Sticky Prices Microfoundations in a Supply Chain Agent Based Model

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Departmental Seminar at CSS

Outline

What are sticky prices and why do we care

- Sticky prices opposed to flexible prices
- Sticky prices are a core assumption for monetary policy
- Why are prices sticky?
  - Direct costs: menu costs, contract fees, price points...
  - Indirect costs: implicit contracts, morale, quality signaling...
- In all cases, sticky prices as a second best.

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What I add to the discourse

- A simple model where sticky prices are superior to flexible pricing
- Extending the zero-knowledge framework to deal with inventory, multiple sectors and learning

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If you ever get lost

The seller problem

- Every day a trader receives 50 units of a good to sell
- Seller would like to attract each day 50 paying customers.
- Seller has no knowledge what the demand looks like
- All the seller can do is set its sale price.

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The Seller pricing behavior

- The seller sets a price and see how many customers it attracts today.
- If too few customers today it decreases the price tomorrow (and viceversa).
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$$e_t = \text{Goods To Sell} - \#\ \text{Customers attracted}$$
$$e_t = \text{Inflow} - \text{Outflow}$$

$$p_{t+1} = ae_t + b\sum_{i=1}^{t} e_i + c(e_t - e_{t-1})$$

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Sample seller run

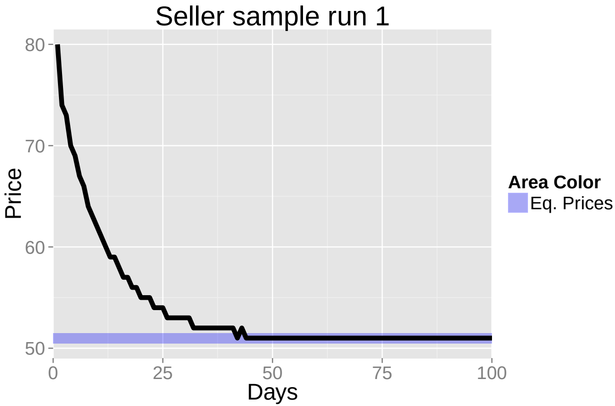
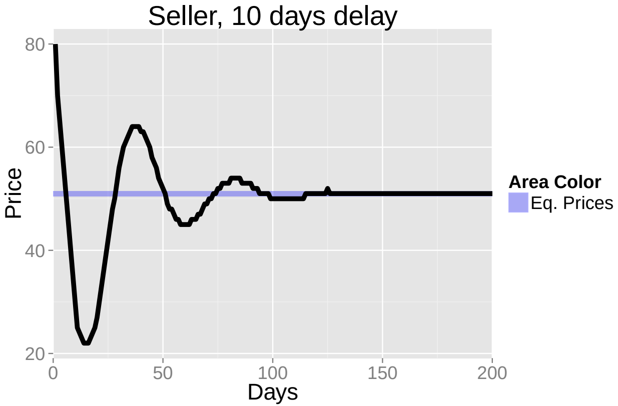


Figure: 50 units of goods to sell, daily linear demand $q = 101 - p$. This trader is using a PID controller with parameters $a = b = .1$ and $c = 0$.

How to annoy zero-knowledge sellers



Same setup as before, 10 days demand delay ($q_t = 101 - p_{t-10}$).
The trader takes longer to find the right price.

How to break zero-knowledge sellers

Figure: 20 days demand delay ($q_t = 101 - p_{t-20}$) The trader never finds the right price.

How to deal with delays

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- Two simple ways to deal with delays:
  - **Stickiness**: wait before each trial so that results are more informative
  - **Timidity**: adjust so slowly that delays catch up with you

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Stickiness to the rescue

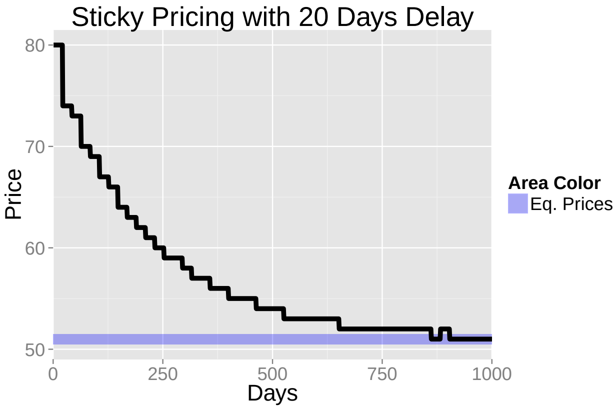

Figure: The same setting of figure 2 but this time the trader adjusts her prices only every 20 days. The result is the same approach as figure **??** but with a longer time frame

Timidity to the rescue

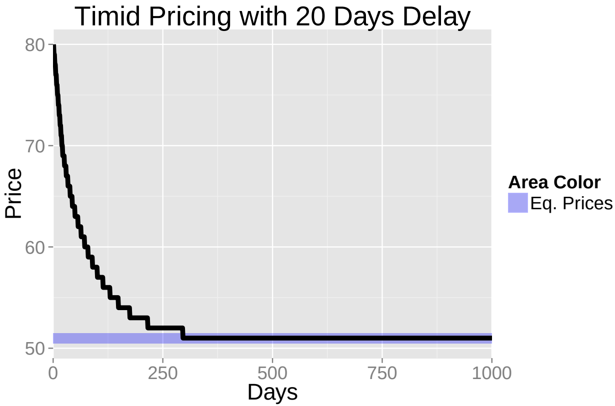

Figure: The same setting of Figure 2 but the PID controller has $a = b = .01$, 10 times smaller than the original.

Parameter's sweep

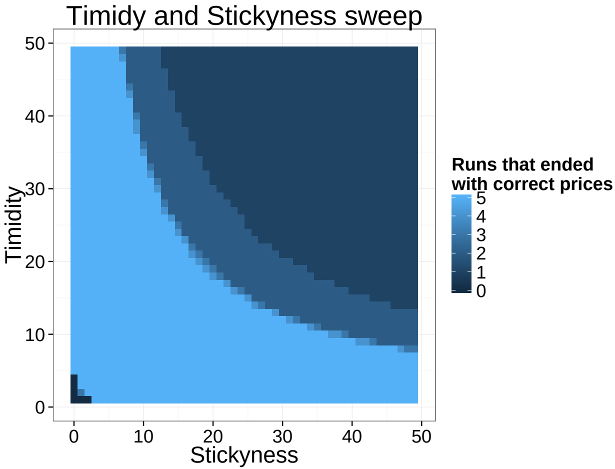

Figure: Run the model 5 times for 15000 market days with fixed PID parameters and speed but different initial prices. Controllers that are too fast or too slow fail in at least some cases. Demand delay is 50 days

Outline

Production

- A firm needs to sell output, hire workers, buy inputs, set production
- A firm is made up of many independent PID controls, each focusing on a price
- Choose how much to produce with the classic rule:

$$\mathrm{MB} > \mathrm{MC}$$

$$p_t + \Delta^p > w_t + \Delta^w$$

- Change production every 20 days

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Monopolist run

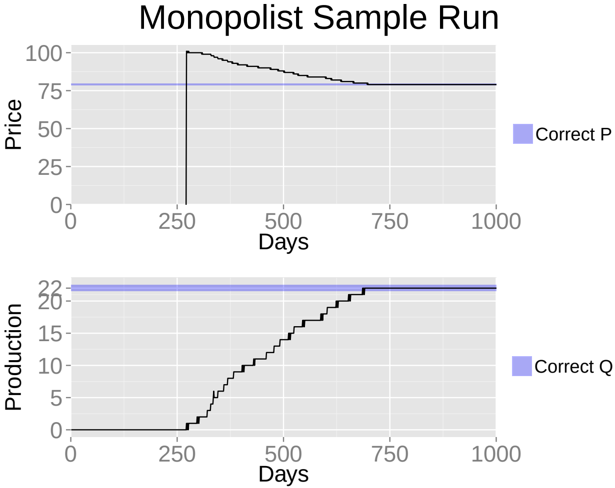

Figure: Monopolist firm facing daily demand function: $q = 101 - p$, with daily production function $q = f(L) = L$ and wage curve $w = 14 + L$. It reaches the correct price and quantity

Competitive Run

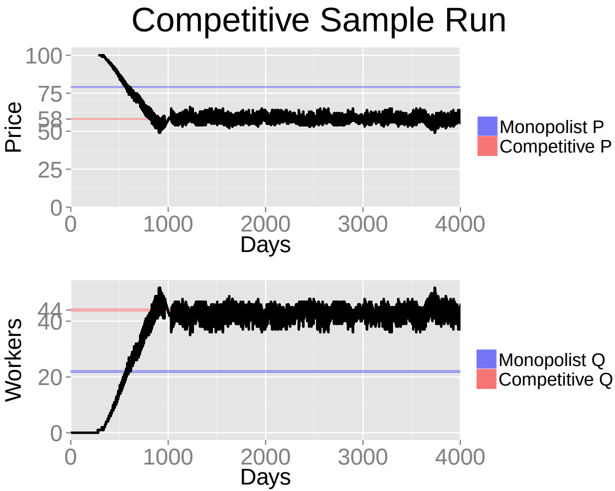

Figure: 5 firms facing daily demand function: $q = 101 - p$, with daily production function $q = f(L) = L$ and wage curve $w = 14 + L$. It reaches the correct price and quantity

Outline

A simple supply chain

- $$\text{Wood} \Rightarrow \text{Furniture} \Rightarrow \text{Fixed Demand}$$
- Wood Sector:
  - Production Function:
    $$q_W = L_W$$
  - Labor Supply
    $$w_W = L_W$$
- Furniture Sector:
  - Production Function
    $$q_F = \min(L_F, q_W)$$
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  - Final Demand:
    $$q_F = 102 - p_F$$

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Solution with monopolist wood and competitive Furniture

- Theoretical solution

$$q_F = q_W = 17$$
$$w_W = w_F = 17$$
$$p_W = 68$$
$$p_F = 85$$

- Theoretical demand faced by the wood monopolist

$$p_W = 102 - 2q_F$$

- The optimal PI parameters for a monopolist facing that theoretical demand are:

$$P = 0.08, I = 0.17, D = 0$$

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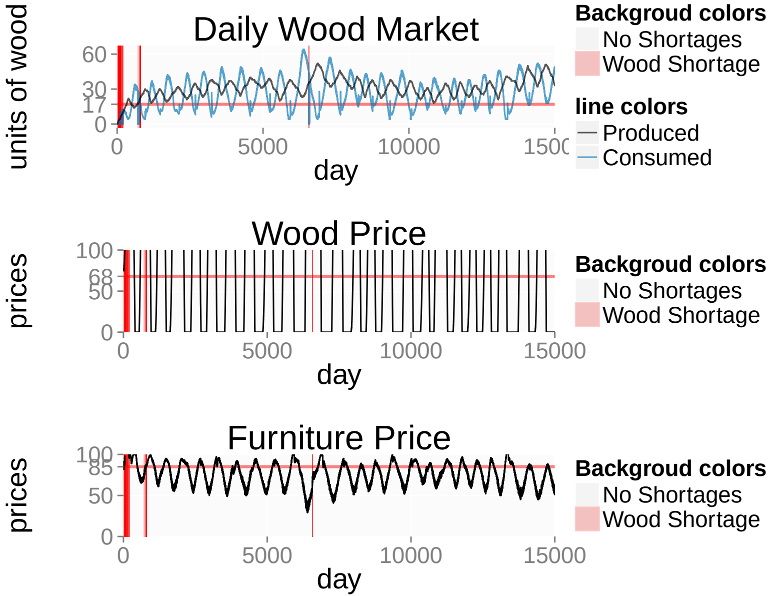
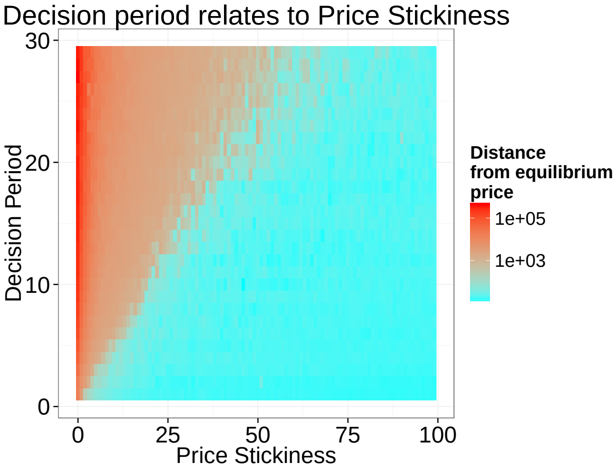
Optimal parameters are messy



Adding stickiness solves it immediately

Relationship between decision period and stickiness



Results Summary

- Optimal parameters for an undelayed demand function perform poorly in a supply chain
- Stickiness (or Timidity) solves the price and achieves the correct prices and quantities
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- Inventories accumulate errors, making sticky prices problematic
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Just change the PID Error

- Firm has inventory target i^*. End of the day distance from inventory:
$$e_i = i^* - i$$
- Firm wants to reach target inventory in T days (30 in all simulations). Target netflow:
$$\frac{1}{T} e_i$$
- Now just add that to the old PID error:
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That's all that is needed

Figure: Inventory target of 100,the daily linear demand $q = 101 - p$. Using a PID controller with parameters $a = b = .1$ and $c = 0$

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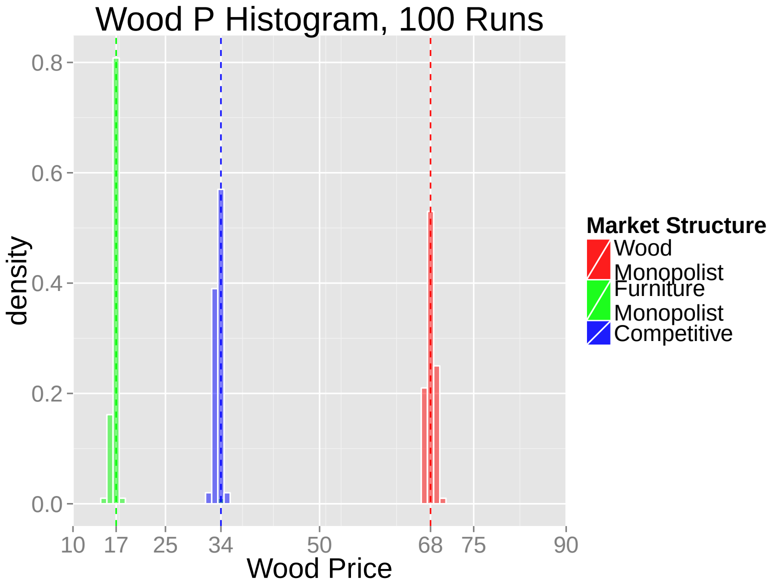
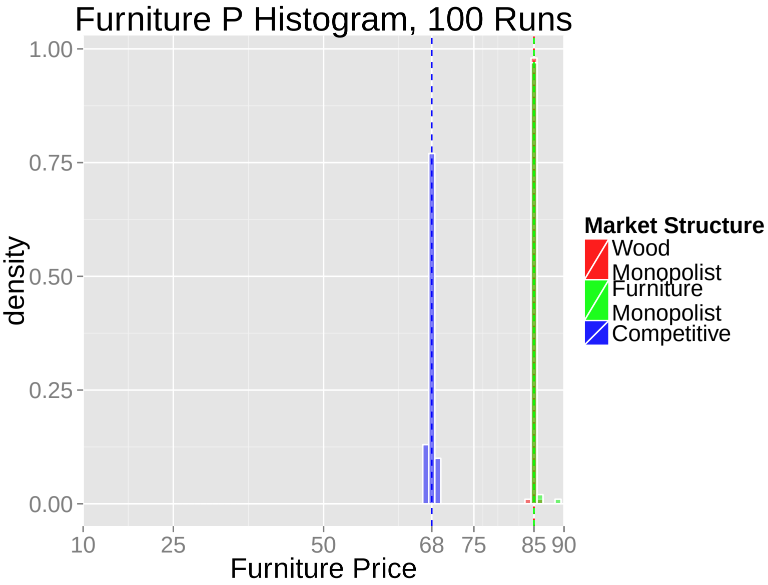


Distribution of furniture prices over 100 runs



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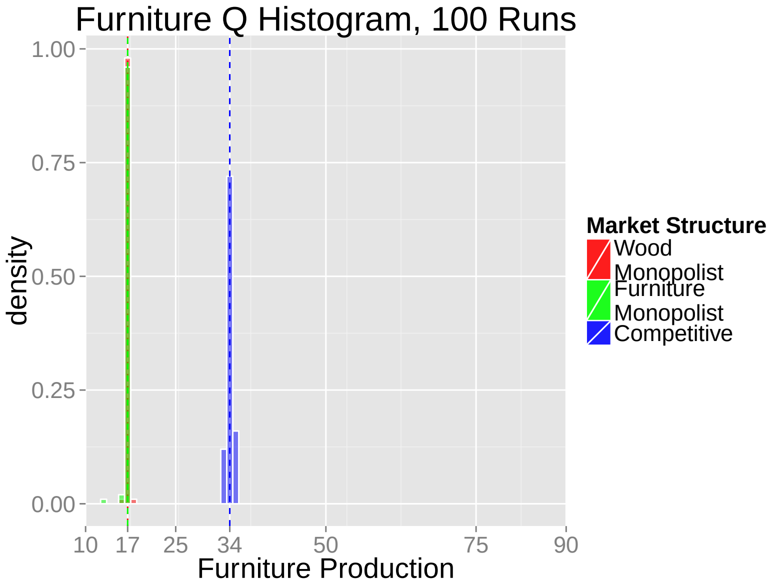

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- In all the previous sections firms knew their market structure.
- Here firms learn it on their own.
- Use Kalman filters to regress prices over quantity to learn supply/demand curves.

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The effectivness of learning

- Learning works flawlessly in one-sector economies.
- Learning works poorly in supply-chains with sticky prices and inventories:
  - The effect of delays on regressing p_t over q_t
  - The effect of stickiness on regressing p_t over q_t
  - The effect of inventories on regressing p_t over q_t
- "Workaround": regress over long moving averages of p_t and q_t.

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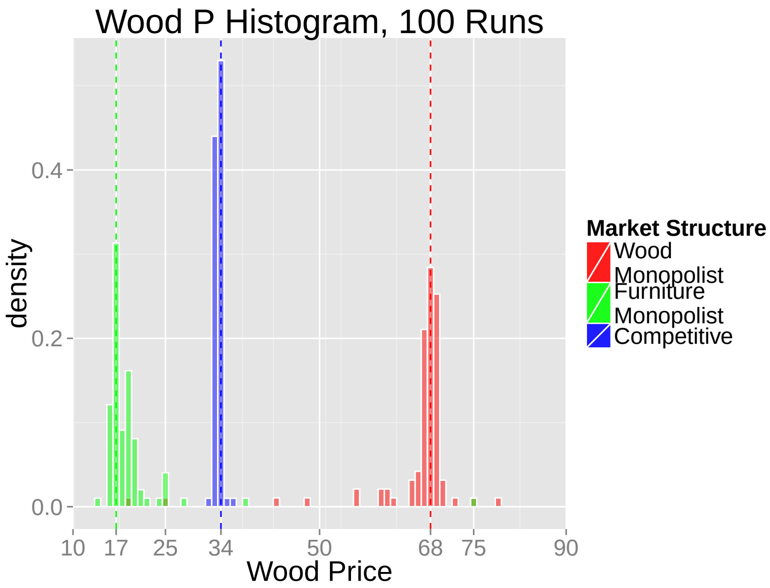
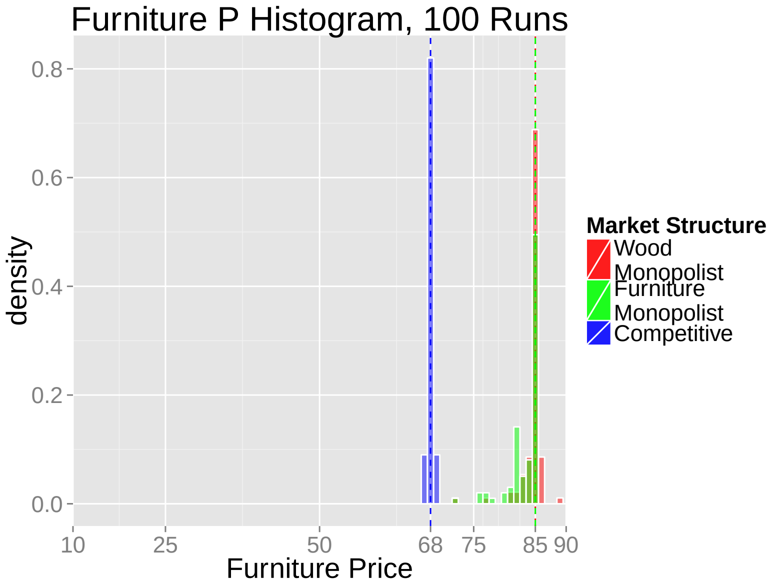


Distribution of furniture prices over 100 runs



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