

APPLYING AN ENDOGENIZED PID CONTROLLER DESIGN TO SPECULATIVE BUBBLE FORMATION

https://www.youtube.com/watch?v=4NLKLO_bEiY



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Speculative Bubbles

Shiller 2015 (and many others)



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<https://ecotalker.com>

Herman & Link 1990



Cheah & Fry 2015 (and many others)



“Historical examples...illustrate that speculative bubbles are not limited to a few industries but can occur in all markets that feature floating prices.”

-Aliber & Kindleberger, 2011



CNBC



wikipedia.org

*...maybe not

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Speculative Bubbles.. And Inventory Control Systems?

Homm & Breitung
"Testing for Speculative Bubbles"

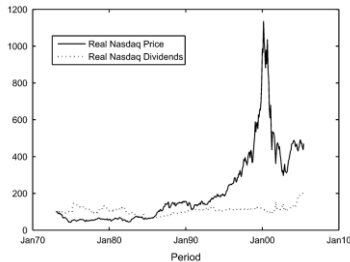
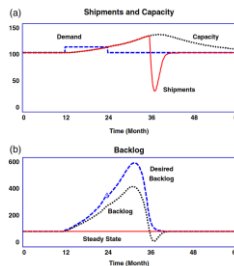


Figure 4 Real Nasdaq price and dividends.

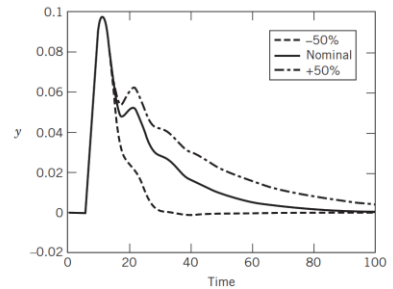
Gonçalves
"From Boom to Bust"

Fig. 9. Supplier (a) shipments, capacity and (b) backlog for a 10% transient increase in customer demand [Color Figure can be viewed at wileyonlinelibrary.com]



Seaborg et. al.
"Process Dynamics and Control"

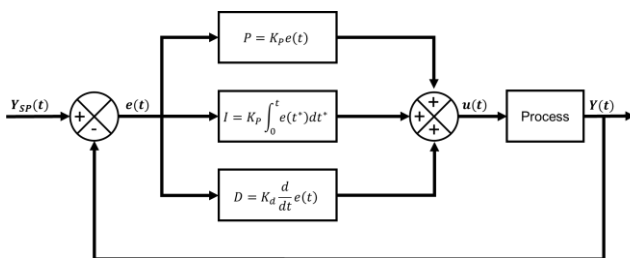
Figure 8.17 The effects of different K_c values for the PID control system of Fig. 8.15.



'Speculation' can be framed as a dynamic control problem
Forward estimation balanced against current risk management



PID Controllers



What action do I take to minimize the difference between the current state of my system and a desired goal?

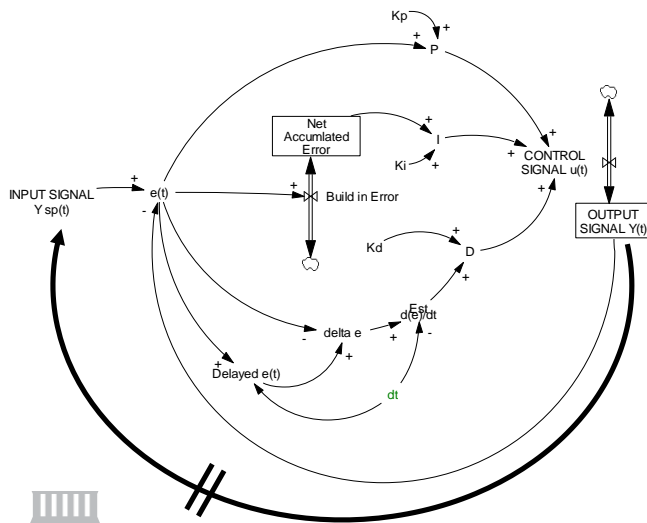
- **Proportional** – How wrong am I right now?
- **Integral** – How wrong have I been so far?
- **Differential** – How wrong will I be in the future?

$$u(t) = K_P e(t) + K_I \int_0^t e(t^*) dt^* + K_D \frac{d}{dt} e(t)$$

$$e(t) = y(t) - r(t)$$



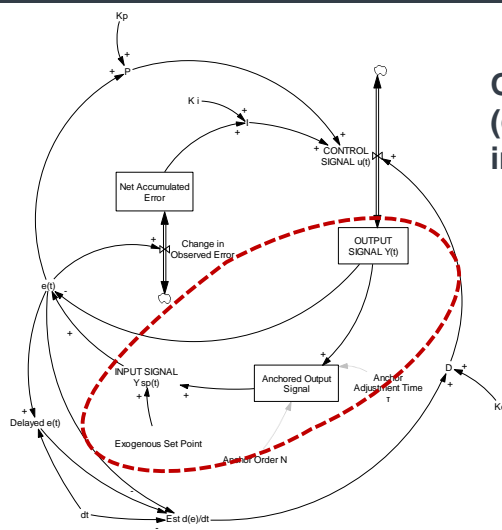
PID Controllers



Real systems: Input (set-point) is not necessarily exogenous!

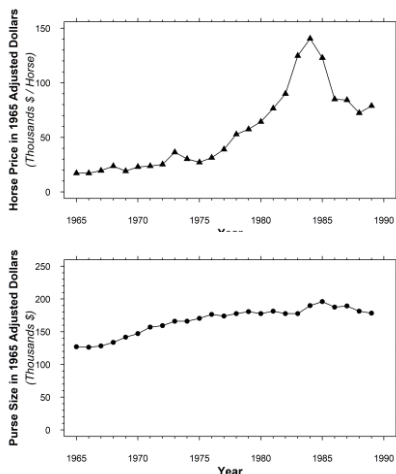
- Direct behavioral sciences literature: Anchoring and Adjustment (Tversky & Kahneman, 1974)
- Other support in supply chain and behavioral econometric literature (Croson et al., 2014; Rabin, 1998; Sterman, 1989; others)
- Directly relevant for speculative bubble formation where current state influences future expectations

Endogenized PID Controllers



Output affects Input signal with some (context specific) degree of information smoothing

Example: Thoroughbred Horse Market



Adapted from Herman & Link 1990 and Sterman 2000



The price of yearling thoroughbred horses in the United States experienced a massive increase in both nominal and inflation adjusted values over 1974-1984 (increasing 10x in nominal terms and 4x in adjusted terms) before then losing nearly 50% of its value in just 4 years.

The underlying value of owning a horse in terms of cash winnings did not materially change over this same period.

What were the mechanisms that led to this surge in value and subsequent correction?

Furthermore, are there policy suggestions for mitigating such events in the future?

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Dynamic Hypothesis

Speculative purchasing based on expected prices = increase in price

Eventual concern about over-speculation causes drop in price

Embed some additional value in horses as speculative asset

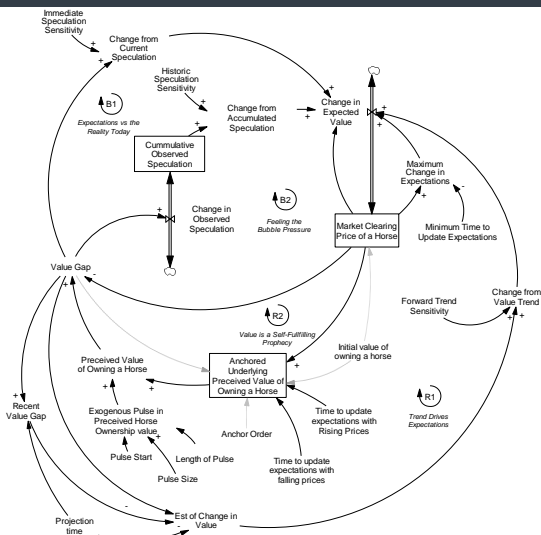
- In the early 1970's prices in thoroughbred horses rose more than expected.
- Expecting future prices rises, speculative purchasing of the animals surged, hoping to resale later
- By the mid-1980's, concern that the horses were overvalued began to outstrip confidence in the future value, increasing sales to avoid future losses
- This caused a rapid decline in prices, but the idea of the horses as an investment asset, not just a source of racing revenue, meant that the fundamental value of the animals was now higher than in the 1960's



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Endogenized PID Controller Operationalized for Speculative Horse Pricing

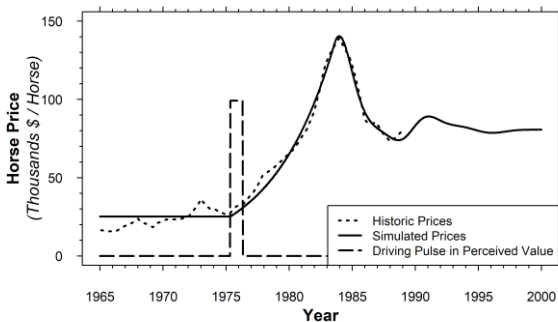


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Observations - Baseline

Parameter	Baseline Value*	Units
Initial value of owning a horse	25.23	\$/Horse
Time to update expectations with falling prices	0.655	Years
Time to update expectations with Rising Prices	1.237	Years
Anchor Order	1.0	dmnl
Immediate Speculation Sensitivity	0.001	dmnl/Year
Historic Speculation Sensitivity	2.803	dmnl/Year/Yea
Forward Trend Sensitivity	1.941	dmnl
Projection time	3.56	Year
Minimum Time to Update Expectations	4.89	Year
Pulse Size	99.18	\$/horse
Pulse Start	1975	Year



*Values from Powell calibration (with 30 random restarts) against 1965 nominal value for thoroughbred horses

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Pulse Size	99.18	\$/horse
Pulse Start	1975	Year
Pulse Length	1	Year

Asymmetric expectation updating

Effectively no immediate sensitivity, rather relying on interplay of forward projection and building risk perception

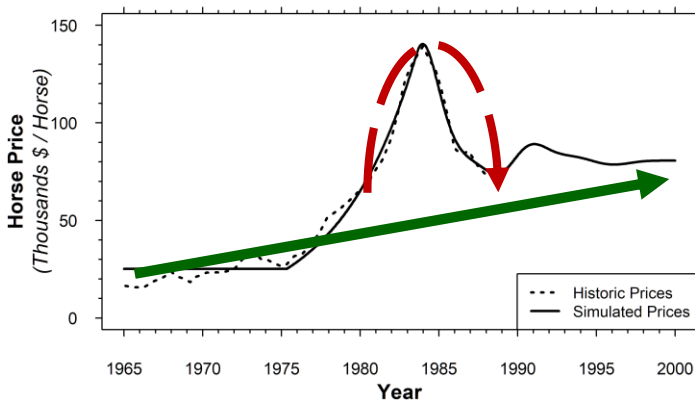
Projecting and Averaging times similar to 3-5 year horse maturation times

Many possible pulses can trigger this, only one considered here (fixed at 1 year length)



Observations and Policy Reccos

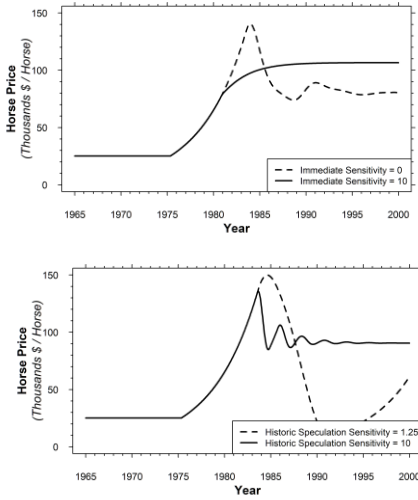
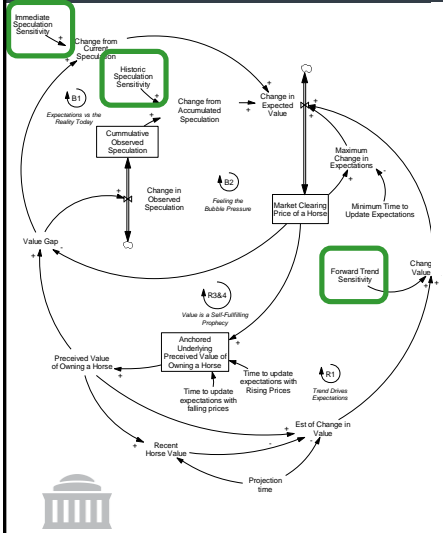
Central problem is *not* the rise of underlying value of thoroughbred horses



But rather the overshoot and correction

Goal: Policy that will *not ignore* pulse in underlying perceptions of value but rather incorporate it smoothly

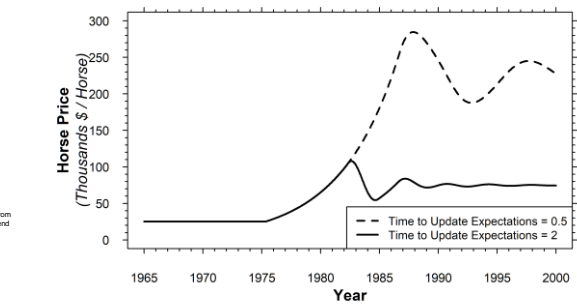
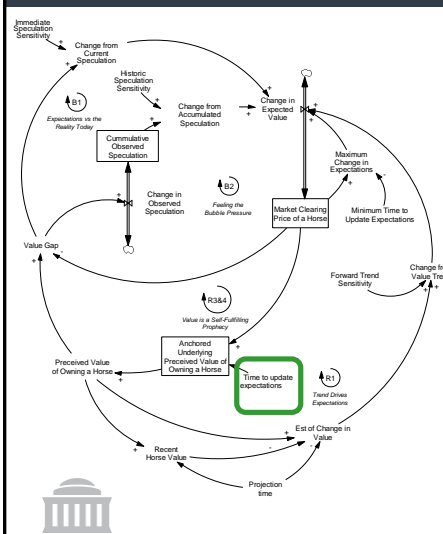
Parameter Effects



Stabilizing policies (generally) have:

- *more* consideration of the immediate moment
- *less* forward projection
- at least *some* consideration of prior cumulative speculation

Parameter Effects

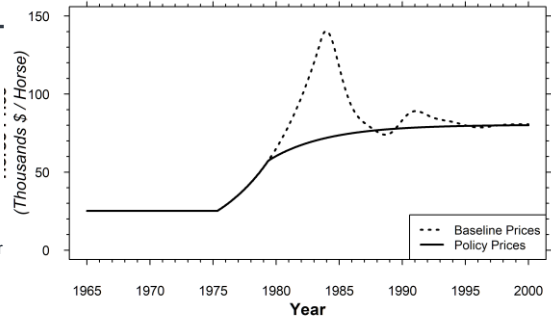


Stabilizing policies (generally) have:

- *Longer and Symmetric* times to update expectations

Policy Recommendation

Parameter	Policy Value	Units
Initial value of owning a horse	25.23	\$/Horse
Time to update expectations with falling prices	1.8	Years
Time to update expectations with Rising Prices	1.8	Years
Anchor Order	1.0	dmnl
Immediate Speculation Sensitivity	10	dmnl/Year
Forward Trend Sensitivity	0	dmnl
Historic Speculation Sensitivity	2.25	dmnl/Year/Year
Projection time	3.56	Year
Minimum Time to Update Expectations	4.89	Year
Pulse Size	99.18	\$/horse
Pulse Start	1975	Year
Pulse Length	1	Year



Policy Recommendation

Parameter	Baseline Value	Policy Value	Units
Initial value of owning a horse	25.23	25.23	\$/Horse
Time to update expectations with falling prices	0.655	1.8	Years
Time to update expectations with Rising Prices	1.237	1.8	Years
Anchor Order	1.0	1.0	dmnl
Immediate Speculation Sensitivity	0.001	10	dmnl/Year
Forward Trend Sensitivity	1.941	0	dmnl
Historic Speculation Sensitivity	2.803	2.25	dmnl/Year/Year
Projection time	3.56	3.56	Year
Minimum Time to Update Expectations	4.89	4.89	Year
Pulse Size	99.18	99.18	\$/horse
Pulse Start	1975	1975	Year
Pulse Length	1	1	Year

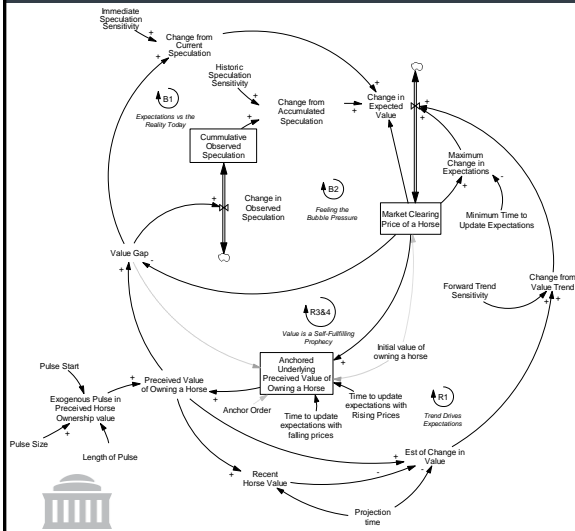
Longer, symmetric, time to incorporate market prices into go-forward expectations

Forward speculation is eliminated, and the *immediate* value discrepancy between expectations and reality is considered

Historic speculation is still considered, and necessary to embed new underlying value



Final Notes and Takeaways



Example here illustrates

- that asymmetric responses and over-weighting an expected future at the detriment of the present exacerbates overshoot
- that it is possible to embed value in the asset without bubble-like outcomes

Endogenized PID model

- is sufficient to generate observed speculative behavioral and provide policy recommendations
- highlights how existing methodological paths in SD can be applied in multiple research areas
- is most appropriate where Speculative Bubble Driven by *expectation dynamics* more than market dynamics

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Thank You!

Please send questions and comment to:

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https://www.youtube.com/watch?v=4NLKLO_bEiY

<http://dx.doi.org/10.2139/ssrn.4137800>
(Paper and example horse market model)

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