Diagnosing the Causes of the Recent El Niño Event and Recommendations for Reform

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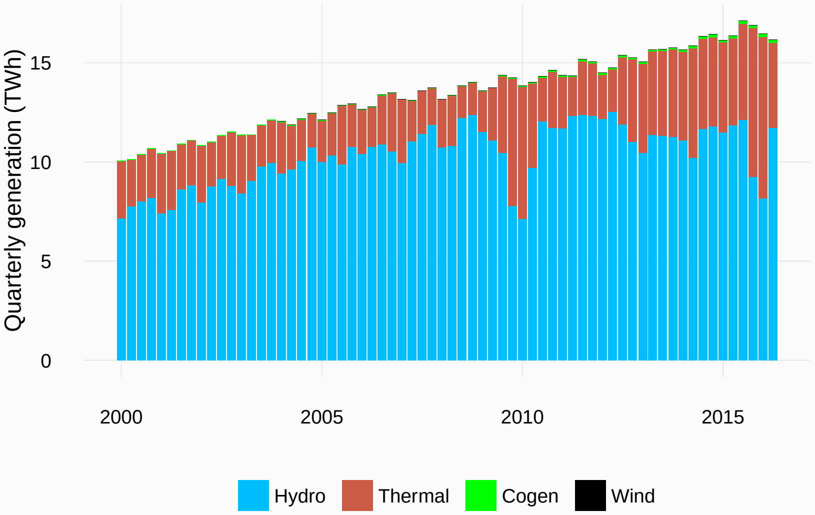
Introduction

Diagnosing Causes of Recent El Niño Event and Recommendations for Reform

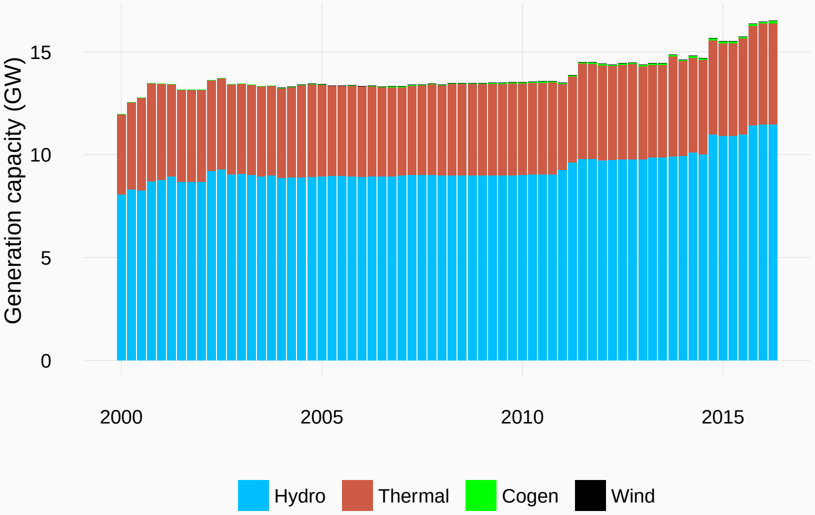
- Provide comprehensive analysis market performance from 2000 to 2016
- Period covers two El Niño Events
    - Focus on explaining differences in market outcomes across two events
- Focus on performance Reliability payment Mechanism (Firm Energy Obligation)
- Provide Recommendations for
    - Reform of reliability mechanism
    - Long-term market reforms

Generation and New Investment

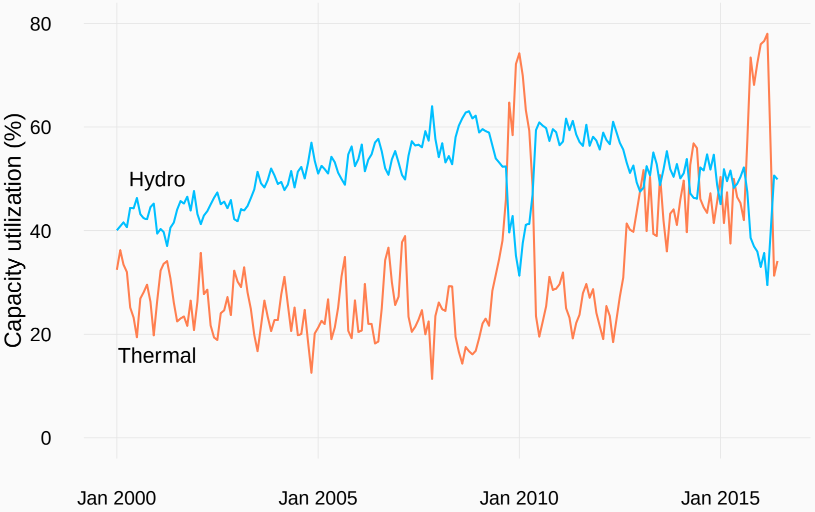
Quarterly electricity generation in TWh, by type of generator



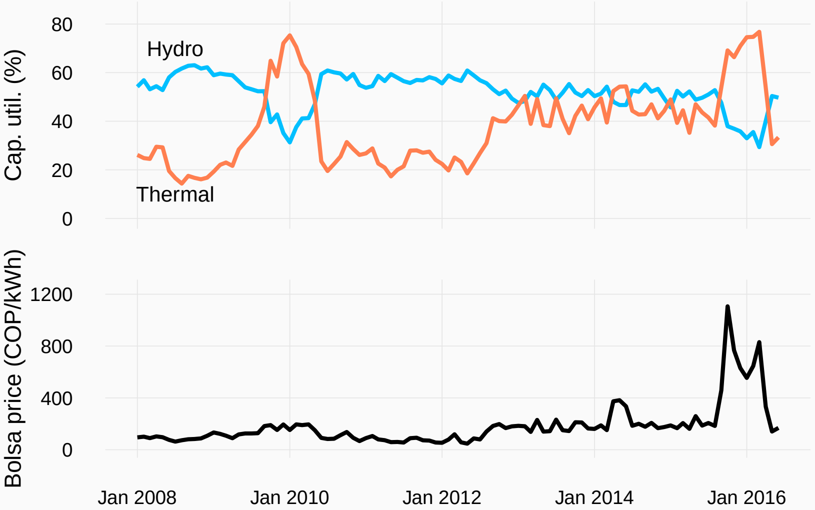
Quarterly generation capacity in GW, by type of generator



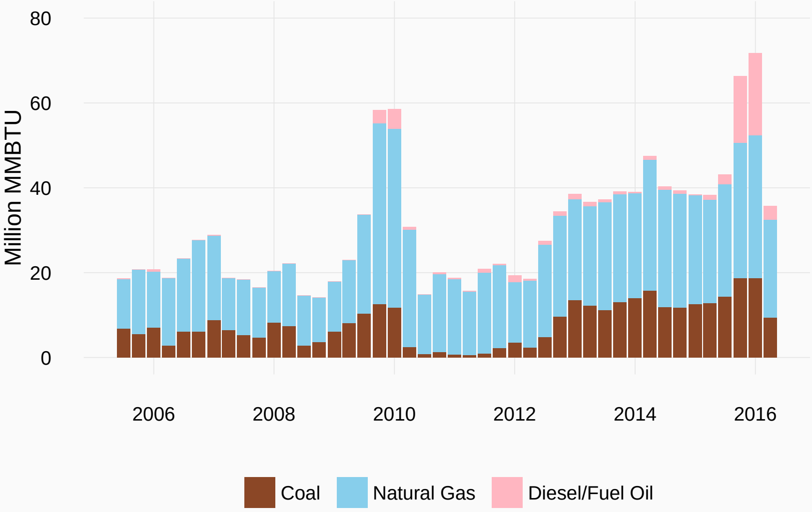
Higher thermal utilization from mid-2012 onward



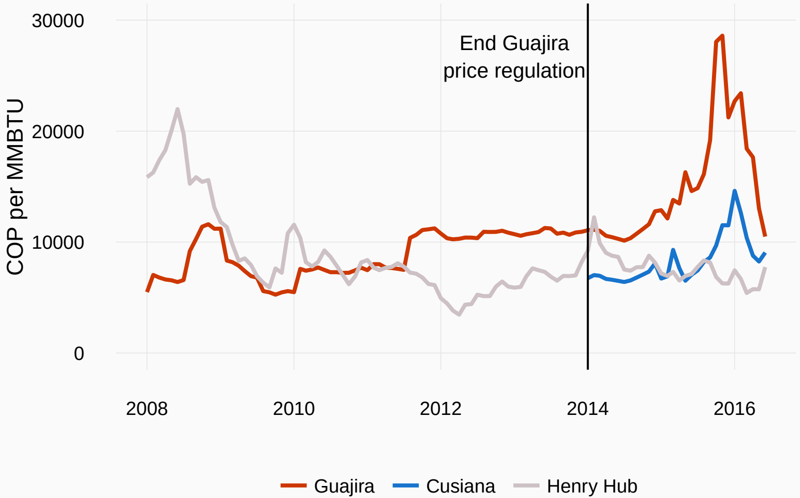
Much larger increase in Bolsa price during 2015-16 despite similar thermal utilization rate to 2009-10



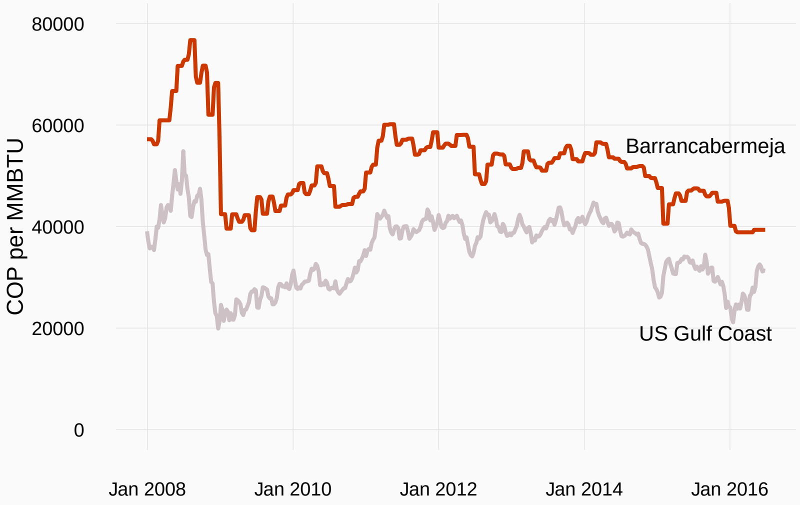
Quarterly fuel consumption by thermal generators



Rise in Colombian natural gas prices after the end of price regulation and the opening of the wholesale gas market



Diesel prices (in pesos) in 2015-16 similar to 2009-10

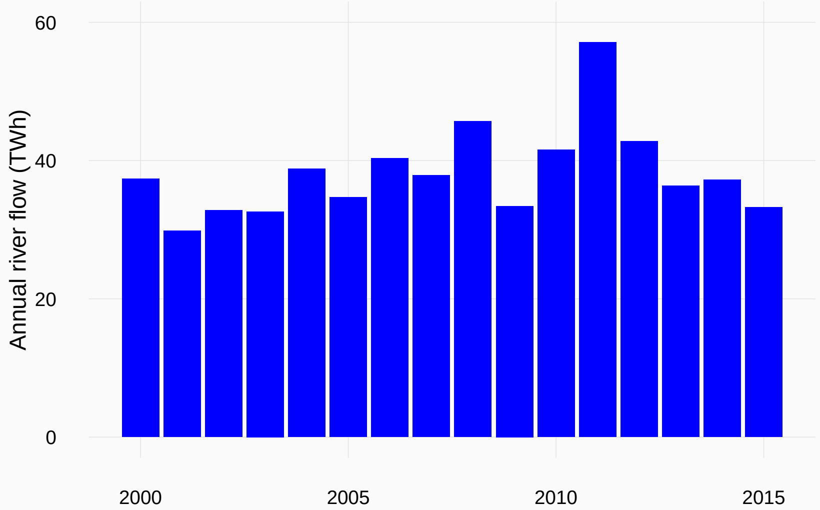


Conclusions from Generation and New Investment

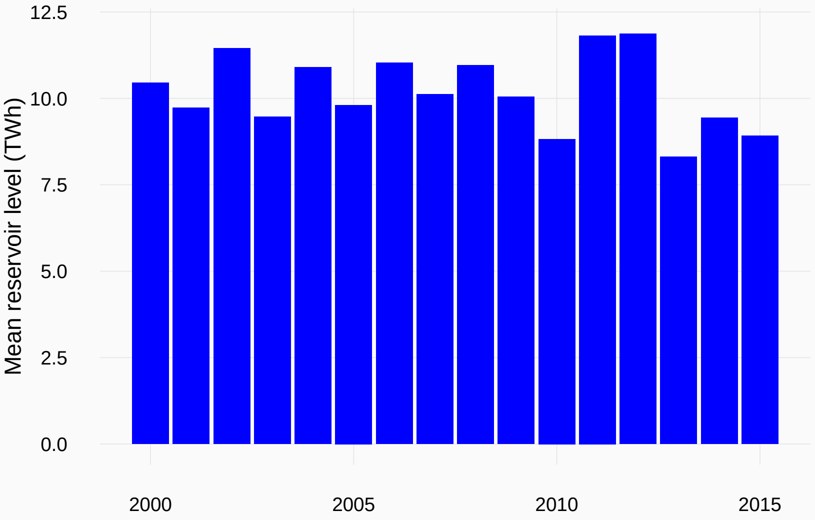
- Increase in hydroelectric generation from 2000 to 2009-2010 El Niño Event
- Decline in hydroelectric generation from peak in 2011
- Increase in thermal generation from 2012 forward
- Virtually all new capacity since 2010 has been hydroelectric
- Higher thermal utilization rate from mid-2012 forward
- Similar significant increase in thermal and significant decline in hydroelectric utilization rates in during both El Niño Events
- Much larger Bolsa price during 2015-2016 versus 2009-2010 El Niño Event largely unrelated to input fuel price changes

Availability of Hydroelectric Energy

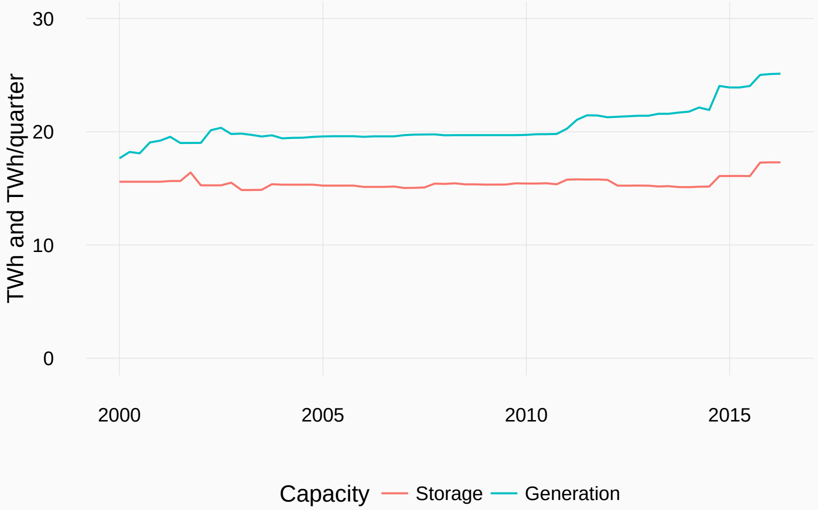
Annual reservoir inflows were similar during 2009-10 and 2015-16 El Niño events



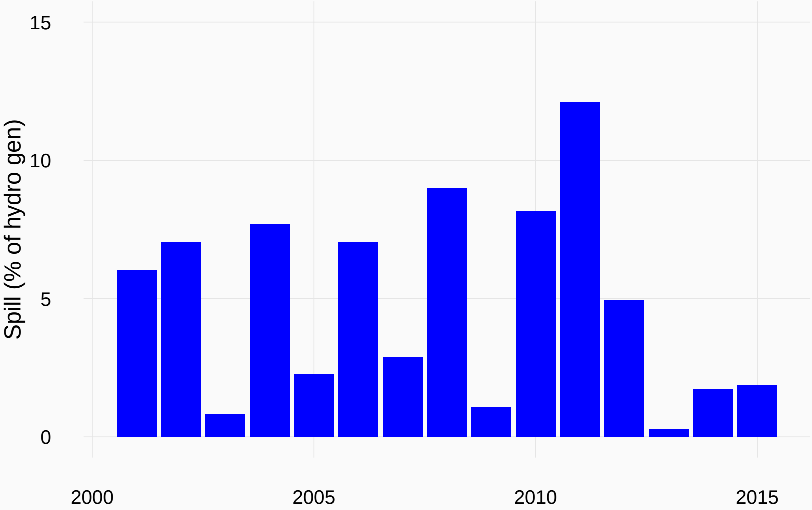
Annual average hydro reservoir levels show similar water levels from 2012 to 2015 as during the 2009-10 El Niño event



Recent additions to hydro generation capacity have added less water storage capacity, relative to existing capacity



Hydro spill during 2014 and 2015 is higher than it was during 2009-10 El Niño event

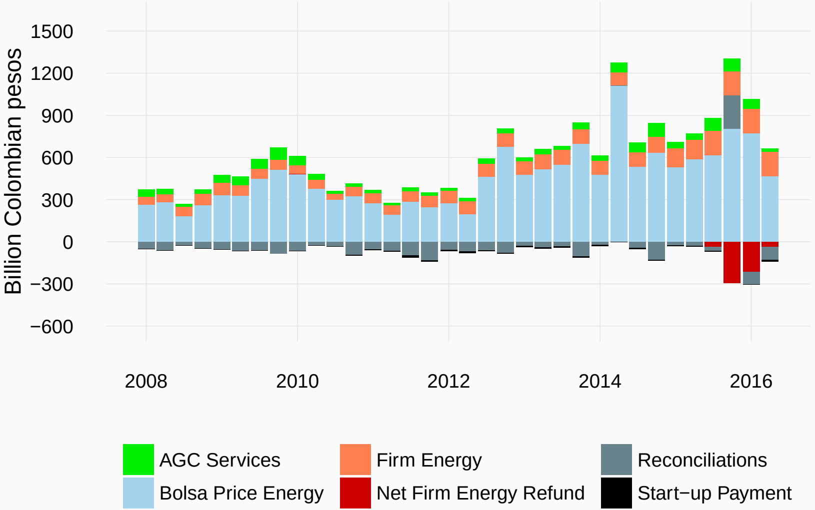


Conclusions from Water Availability Analysis

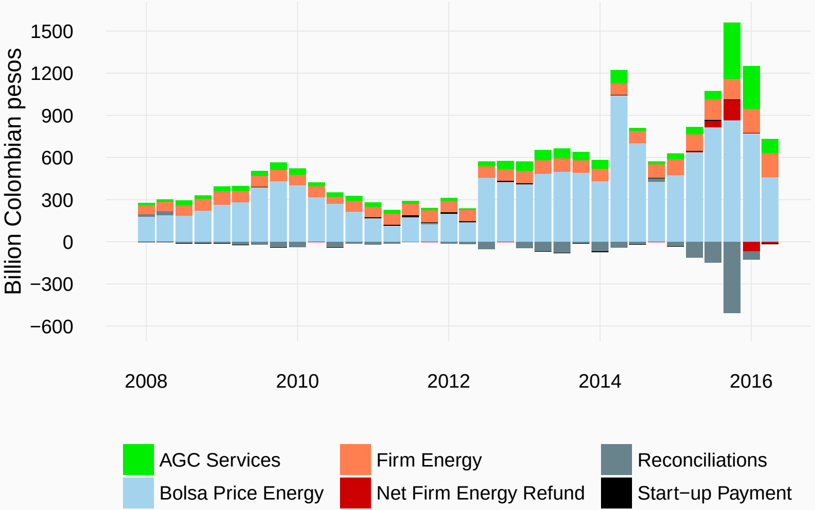
- Similar monthly inflows during 2009-2010 and 2015-2016 El Niño Events
- Steady decline in monthly inflows starting in 2011
- Low Water levels from 2012 to 2015 (very similar to 2009-2010 El Niño Event)
- New hydroelectric generation capacity did not add as much water storage capacity on per MW of installed capacity basis as existing hydroelectric capacity
- Spill during 2014 and 2015 higher than 2009

Reliability Payment Mechanism (RPM)

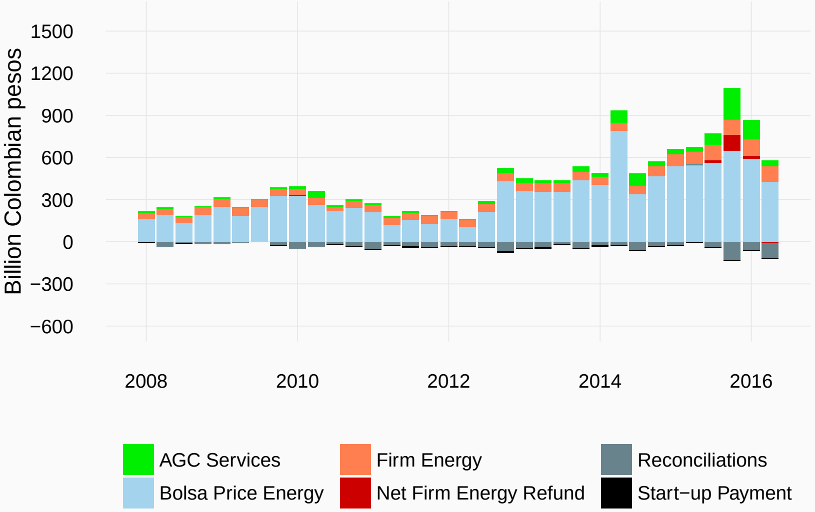
Reliability payments make up about 15% of revenue for largest three firms: EPM



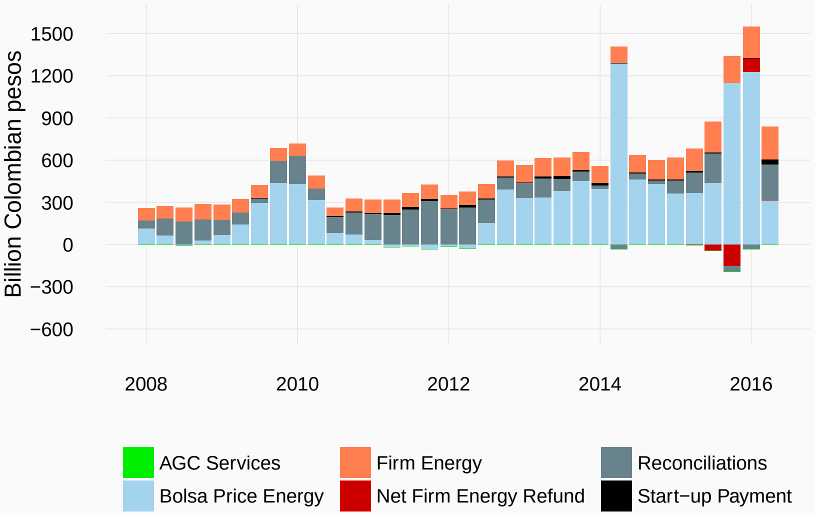
Reliability payments make up about 15% of revenue for largest three firms: Emgesa



Reliability payments make up about 15% of revenue for largest three firms: Isagen



Reliability payments make up a larger share of revenue for independent thermal generators (over 50% for some plants)

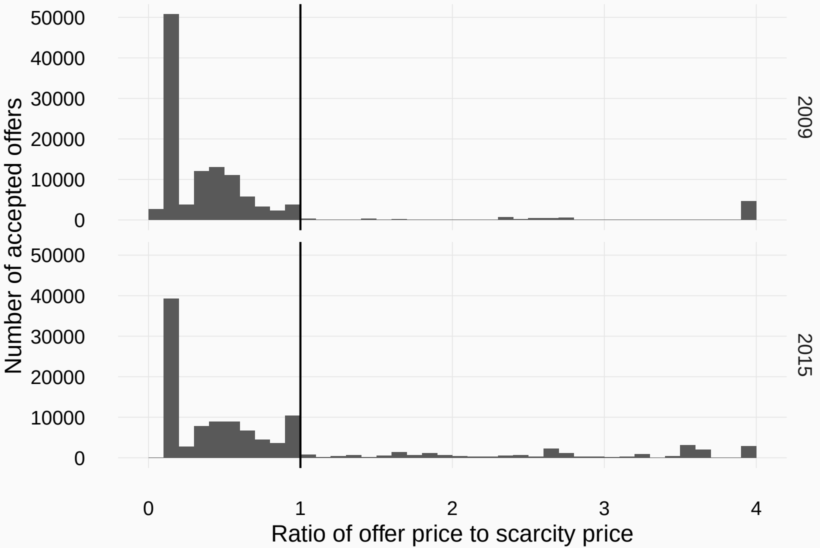


Conclusions from RPM Analysis

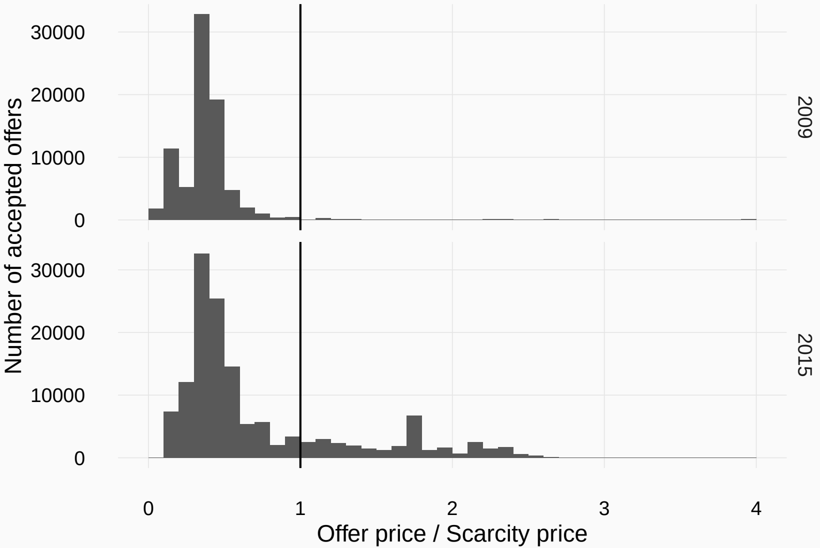
- Large suppliers that own thermal and hydroelectric units earn vast majority of revenues from energy sales at Bolsa price
- Except for EPM, Net Firm Energy Refunds were positive for large firms during 2015-2016 El Niño Event
- Reconciliation are typically negative for large firms
- For independent thermal generators, Firm Energy revenues are large fraction of total revenues and reconciliation are typically positive Remaining unit owners in total look like large hydroelectric and thermal generation owners

Offer Prices and Market Prices

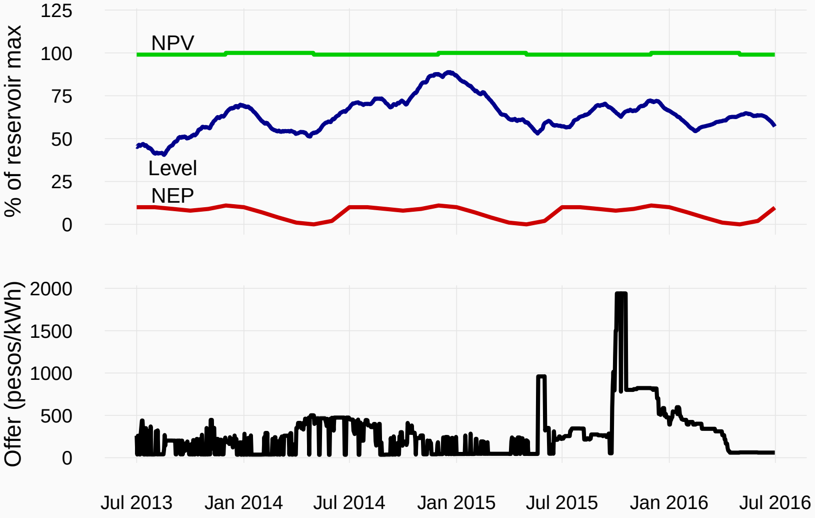
Distribution of the ratio of accepted offer prices to the scarcity price: hydro units



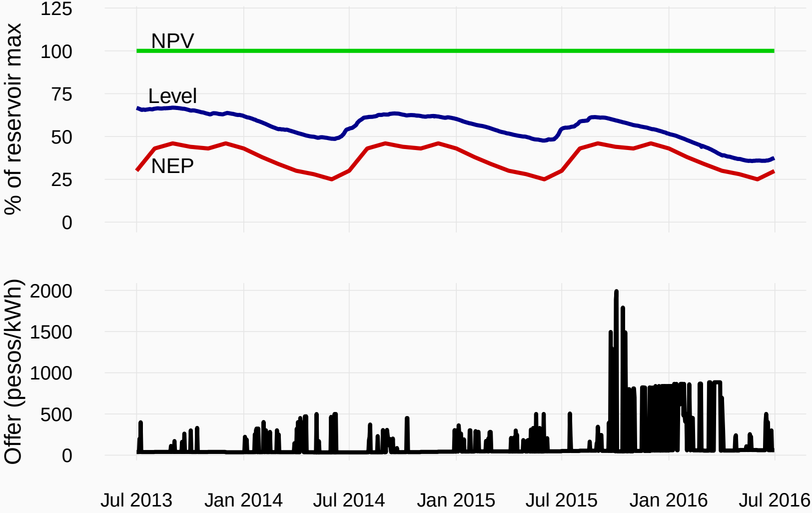
Distribution of the ratio of accepted offer prices to the scarcity price: thermal units



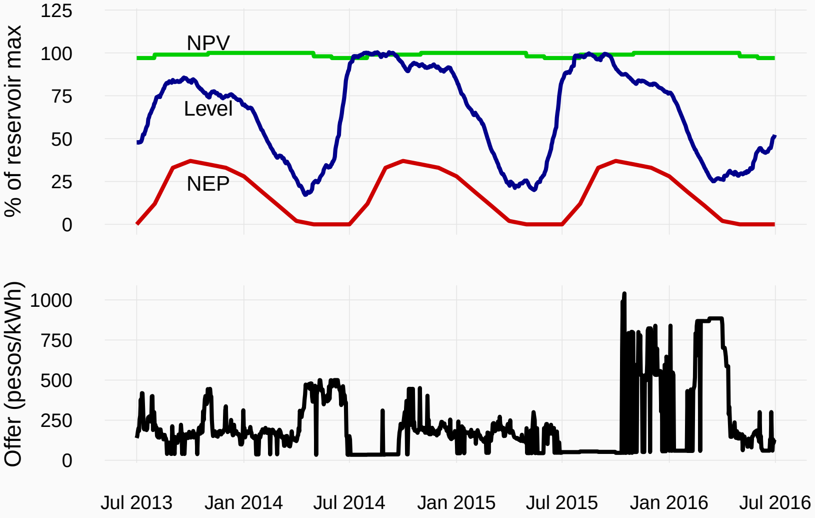
Reservoir water levels and daily offer prices: Guatape (EPM)



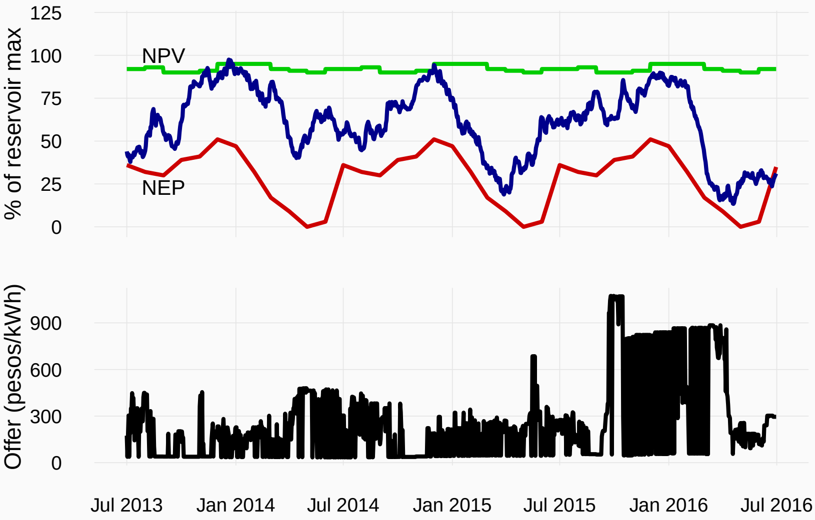
Reservoir water levels and daily offer prices: Pagua (Emgesa)



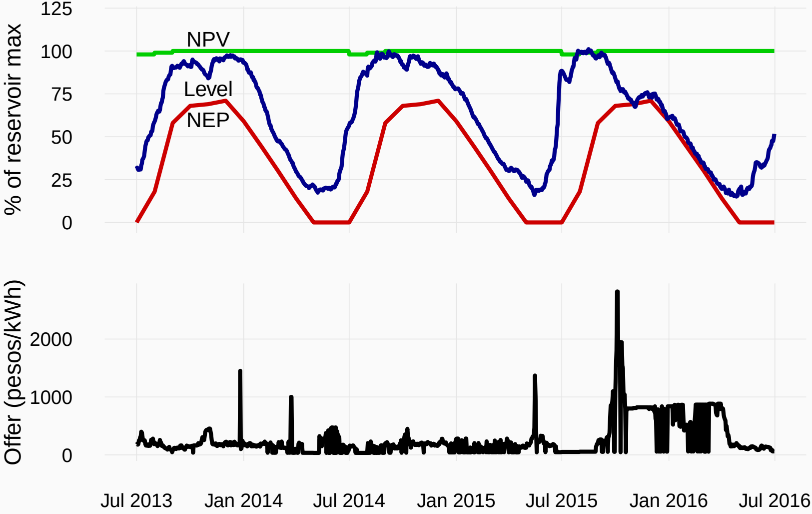
Reservoir water levels and daily offer prices: Guavio (Emgesa)



Reservoir water levels and daily offer prices: Jaguas (Isagen)



Reservoir water levels and daily offer prices: Chivor (AES Chivor)



Conclusions from Offer Prices and Market Prices Analyses

- Distribution of [P(Offer)/P(Scarcity)] for hydro units similar in 2009 and 2015, with few values greater than 1
- Distribution of [P(offer)/P(Scarcity)] for thermal units has much higher frequency of values above 1 during 2015
- Offer behavior consistent with desire to run hydro units rather than thermal units during first two quarters of 2015
- Offer prices of hydro units owned by large suppliers were not significantly higher than in 2013 and 2014 until final two quarters of 2015
- Substantial increase in all offer prices of hydro units following XM announcement on September 22, 2015 about reservoir levels

Forward Contract and Firm Energy Positions

Impact of Forward Contracts and Firm Energy Value on Offers

Supplier k's variable profit during hour h:

$$\begin{aligned}
&\pi_{hk}(P_h(Bolsa)) \\
&= (Q_{hk}(Ideal) - Q_{hk}(Contract)) \times \min(P_h(Bolsa), P_h(Scarcity)) \\
&\quad + P_{hk}(Contract)Q_{hk}(Contract) + Q_{hk}(Firm)P_h(Firm) \\
&\quad + [Q_{hk}(Ideal) - Q_{hk}(Firm)] \times \max(0, ((P_h(Bolsa) - P_h(Scarcity))) \\
&\quad - C_k(Q_{hk}(Ideal)), \qquad (1)
\end{aligned}$$

Expression excludes payments for providing ancillary services and positive and negative reconciliation payments (so that $Q_{hk}(Ideal) = Q_{hk}(Actual)$), and start-up payments

($P(Bolsa) < P(Scarcity)$) Forward Contracts and Offer Behavior

Supplier k's variable profit during hour h:

$$\begin{aligned}\pi_{hk}(P_h(Bolsa)) &= (Q_{hk}(Ideal) - Q_{hk}(Contract)) \times P_h(Bolsa) \\ &+ P_{hk}(Contract)Q_{hk}(Contract) + Q_{hk}(Firm)P_h(Firm) \\ &- C_k(Q_{hk}(Ideal)), \quad (2)\end{aligned}$$

Value of $Q_{hk}(Contract)$ relative to $Q_{hk}(Ideal)$ impacts incentive of supplier to raise or lower Bolsa price by exercising unilateral market power

($P(Bolsa) > P(Scarcity)$) Firm Energy Value and Offer Behavior

Supplier k's variable profit during hour h:

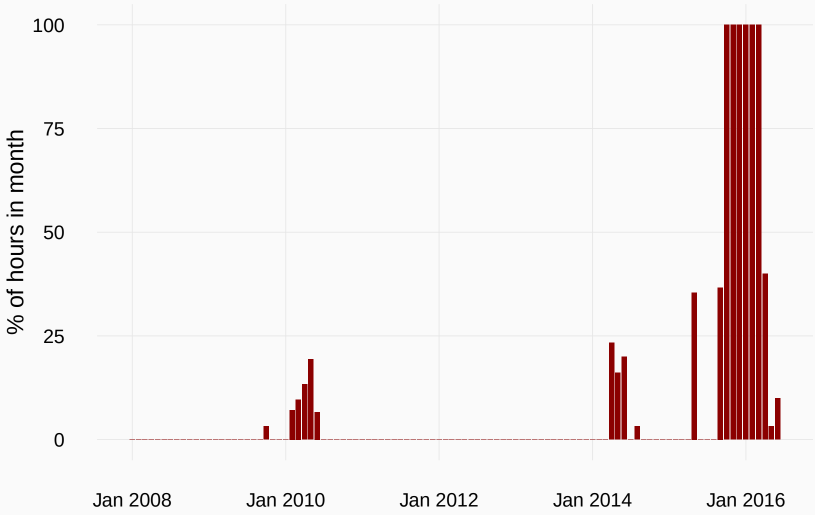
$$
\begin{aligned}
&\pi_{hk}(P_h(Bolsa)) \\
&\quad = (Q_{hk}(Ideal) - Q_{hk}(Contract)) \times P_h(Scarcity) \\
&\quad + P_{hk}(Contract)Q_{hk}(Contract) + Q_{hk}(Firm)P_h(Firm) \\
&\quad + [Q_{hk}(Ideal) - Q_{hk}(Firm)] \times (P_h(Bolsa) - P_h(Scarcity)) \\
&\quad - C_k(Q_{hk}(Ideal)), \qquad (3)
\end{aligned}
$$

Value of $Q_{hk}(Firm)$ relative to $Q_{hk}(Ideal)$ impacts incentive of supplier to raise or lower Bolsa price by exercising unilateral market power

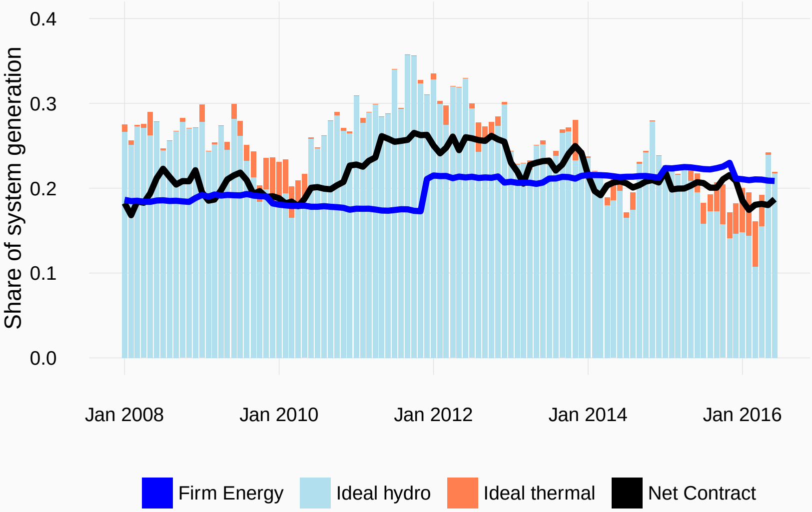
Relative value of Q(Firm), Q(Contract) and Q(Ideal) creates perverse incentives for offer behavior

- If Q(Contract) > Q(Ideal) > Q(Firm) then supplier wants to lower Bolsa price if (P(Scarcity) > P(Bolsa) and raise Bolsa price if P(Bolsa) > P(Scarcity)
- If Q(Firm) > Q(Ideal) > Q(Contract) then supplier wants to raise Bolsa price if (P(Scarcity) > P(Bolsa) and lower Bolsa price if P(Bolsa) > P(Scarcity)
- If Q(Ideal) is greater than Q(Contract) and Q(Firm) then supplier wants to raise Bolsa price regardless of its value
- These circumstances occur frequently during 2015-2016 El Niño Event period for all large suppliers

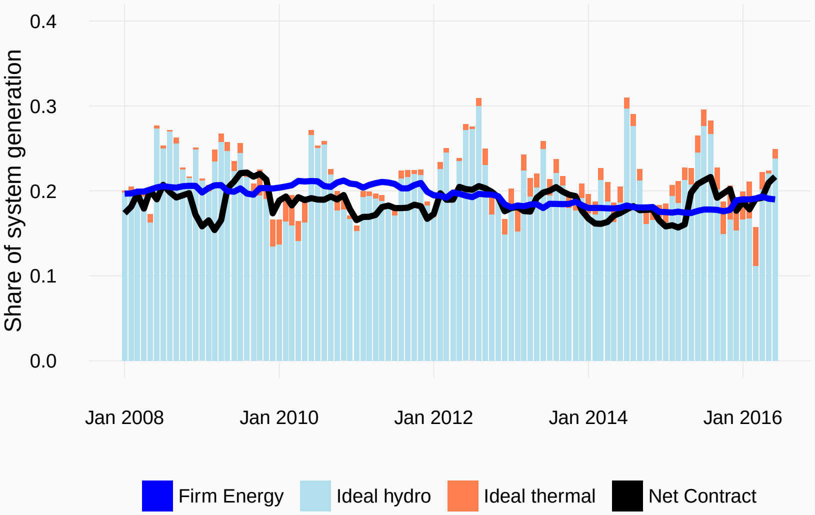
Very few hours during 2015-16 El Niño event when Bolsa price was less than scarcity price



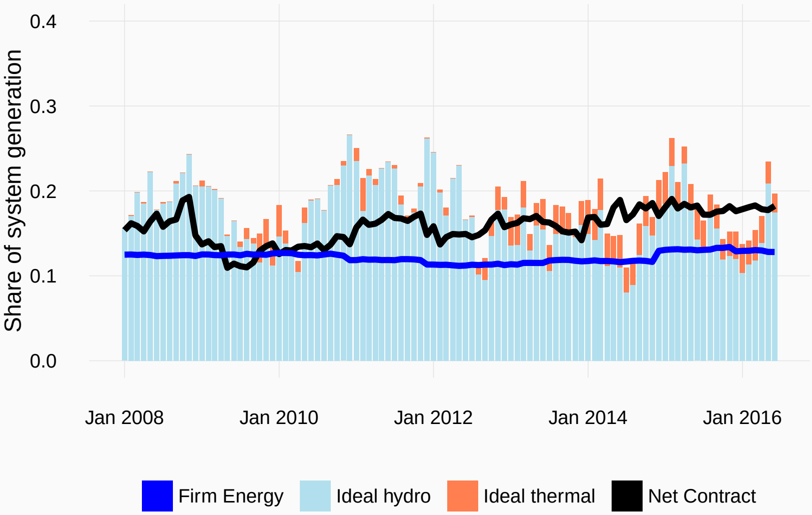
Monthly ideal generation, firm energy and net contract position: EPM



Monthly ideal generation, firm energy and net contract position: Emgesa



Monthly ideal generation, firm energy and net contract position: Isagen

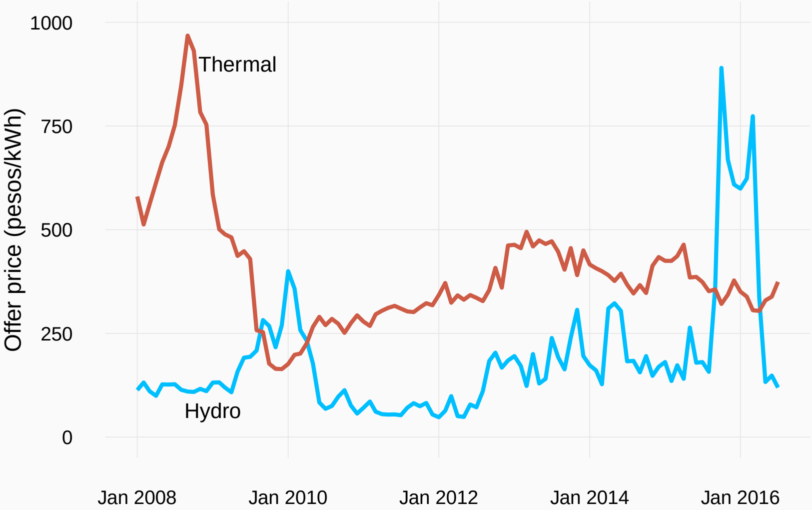


Frequency of perverse market outcomes because of relationship between Q(Firm), Q(Contract) and Q(Ideal)

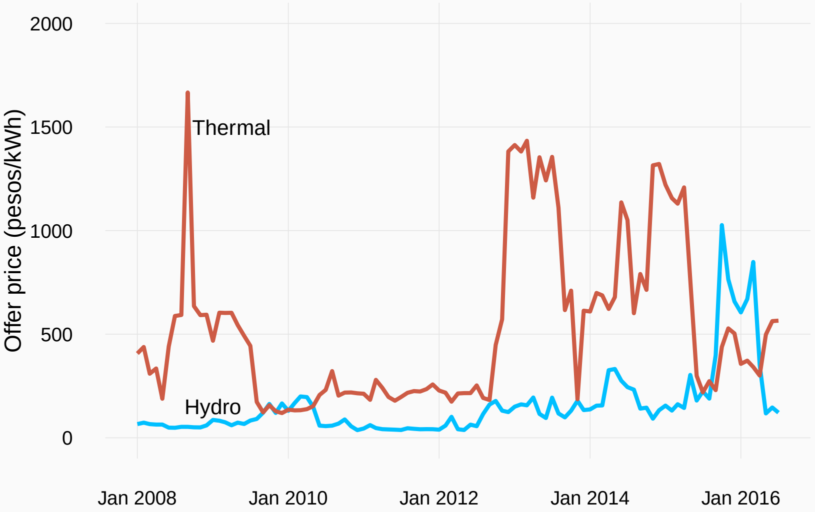
Proportion of days between Oct 1, 2015 and Mar 31, 2016 in which condition holds for each firm

	EPM	Emgesa	Isagen
$Q_c > Q_f$	2.2	43.7	100.0
$Q_i > Q_c > Q_f$	1.6	16.4	24.0
$Q_c > Q_i > Q_f$	0.0	12.0	41.0
$Q_c > Q_f > Q_i$	0.5	15.3	35.0
$Q_f > Q_c$	97.8	56.3	0.0
$Q_i > Q_f > Q_c$	26.2	33.9	0.0
$Q_f > Q_i > Q_c$	14.8	1.6	0.0
$Q_f > Q_c > Q_i$	56.8	20.8	0.0

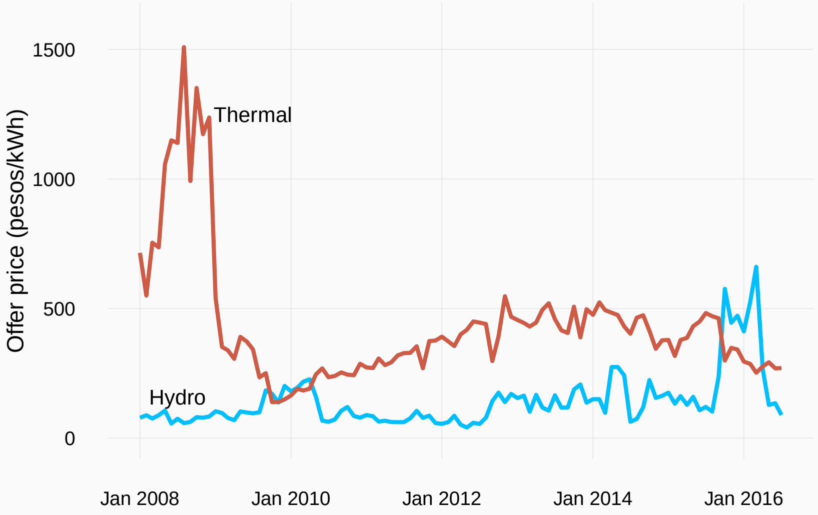
Monthly average offers (weighted by availability) for thermal and hydro units: all firms



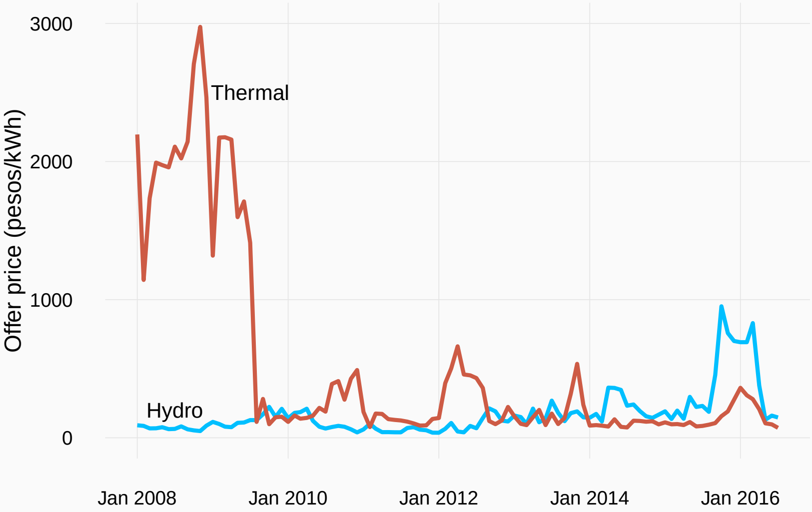
Monthly average offers for thermal and hydro units: EPM



Monthly average offers for thermal and hydro units: Emgesa



Monthly average offers for thermal and hydro units: Isagen

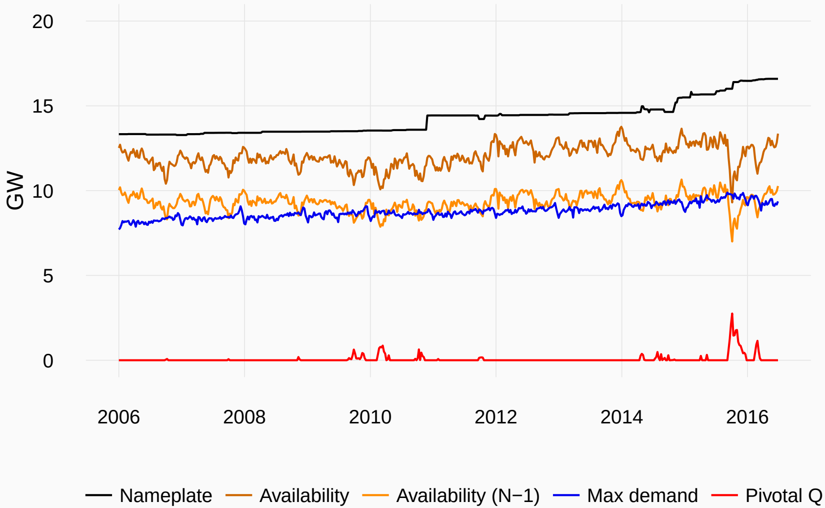


Conclusions from Interactions Between Q(Firm), Q(Contract) and Q(Ideal)

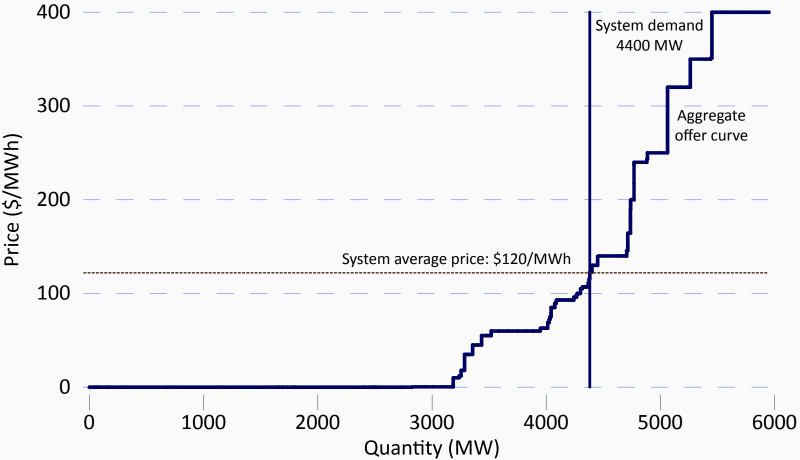
- Few hours during 2009-2010 El Niño Event period when P(Bolsa) > P(Scarcity)
- Virtually all hours during 2015-2016 El Niño Event Period have P(Bolsa) > P(Scarcity)
- Many hours when Q(Contract) > Q(Ideal) > Q(Firm), Q(Firm) > Q(Ideal) > Q(Contract), and Q(Ideal) is greater than Q(Contract) and Q(Firm)
- Offers of EPM and Emgesa from mid-2012 appear to favor running hydro units over thermal units, opposite is true for Isagen and Celsia

Measuring the Ability to Exercise Unilateral Market Power

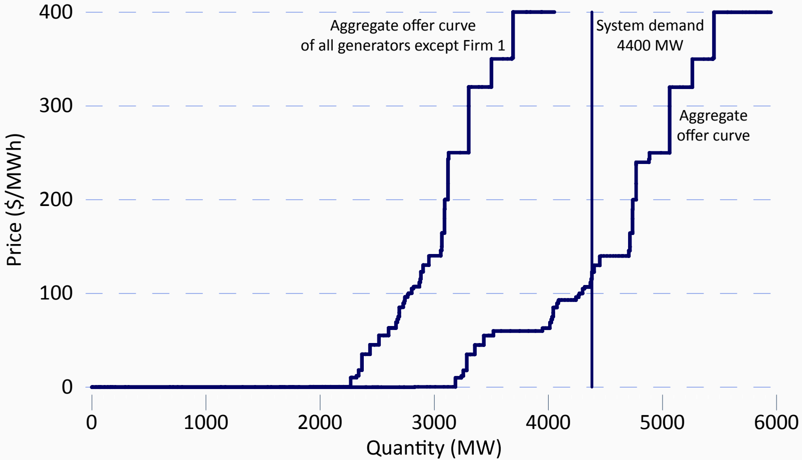
Declining availability factor led to many more hours in which at least one firm was pivotal in the 2015-16 El Niño event



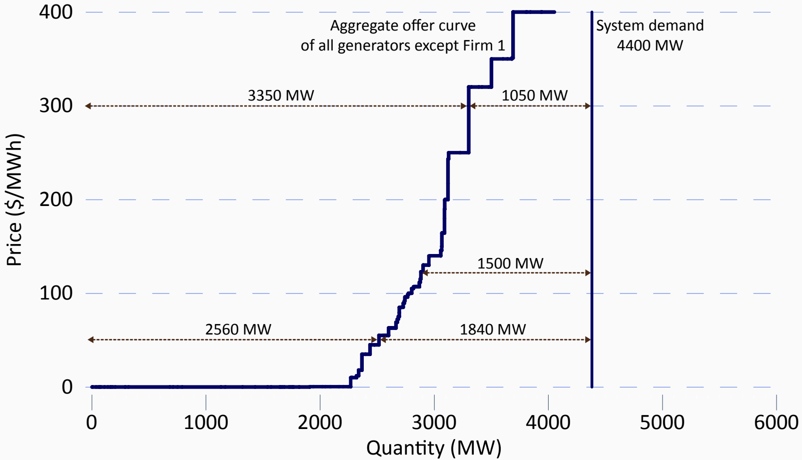
Determination of system price from supplier offer curve and system demand



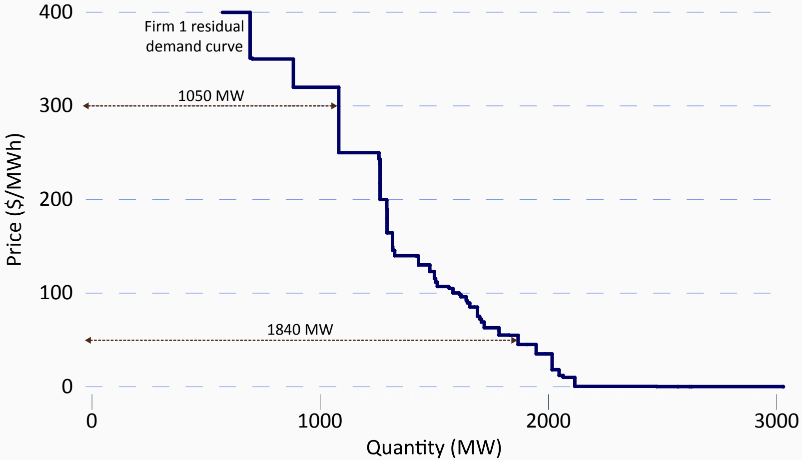
Calculation of residual demand curve: start with combined offer curve for all other suppliers



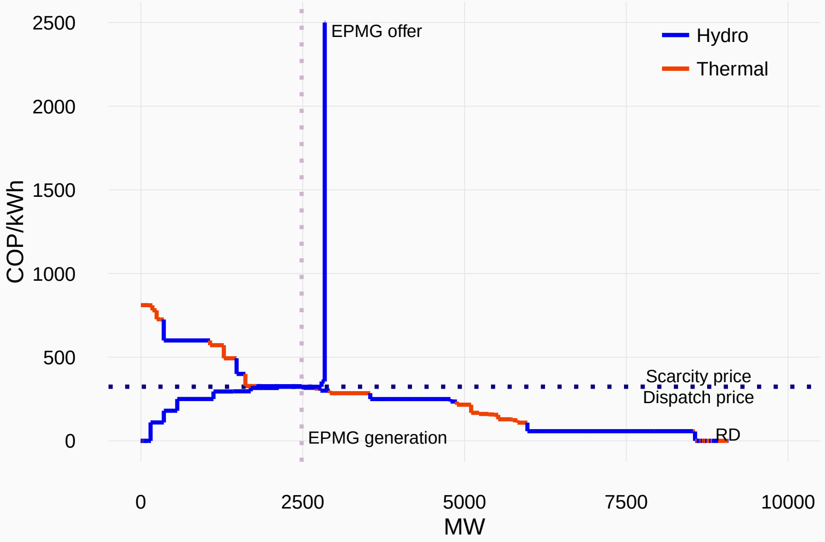
Residual demand is defined as the difference between market demand and the supply of all other firms in the market



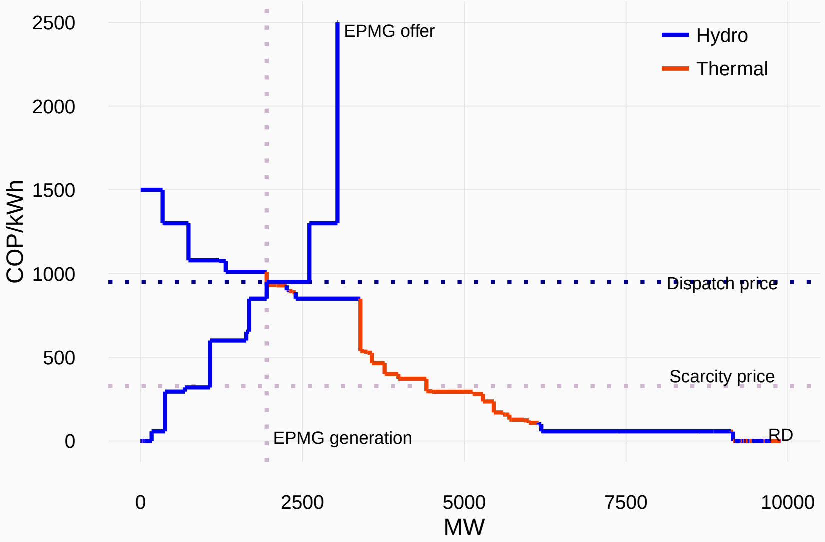
Residual demand depends only on market demand and the offers of other firms in the market



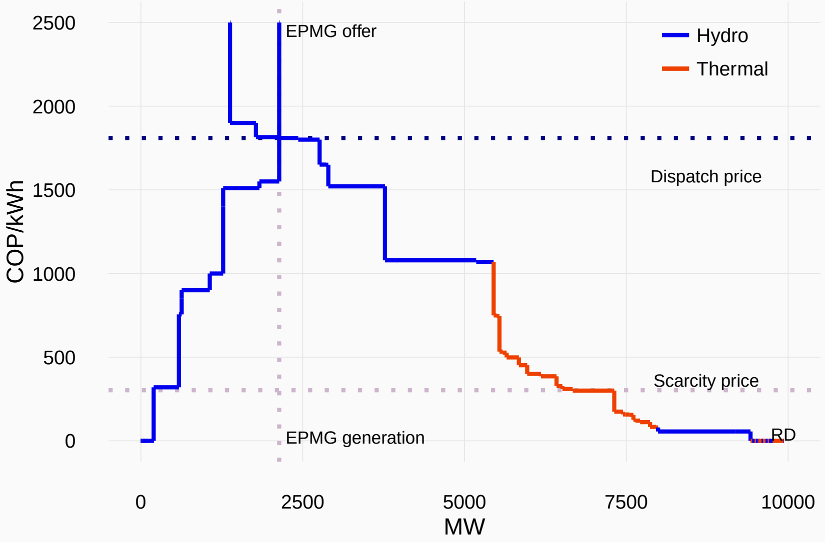
Residual demand and offer curve at 18:00 hrs on September 18, 2015: EPM



Residual demand and offer curve at 18:00 hrs on September 25, 2015: EPM



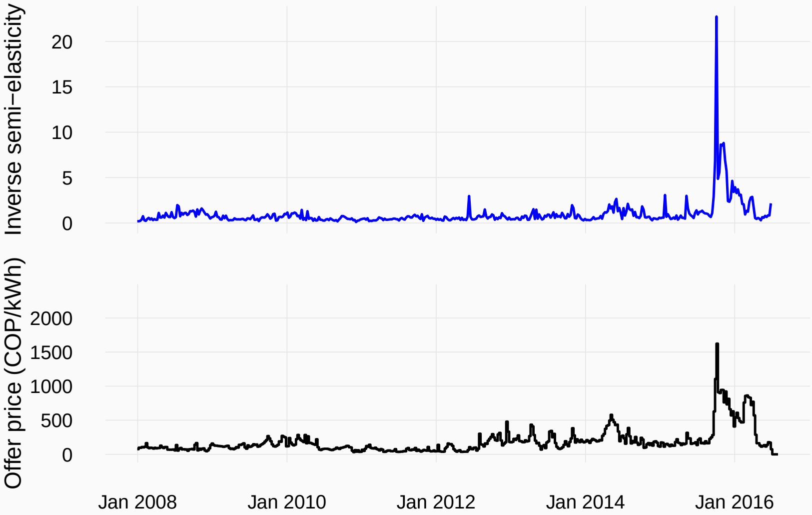
Residual demand and offer curve at 18:00 hrs on October 2, 2015: EPM



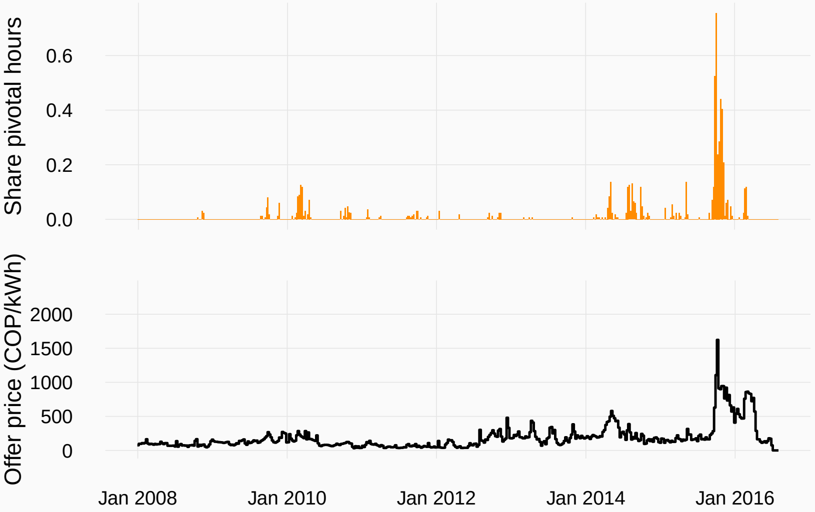
Two Measures of Ability to Exercise Unilateral Market Power Based on Residual Demand Curve

- Inverse semi-elasticity, $\eta_{hk} = -\frac{1}{100}\frac{DR_{hk}(p_h)}{DR'_{hk}(p_h)}$, quantifies COP per kWh increase in Bolsa price from supplier k reducing it actual output by one percent
- Pivotal supplier frequency is the fraction of hours in the week that $DR_{hk}(\infty) > 0$, supplier k's residual demand is positive for all possible Bolsa Prices, meaning that some of supplier k's available capacity is required to serve demand during hour h
- A pivotal supplier can raise the price has high it would like if it is willing to only sell its pivotal quantity, $DR_{hk}(\infty) > 0$
- η_{hk} measures the ability of supplier k to raise the market price at their actual level of output during hour h

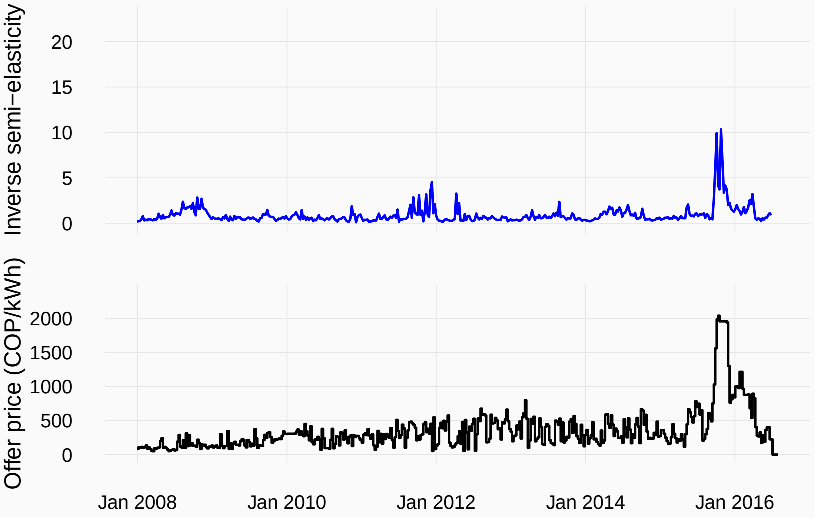
Offer prices and inverse semi-elasticities: EPM



Offer prices and proportion of pivotal hours: EPM



Offer prices and inverse semi-elasticities: Emgesa



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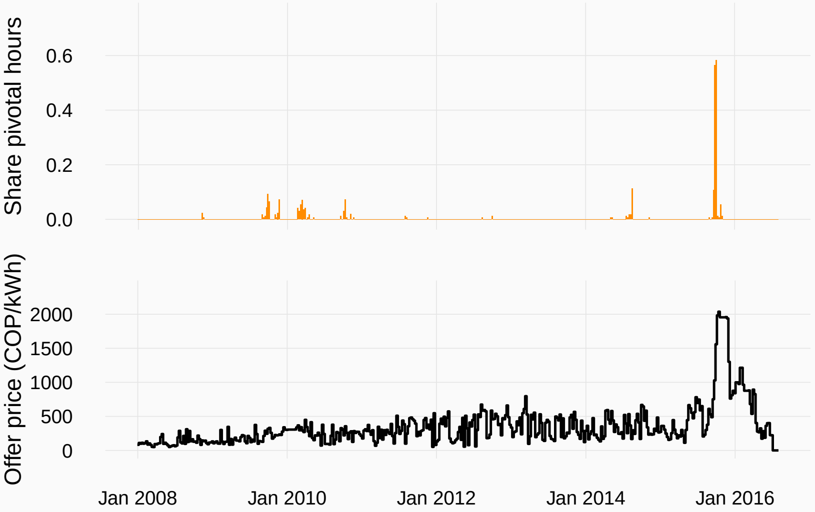
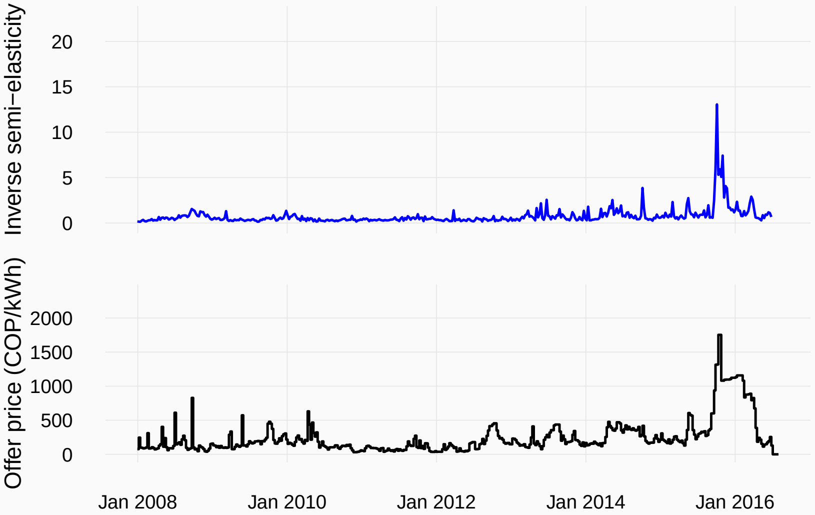
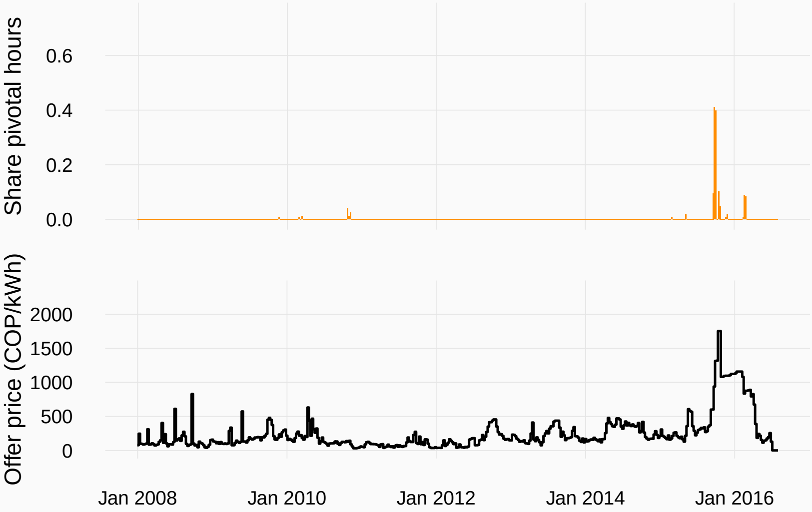


Offer prices and inverse semi-elasticities: Isagen



Offer prices and proportion of pivotal hours: Isagen

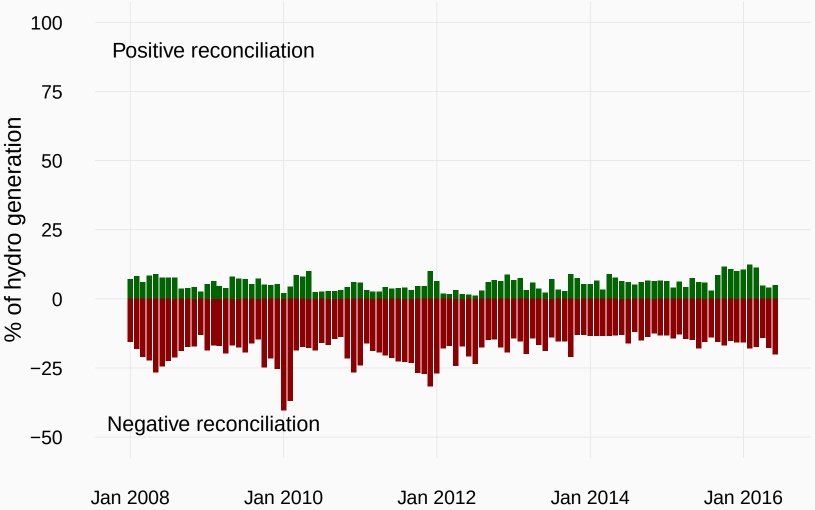


Conclusions from Analysis of Ability to Exercise Unilateral Market Power

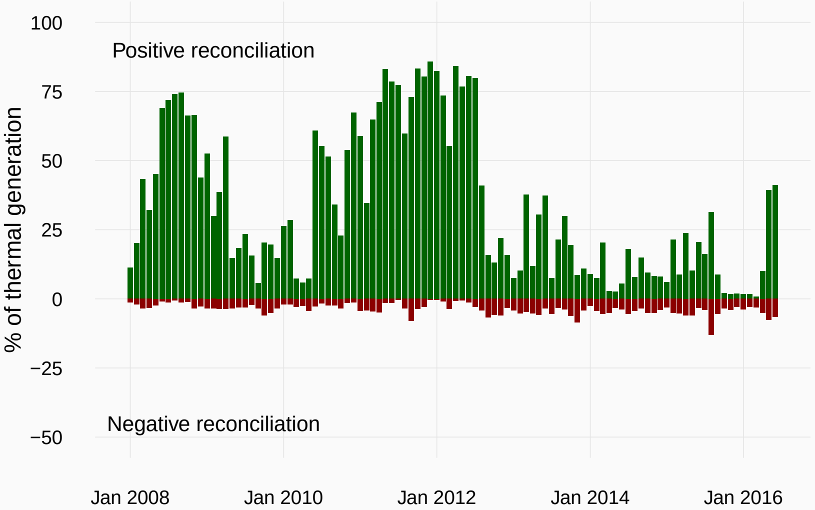
- By inverse semi-elasticity measure η_{hk} and pivotal supplier frequency all suppliers have little, if any ability to exercise unilateral market power until early 2014, even during 2009-2010 El Niño Event
- From October 2015 onwards, all suppliers both measures showed massive increase in unilateral ability to exercise market power
- This fact explains massive increase in Bolsa prices during most recent El Niño Event relative to 2009-2010 Event

The Effect of Transmission Constraints

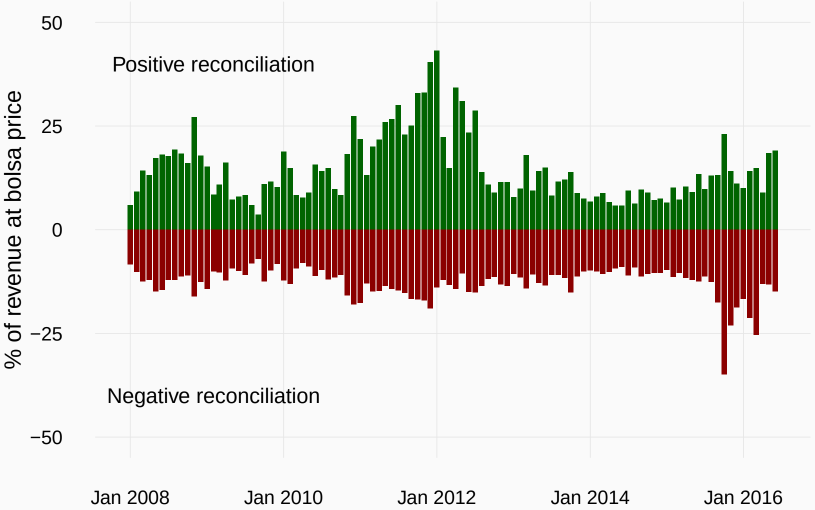
Positive and negative reconciliations for hydro generators, as percentage of hydro generation



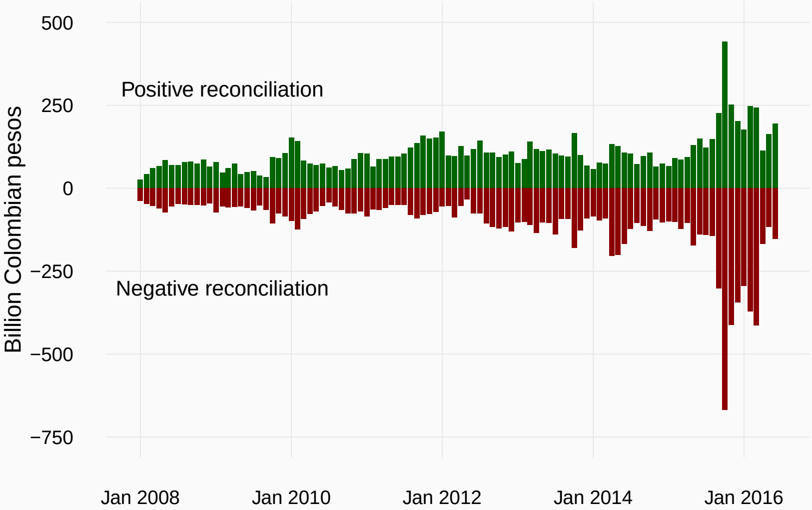
Positive and negative reconciliations for thermal generators, as percentage of thermal generation



Revenue for positive and negative reconciliations for all generators, as percentage of total revenue



Revenue for positive and negative reconciliations for all generators, in Colombian pesos



Conclusions from Analysis of Transmission Constraints

- Hydro generators receive more negative reconciliations ($\approx$ 20 percent of hydro generation) than positive reconcilations ($\approx$ 5 percent)
- Value of both positive and negative reconciliations payments in Colombia Peso fairly constant over 2008 to 2016 period, except for substantial increase during 2015-2016 period
- Both postive and negative reconciliations payments as a share of energy market as remained relatively constant over 2008 to 2016 time period, with slight increase during 2015-2016 time period

Diagnosing the 2015-2016 El Niño Event

Initial Conditions in 2015 versus 2009

- Increasing share of hydro generation capacity from 2010 to 2016 with growing demand for electricity suggests need for more conservative use of water
    - Less margin for error in surviving low water conditions in 2015-16 versus 2009-10
- Major difference between 2015-16 Event and 2009-10 Event is low water inflows in 2013 and 2014 and first three quarter of 2015 and relatively small increase in utilization of thermal capacity
- Offer behavior of large suppliers appeared to favor hydro units versus thermal units during this time period
    - Rational response to incentives created by RPM given Bolsa prices during 2009-10 Event

Market notice from XM on September 22, 2015

Boletín Energético #74

Seguimiento a Variables – Septiembre 22 de 2015

Cualquier inquietud por favor escribirla al buzón seguimientosituacionenergetica@XM.com.co

xm ■ filial de isa

Algunos embalses alcanzan niveles cercanos al 0% en algunas de las etapas de la simulación.

Racionamiento (2016):
Semana 9: 3.2% (6.3 GWh-día)
Semana 10: 5.9% (11.8 GWh-día)
Semana 11: 10.9% (21.8 GWh-día)
Semana 12: 7.3% (14.6 GWh-día)

Post September 22, 2015 Market Participant Behavior

- Following XM Market Notice on September 22, 2015, close to 100 percent of hours had P(Bolsa) > P(Scarcity)
  - Implies that only [Q(Ideal) - Q(Firm)] is relevant to supplier's incentive of exercise unilateral market power
- Many days when Q(Firm) and Q(Contract) created incentive for suppliers to set Bolsa prices at or above P(Scarcity)
- For all six large suppliers, massive increase in unilateral ability to exercise market power
- Just when regulator wants suppliers to manage water prudently and set reasonable prices
  - Interaction between RPM and forward contract levels created incentive to use this increased ability set to extremely Bolsa high prices

Can RPM Mechanism Be Salvaged?

Problems with RPM Mechanism

- RPM Mechanism administratively complex is often opaque in terms of incentives creates for supplier behavior
- Requires setting a number of parameters that are difficult, if not impossible, to set ”correctly”
- Requires an ”reasonable” level of contract enforcement that does not exist in other forward markets
- Requires ”unreasonable” degree of sophistication in managing risk of El Niño Event risk from market participants
- Readily available alternative that does not have these features that can be easily implemented

Administratively Complex and Opaque

- Firm Energy Value of a generation unit is administratively determined
- Hourly Firm Energy is administratively determined and confidential
    - Supplier does not know hourly values of Firm Energy of its competitors, different from forward contracts for energy
- Increases uncertainty how a supplier perceives its competitors will behave, which increases uncertainty in market outcomes
- Adverse impact of lack of transparency likely to be greatest during periods with low water levels
    - Periods suspected of turning into El Niño Events

The Problem of ”Impossible-to-Set” Parameters

- Impossible for regulator to know maximum energy a hydro supplier can produce during future El Niño Event
  - Firm Energy Value equal to historically lowest hydro output is a feasible, but most likely, incorrect
- Impossible for regulator to know minimum ”safe” water level for a hydro electric generation
  - Regulatory requirement to maintain water level above value set by regulator likely to increase cost of managing low water conditions
- Impossible to set ”correct” level for Scarcity Price
  - Cannot account for all causs of a Scarcity Price above variable cost of highest cost unit on system
- Impossible to set ”correct” level for total Firm Energy

”Unreasonable” Level of Contract Enforcement

- RPM supplier receives Firm Energy Payments for many years without ever having to supply energy
- During El Niño Events thermal suppliers asked to produce much more energy
  - Supplier’s input costs–fuel, labor, and materials–rapidly increase which increases cost of honoring RPM contract
- Implication: Precisely when RPM should provide incentive for supplier to honor contract, it has greatest incentive to default
- Virtually impossible to verify if supplier’s claims that variable cost of supplying energy is above P(Scarcity), regardless of mechanism used to set P(Scarcity)
  - Termocandelaria’s claim during El Niño Event

Downside of Setting Enforceable Scarcity Price

- Can focus on setting an enforceable Scarcity Price
    - Recognize that cannot set ”correct” price, so focus on enforcing Scarcity Price
- Ensure supplier sells Q(Ideal) at P(Scarcity) and honors $max(0, (P(Bolsa) - P(Scarcity))(Q(Ideal) - Q(Firm))$, regardless of its variable cost of production
- Enforcing $P(Scarcity)$ requires managing incentive of supplier to default on contract
    - Hold Firm Energy Payments in account that counter-party can access to cover damages if supplier defaults
    - Could require very large amount of money to be held in this account for thermal suppliers

Downside of Setting Firm Energy Requirement

- Impossible to know how much Firm Energy is required for reliable system operation
    - Recall that it is impossible to determine maximum amount of energy that can be provided by a hydro unit during future El Niño Event
- Purpose of running a market it to find out least cost mix of capacity needed to meet system demand
- RPM Firm Energy mechanism assumes this is known by regulator
- Reliability Mechanism should focus on supplying what can be known–Demand for Energy

Structural Flaws in RPM Cannot Be Fixed

- Unnecessarily complex and opaque, especially during low water conditions
- Many impossible-to-set parameters
  - Scarcity Price becomes focal point for Bolsa prices during low water events
- Requires ”unreasonable” level of contract enforcement
  - Less unreasonable for thermal-based market than hydro-based market
  - Short duration supply versus long-duration supply during low water conditions

An Alternative Approach to Managing El Niño Events

Alternative Solution to Reliability and Long-Term Market Design

- Eliminate Reliability Payment Mechanism (Firm Energy Obligation)
- Replace with alternative approach based on standardized forward contracts for energy
  - Product can be traded through Derivex or XM
- Implement multi-settlement locational marginal (LMP) markets with local market power mitigation mechanism
  - Increase number of offer steps for each generation unit to at least five steps
- Encourage participation of purely financial participants in wholesale and retail market

Mandated Standardized Forward Contracts for Energy

- Focus on achieving reliable supply of energy at a reasonable price
- Mandate that all retailers and free consumers must purchase pre-specified fraction of realized demand and various horizons to delivery in standardized forward contract
  - 95 percent one year in advance
  - 90 percent two years in advance
  - 85 percent three years in advance
- Retailers and free consumers subject to financial penalties for under-procurement
  - No prohibition on additional bilateral trading of energy by retailers or suppliers
- Goal of mechanism is to encourage development long-horizon forward market for energy

Mandated Standardized Forward Contracts for Energy

- Contracts used for compliance with obligation by retailer or free consumer must be held until expiration
  - Contracts used for compliance are placed separate account and cannot be sold
- If regulator believes that insufficient generation capacity is being built, it can annual increase contracting percentage and length of contracting horizon
  - 98 percent one year in advance
  - 93 percent two years in advance
  - 90 percent three years in advance
  - 87 percent four years in advance
- Suppliers decide how much and what mix of generation capacity is necessary to contracted levels of demand

Restrictions on Sales of Standardized Forward Contracts for Energy

- Hydro resource owner can sell $Q(Contract) \leq Q(Firm)$
- Thermal resource owner must sell $Q(Contact) \geq Q(Firm)$
  - And $Q(Contract) \leq Capacity\ of\ Unit$
- Restrictions on standardized energy contract sales by technology ensures a reliable supply of energy at a reasonable price during El Niño Events
- Restrictions rely on competition among all suppliers to ensure reasonable prices during other system conditions
- Strong incentive to manage prudently low water conditions that may turn into an El Niño Event

Incentive for Supplier Behavior with Standardized Forward Contracts

Supplier k's variable profit during hour h:

$$\begin{aligned}
\pi_{hk}(P_h(Bolsa)) \\
&= (Q_{hk}(Ideal) - Q_{hk}(Contract)) \times P_h(Bolsa) \\
&\quad + P_{hk}(Contract)Q_{hk}(Contract) - C_k(Q_{hk}(Ideal)), \quad (4)
\end{aligned}$$

- Value of $Q(Contract)(\leq Q(Firm))$ for hydro supplier provides strong incentive to supply Q(Contract) at least cost
- Value of $Q(Contract)(\geq Q(Firm))$ for thermal supplier provides strong incentive to supply Q(Contract) at least cost

Incentive for Supplier Behavior with Standardized Forward Contracts

Suppose that supplier k is a thermal unit and there is plenty of water, its variable profit during hour h:

$$\pi_{hk}(P_h(Bolsa)) = (P_{hK}(Contract) - P_h(Bolsa)) \times Q_{hk}(Contract) \quad (5)$$

- Supplier earns profit by selling at P(Contract) and buying from market at P(Bolsa)
- To discipline incentive of hydro suppliers to exercise unilateral market power thermal supplier should submit offer into short-term market at its marginal cost
- This ensures efficient ”make versus buy” decision by thermal unit to supply Q(Contract)

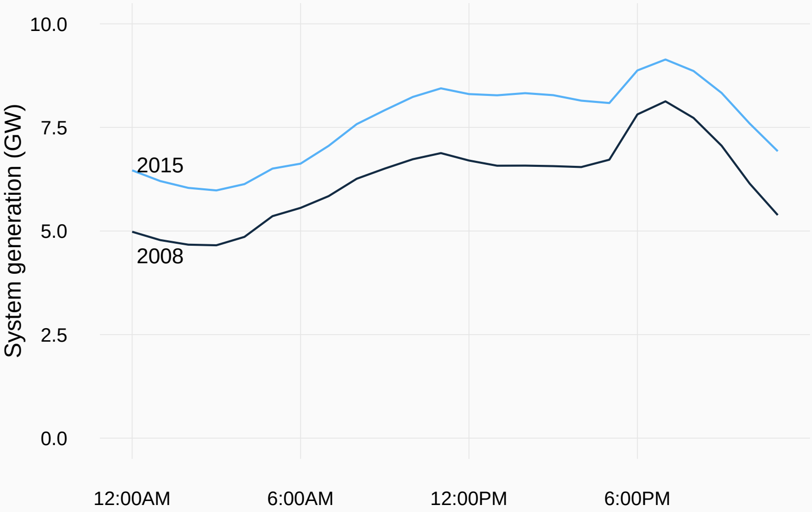
Efficient ”Make versus Buy” Decision by Thermal Supplier Manages Low Water

- Note that during all other water conditions, hydro suppliers are selling much more than $Q(Contract) \leq Q(Firm)$
- As water levels fall, hydro suppliers begin to increase offers to conserve water
- Higher hydro offers imply more thermal supplier ”make” energy than ”buy” energy which conserves water
- As water levels fall, hydro offers increase and more thermal units ”make” rather than ”buy” energy
- Standardized contract approach has both carrot and stick
    - Purchases from short-term market punishes high short-term prices
    - Maximum output during El Niño Event receives p(Bolsa) for Q(Ideal) - Q(Contract)

Load-Profile-Shaped Standardized Forward Contract

- Goal of alternative approach is to make $Q_{hk}(Contract)$ as close as possible output of supplier k in hour h under least cost dispatch of system
- Compute $w_{hd} = \frac{QD_{hd}}{\sum_{d=1}^{D}\sum_{h=1}^{24} QD_{hd}}$, where QD_{hd} is system demand in hour h of day d
- $Q_{hd}(Contract) = Q(Contract) \times w_{hd}$
- Allocate more of total quarterly energy sold to higher demand hours of the day
- This provides incentive for thermal suppliers to submit offers for peak hours of day
    - Thermal suppliers are compensated for start-up costs

Load profile for Colombia



Advantages of Standardized Forward Contract Approach

- Does not require setting impossible-to-set parameters
    - Does use Firm Energy Value from RPM
- Does not require unreasonable level of contract enforcement
    - Can take advantage of existing clearinghouse and margin process at Derivex or XM
- Focuses on ensuring adequate energy at reasonable price during El Niño Events
- Ensures prudent use of water early in possible El Niño Events
- Stimulates development of liquid forward market for energy at long horizons to delivery

Longer-Term Market Design Changes

Match Between Market Mechanism and System operation

- Assuming a market model that does not reflect actual system operation creates incentives for inefficient behavior that takes advantage of this fact
- Colombian market model assumes no transmission congestion–Single Country-wide price
- Possible explanation for high cost of managing transmission congestion and AGC
- Implement market model that respects transmission constraints and all other relevant operating constraints
- Eliminates need for positive and negative reconciliation process

Locational Marginal Pricing Market

- Set prices by minimizing as-offered cost to serve demand at all locations in Colombia
- Suppliers submit location-specific offer curves
  - Energy and ancillary services markets can be run simultaneous to set internally consistent locational prices for both energy and ancillary services
- Can charge all loads in Colombia quantity-weighted average of all LMPs at withdrawals points in Colombia each hour
  - Addresses concerns about different loads paying different prices
- Market also requires a local market power mitigation mechanism (LMPM) to mitigate offers of suppliers than possess substantial local market power

Multi-Settlement Market

- Run day-ahead forward market using LMP to set firm financial commitments for suppliers and loads
    - Suppliers submit location-specific offers for all 24 hours of following day
    - Loads submit location-specific bids for all 24 hours of following day
- All market participants clear deviation from day-ahead commitments in real-time LMP market
    - If supply less than day-ahead schedule must buy difference from real-time market
    - If supply more than day-ahead schedule must sell difference in real-time market
- Same applies to load-serving entities

Allowing Financial Participants

- Multi-Settlement market facilitates participation of purely financial participants in wholesale and retail market
- Can purchase energy in standardized forward market and sell retail electricity to final consumers
- Ample evidence that presence of financial participants increases competitiveness of retail and wholesale markets
- Singapore introduced standardized forward market for energy in April 2015
  - Lower retail prices as volume long-term contracts outstanding during term of retail contract increases
  - Lower wholesale price as volume of long-term contracts clearing during period increases
- Similar results likely to occur in Colombia

Conclusions and Recommendations

- RPM mechanism worked against goal of reliable supply of energy at a reasonable price during most recent El Niño Event
- Many features of RPM make it extremely challenging to modify to achieve goals
- Standardized forward market for energy approach can be easily implemented to achieve goals
- Multi-Settlement LMP market with Local Market Power Mitigation Mechanism in long-term market design change
- Increase number of offer step for genrations units and all purely financial participants in energy market