A Structural Model to Evaluate the Transition from Self Unit Commitment to Centralized Unit Commitment

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Plan of presentation

- Introduction

- Model and methodology
  - ✓ Marginal and opportunity costs
  - ✓ Counterfactuals

- Results: Competitive benchmark vs Bid-based simulation
  - ✓ Hydro and thermal generation
  - ✓ Economic efficiency

- Conclusions and extensions

Introduction

- **Different dispatch models**: Self Unit commitment vs.. Centralize Unit Commitment.

Introduction: Self Unit Commitment

- Before 2009 generators submitted **simple energy bids** (one price for 24 hours and declared hourly generating capacity).

- System operator (XM) solved optimization problem: **Reduce hourly total generating variable costs** (similar to uniform auction)**.**

- Plants self commit: Risk of not covering startup costs (**self unit commitment**).

Introduction: Centralized Unit Commitment

➢ After 2009 generators submitted **“complex bids”**: “simple bids” + startup and shut down costs.

➢ System operator (XM) solved optimization problem: **Reduce day total costs.**

➢ System operator commits plants: No risk of not recovering startup costs (**centralized unit commitment**).

Introduction: Inneficiency Problem

- **Self Unit Commitment:**

- In the **presence of non-convexities**, self-committed uniform price auctions with energy only offer prices can lead to productive inefficiencies:

  - ✓ **Thermal units face an unnecessary risk** when restricted to submit energy only offer prices.

  - ✓ **Turning off thermal plants** that are already running and turning on a lower marginal cost unit could result in inefficient production due to ignoring startup costs.

Introduction: Incentives Problem

- **Centralized Unit Commitment:**

- The mechanism is meant to improve **productive efficiency**.

- But the **mechanism used to solicit generator data**, upon which the market clearing prices and settlements are based, may compel generators to overstate costs.

- This incentive to overstate costs is also true of self-commitment in an energy exchange, but **complex bids allow for further strategic behavior.**

Introduction: Empirical Problem

- There are no theoretical studies with **clear-cut results** that rank the performance of one design relative the other, so the question remains an empirical one.

- **It is an empirical problem**: This study proposes a structural model of the dispatch to evaluate empirically the ultimate benefits (if any) of the 2009 regulatory intervention in Colombia.

Introduction: Related Literature

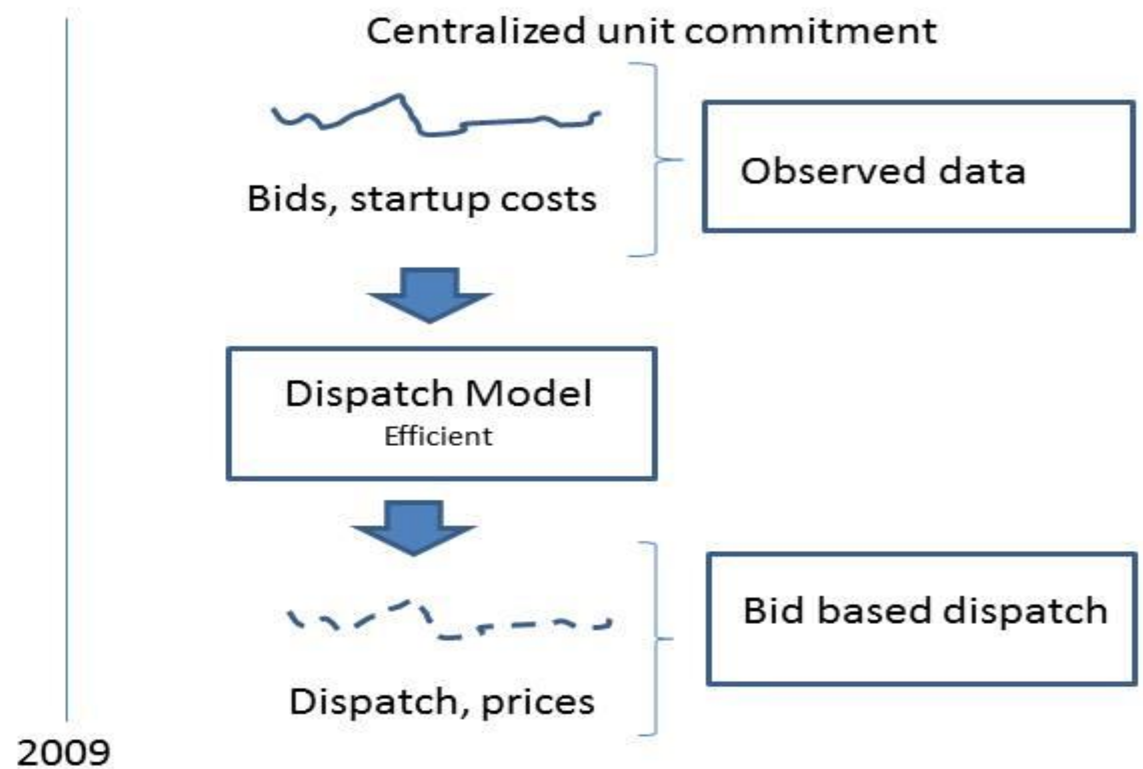
- Centralized unit commitment: Sioshansi, O’Neill and Oren (2008), (2008b), (2010), O’Neill, Sotkiewicz, Hobbs, B.F., Rothkopf, and Stewart, (2005).

- Incentives: Sioshani, Oren and O’Neill (2010) provide a stylized example which shows that self-commitment in an energy exchange can result in inefficient production of energy even if generators are price takers. This is a phenomenon due only to non-convexities in the cost structure of some generating units.

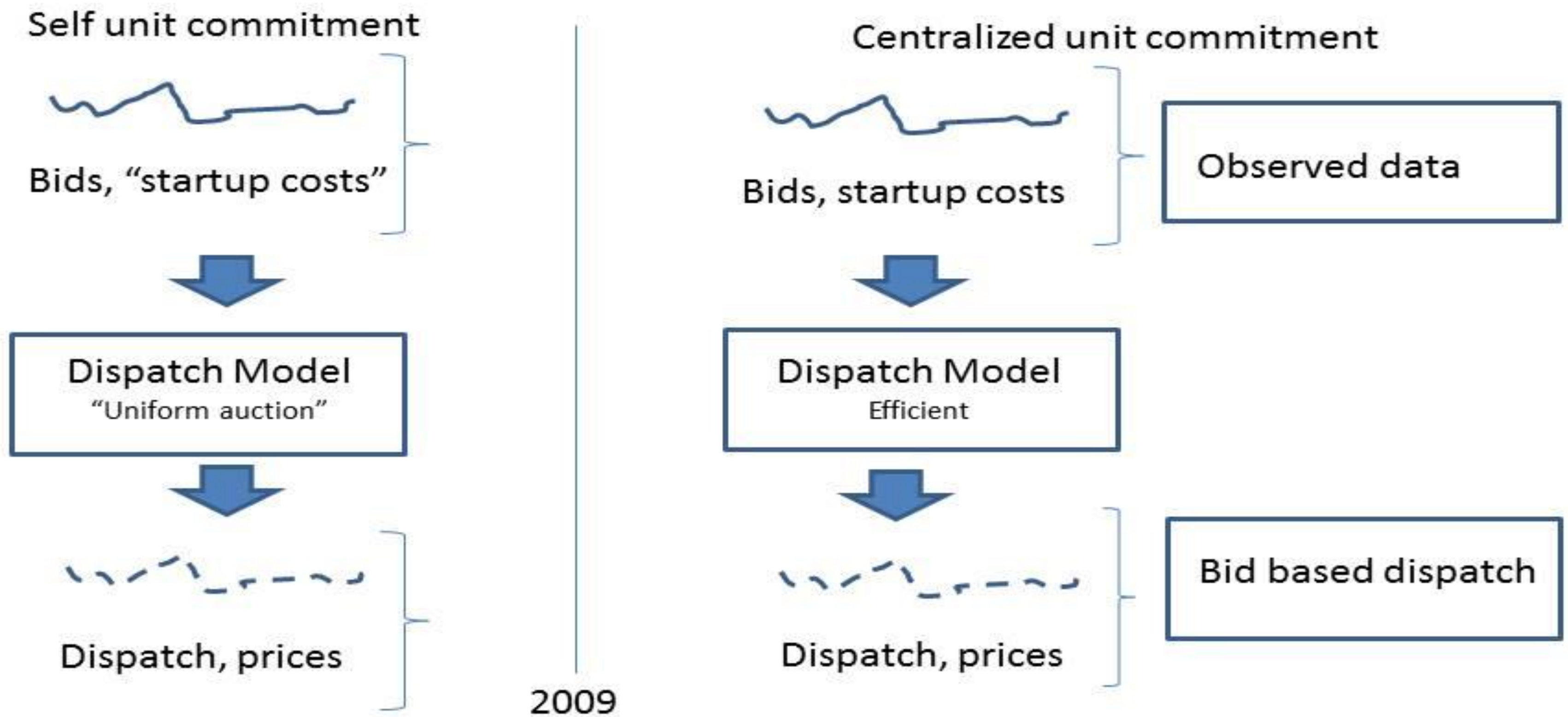
- Theory: Sioshansi and Nicholson (2011)

- Econometric: Riascos, Bernal, de Castro and Oren (2015). The Energy Journal. (2015).

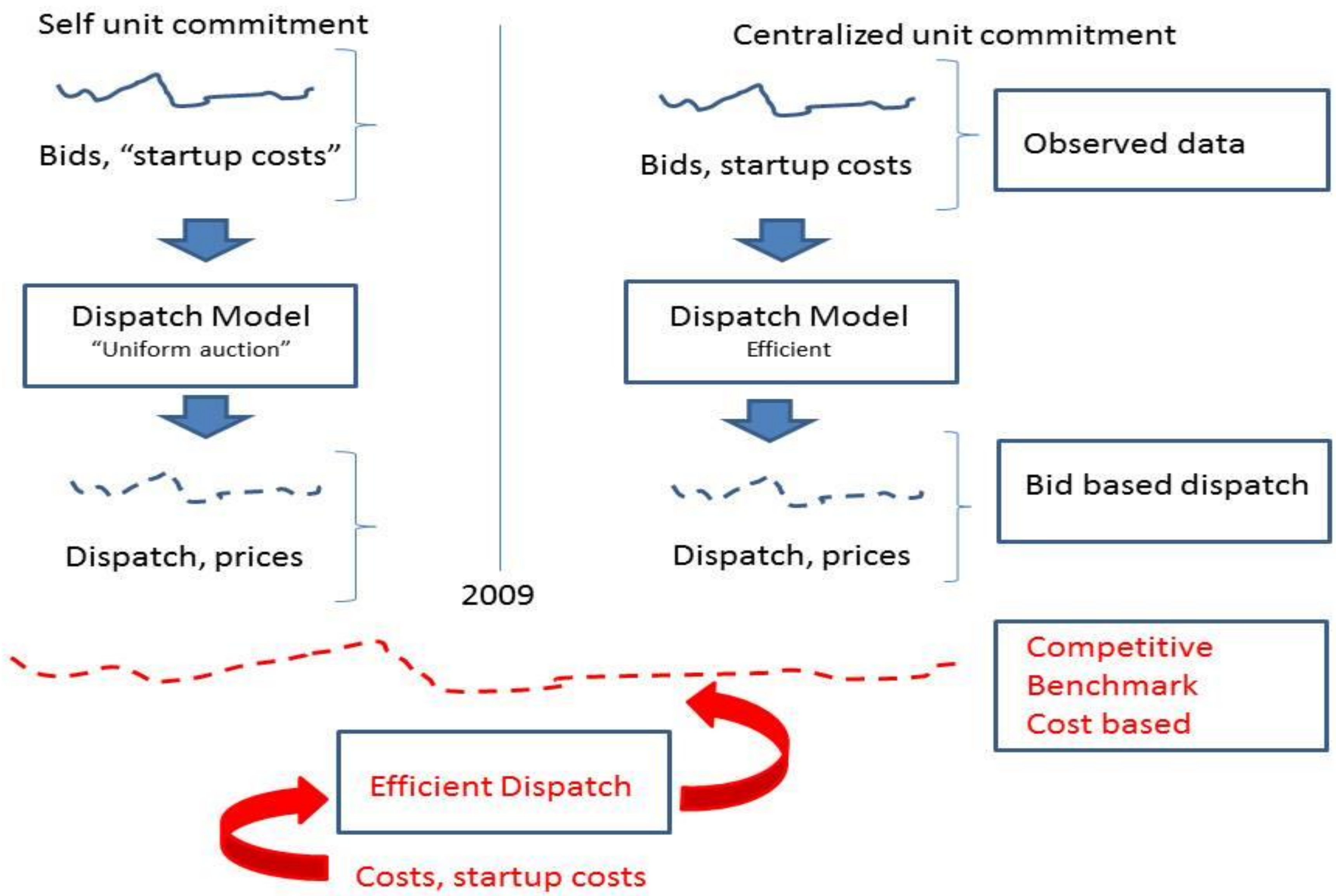
Model and Methodology: General View



Model and Methodology



Model and Methodology



Model and Methodology: Efficient Dispatch

➢ Optimization problem:

$$\min_{p_{i,t},p_{i,t}^{soak},p_{i,t}^{disp},p_{i,t}^{des},s_{i,t},h_{i,t},u_{i,t},u_{i,t}^{soak},u_{i,t}^{disp},u_{i,t}^{des}} \sum_{t=0,\ldots,23} \sum_{i} Pof_i \times p_{i,t} + Par_i s_{i,t}$$

➢ Subject to **many restrictions** (seventeen thousand equations): demand, thermal plants technical restrictions, hydro plants environmental restrictions.

Model and Methodology: Efficient Dispatch

- The marginal price MPO_t is calculated as the price bid of the marginal plant that is flexible.

- The hourly spot price P_t is defined as:

$$P_i = MPO_t + \Delta I$$

- ΔI is the uplift (transfer payments):

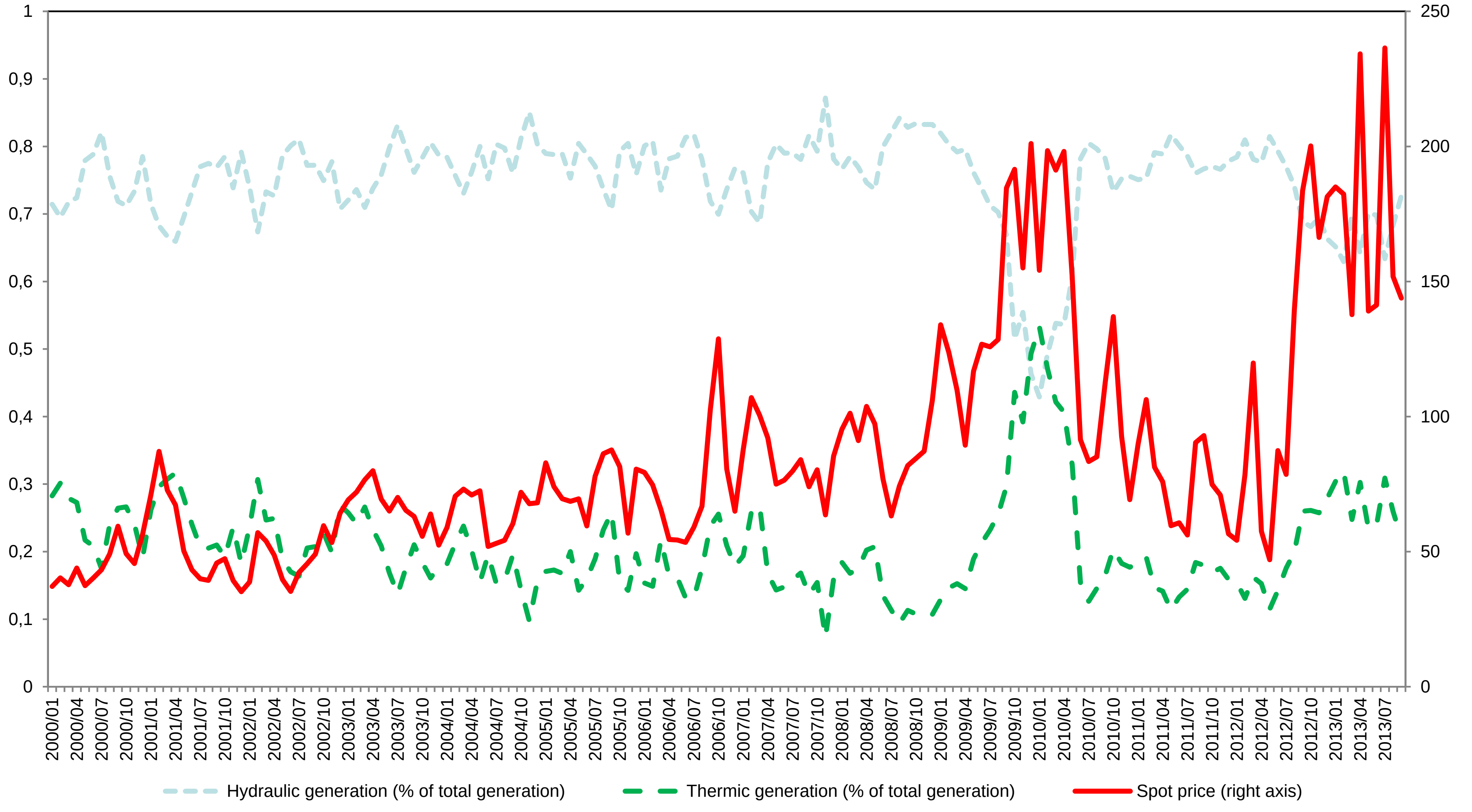
$$\Delta I = \frac{\sum_i \max\{0, C_i - R_i\}}{\sum_{t=1}^{24} D_t}$$

- R_i revenue, C_i cost.

Model and Methodology: Data

- National demand
- 50 plants (30 thermal plants, 20 hydro).
- Marginal costs
- Opportunity costs,
- Start up and shut down costs.
- Technical parameters (thermal plants)
- Enviormental restrictions.

Model and Methodology: Data



Model and Methodology: Costs

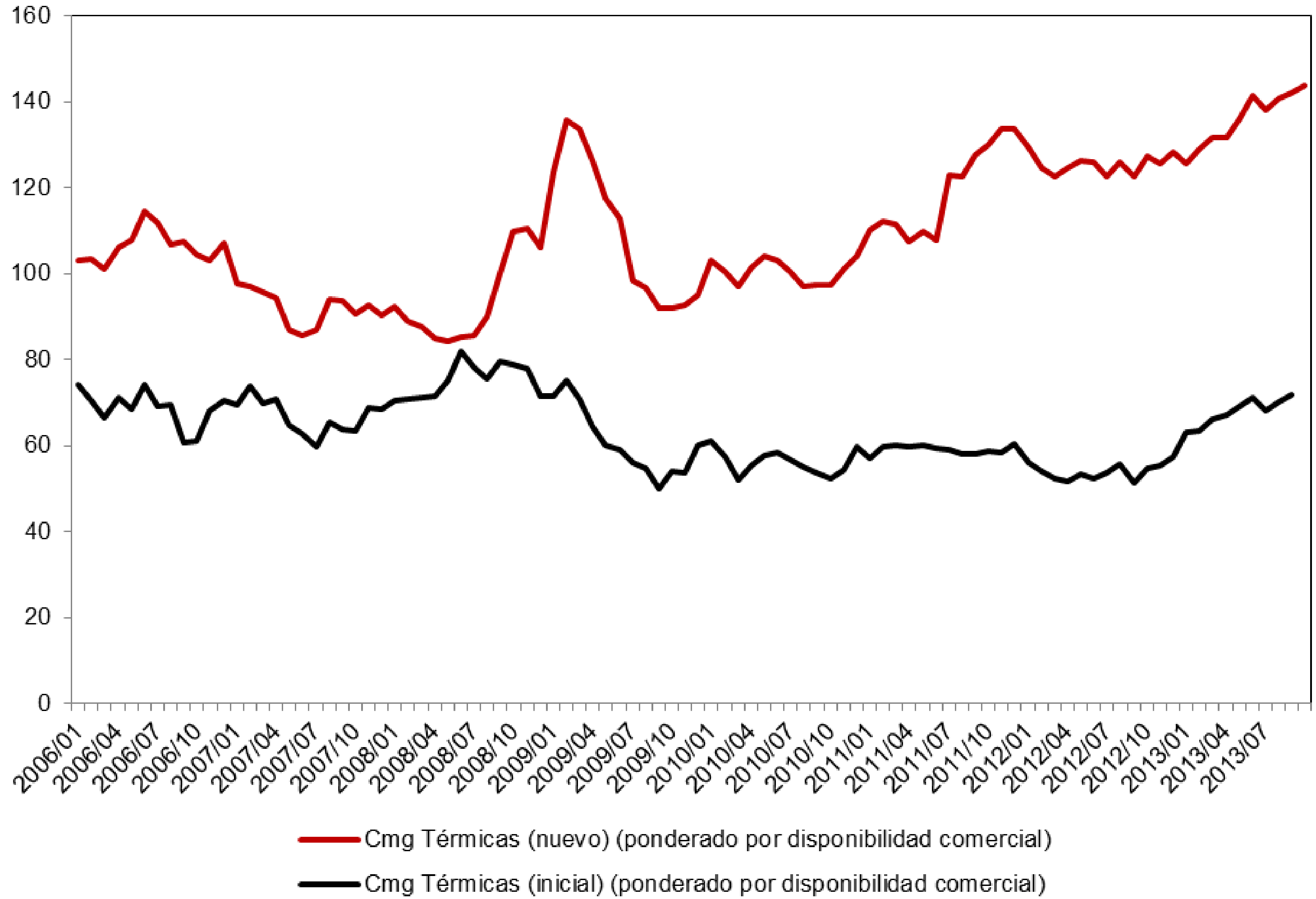
- Marginal costs

$$\text{Marginal Cost } = \frac{\text{Heat Rate}}{\text{Calorific Value}} * \text{P} + \text{VOM} + \text{TAXES}$$

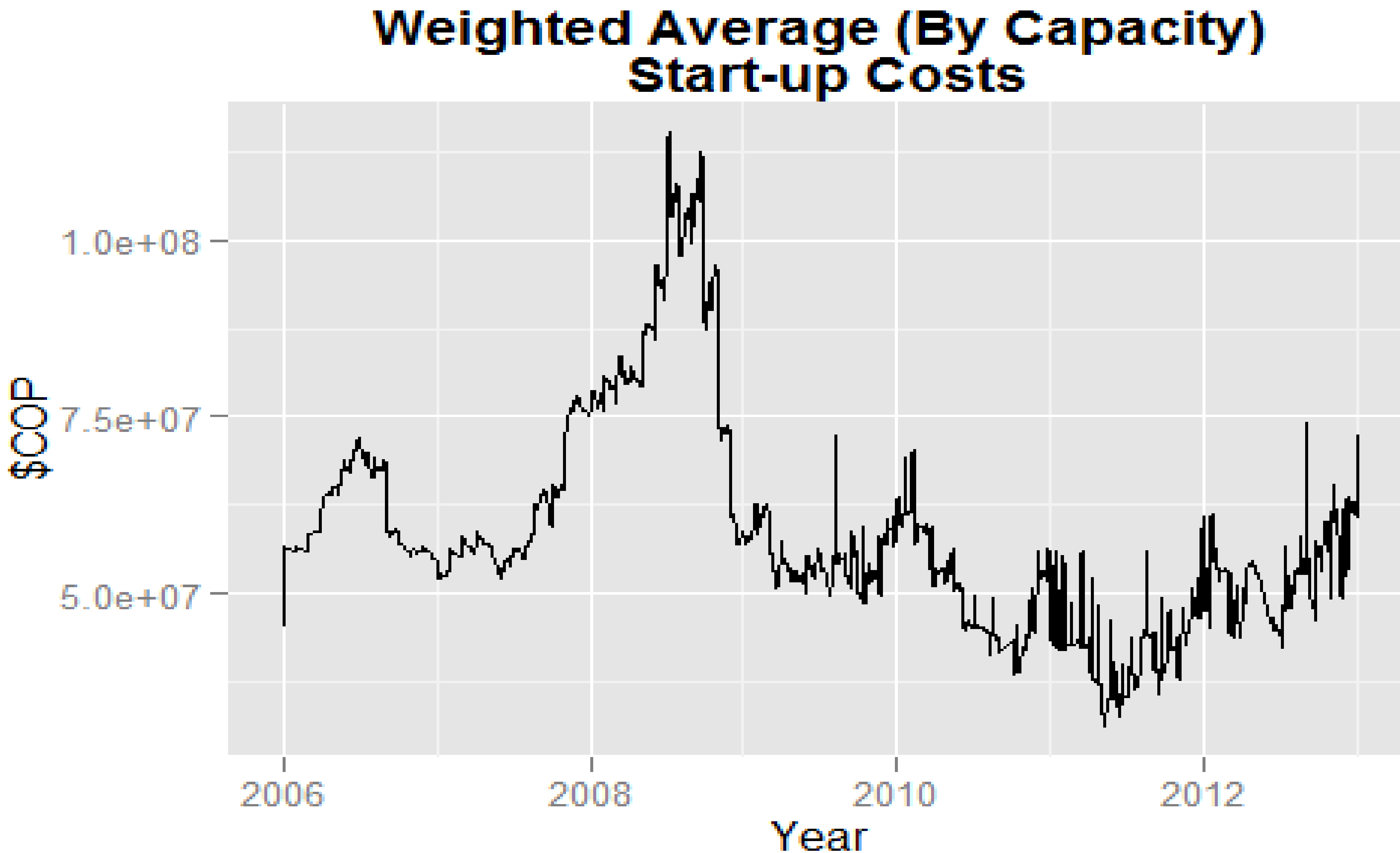
- Opportunity costs

$$\widehat{MC_{gt}} = \min\left(ThermoMPO_{gt}, Bid_{gt}\right),$$

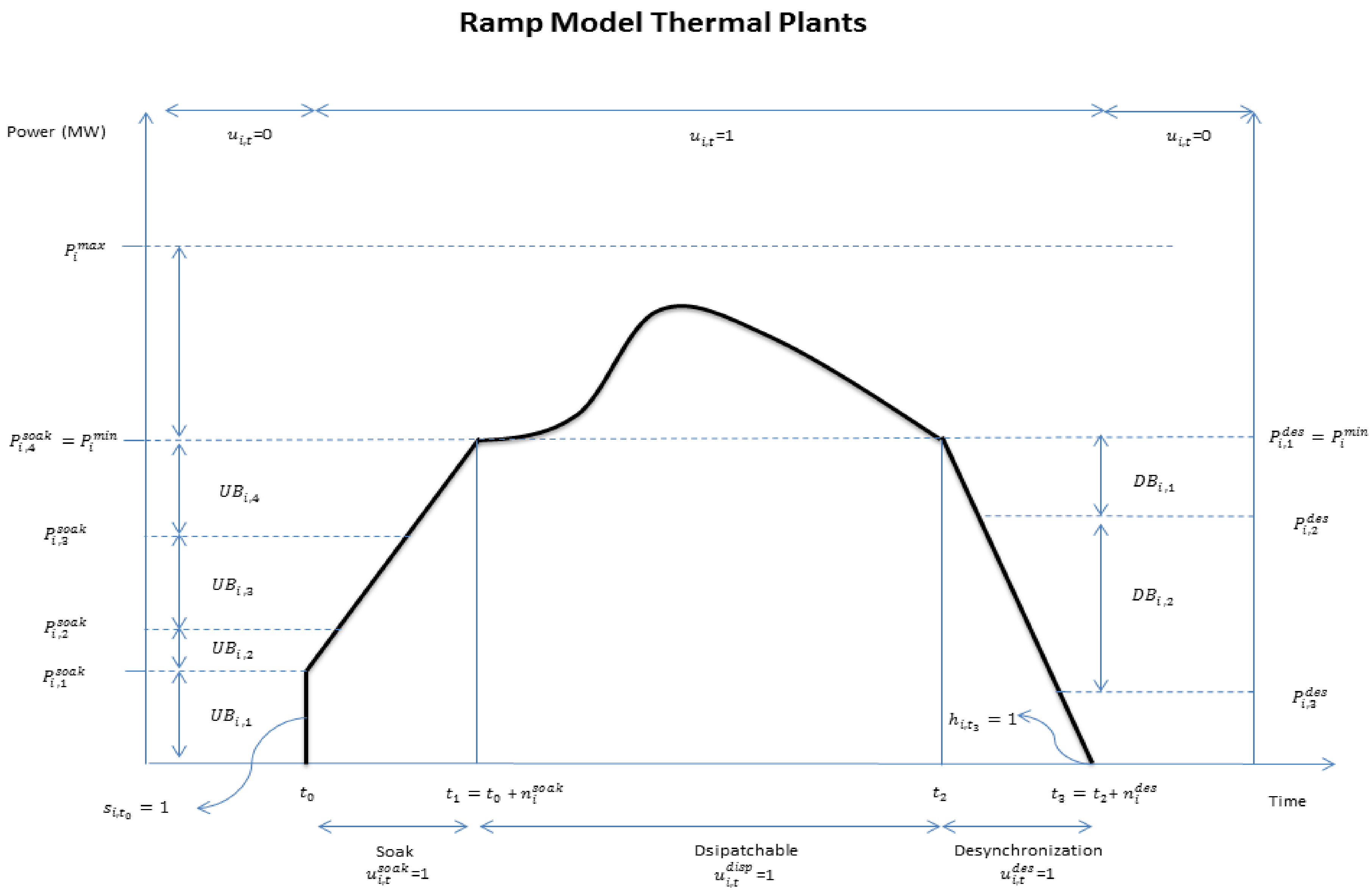
Model and Methodology: Costs



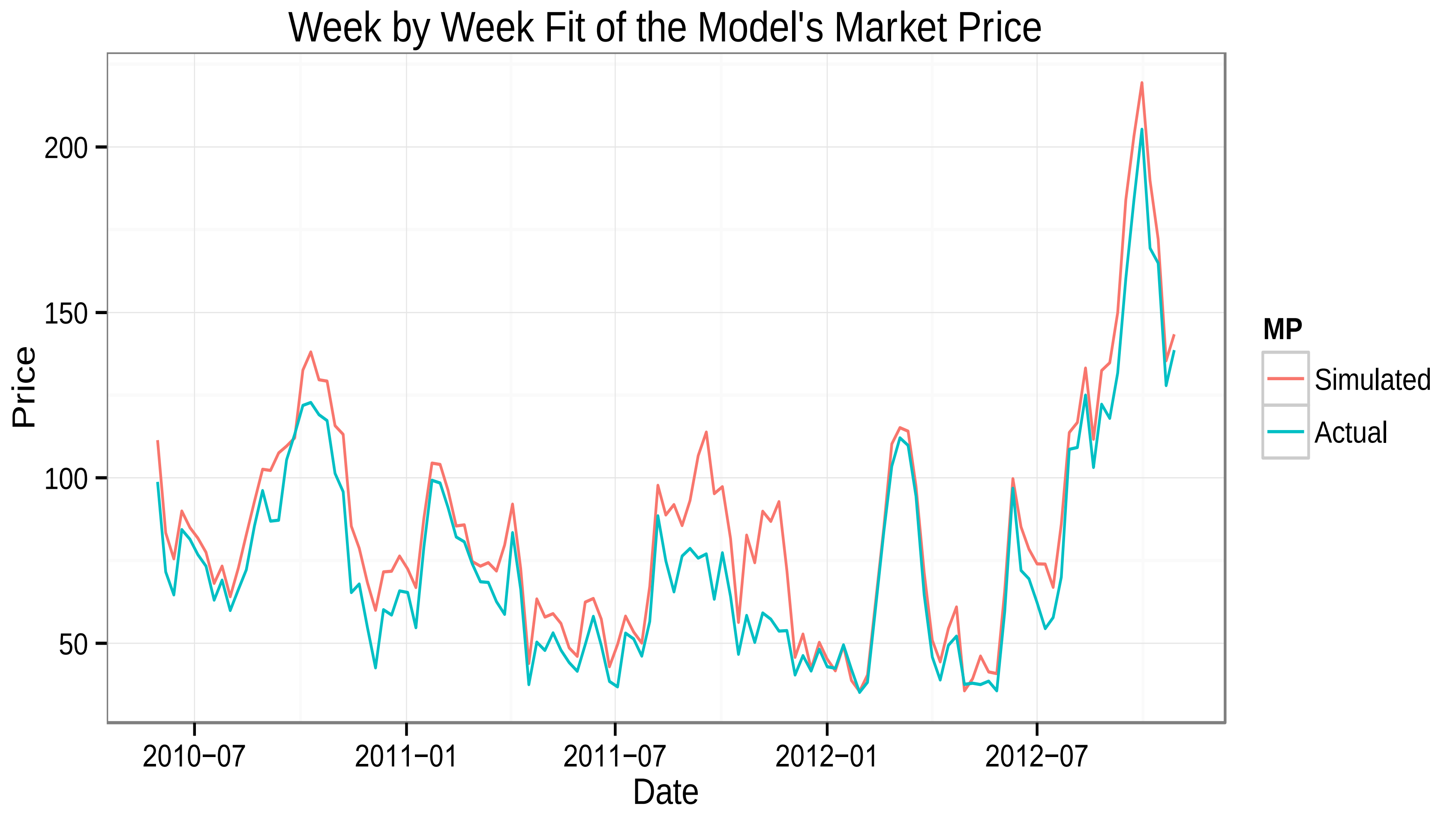
Model and Methodology: Startup Costs



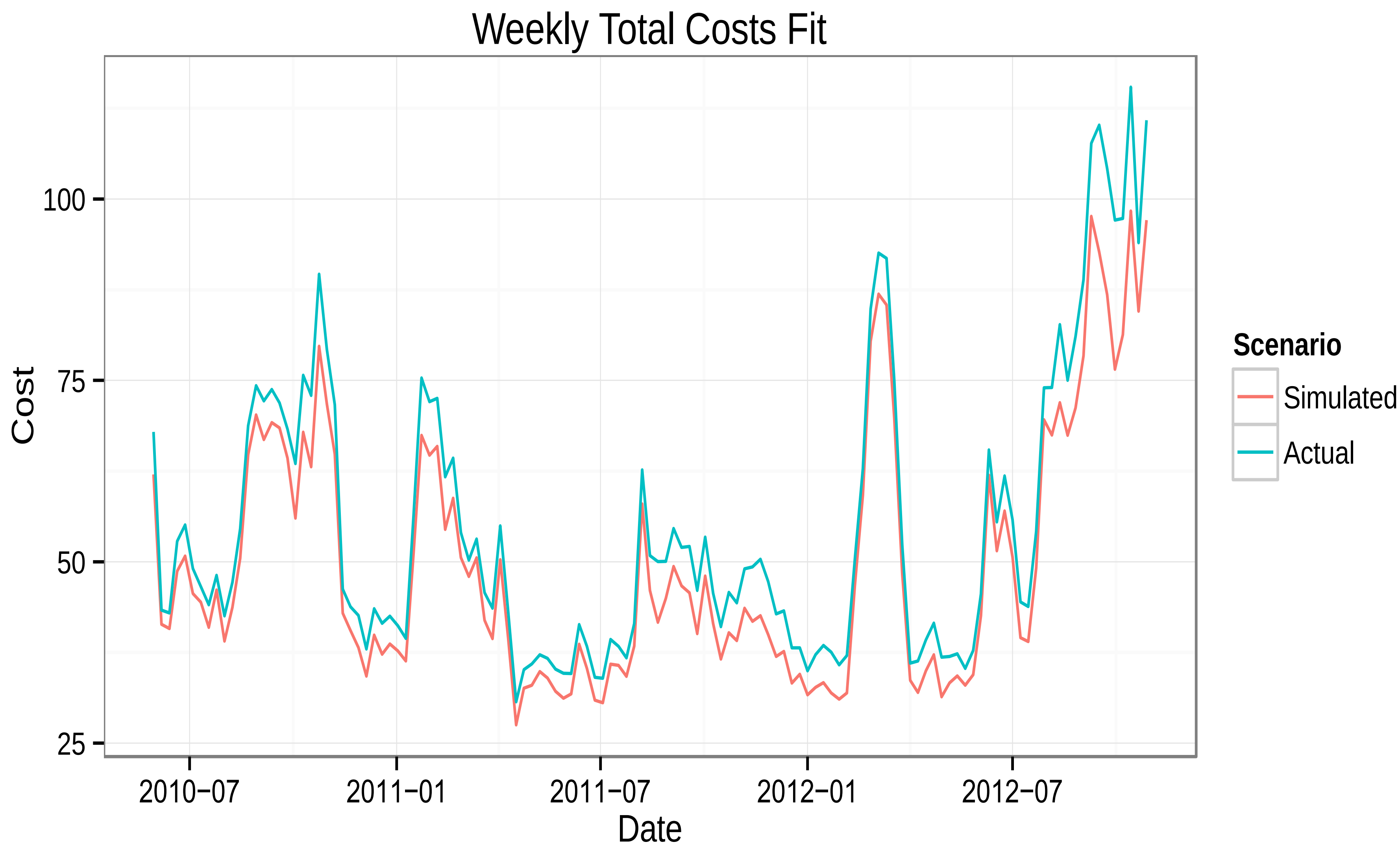
Model and Methodology: Restrictions



Model and Methodology: Model's fit



Model and Methodology: : Model's fit



Counterfactuals: Competitive Benchmark vs Bid-based simulation

- We perform three simulations:

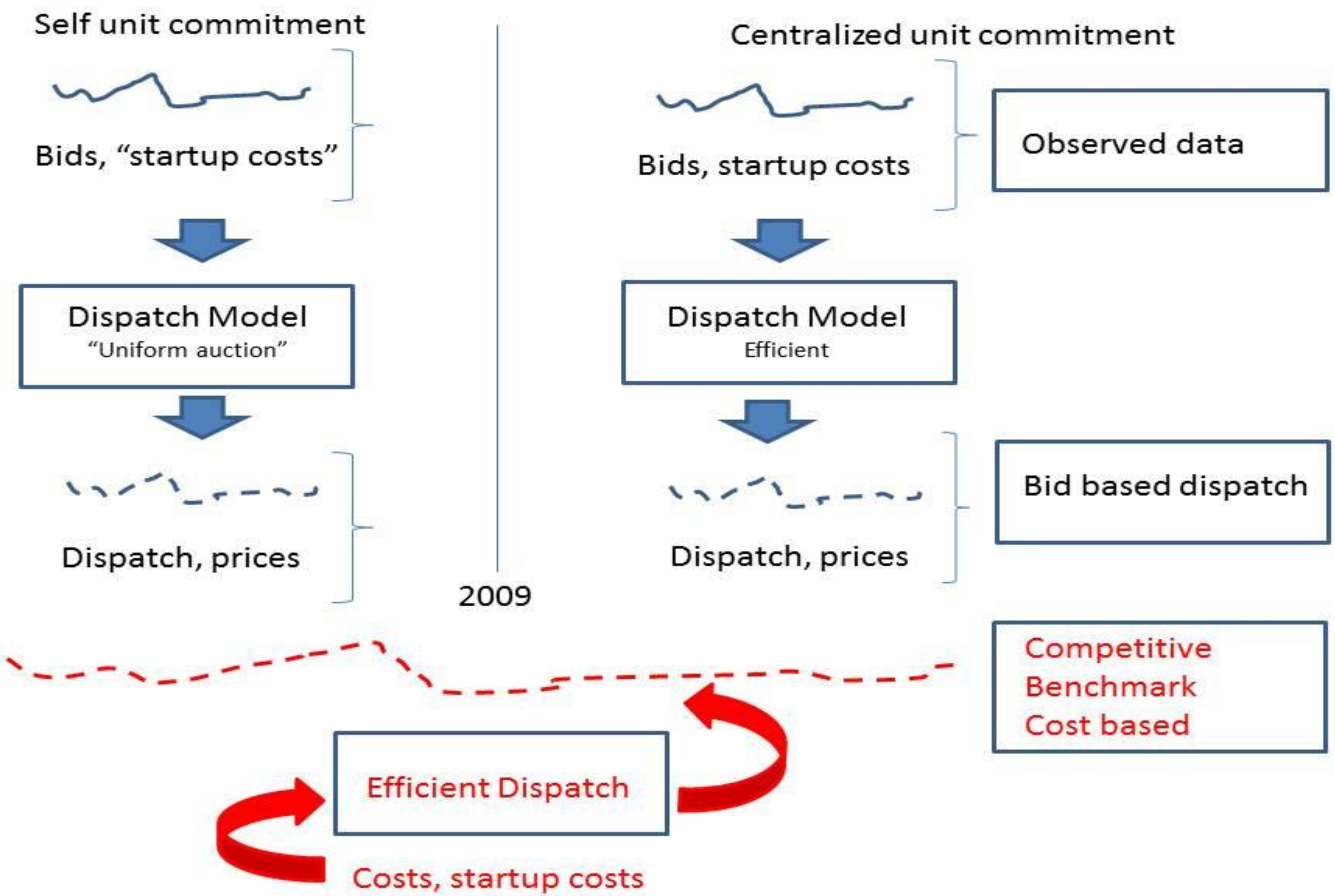
(1) The competitive benchmark for the whole period of study.

(2) The simulated real scenario before 2009, result of using our structural model of the dispatch under self-unit commitment.

(3). The simulated real scenario after 2009, result of using our structural model of the dispatch under centralized-unit commitment.

Main hypothesis: Agents bid the same when faced with our dispatch model (before or after 2009) rather than SO dispatch model.

Model and Methodology

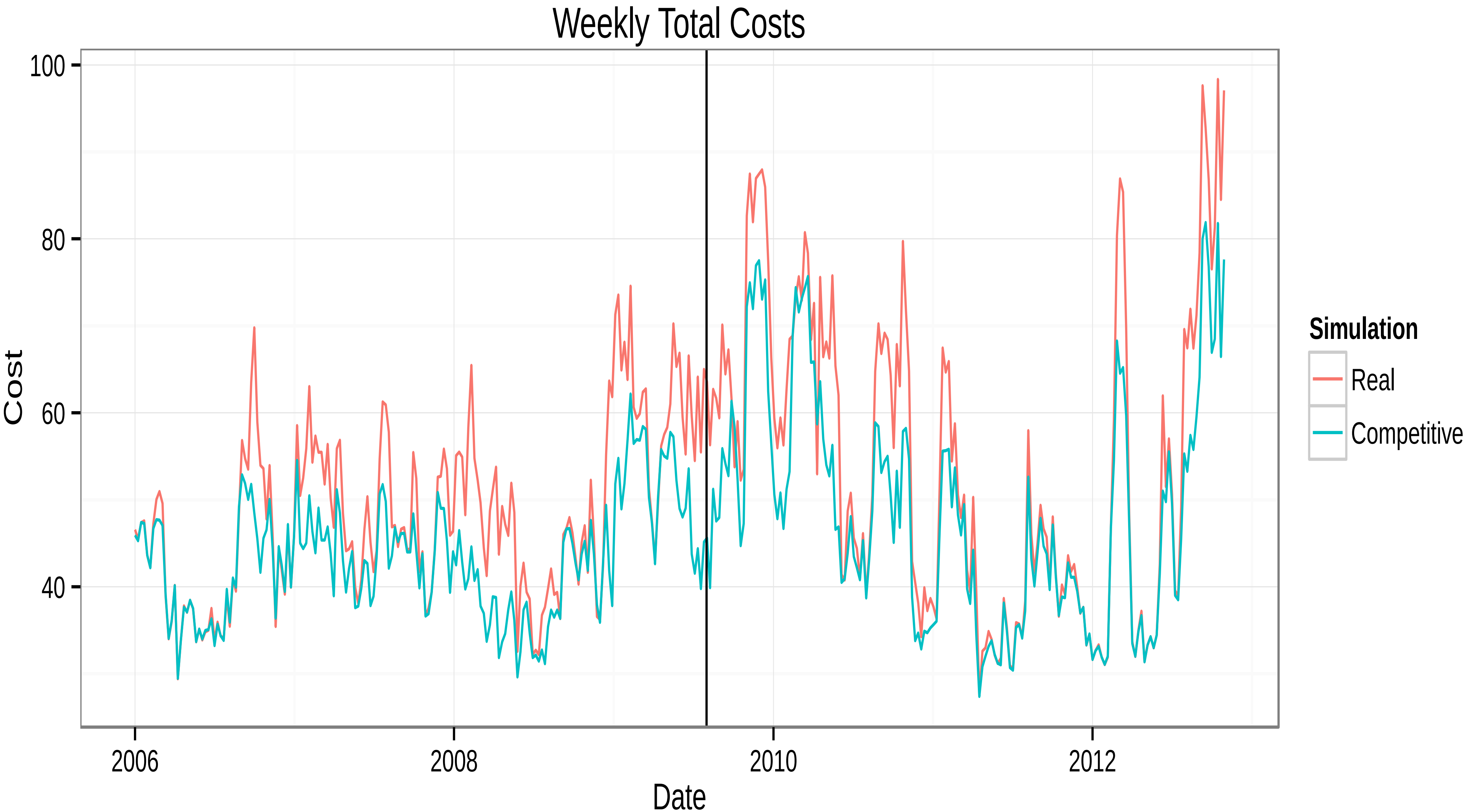


Results: Economic Efficiency

$$Real\ Costs = \sum_{t=1}^{24} \sum_{g \in G} q_{gt}^{R} p_{gt}^{R} + \sum_{t=1}^{24} \sum_{g \in T} u_{gt} s_{gt}$$

$$Competitive\ Costs = \sum_{t=1}^{24} \sum_{g \in G} q_{gt}^{C} p_{gt}^{C} + \sum_{t=1}^{24} \sum_{g \in T} u_{gt} s_{gt}$$

Results: Economic Efficiency



Results: Economic Efficiency

Table 6: Average weekly deadweight loss ratios

Year	2006	2007	2008	2009BR	2009AR	2010	2011	2012
Deadweight	3.87%	10.90%	17.95%	18.70%	19.04%	14.69%	4.23%	10.26%

Table 7: Average weekly deadweight loss ratios with exclusion of a period of very high fuel prices

Reform	Before	After
Deadweight	12.12%	8.80%

Conclusions

- In the presence of non-convexities, self-committed uniform price auctions with energy only offer prices can lead to **productive inefficiencies**.

- This paper capitalizes on the recent transition in Colombia from self-commitment to centralized unit-commitment to **empirically evaluate the relative economic efficiency** under the two regimes.

- We estimate the observed relative **deadweight loss reduction of at least 3.32% after reform.**

- This can be explained in part be by the fact that, before 2009, there was an **underproduction of thermal energy**.