

Deconstructing Amazon EC2 Spot Instance Pricing

Orna Agmon Ben-Yehuda Muli Ben-Yehuda
Assaf Schuster Dan Tsafir

Department of Computer Science
Technion — Israel Institute of Technology

CloudCom, Athens, 30.11.2011

Amazon rents virtual machines with prices which vary according to:

- Instance types
- Regions
- operating systems
- Commitment level: reserved, on-demand, spot
- Payment by the hour, except for the last hour fraction of a terminated spot instance.

What are spot Instances?

- Clients bid (attach a maximal price to the instance request).
- The provider publishes a uniform spot price every so often, which the user pays.
- As long as the bid exceed the spot price, the instance can stay.
- An instance is killed if the price goes above the bid.

Why sell spot instances?

Idle machines	Spot Instances
kept for elasticity	easily evacuated
can be sold cheap	must be sold cheap

Amazon EC2 Spot instances declaration

“The Spot Price changes periodically *based on supply and demand*...”

- How does Amazon price its spot instances?
- Are spot prices really based on natural supply and demand? Or
- Are they artificially set, raised above the market value?

Who Cares?

- Researchers learn about the market from EC2 price histories; they assume (following Amazon's statement) that spot prices reflect real bids [Zhang et al. 2011], or represent market clearing prices [Chen et al. 2011].
- Clients bid and evaluate bidding strategies using price histories.
- Other providers seek information about the market and pricing algorithms.

Who Cares?

- Researchers learn about the market from EC2 price histories; they assume (following Amazon's statement) that spot prices reflect real bids [Zhang et al. 2011], or represent market clearing prices [Chen et al. 2011].
 - If prices are artificial, their results is questionable.
- Clients bid and evaluate bidding strategies using price histories.
- Other providers seek information about the market and pricing algorithms.

Who Cares?

- Researchers learn about the market from EC2 price histories; they assume (following Amazon's statement) that spot prices reflect real bids [Zhang et al. 2011], or represent market clearing prices [Chen et al. 2011].
- Clients bid and evaluate bidding strategies using price histories.
 - If prices are artificial, an algorithm change may make the past irrelevant to future predictions.
- Other providers seek information about the market and pricing algorithms.

Who Cares?

- Researchers learn about the market from EC2 price histories; they assume (following Amazon's statement) that spot prices reflect real bids [Zhang et al. 2011], or represent market clearing prices [Chen et al. 2011].
- Clients bid and evaluate bidding strategies using price histories.
- Other providers seek information about the market and pricing algorithms.
 - If Prices are artificial, they do not supply such information.

Examples of spot instance market-driven mechanisms

- Clients bid secretly.
- The provider sorts the bids (descending order).
- Uniform price for all granted instances.
- The provider grants only the first N bids. N is limited:
 - supply
 - revenue maximization
 - minimal price
 - (hidden) reserve price.
- Pricing according to minimal price or bid $N + 1$.

Price histories

Amazon encourages clients to look at price histories and bid accordingly. A common view:

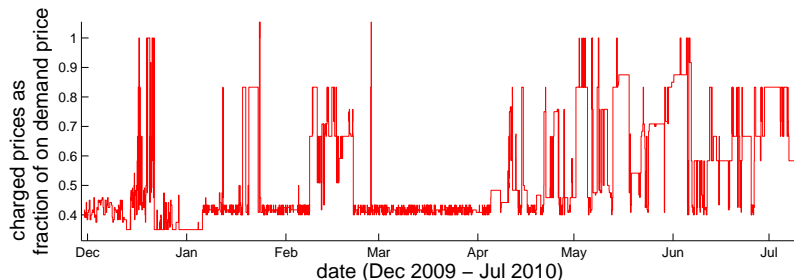
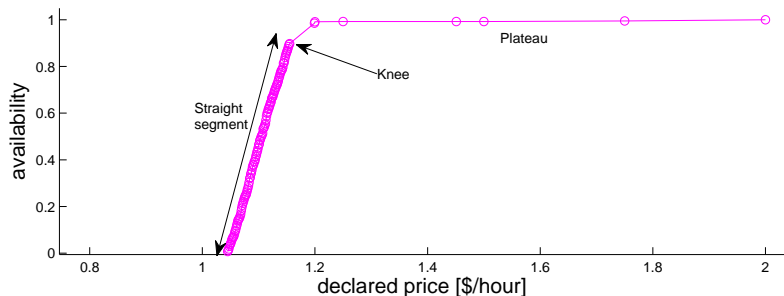


Figure: windows.m1.small.us-east

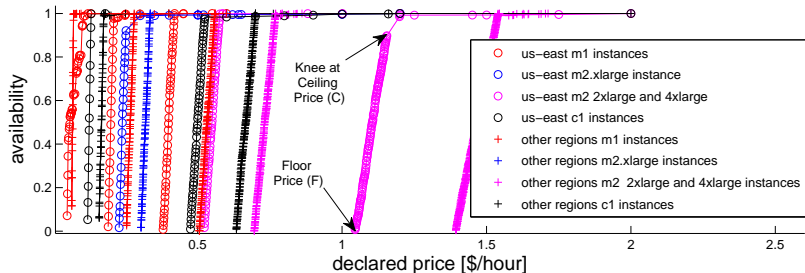
Alternative view—availability of bid price

The time in which the spot price was below the bid price, divided by the total time.



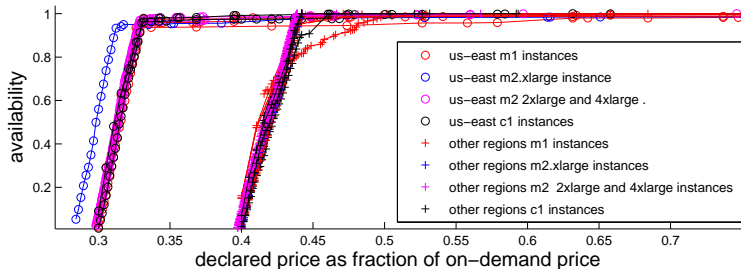
Typical shape: a straight segment and a high knee.

Windows instance availability as a function of price



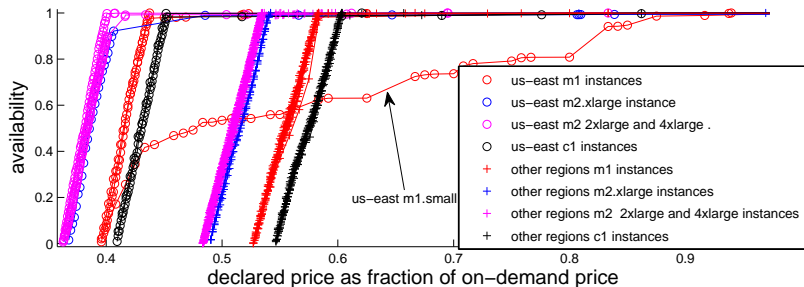
The typical shape at different prices. Looks similar for Linux.

Linux instance availability as a function of normalized price



Two groups of regions (one and the rest). The forest disappears.

Windows instance availability as a function of normalized price



A repeating pattern within the two region groups.
Windows clients differ from Linux clients.

Natural supply and demand conditions cause all this? Gee, that's funny.

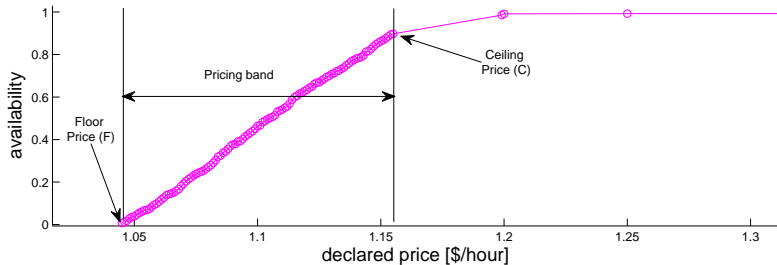
Alternatively...

- Amazon often changes the auction's reserve price, independently of client bids.
- Usually, the spot price is identical to the reserve price. Its value and its changing frequency are not market driven.
- Hence, **the spot prices are usually not market-driven.**
 - In contradiction to Amazon's statement.

Why dynamic secret reserve price?

- A dynamic reserve price maintains an **impression of constant change**. Forces clients to
 - Bid higher or
 - Tolerate sudden unavailability.
- A **secret** dynamic reserve price also masks times of low demand and price inactivity, by giving an illusion of false activity.

Planning the dynamic reserve price algorithm

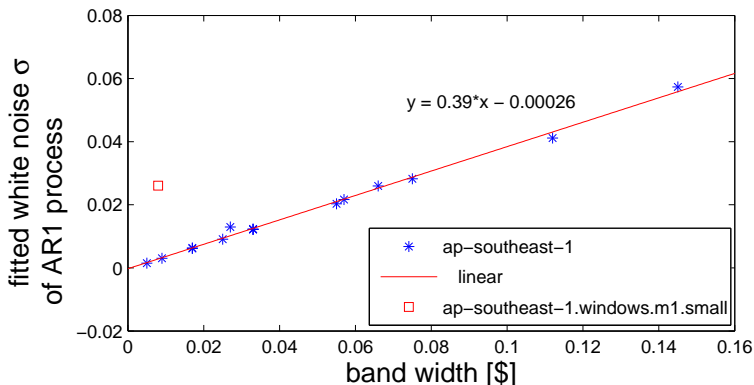


Fitting an auto-regressive process $AR(1)$ for ap-southeast.windows types

$$\Delta_j = -a_1 \Delta_{j-1} + \epsilon(\sigma)$$

- Δ_j is the difference of two consequent prices.
- $a_1 = 0.7$.
- $\epsilon(\sigma)$ —white noise with a standard deviation $\sigma = 0.39(C - F)$.
- m1.small matched $a_1 = 0.5, \sigma = 0.5(C - F)$.

Variance of the fitted AR(1) process



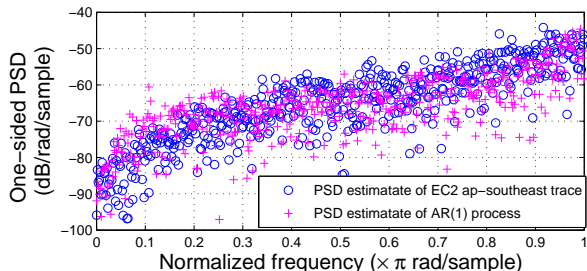
The close fit supports our hypothesis.

Constructing the reserve price algorithm

- Initial price is F .
- Initial change is $-0.1(C - F)$.
 - Not all initial conditions are good.
- Compute next price change using the fitted AR(1) process.
- Advance the next price $P_i = P_{i-1} + \Delta_i$.
- Truncate the process to the range $[F, C]$ by regenerating the white noise component while P_i is outside the $[F, C]$ range or identical to P_{i-1} .
- Round all prices to 0.1 cent.

Is the constructed algorithm consistent with reality?

Periodogram (power spectral density): a power-normalized discrete Fourier transform.



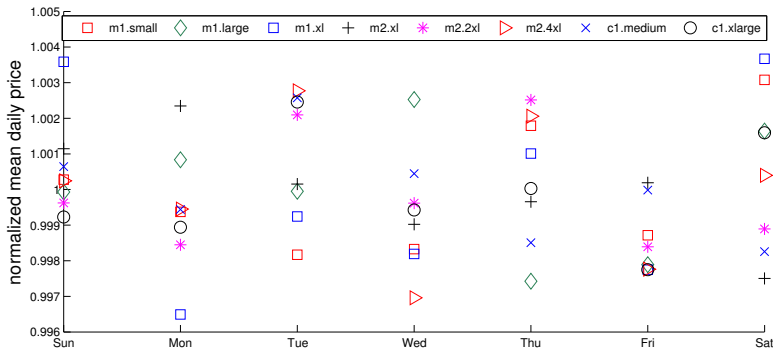
The close fit supports our hypothesis.

Is the AR(1) process natural or artificial?

A natural process would have a significant weekly cycle.

The normalized weekly averages of ap-southeast.window types do not show a weekly cycle:

The day-of-week impact is smaller than the noise (impact of types).



The AR(1) process is inconsistent with a natural process.

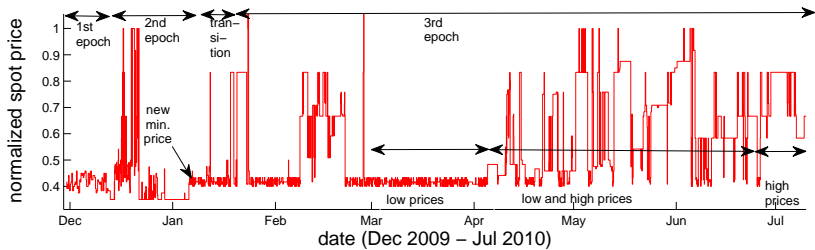
Is the AR(1) process partly natural or artificial?

- Partly natural: some real bids within band above the reserve price, some reserve prices. Expected to have a mean price above mid-range.
- The mean price is lower than the mid-range (by up to 2%).
- Many clients already noted that bidding inside the band is not cost effective.
- The AR(1) process's average is consistent with an average of an artificial process.

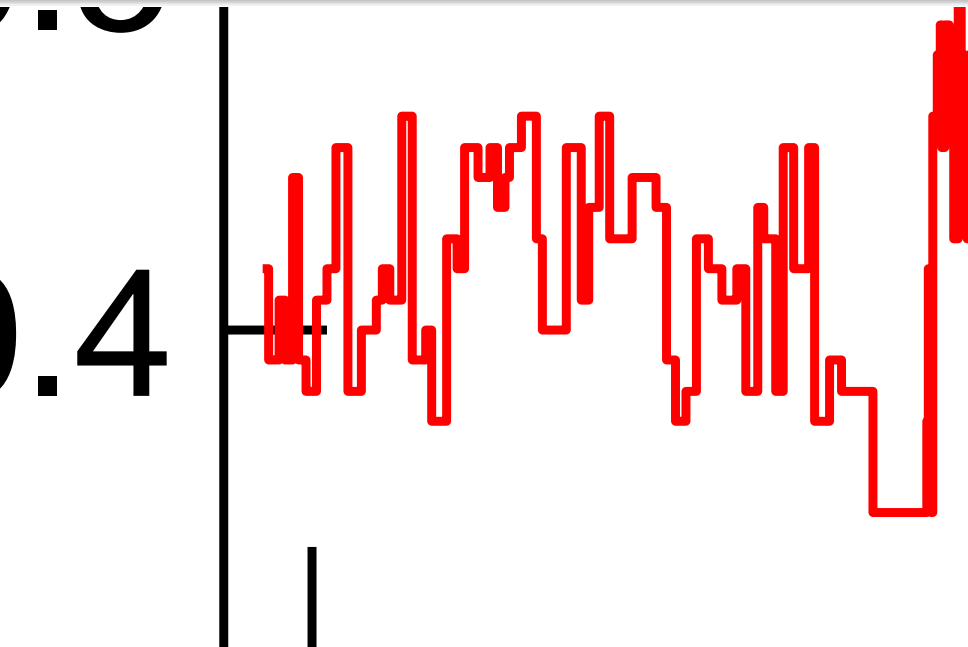
If our hypothesis is correct, then:

- 98% of the time spot prices carry little information about real client bids!
- Researchers *cannot* learn from spot prices about client valuations for products, nor about supply and demand.
- The spot price is *not necessarily* a market clearing price.

Pricing epochs



Pricing epochs

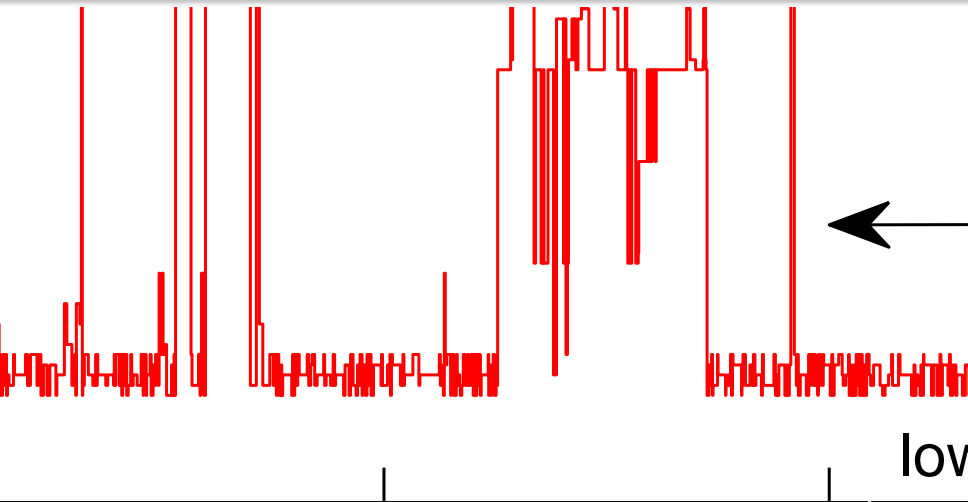


Pricing epochs

new
min.
price



Pricing epochs



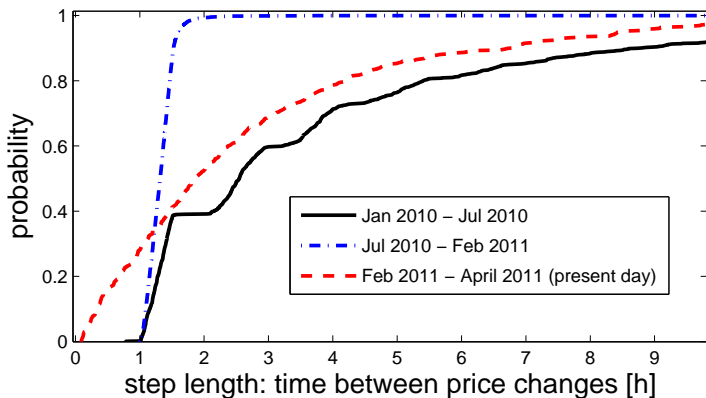
Feb

Mar

low

date (Dec

Price changing timing (us-east)



No data!

We test three models, to show that the qualitative results are insensitive to the model.

Bids are concentrated between a minimal price (0.4) and the on-demand price (1).

- Pareto distribution (minimal value of 0.4, Pareto index of 2).
- $\mathcal{N}(0.7, 0.3^2)$, truncated at 0.4.
- A linear mapping from runtimes to $(0.4, 1]$, which reflects client aversion to having long-running instances terminated.

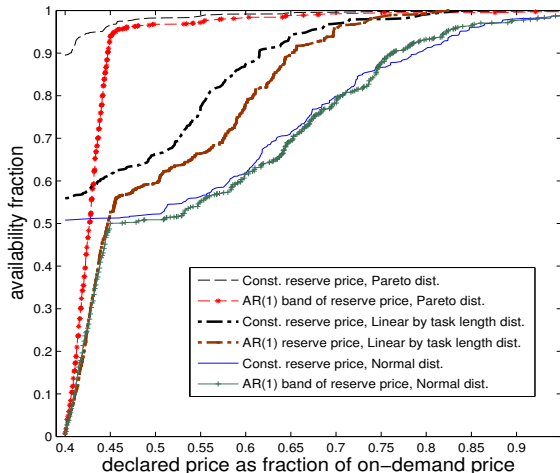
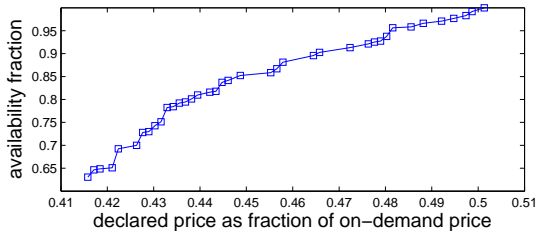
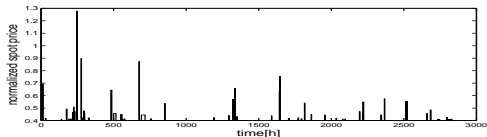


Figure: Linear segment and knee iff simulating with AR1 dynamic reserve price, insensitive to client bidding. Consistent with traces.

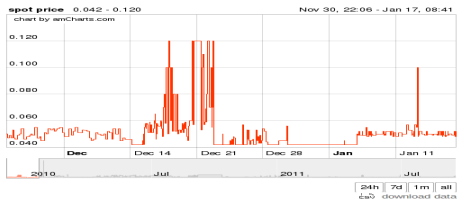
Epoch 2



Price trace comparison



(a) LPC-EGEE, constant reserve price



(b) Second Epoch

The second epoch is consistent with a constant reserve price.

Conclusions

- It is likely that Amazon sets spot prices using an **AR(1)** (hidden) reserve price.
- 98% of the time:
 - The spot price is probably just the reserve price.
 - **EC2 traces do not necessarily represent clearing prices or real bids.**
- Many **features** (minimal price, band width, change timing) are **artificial, have changed and may suddenly change again.**

Questions?

Contact us at:

{[ladypine](#), muli, assaf, dan } at cs.technion.ac.il

Thank You!