Market Power in a Hydro-Dominated Wholesale Electricity Market

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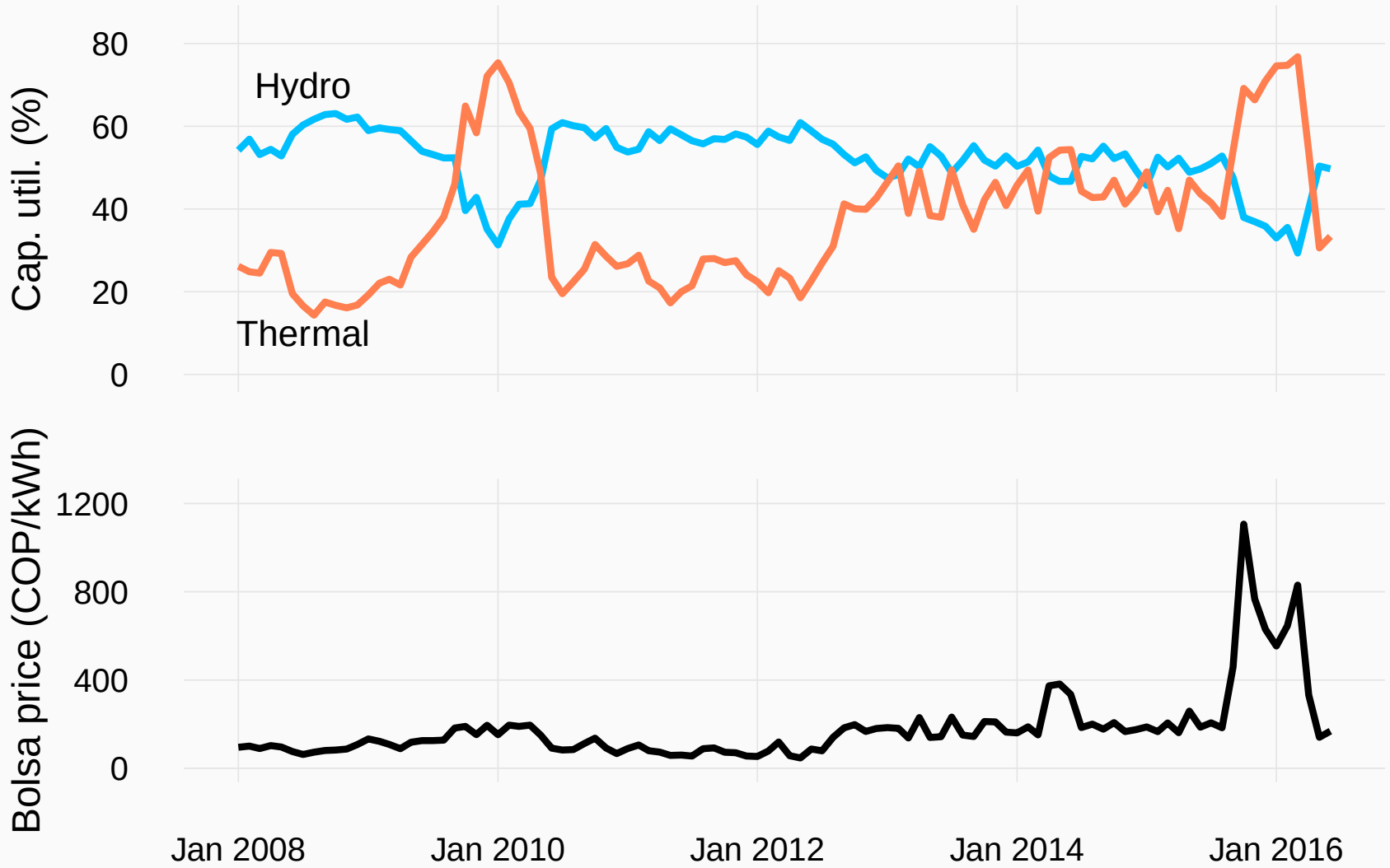
We study the market power in the Colombian wholesale electricity market: a bid-based, hydro-dominated system

- Majority of generation capacity in Colombia is hydroelectric
  - Susceptible to periodic shortfalls in water inflows during *El Niño* events
- Market prices are determined using price and quantity bids submitted by generation owners
  - Other Latin American electricity markets use cost-based dispatch

Much larger increase in wholesale price during 2015–16 El Niño event despite similar thermal utilization rate to 2009–10

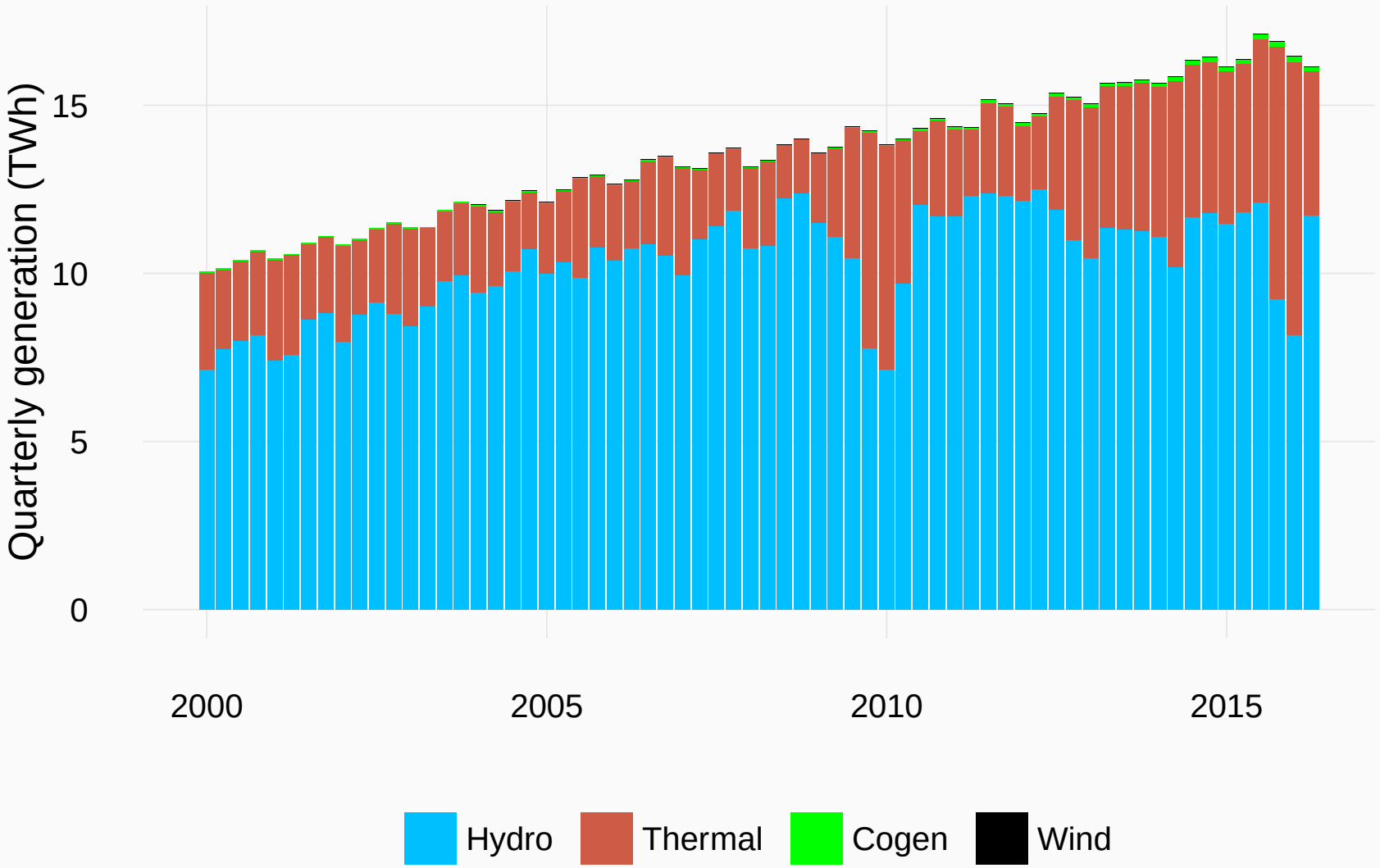


Why do we study this question?

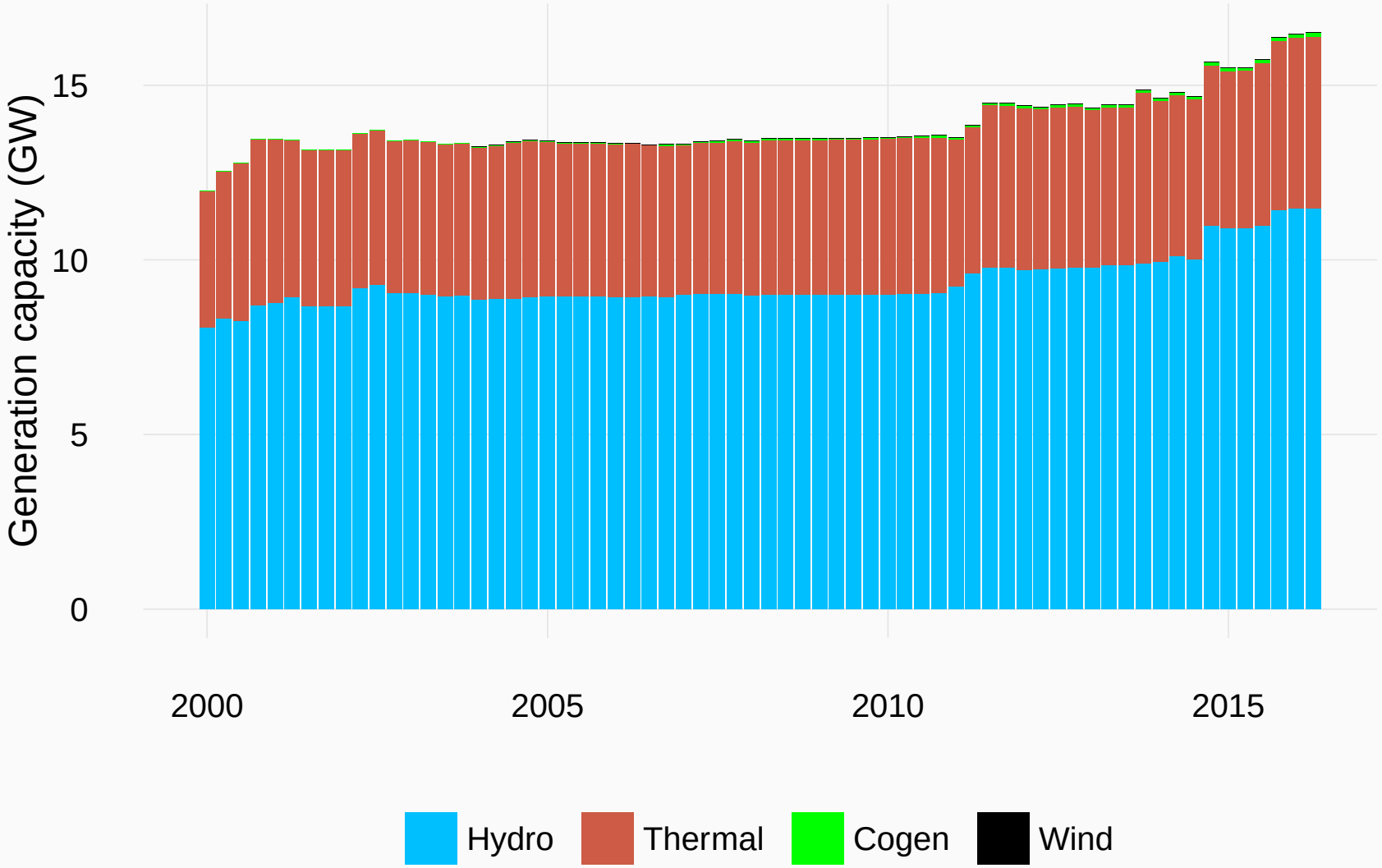
- General interest in the use of wholesale electricity markets as a data-rich “laboratory” for understanding firm behavior
- Policy tension between “regulators” and “markets” in electricity
    - Most restructured electricity markets have an increasingly large role for regulation in determining short-term prices and long-term investment
- How should we balance the costs and benefits of regulation in these markets?

Colombian electricity market

Share of thermal generation has been increasing since 2009, even in years with no adverse hydrological conditions



Most new capacity investment in past decade has been in hydroelectric generation

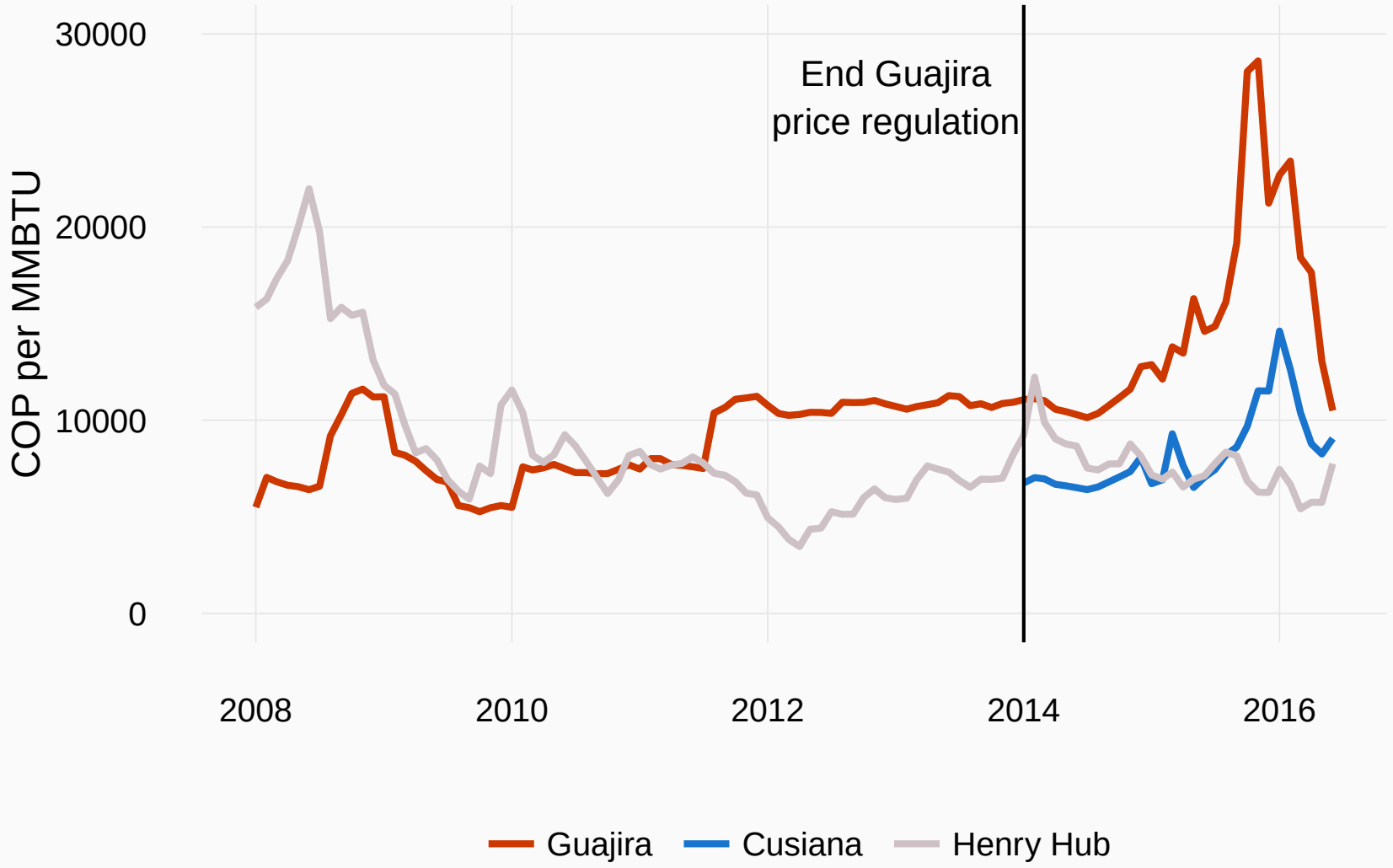


Comparison of *El Niño* events

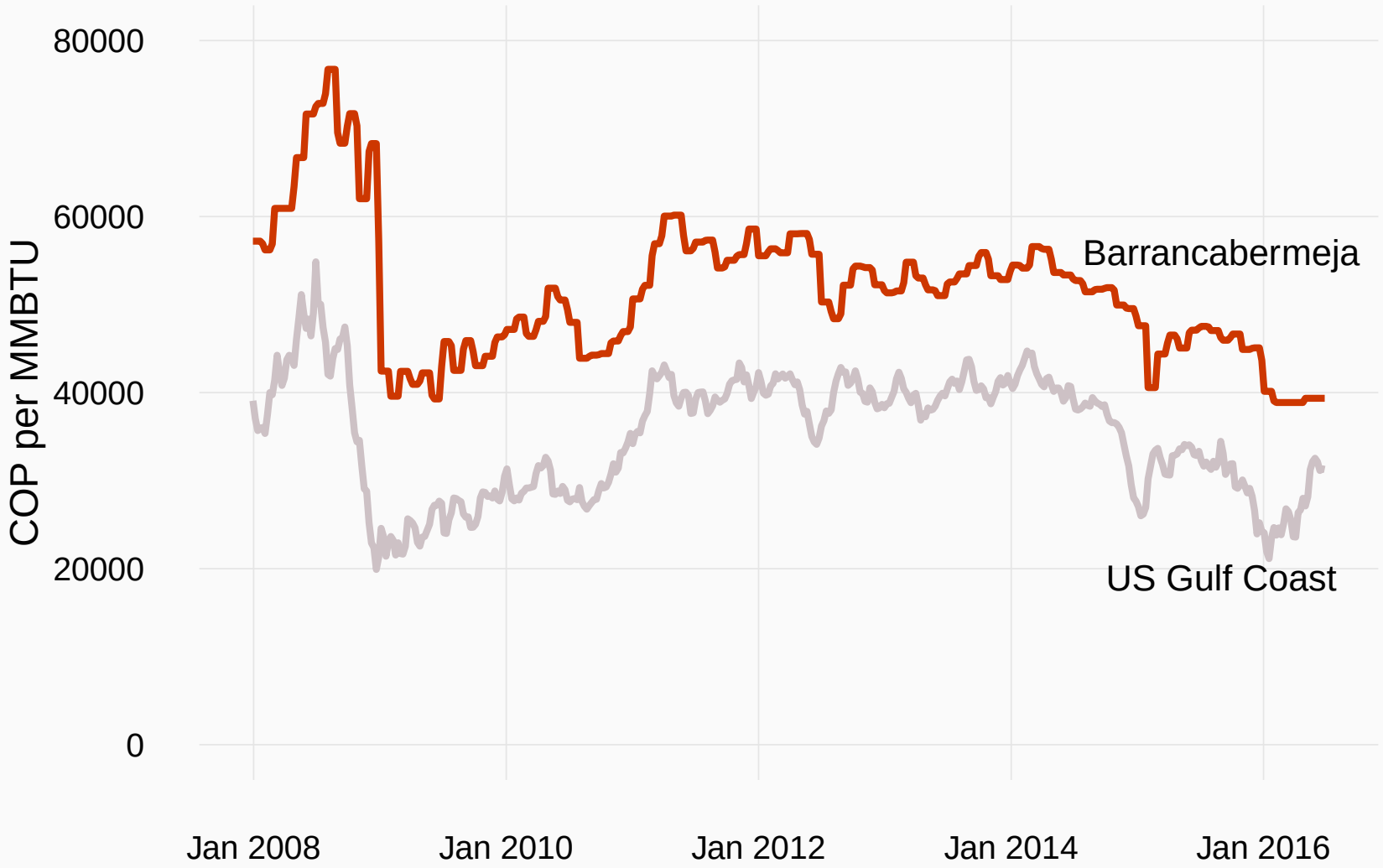
What explains the large difference in prices between the two most recent El Niño events?

- Mean price in 2009–10 El Niño: 185 COP/kWh (US$95/MWh)
- Mean price in 2015–16 El Niño: 675 COP/kWh (US$217/MWh)
- Market structure (institutions and actors) changed little between the two events
- Was there a difference in the hydrological conditions or fuel prices?

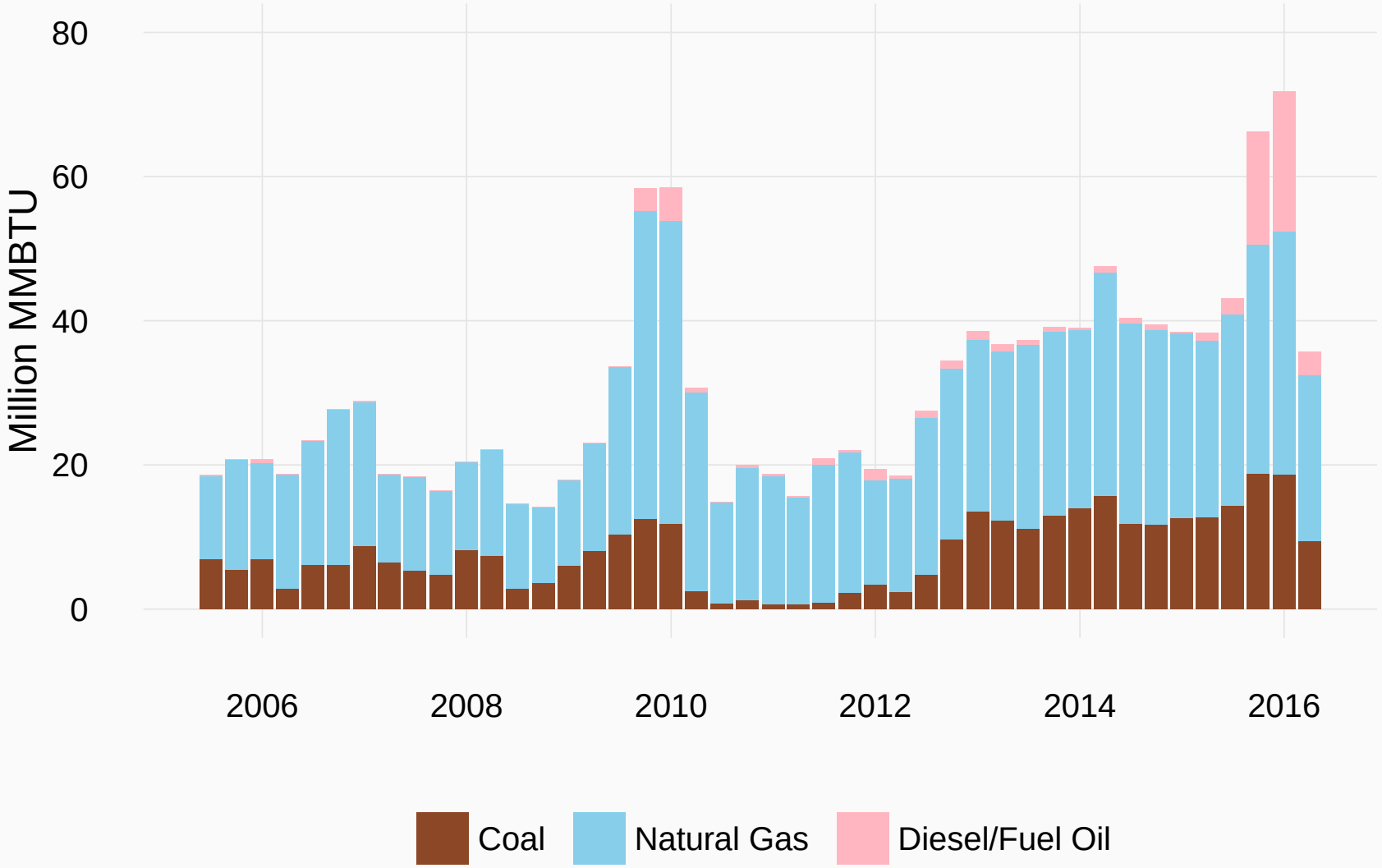
Rise in Colombian natural gas prices after the end of price regulation and the opening of the wholesale gas market



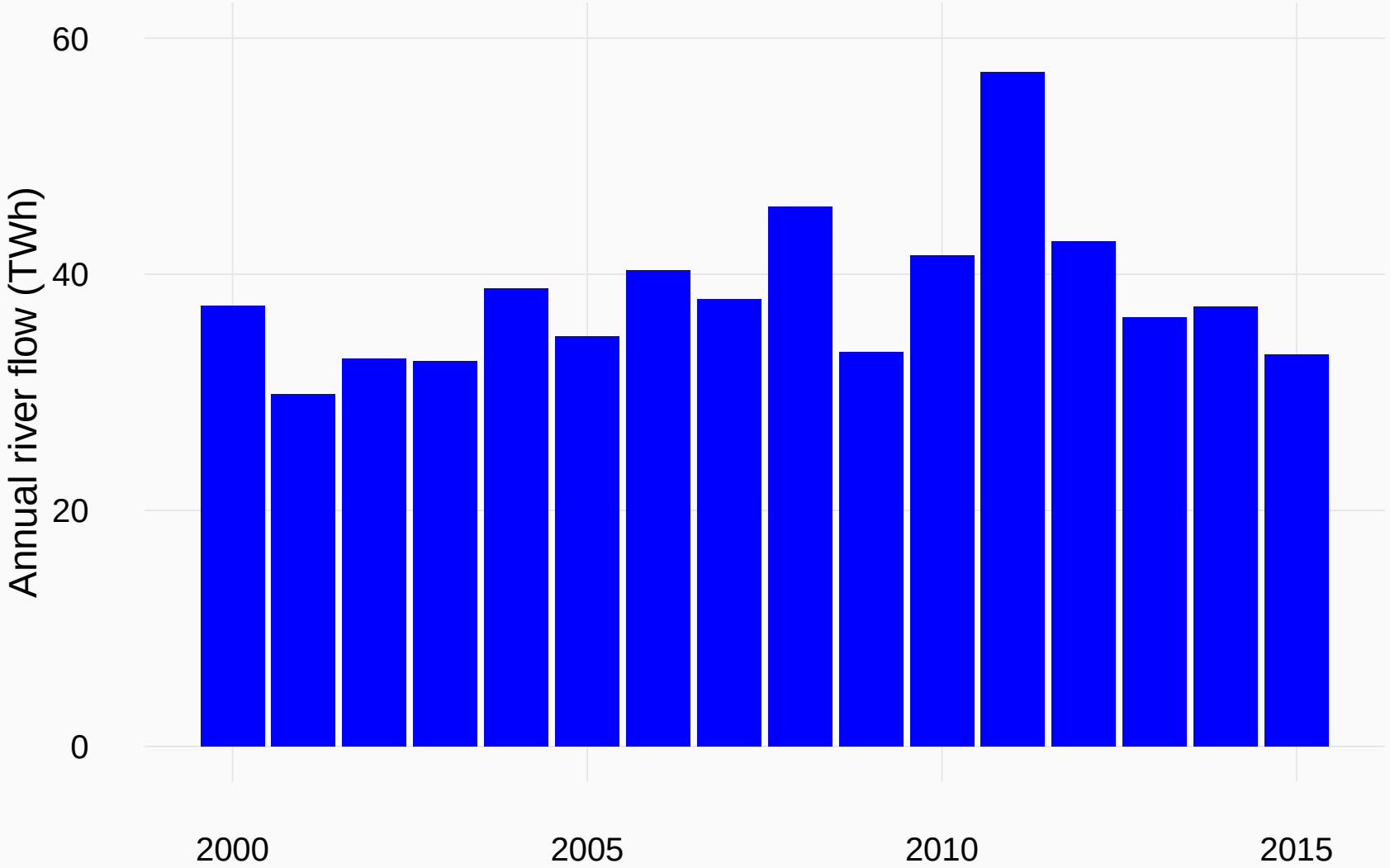
Diesel prices (in pesos) in 2015-16 similar to 2009-10



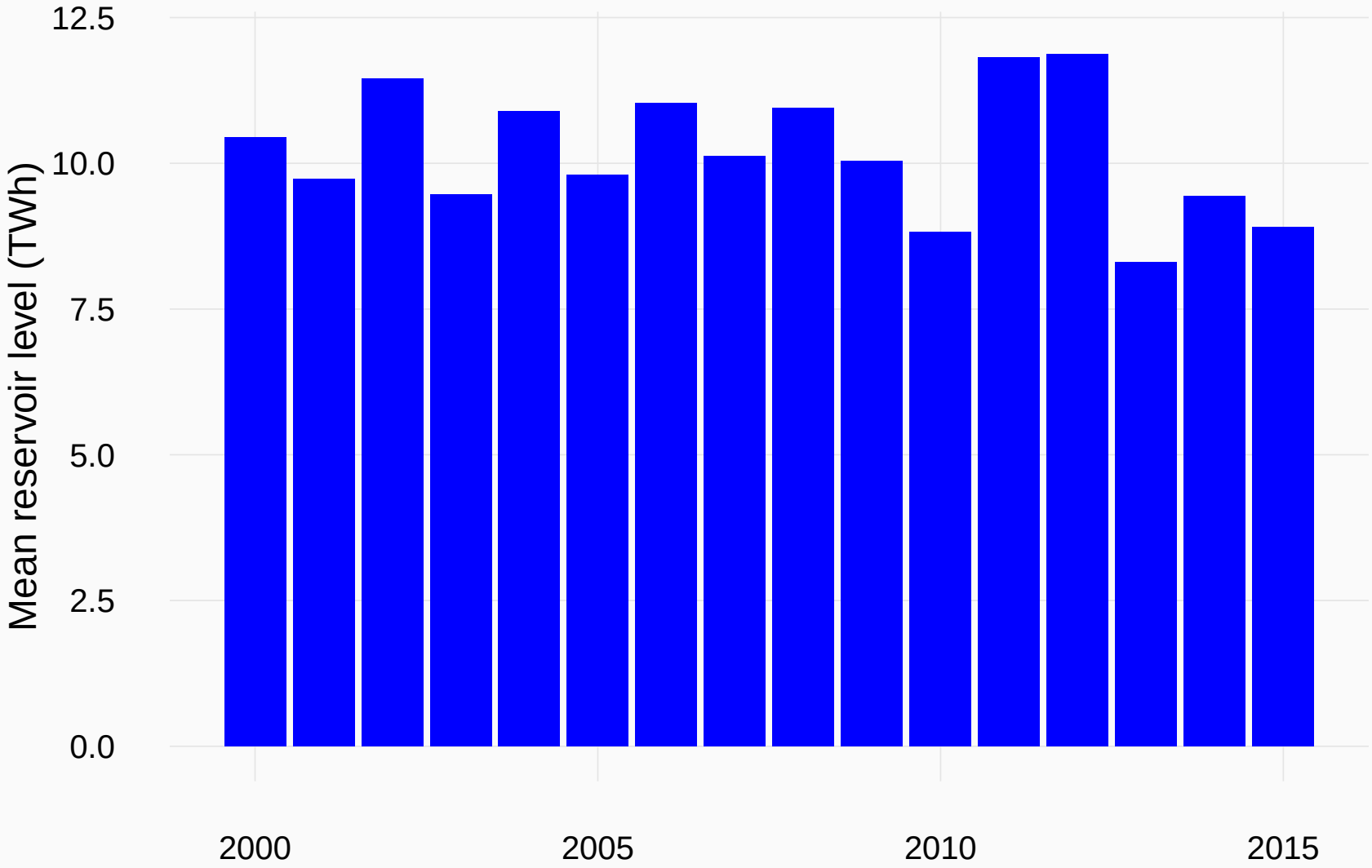
Note that natural gas was inframarginal during both El Niño events (so diesel prices are what matter)



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

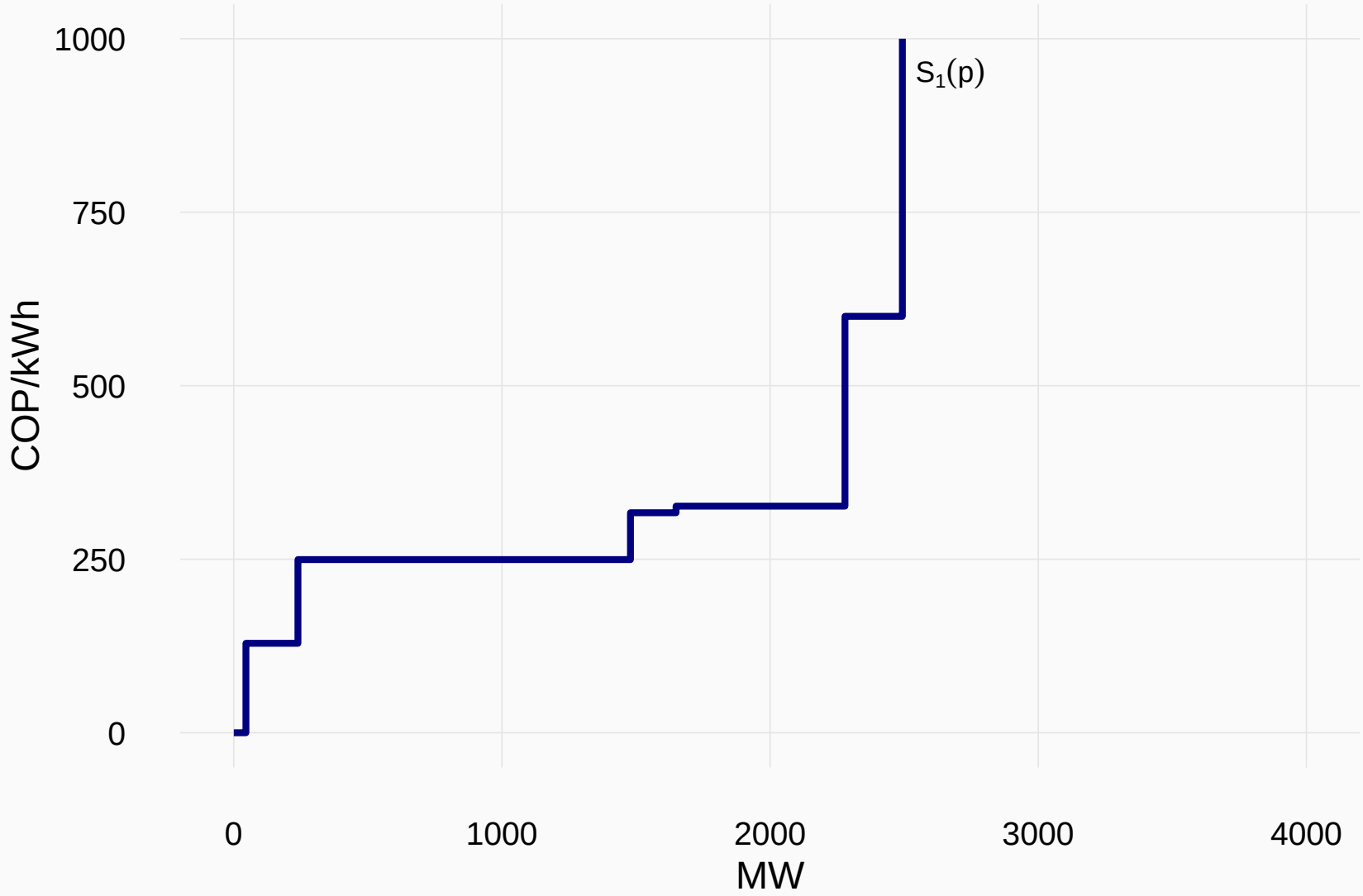


Annual average hydro reservoir levels show similar water levels from 2012 to 2015 as during the 2009-10 El Niño event

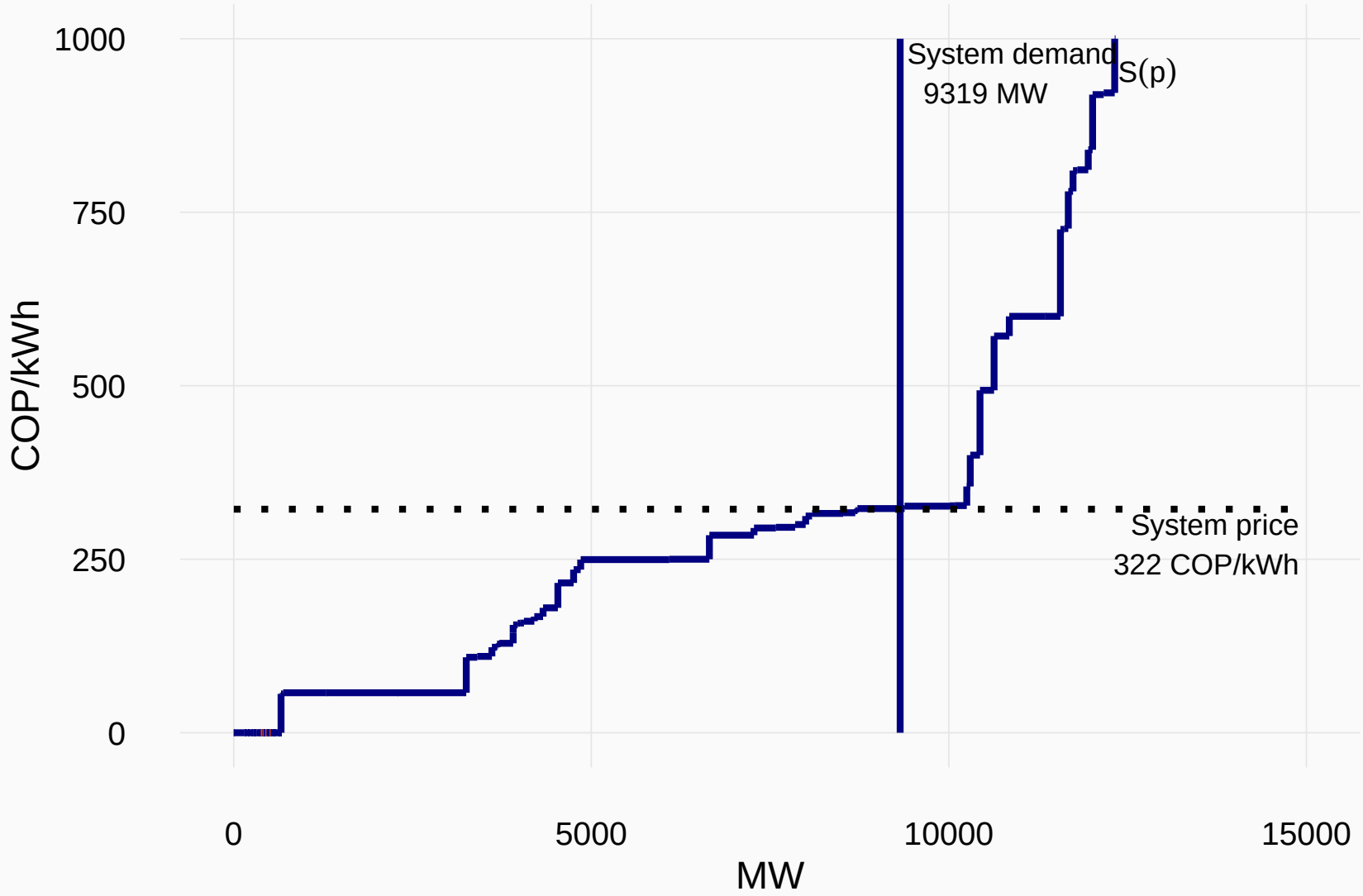


Market power in wholesale electricity markets

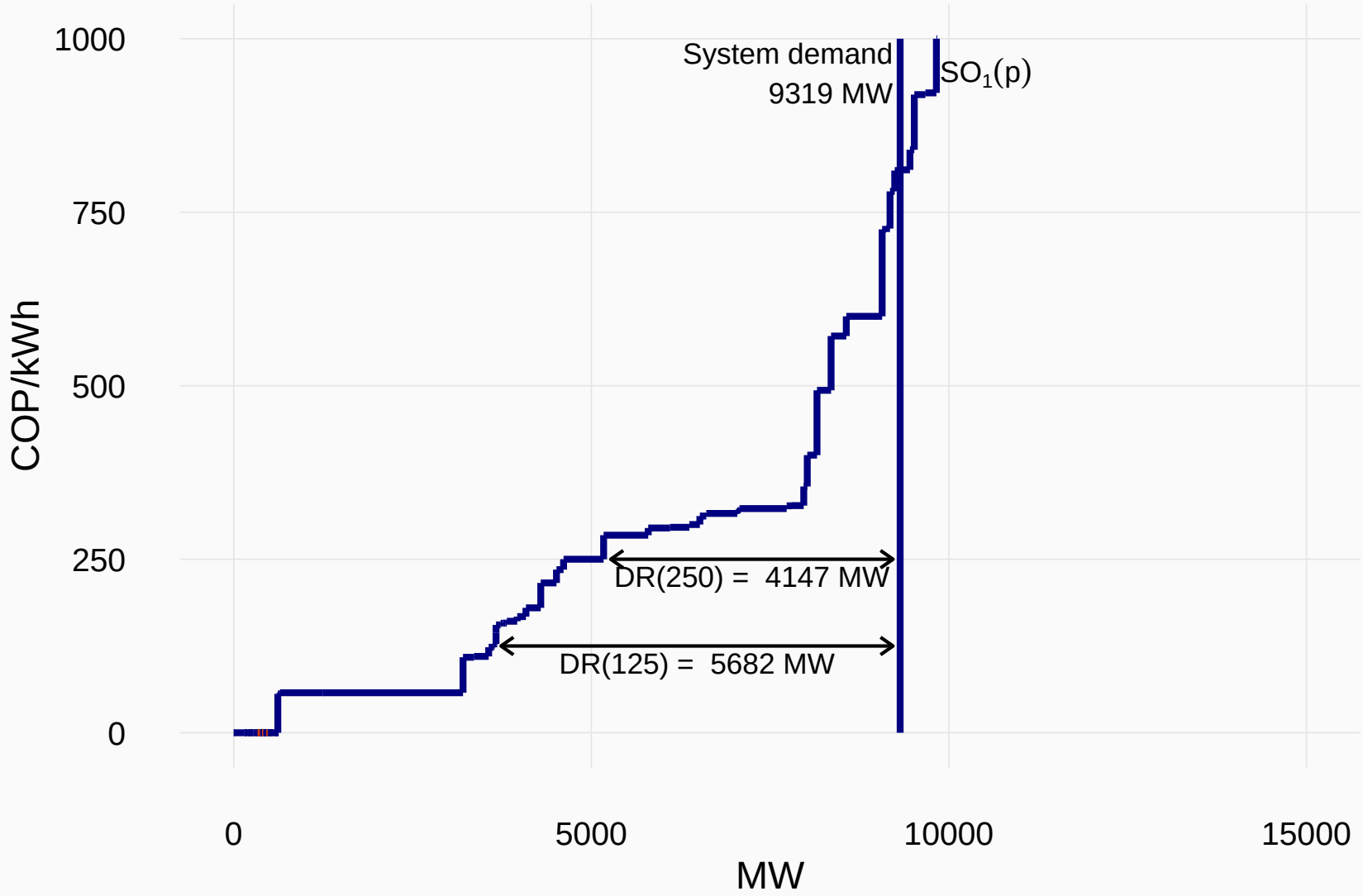
Every day and hour, electricity generators submit a step function supply curve to the system operator



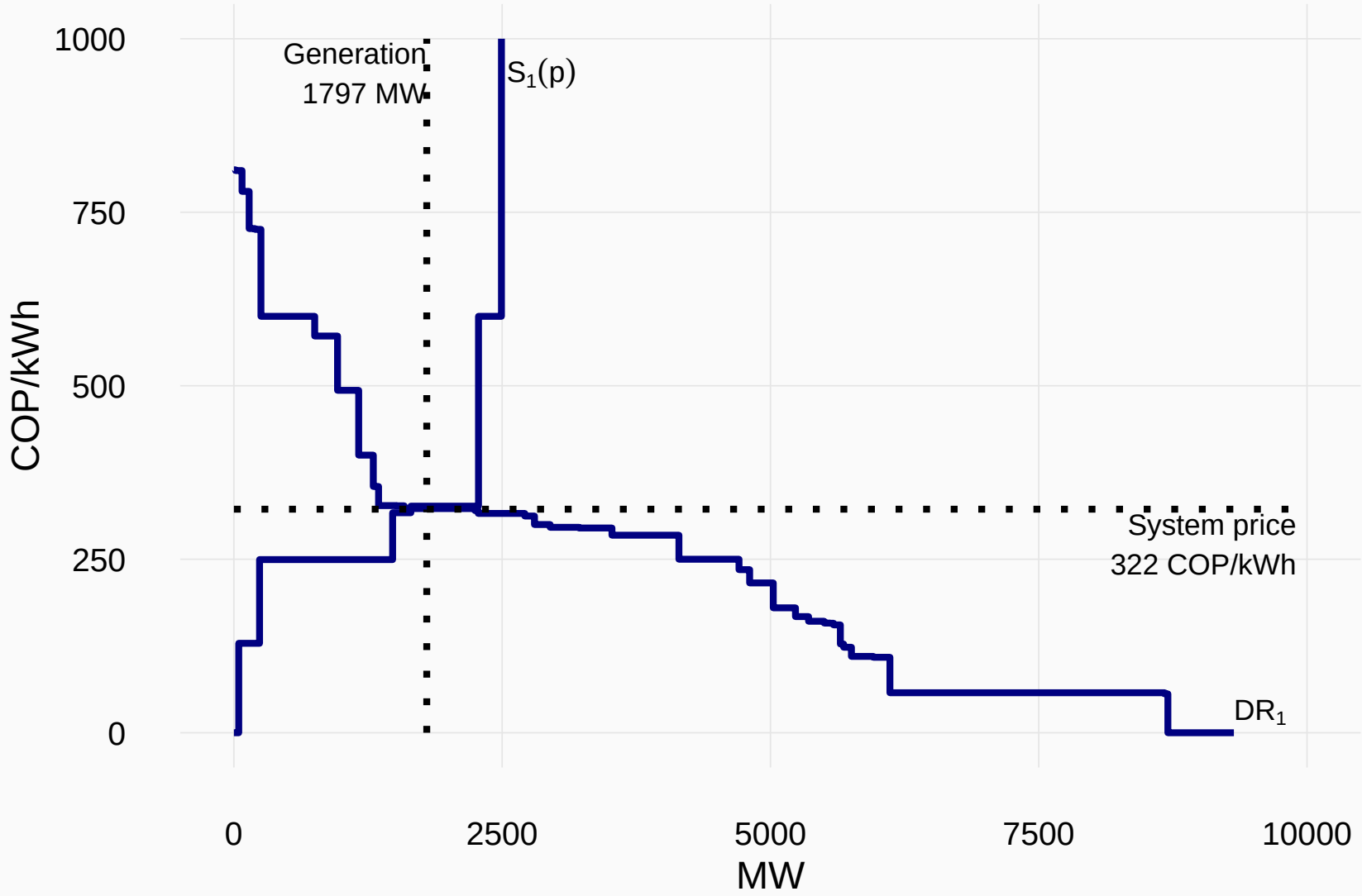
System operator determines market price where the aggregate supply curve crosses aggregate demand (perfectly inelastic)



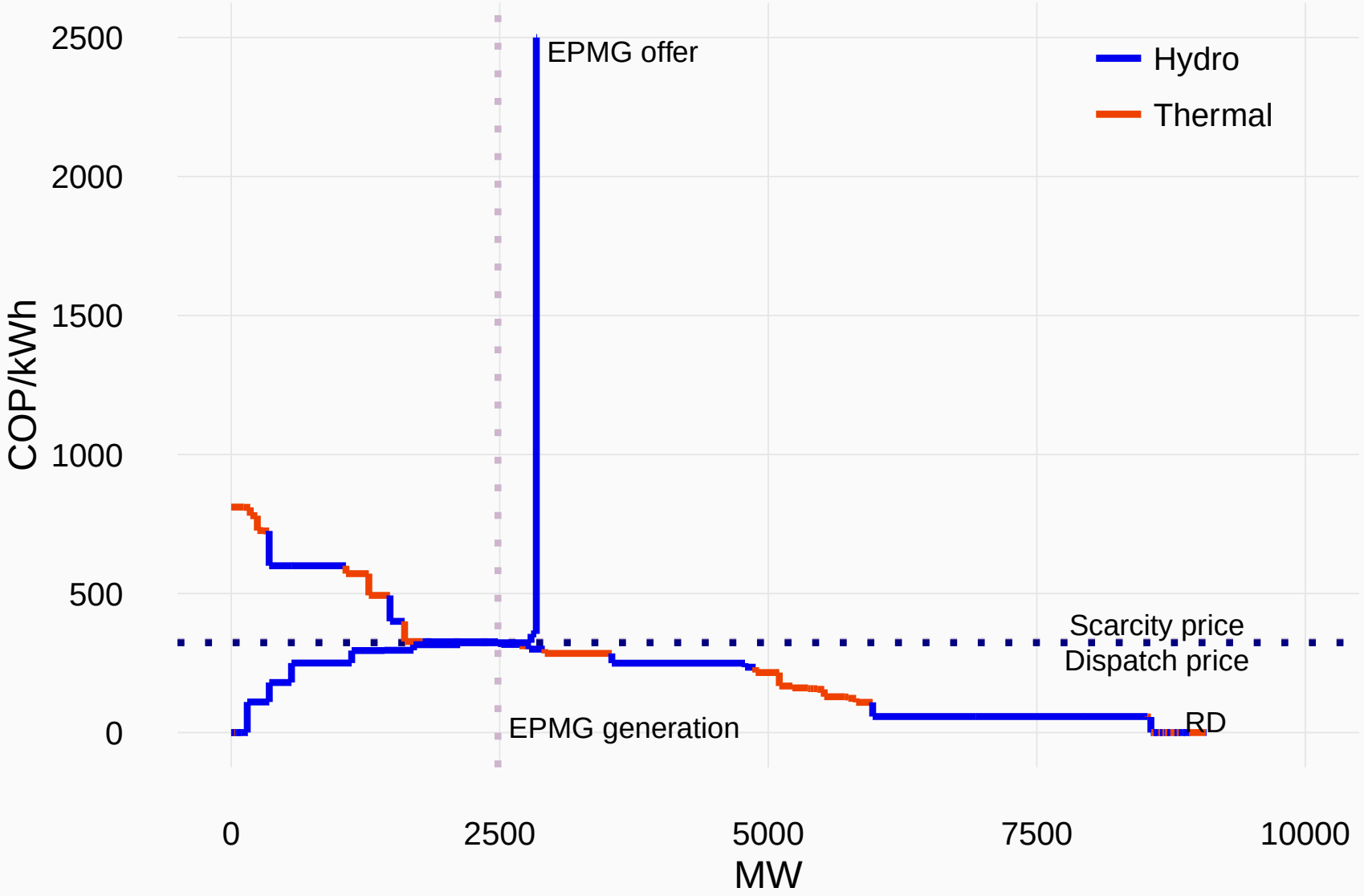
Residual demand for a firm is the difference between system demand and the aggregate offers of all other firms



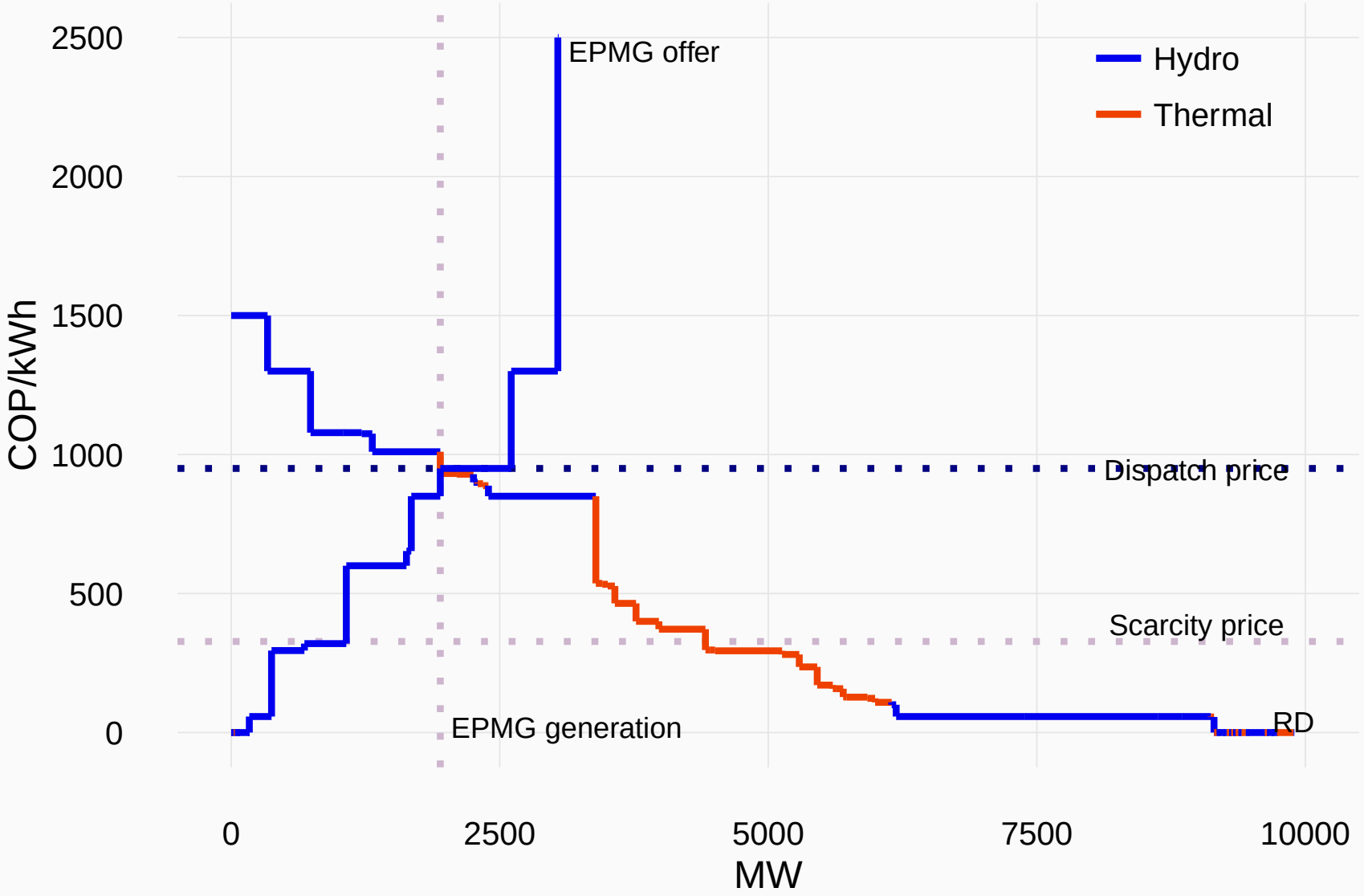
Generation firms can choose the optimal (price, quantity) combination along their residual demand curve



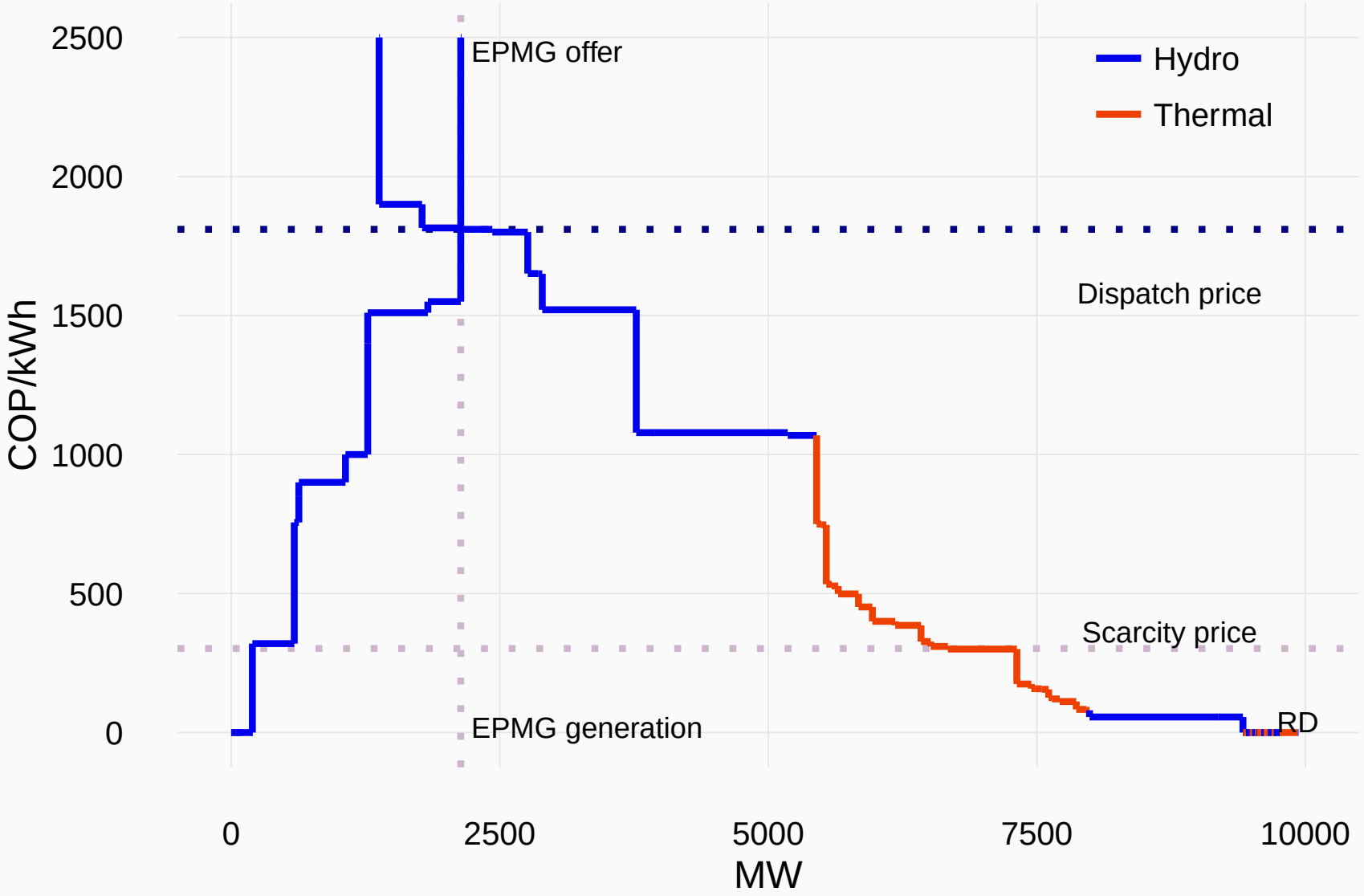
Residual demand and offer curve at 18:00 hrs on September 18, 2015: EPM



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

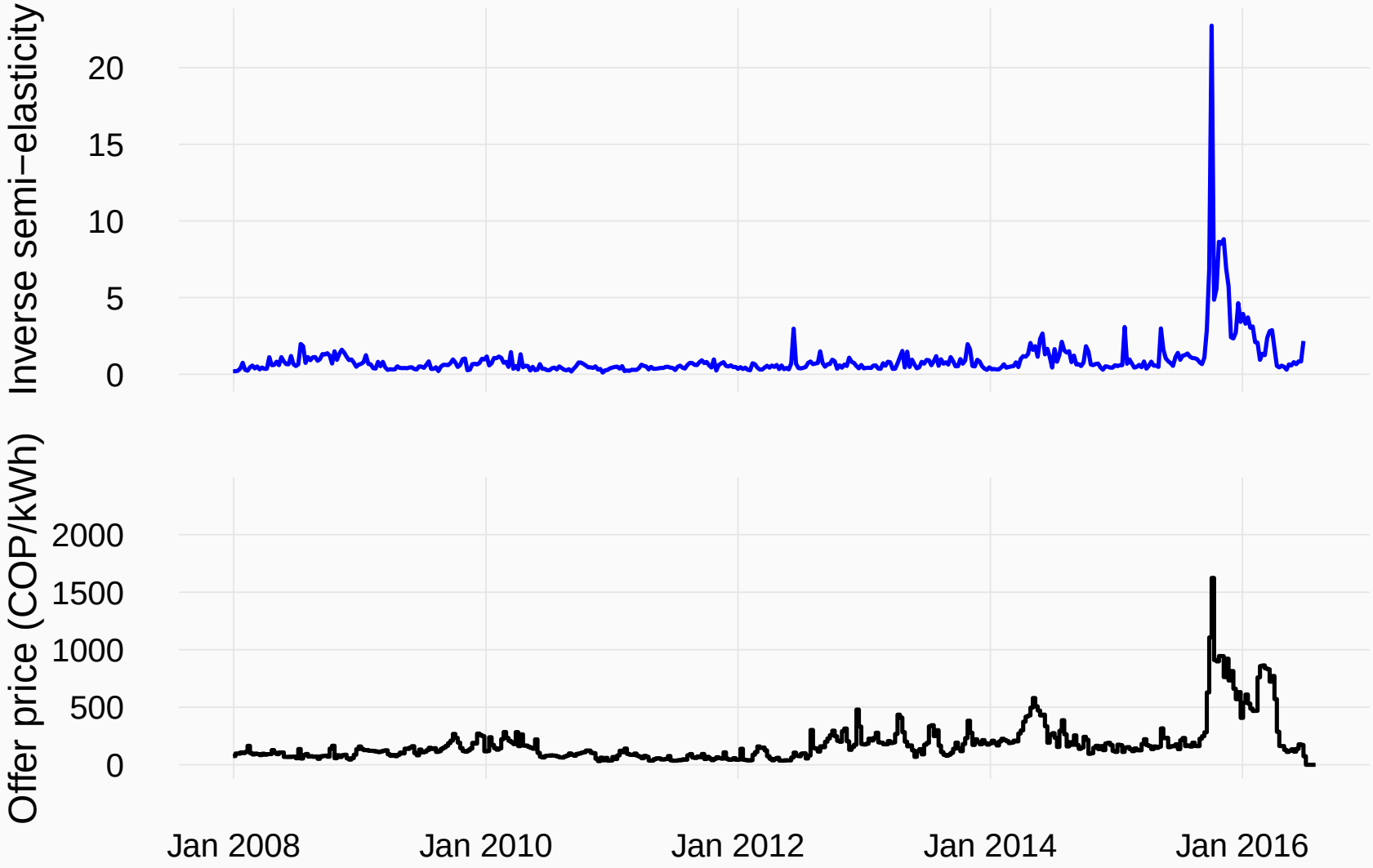
- Inverse semi-elasticity, $\eta_{hk} = -\frac{1}{100}\frac{DR_{hk}(p_h)}{DR'_{hk}(p_h)}$, quantifies COP per kWh increase in wholesale price from supplier k reducing its actual output by one percent
- η_{hk} measures the ability of supplier k to raise the market price at their actual level of output during hour h

Two measures of ability to exercise unilateral market power based on residual demand curve

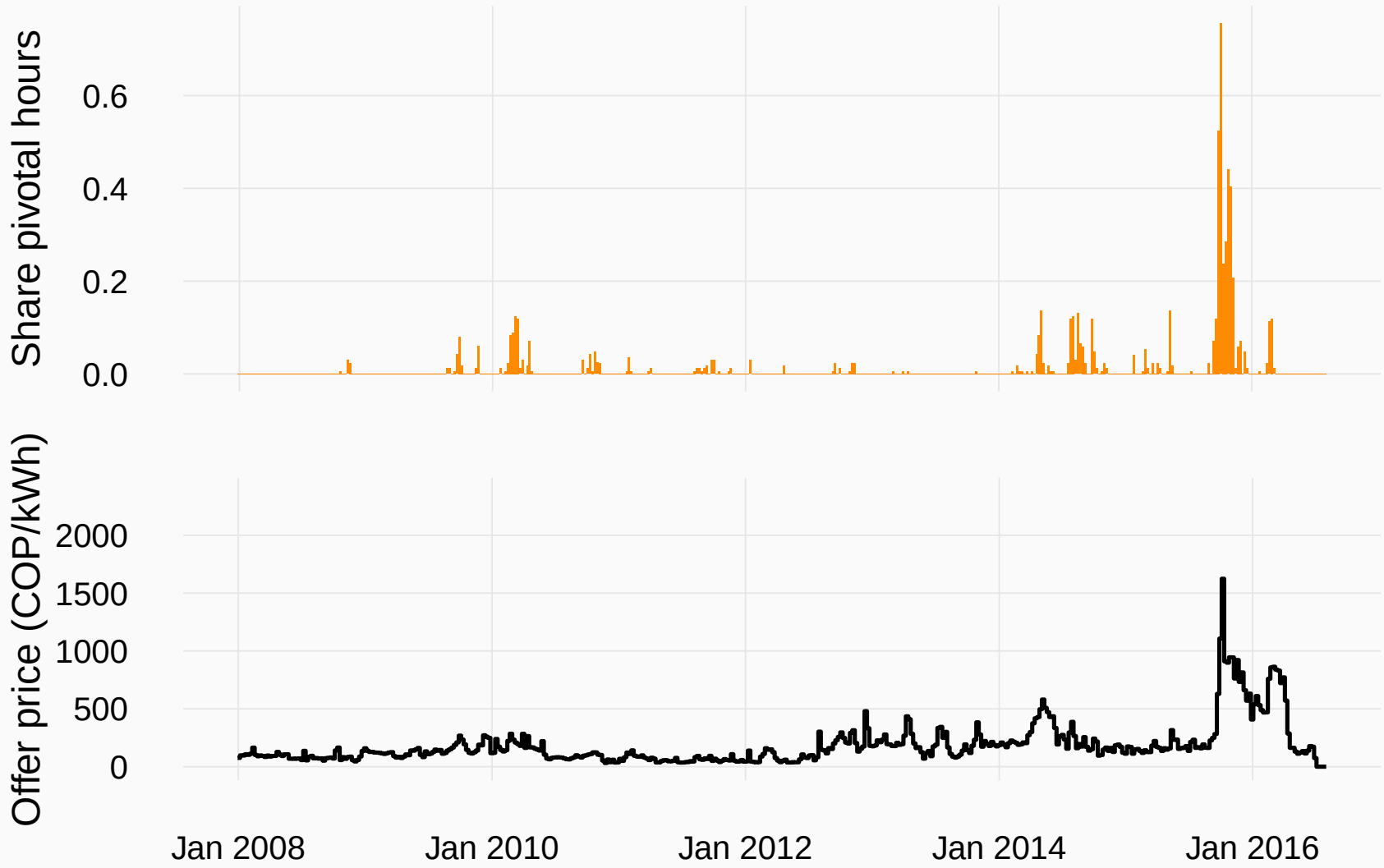
- Pivotal supplier frequency is the fraction of hours in the week that $DR_{hk}(\infty) > 0$, supplier k's residual demand is positive for all possible wholesale prices, meaning that some of supplier k's available capacity is required to serve demand during hour h
- A pivotal supplier can raise the price has high it would like if it is willing to only sell its pivotal quantity, $DR_{hk}(\infty) > 0$

Empirical analysis of market power in Colombian electricity market

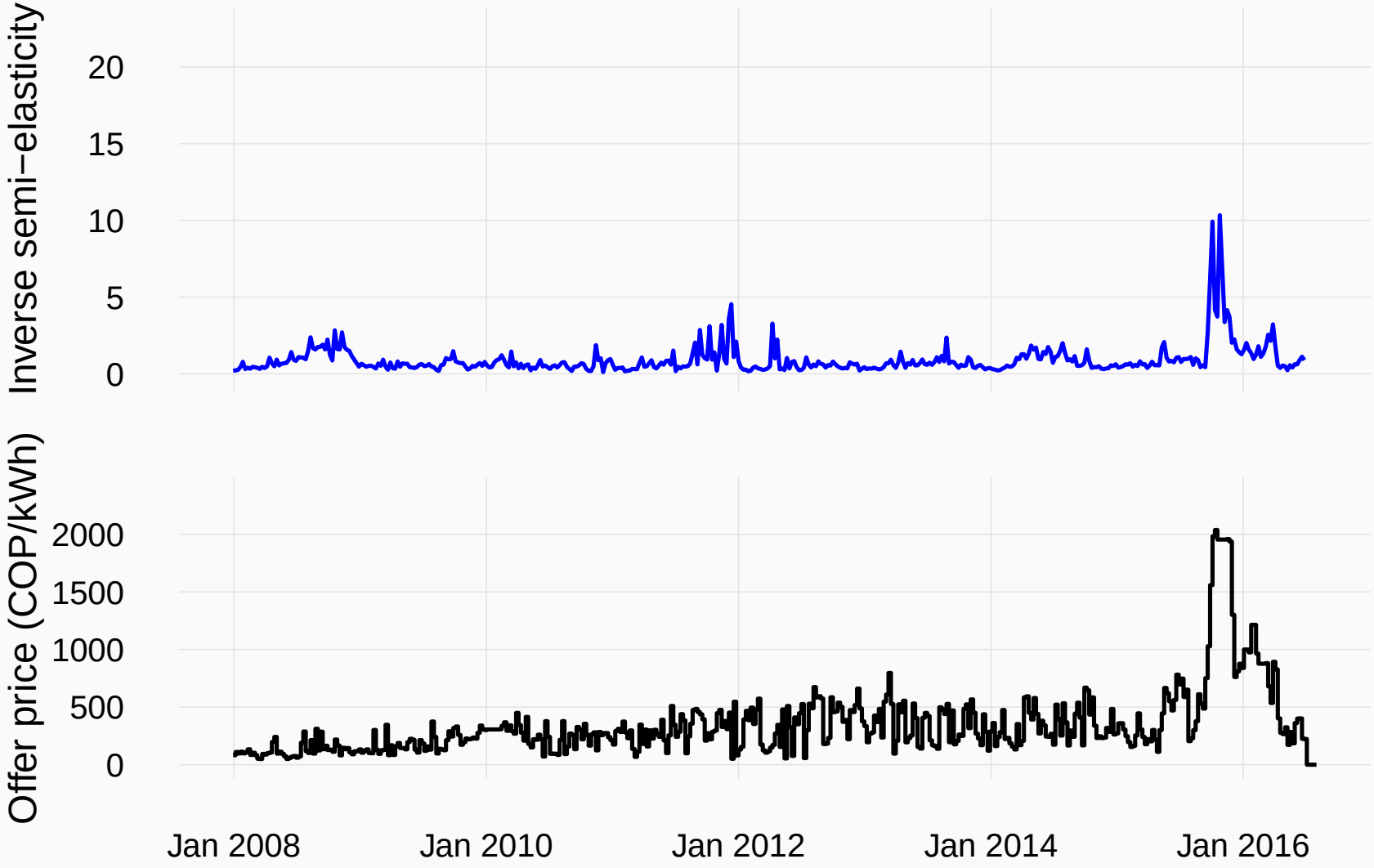
Offer prices and inverse semi-elasticities: EPM



Offer prices and proportion of pivotal hours: EPM



Offer prices and inverse semi-elasticities: Emgesa



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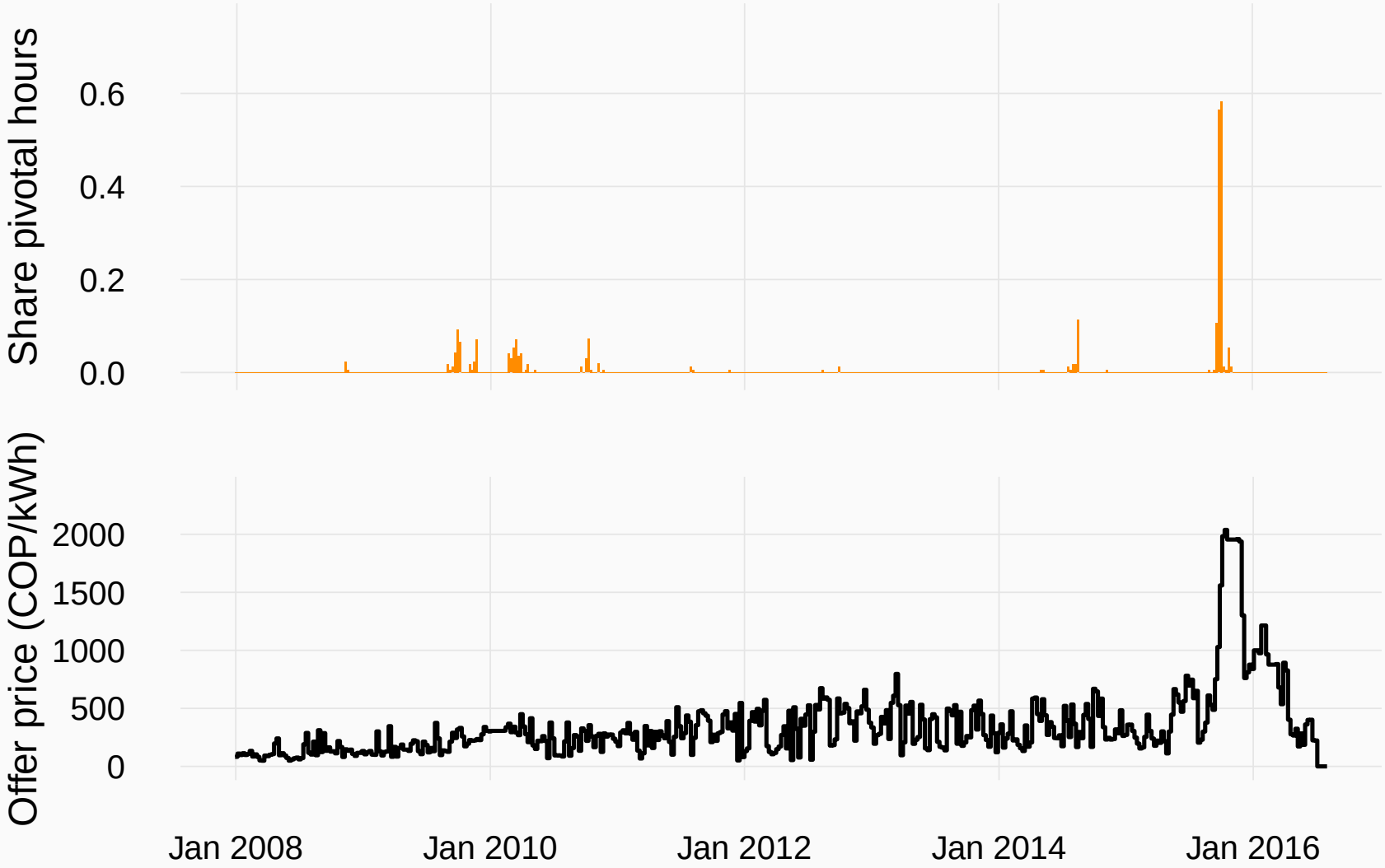
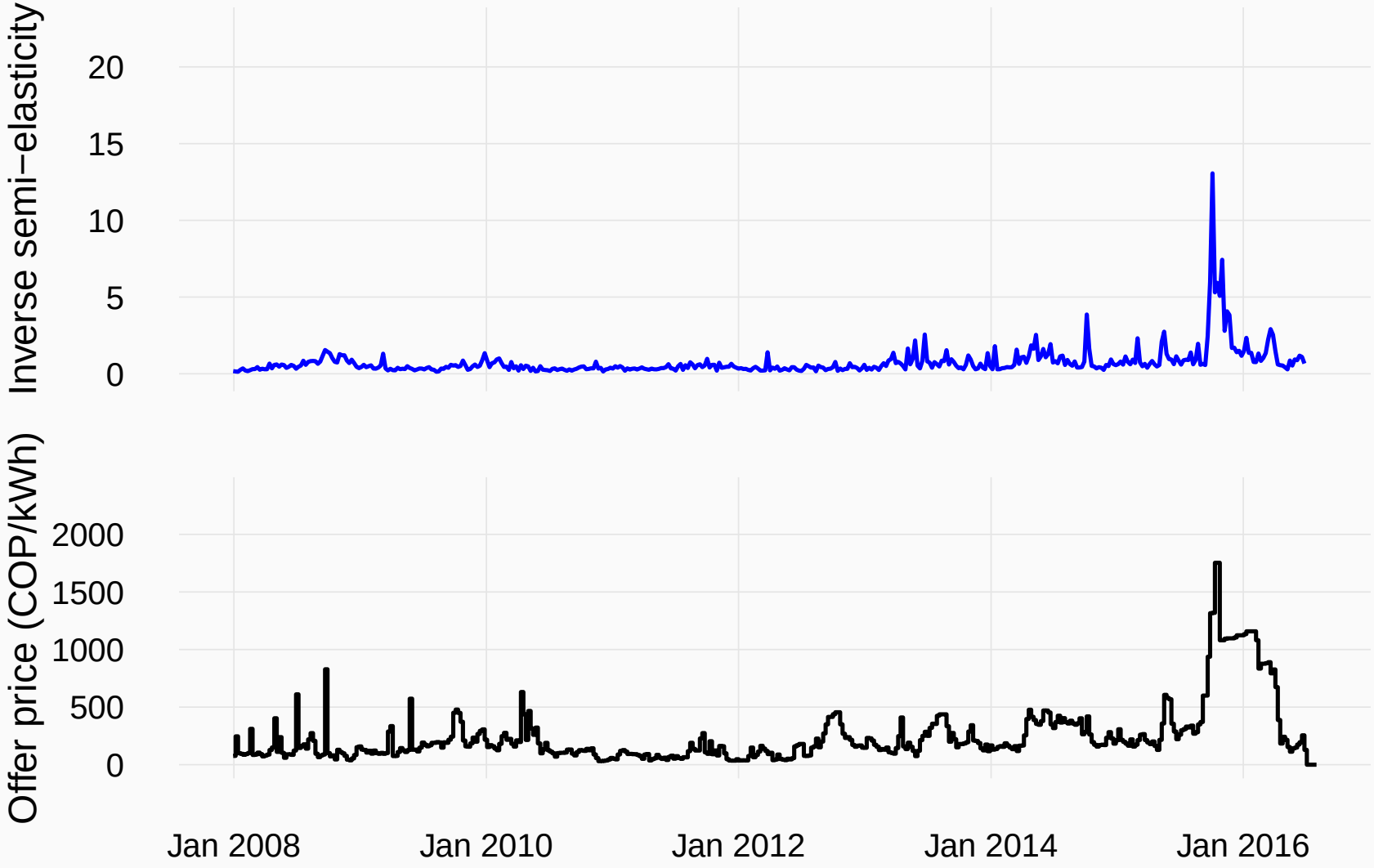
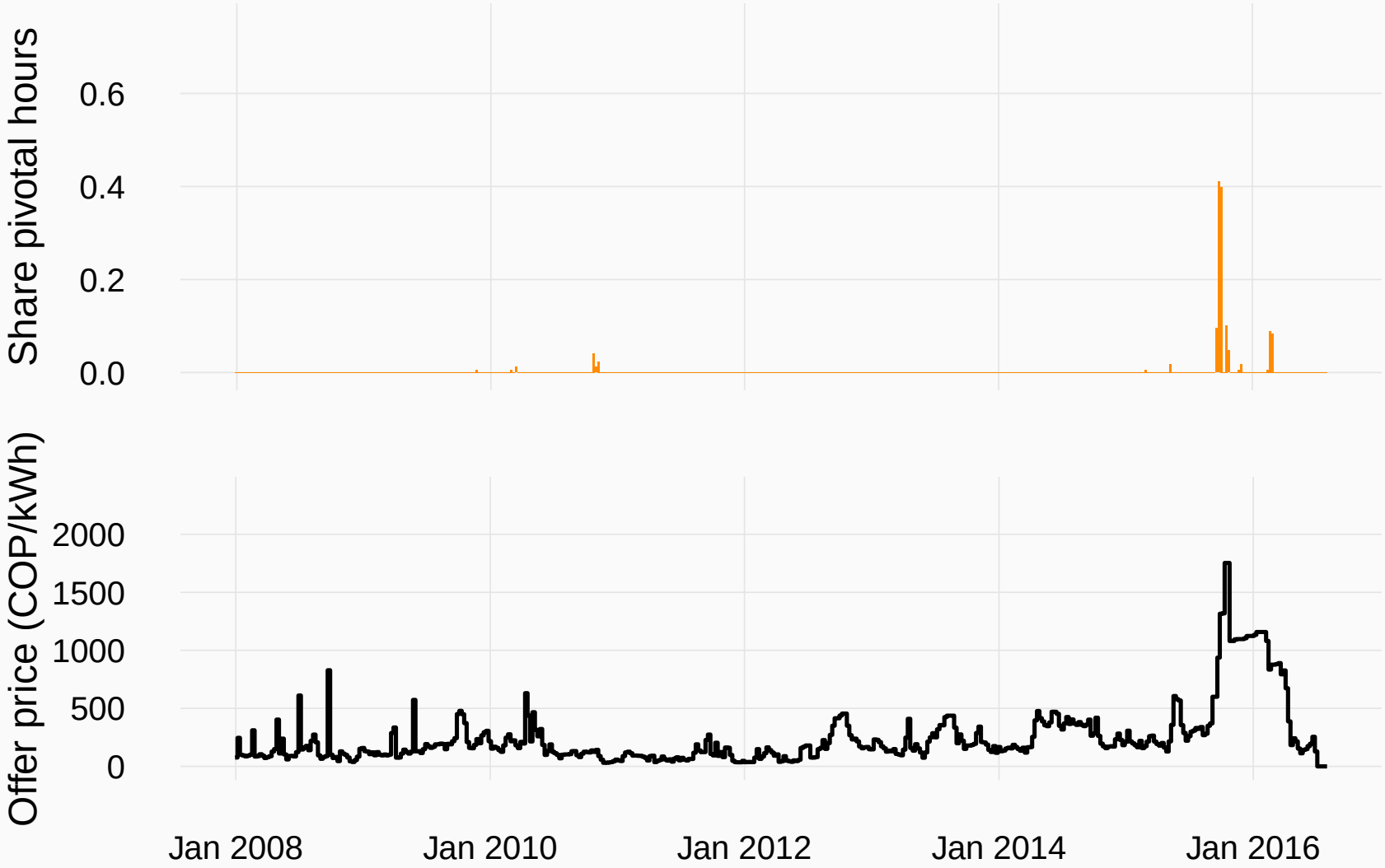


Offer prices and inverse semi-elasticities: Isagen



Offer prices and proportion of pivotal hours: Isagen



Wholesale price is higher in those periods where firms have more market power on average

	(1)	(2)	(3)	(4)
Mean η	18.15			11.90
	(6.16)			(3.44)
Mean pivotal (0/1)		858.22		200.12
		(246.13)		(138.19)
Mean pivotal q (MW)			1.70	1.26
			(0.21)	(0.18)
Hour × year	Y	Y	Y	Y
Month-of-sample	Y	Y	Y	Y
Gen bin × year	Y	Y	Y	Y
Observations	73,742	73,742	73,742	73,742

Offer prices for largest firms are higher for those periods in which firms have greater market power

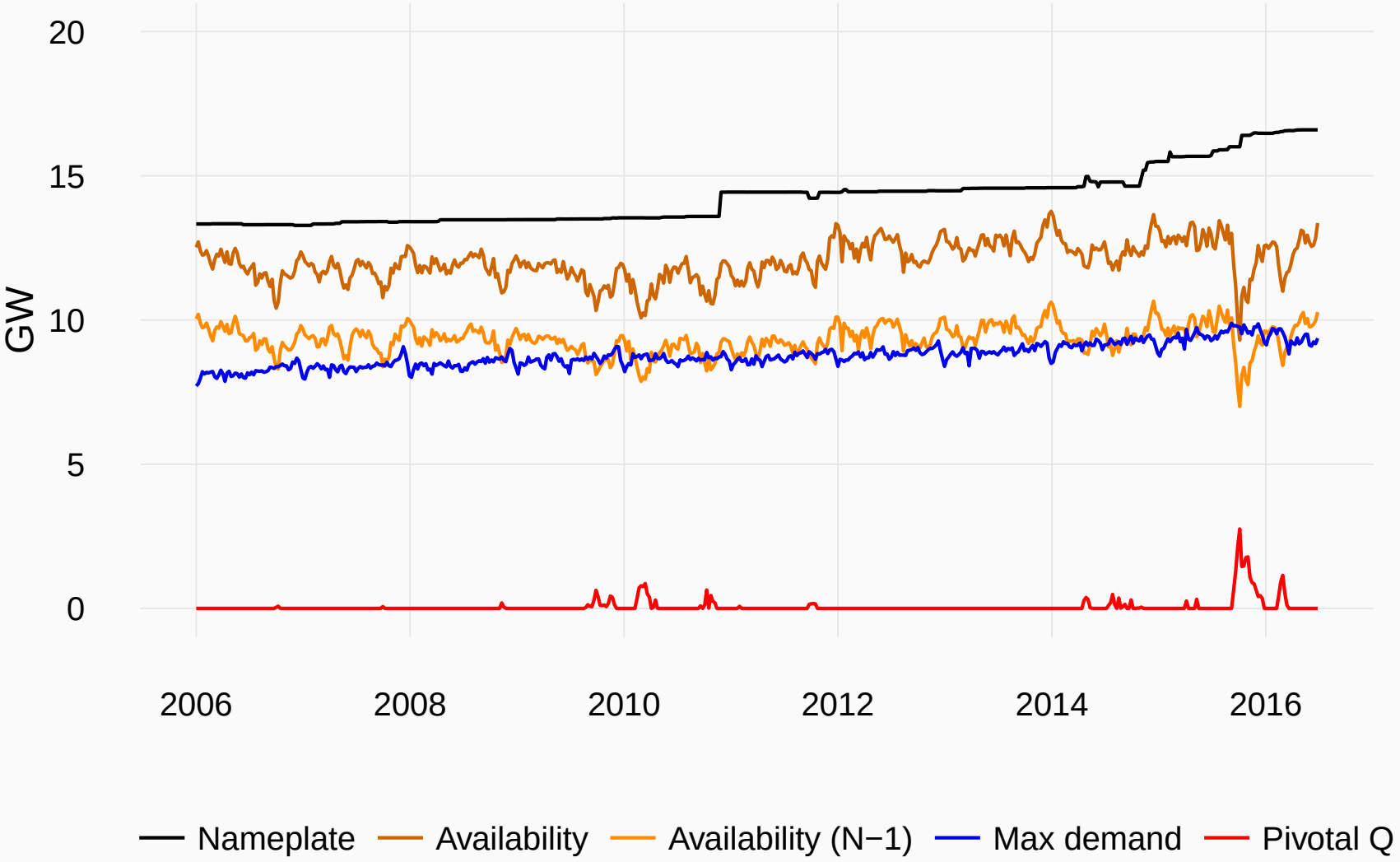
	(1)	(2)	(3)	(4)
η	14.18	3.18	6.59	6.55
	(5.44)	(1.79)	(1.92)	(2.21)
Pivotal (0/1)	337.58	58.51	129.20	−28.29
	(99.58)	(73.09)	(44.95)	(115.87)
Generator	AES Chivor	Emgesa	EPM	Isagen
Hour × year	Y	Y	Y	Y
Month-of-sample	Y	Y	Y	Y
Gen bin × year	Y	Y	Y	Y
Observations	46,765	73,407	73,649	73,188

Conclusions from market power analysis

- 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 very large increase in unilateral ability to exercise market power
- This fact explains remarkable increase in wholesale prices during 2015–16 El Niño event relative to 2009–10

Discussion

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



Most new generation investment in Colombia has been hydro-electric

- Steady increase in electricity demand and share of thermal generation in total
- Most new generation is hydroelectric, with relatively limited storage capacity
- Increased susceptibility to declines in water inflows during El Niño events
    - Reduced buffer to deal with adverse hydrological conditions
    - This becomes even more important as climate variability increases

Current design of capacity market has been less-than-successful at ensuring availability of thermal backup generation

- Capacity markets pay generators for their availability, even when they are not producing electricity
- Current capacity payment mechanism was set up in 2006
  - Several new thermal plants assigned in the capacity auction were not built or were built behind schedule
  - One thermal plant walked away from its obligation to produce electricity in spite of having received capacity payments for nine years
- Capacity mechanism places regulatory restrictions on ability of hydro owners to manage their water resources

Conclusion

- Major challenges for all electricity markets relying on renewables
  - How to meet system demand during adverse climate shocks?
  - How to limit ability and incentive of firms to exercise market power during these events?
- Recent large price spikes in Colombian electricity market due to high level of market power for generators during dry periods
- Underlying cause has been the shortfall in investment in thermal generation capacity