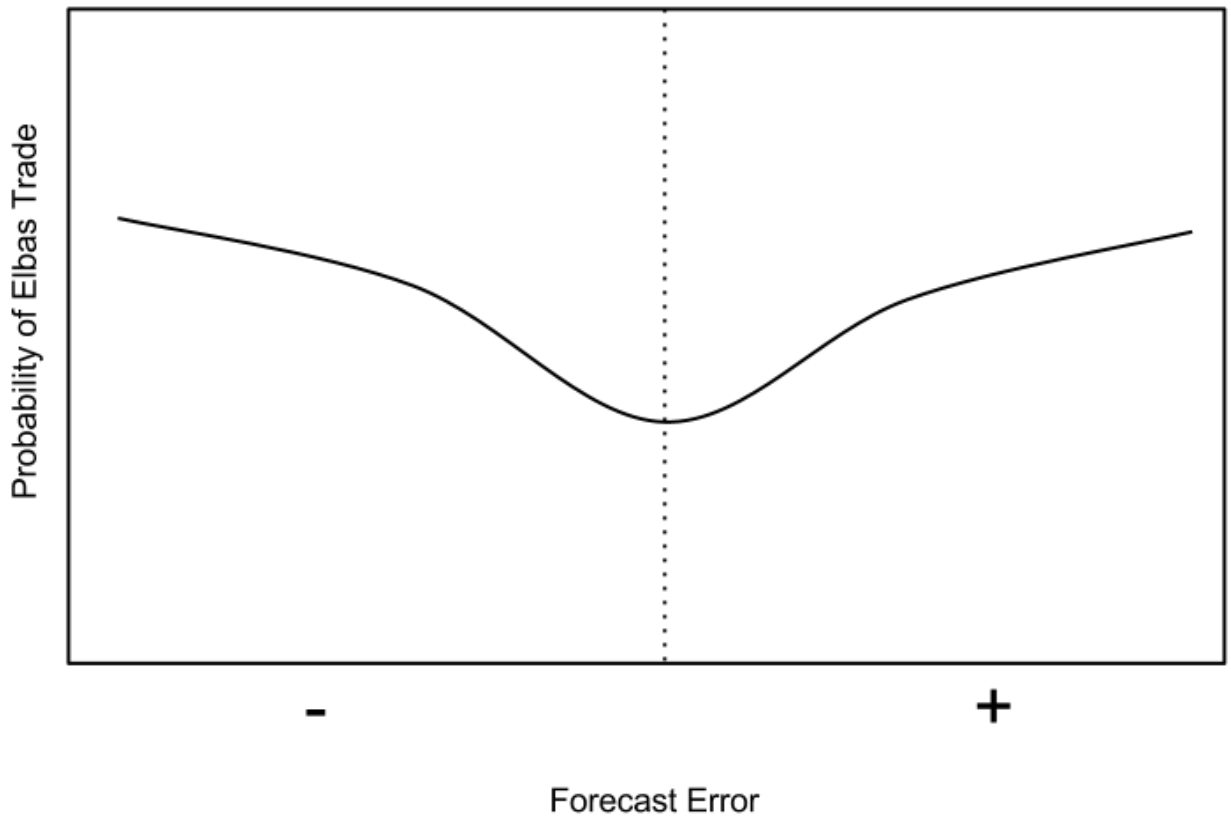
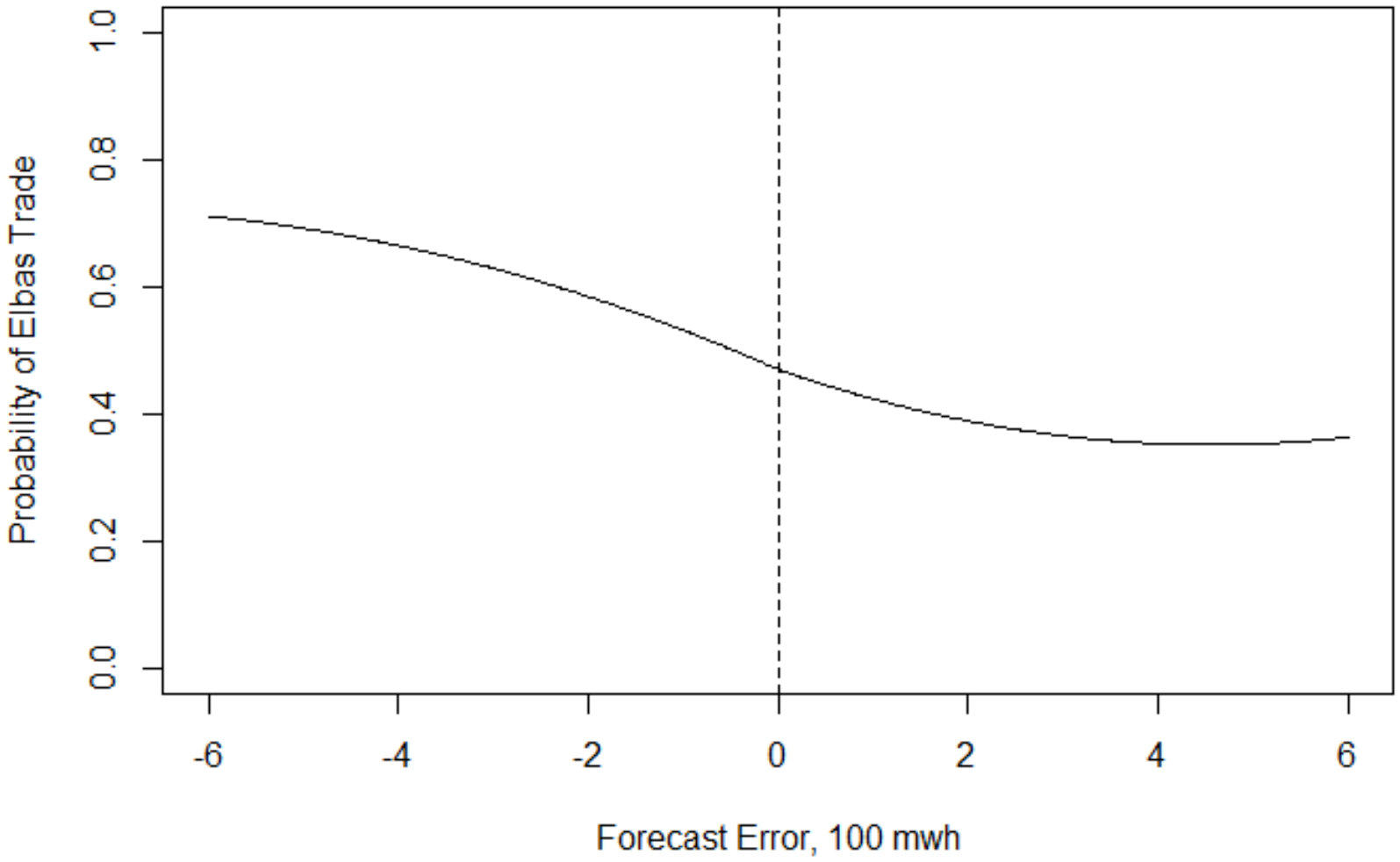
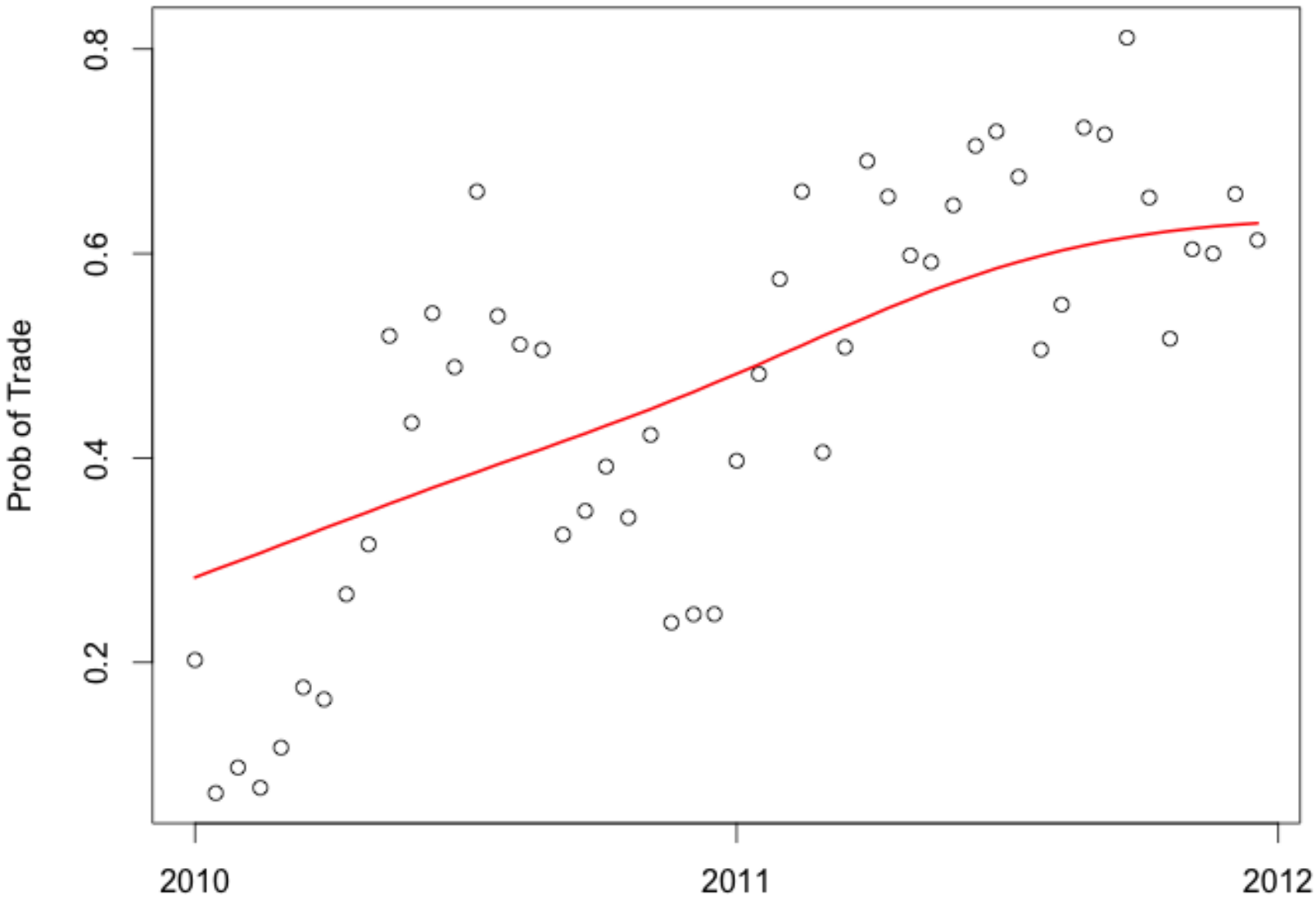
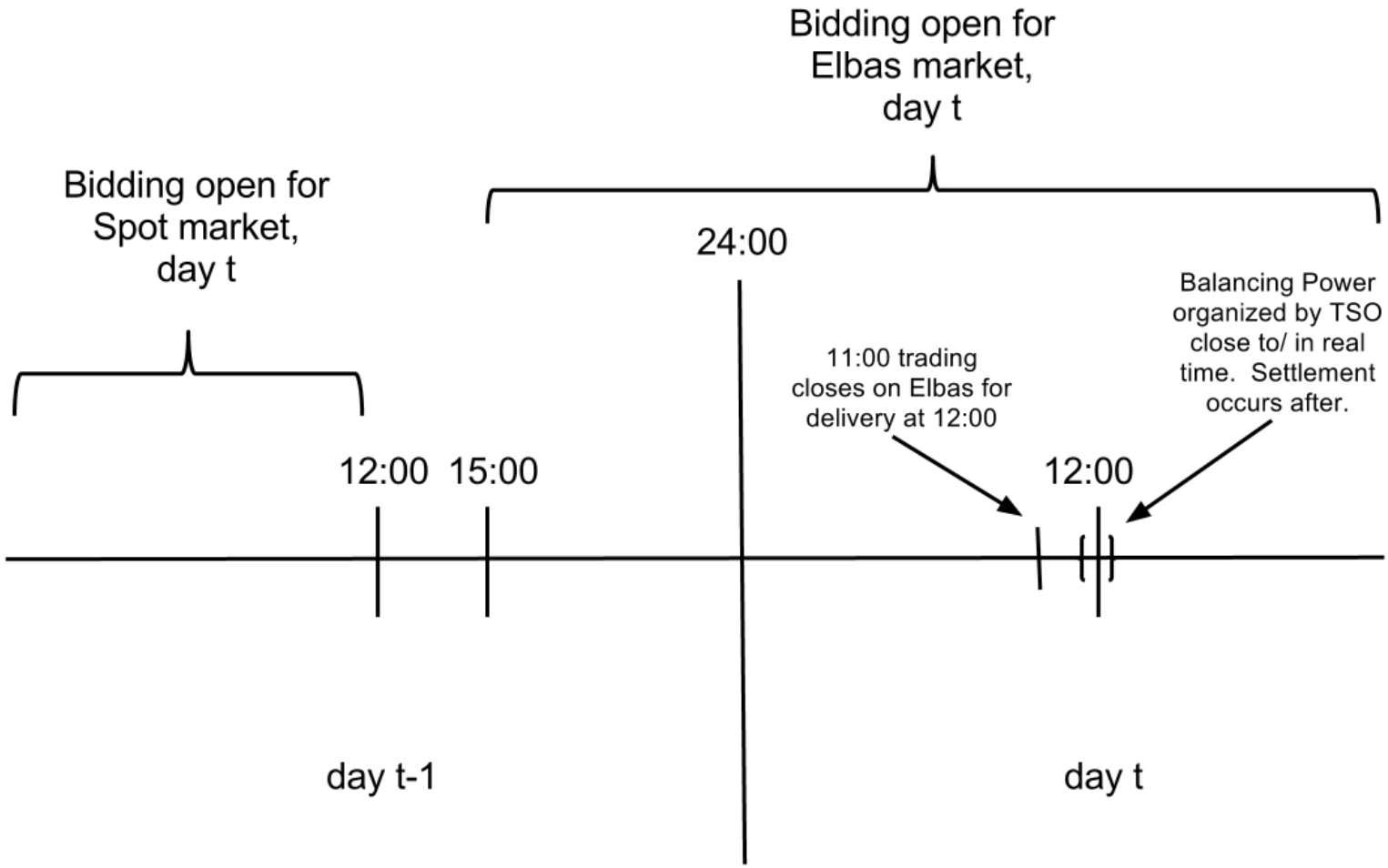

Probability of Elbas Trade
-
+
Forecast Error

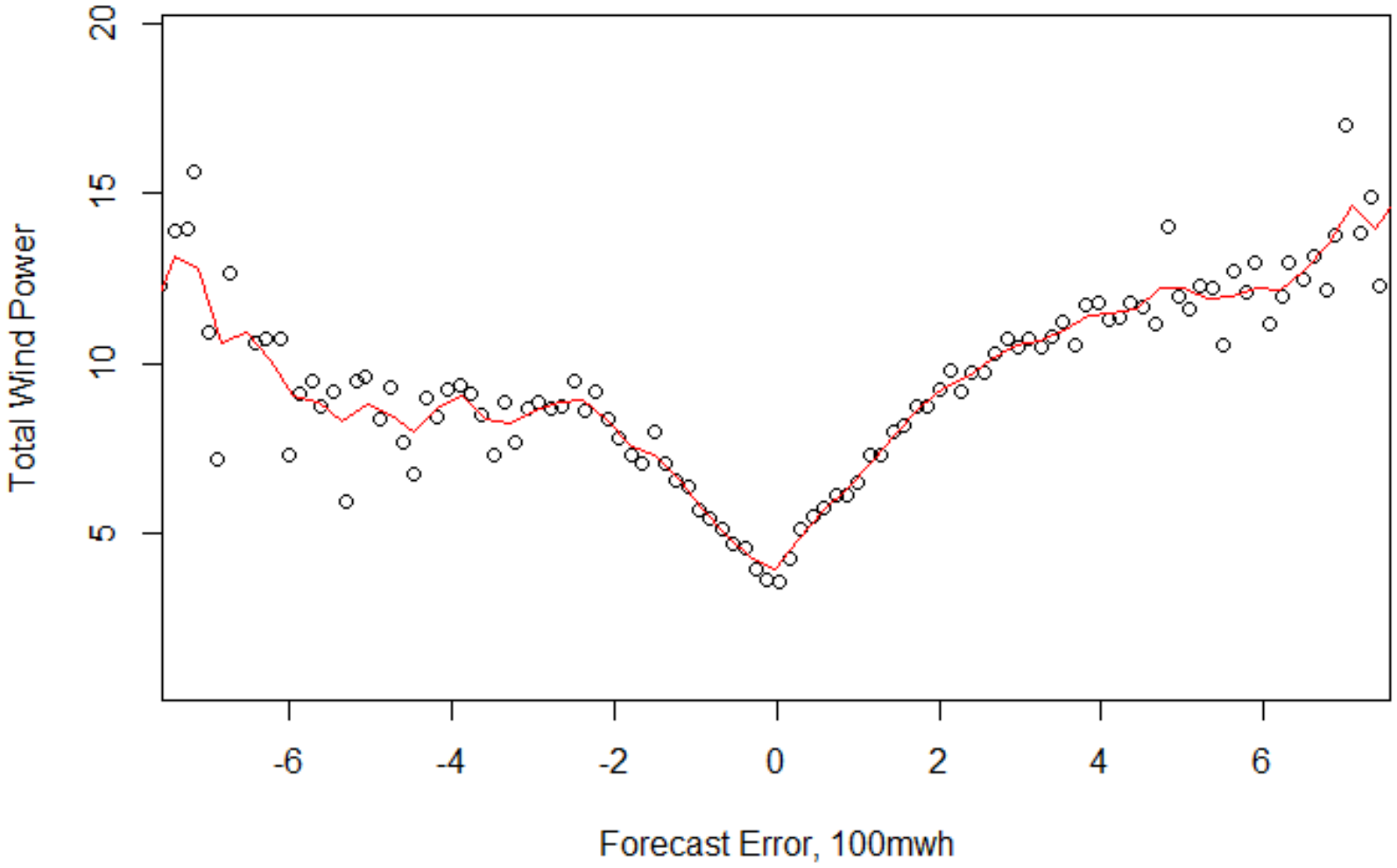

Probability of Elbas Trade
0.0
0.2
0.4
0.6
0.8
1.0
-6
-4
-2
0
2
4
6
Forecast Error, 100 mwh

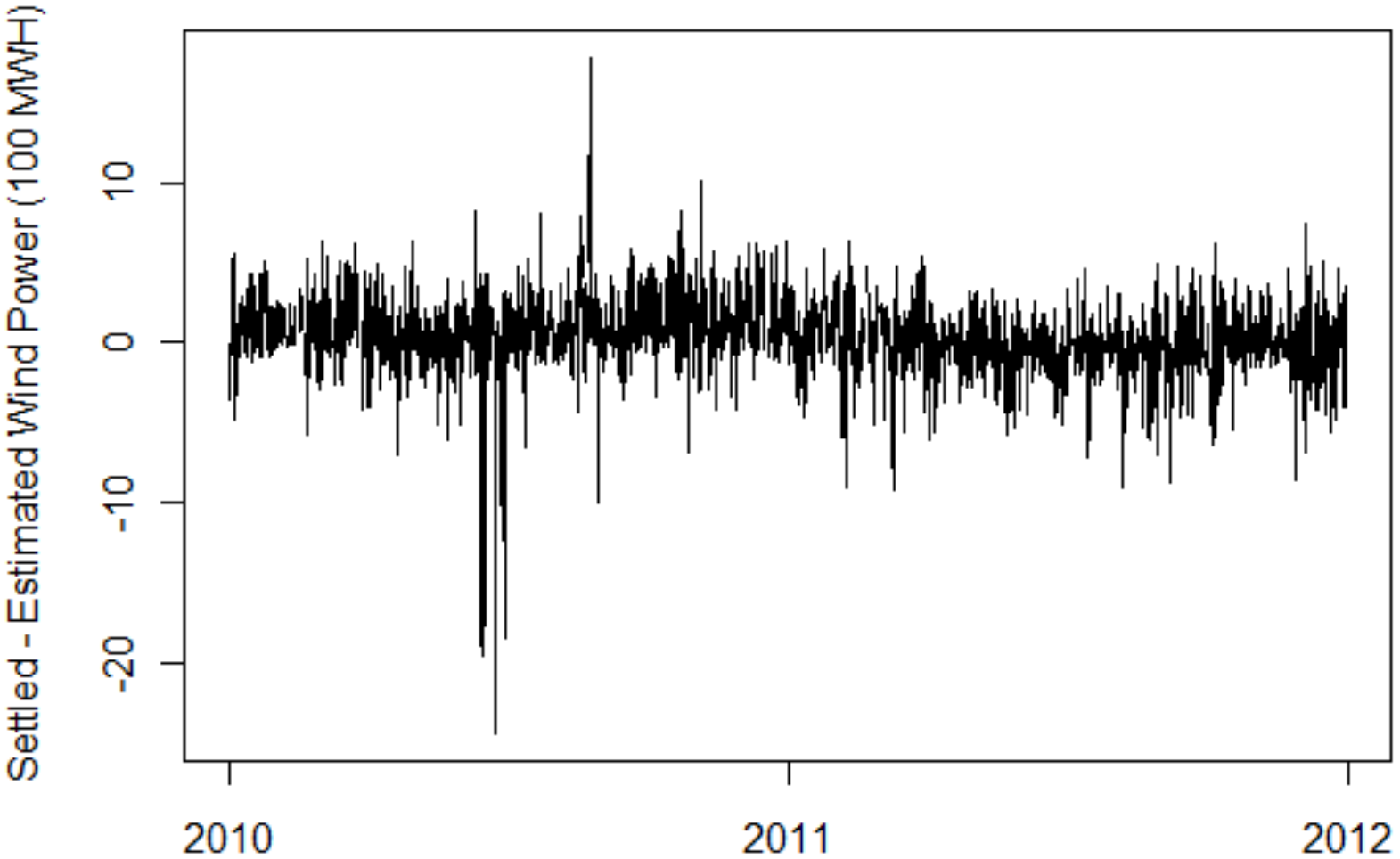
- Holttinen (2005) “Optimal Electricity Market for Wind Power”
- Holttinen et al. (2006) “Prediction Errors and Balancing Costs for Wind Power Production in Finland”


Prob of Trade
0.2
0.4
0.6
0.8
2010
2011
2012

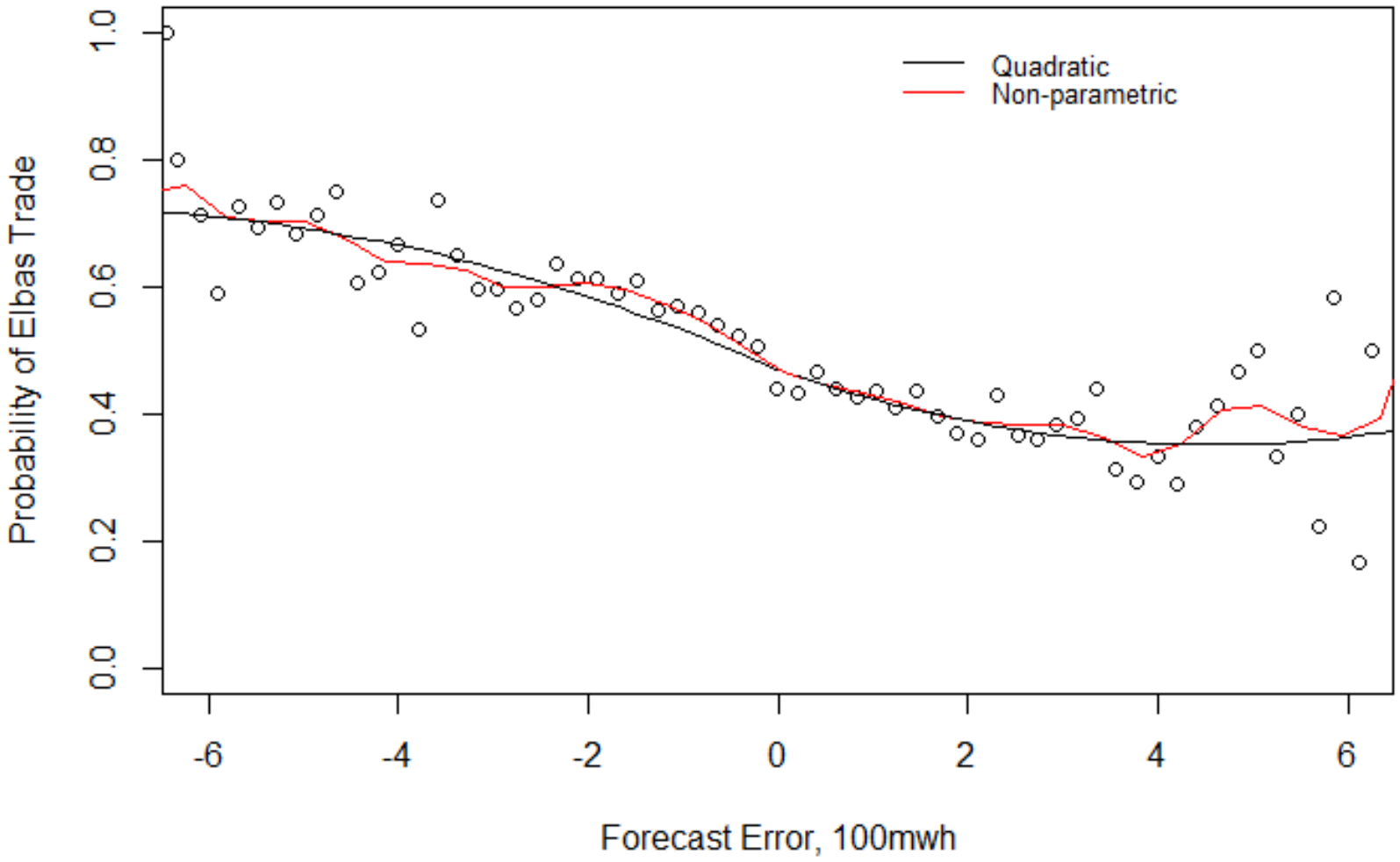
- Weber (2010) “Adequate Intraday Market Design to Enable the Integration of Wind Energy into the European Power Systems”

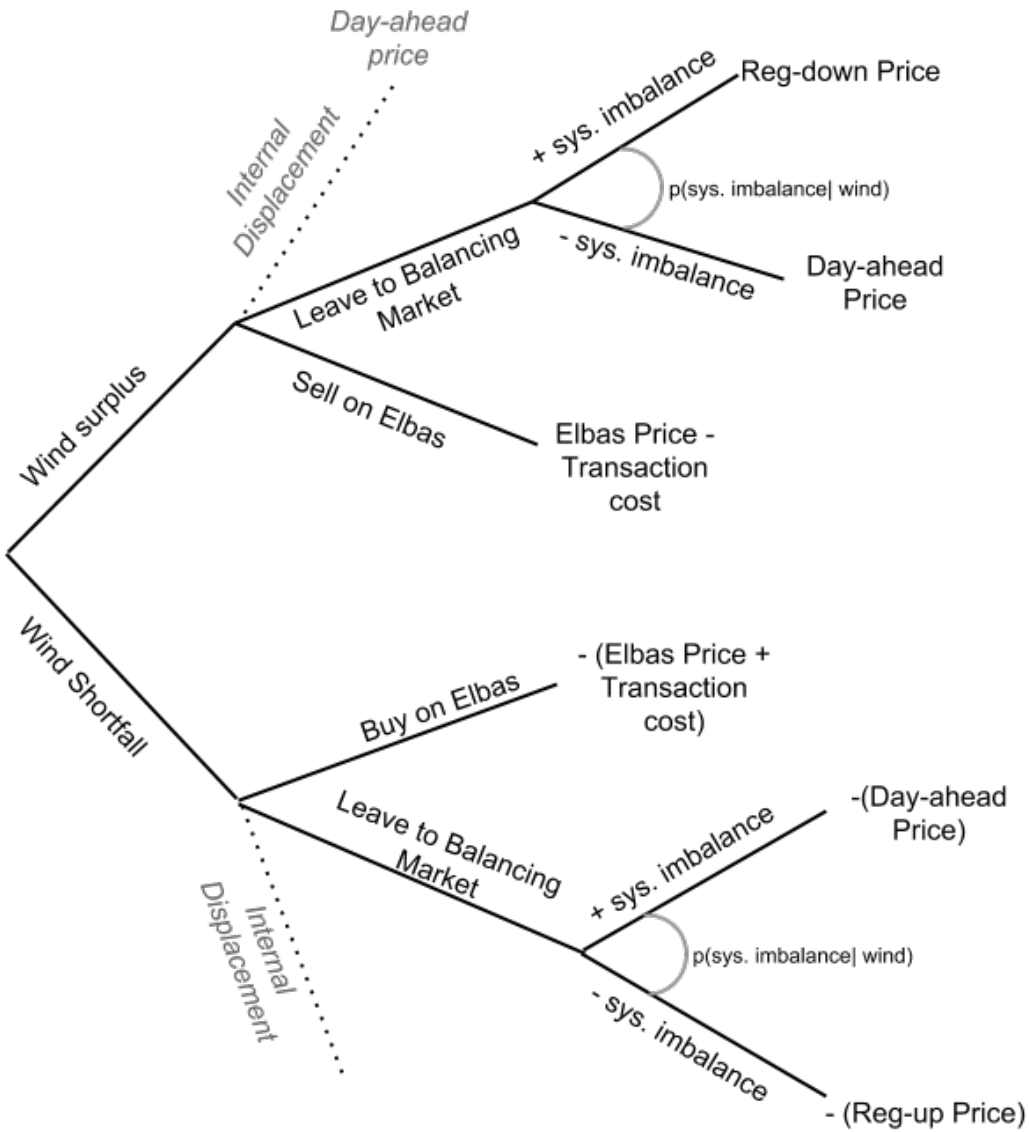

Bidding open for
Elbas market,
day t
Bidding open for
Spot market,
day t
24:00
Balancing Power
organized by TSO
close to/ in real
time. Settlement
occurs after.
11:00 trading
closes on Elbas for
delivery at 12:00
12:00
15:00
12:00
day t-1
day t

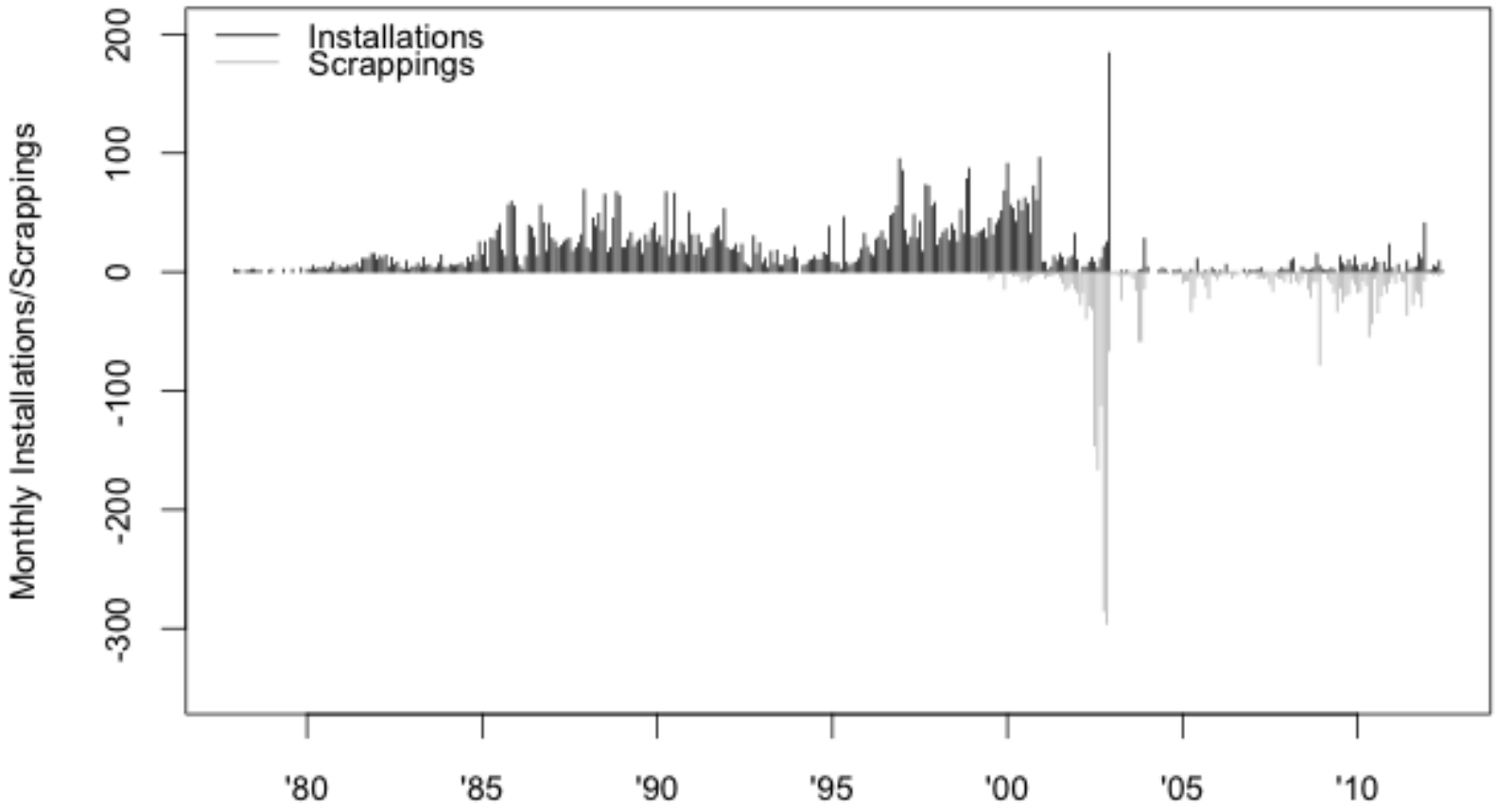

Total Wind Power
20
15
10
5
-6
-4
-2
0
2
4
6
Forecast Error, 100mwh

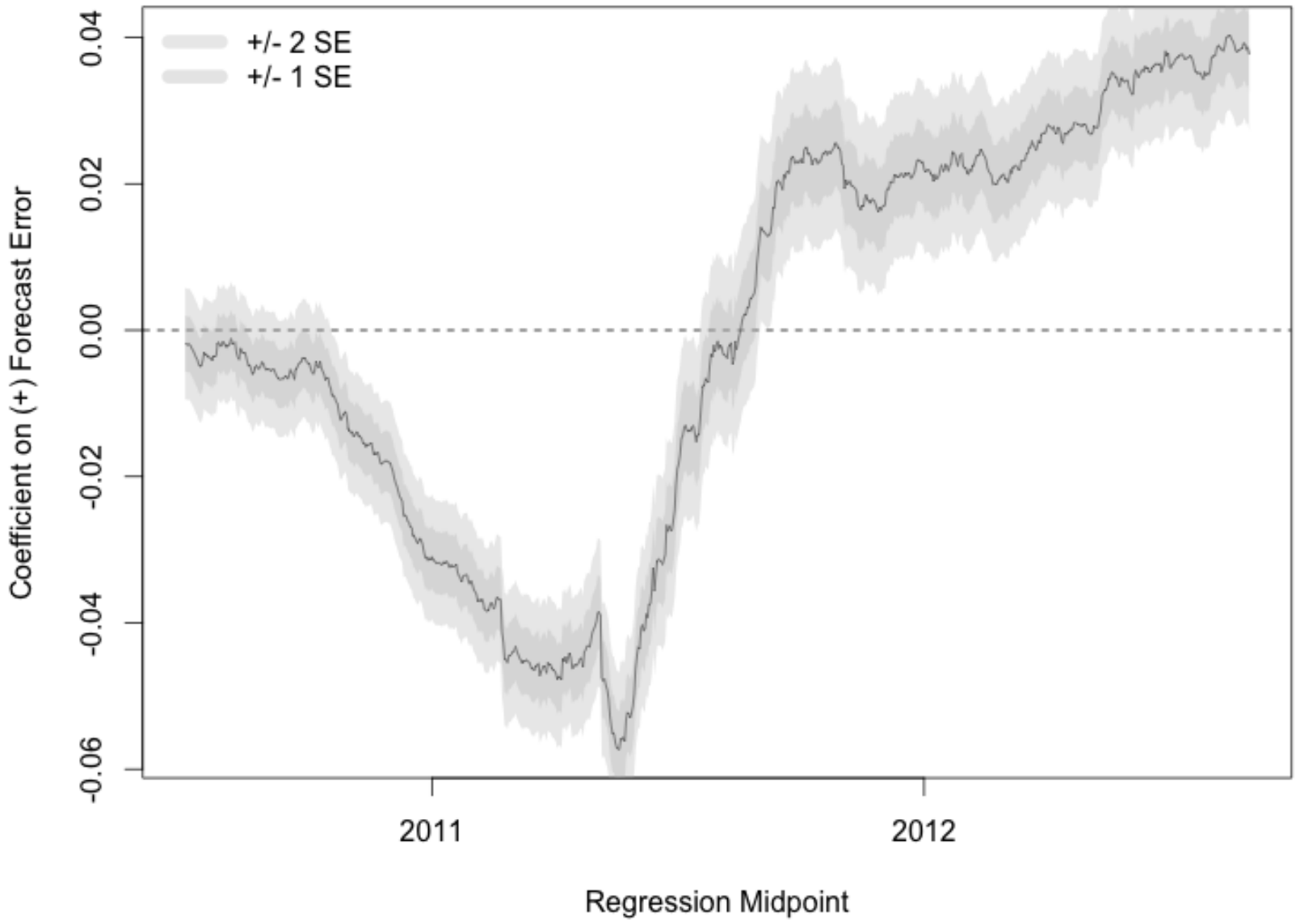

Settled - Estimated Wind Power (100 MWH)
10
0
-10
-20
2010
2011
2012

$$Prob_t^{Elbas} = \alpha + \beta_1 forError_t^+ + \beta_2 (forError^+)_t^2 + \beta_3 forError_t^- + \beta_4 (forError^-)_t^2 + \epsilon_t \quad (1)$$


Quadratic
Non-parametric
Probability of Elbas Trade
0.0
0.2
0.4
0.6
0.8
1.0
-6
-4
-2
0
2
4
6
Forecast Error, 100mwh

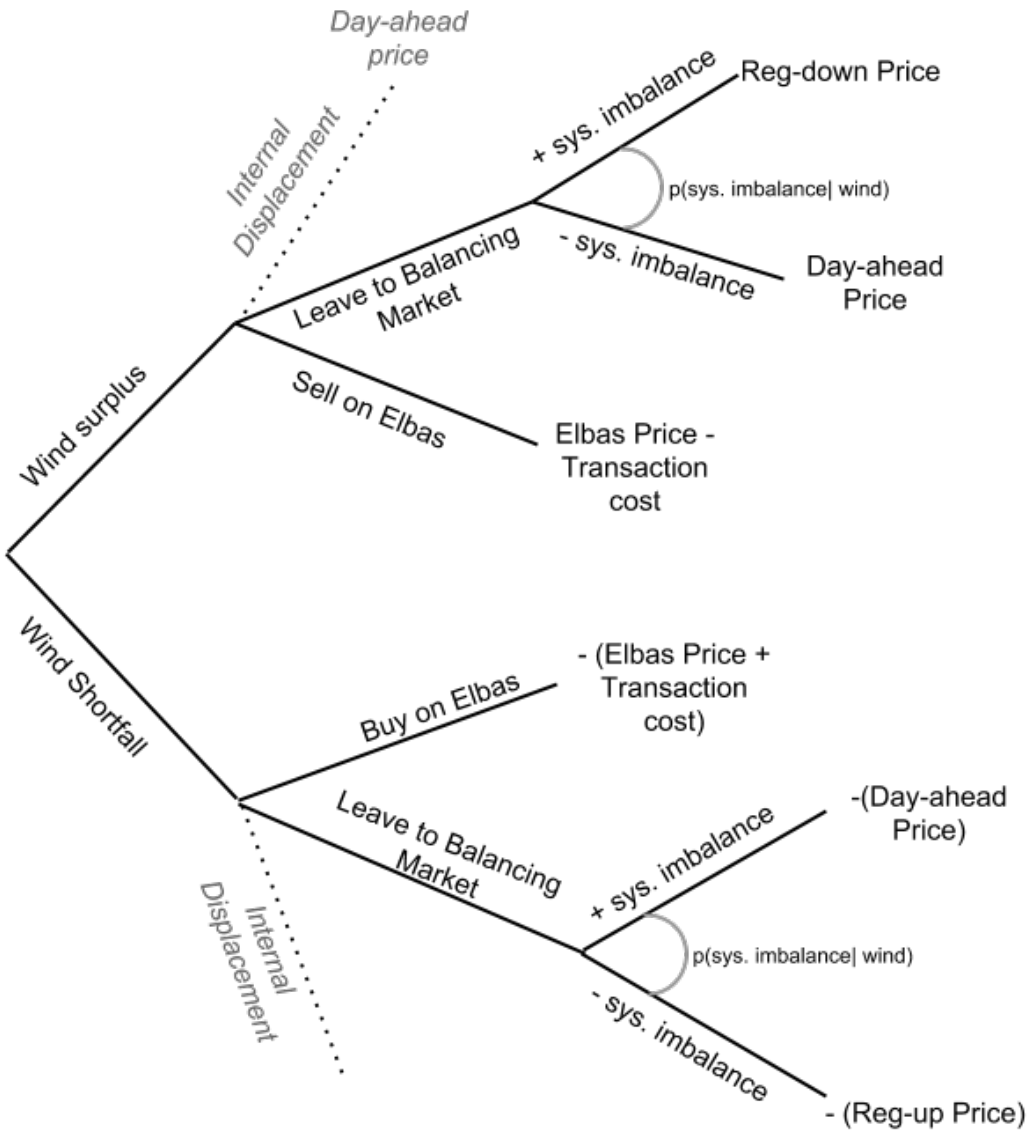

Day-ahead price
Internal Displacement
+ sys. imbalance
Reg-down Price
p(sys. imbalance| wind)
- sys. imbalance
Day-ahead Price
Leave to Balancing Market
Sell on Elbas
Elbas Price - Transaction cost
Wind surplus
Wind Shortfall
Buy on Elbas
- (Elbas Price + Transaction cost)
Leave to Balancing Market
-(Day-ahead Price)
+ sys. imbalance
p(sys. imbalance| wind)
- sys. imbalance
- (Reg-up Price)
Internal Displacement


Installations
Scrappings
Monthly Installations/Scrappings
200
100
0
-100
-200
-300
'80
'85
'90
'95
'00
'05
'10


+/- 2 SE
+/- 1 SE
0.04
0.02
0.00
-0.02
-0.04
-0.06
Coefficient on (+) Forecast Error
2011
2012
Regression Midpoint

Trade on Elbas Decision Rule:

$$E(\pi_{elbas}) > E(\pi_{balancing})) \tag{2}$$


Day-ahead price
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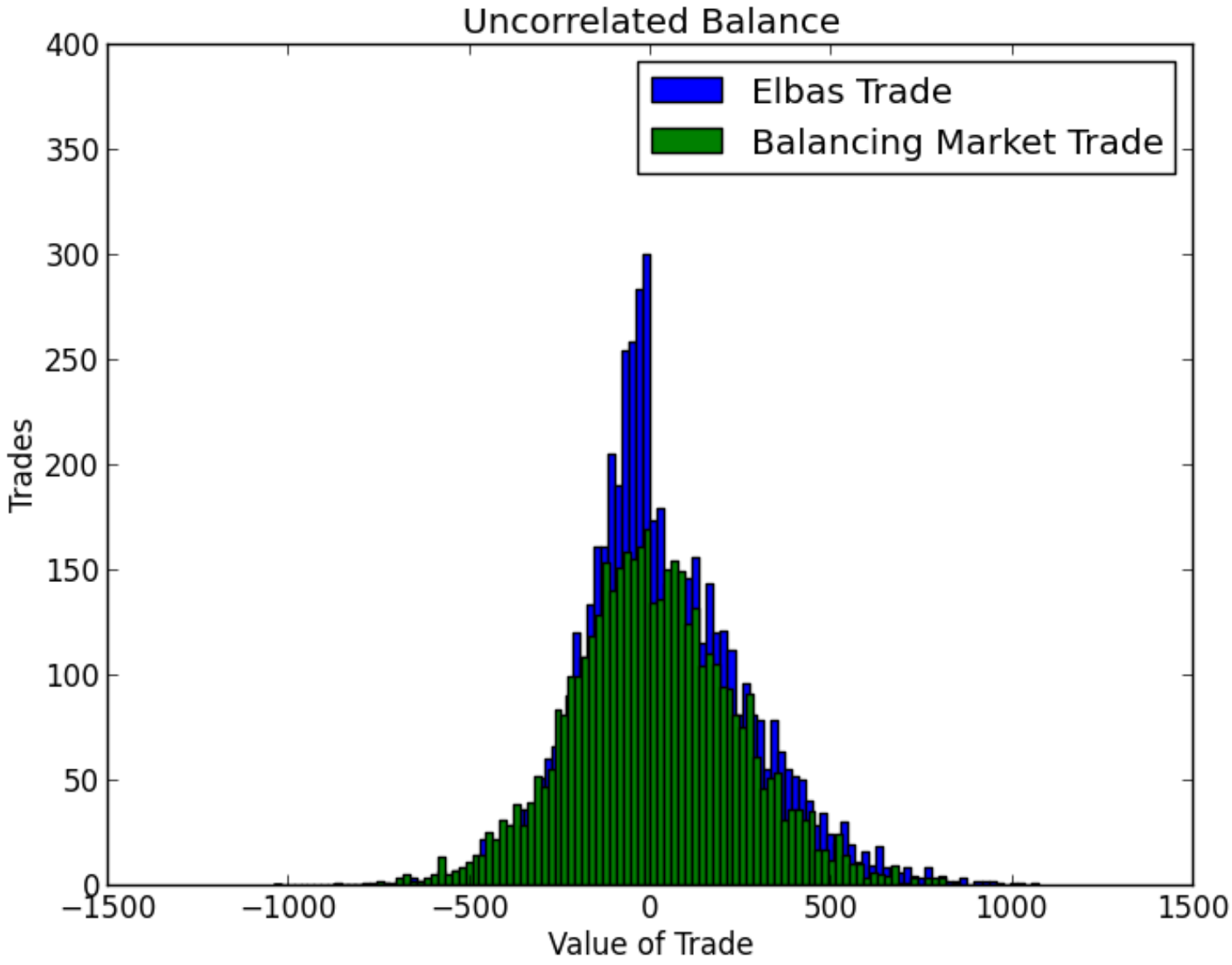
Day-ahead Price
Leave to Balancing Market
Sell on Elbas
Elbas Price - Transaction cost
Wind surplus
Wind Shortfall
Buy on Elbas
- (Elbas Price + Transaction cost)
Leave to Balancing Market
-(Day-ahead Price)
+ sys. imbalance
p(sys. imbalance| wind)
- sys. imbalance
- (Reg-up Price)
Internal Displacement

$$
\begin{aligned}
pi_{elbas} &= p_{elbas} * q_{imbalance} - t \\
pi^{+}_{balancing} &= \theta * E(P_{regDown}) * q^{+}_{imbalance} + (1-\theta) * p_{spot} * q^{+}_{imbalance} \\
pi^{-}_{balancing} &= \theta * p_{spot} * q^{-}_{imbalance} + (1-\theta) * E(P_{regUp}) * q^{-}_{imbalance}
\end{aligned}
$$

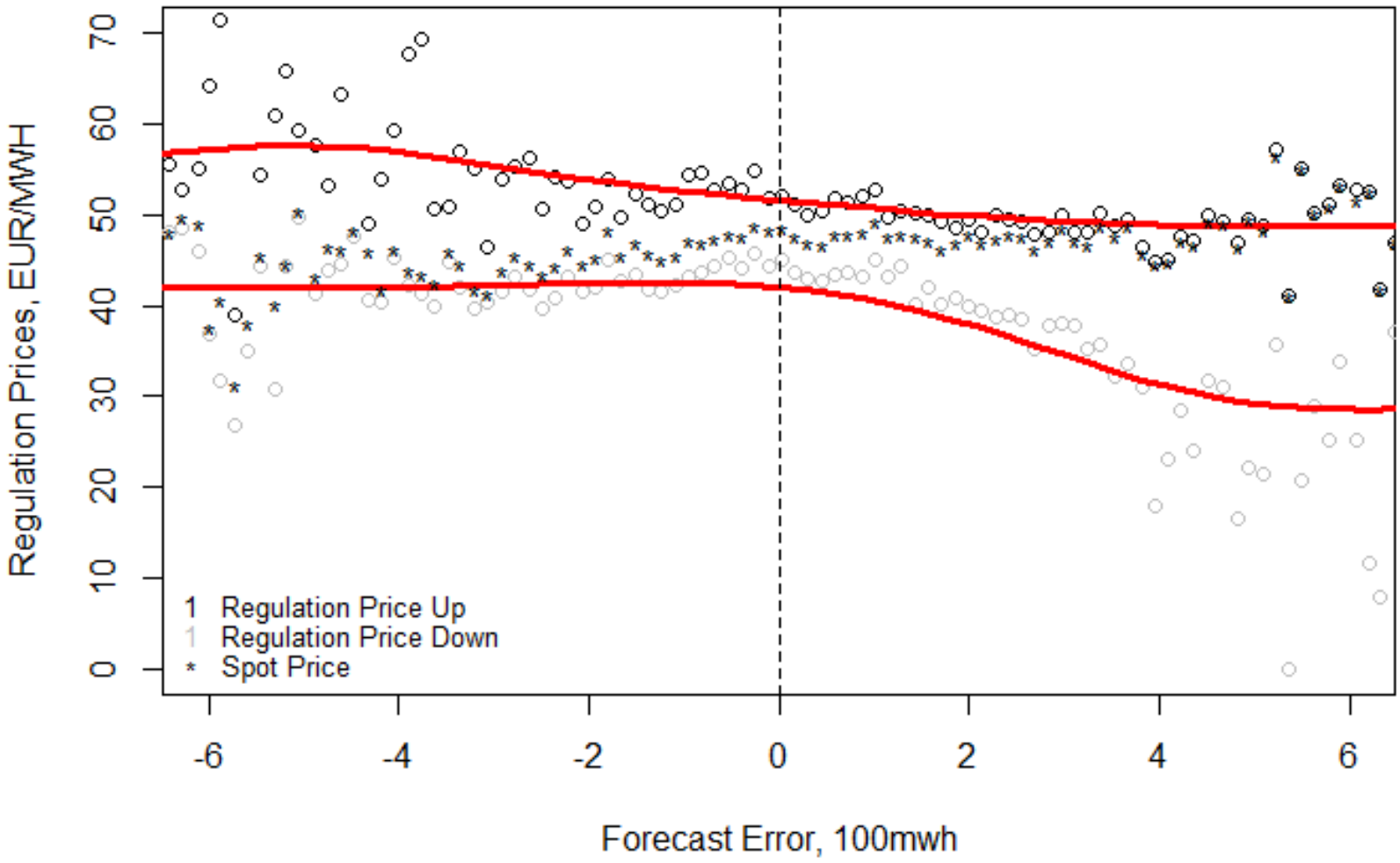
Simulated Data (Very Unrealistic!)

$$
\begin{aligned}
imbalance_i &\sim N(0, capcity/4) \\
p_{spot} &\sim N(30, 10) \\
p_{elbas} &= p_{spot} + \epsilon \\
p_{regDown} &= p_{spot} - abs(\epsilon) \\
p_{regUp} &= p_{spot} + abs(\epsilon) \\
\epsilon &\sim N(0, 4) \\
\Theta = .5 & t = 0
\end{aligned}
$$


Uncorrelated Balance
Elbas Trade
Balancing Market Trade
Trades
Value of Trade
400
350
300
250
200
150
100
50
0
−1500
−1000
−500
0
500
1000
1500

Extensions

- θ (system imbalance) correlated with generator imbalance
- Elbas and Regulation Prices Correlated with Wind Power Imbalances


Regulation Prices, EUR/MWH
0
10
20
30
40
50
60
70
-6
-4
-2
0
2
4
6
Forecast Error, 100mwh
1 Regulation Price Up
1 Regulation Price Down
* Spot Price

Extensions

- θ (system imbalance) correlated with generator imbalance
- Elbas and regulation prices correlated with wind power imbalances
- Strategic interactions