School of
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Sustainability: oxymoron or measurable goal

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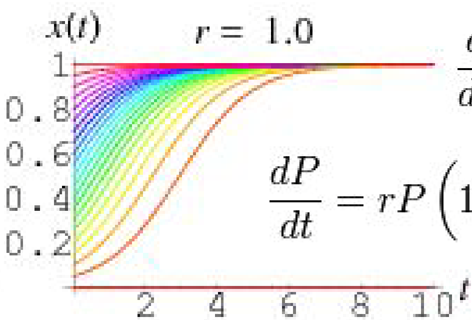
What does sustainability look like?



$$\frac{d}{dt}\frac{P}{K} = r\frac{P}{K}\left(1-\frac{P}{K}\right)$$

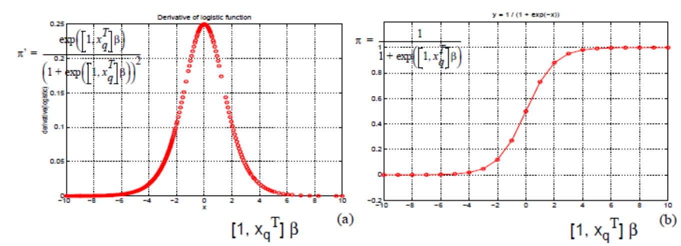
$$\frac{dx}{dt} = rx(1-x)$$

$$\frac{dP}{dt} = rP\left(1-\frac{P}{K}\right)$$

$$P(t) = \frac{KP_0e^{rt}}{K+P_0\left(e^{rt}-1\right)}$$

where

$$\lim_{t\to\infty} P(t) = K.$$



$$H' = -\sum_{i=1}^{S}\frac{n_i}{N}\ln\frac{n_i}{N}$$

$$\cdot k\sum_i P_i\ln(P_i)$$

$$\begin{aligned} f(x) &= e^{-x^2} \\ f'(x) &= -2xe^{-x^2} \\ f''(x) &= (-2x)^2e^{-x^2} - 2e^{-x^2} \\ &= 2(2x^2-1)e^{-x^2}. \end{aligned}$$

FY 2011-2015 EPA Strategic Plan Cross-Cutting Fundamental Strategy: Advancing Science, Research, and Technological Innovation

Environmental sustainability is a guidepost for science, research, and technological innovation at EPA.[3] Sustainability is a broader approach to environmental protection that considers trade-offs in production processes and materials use. Sustainable solutions prevent chemicals from entering the environment or eliminate, rather than simply reduce, the production of waste through better materials management.

The goal of sustainability is "True North." EPA's new Assistant Administrator for Research and Development (ORD) Paul Anastas has underlined in an extended memo to ORD staff. **The "path forward" outlined by Dr. Anastas makes the goal of sustainability one of ORD's long-term research objectives.**

International Institute for Sustainable Development IISD2010 data base
Searched >1000 sources without finding more than scoring codification

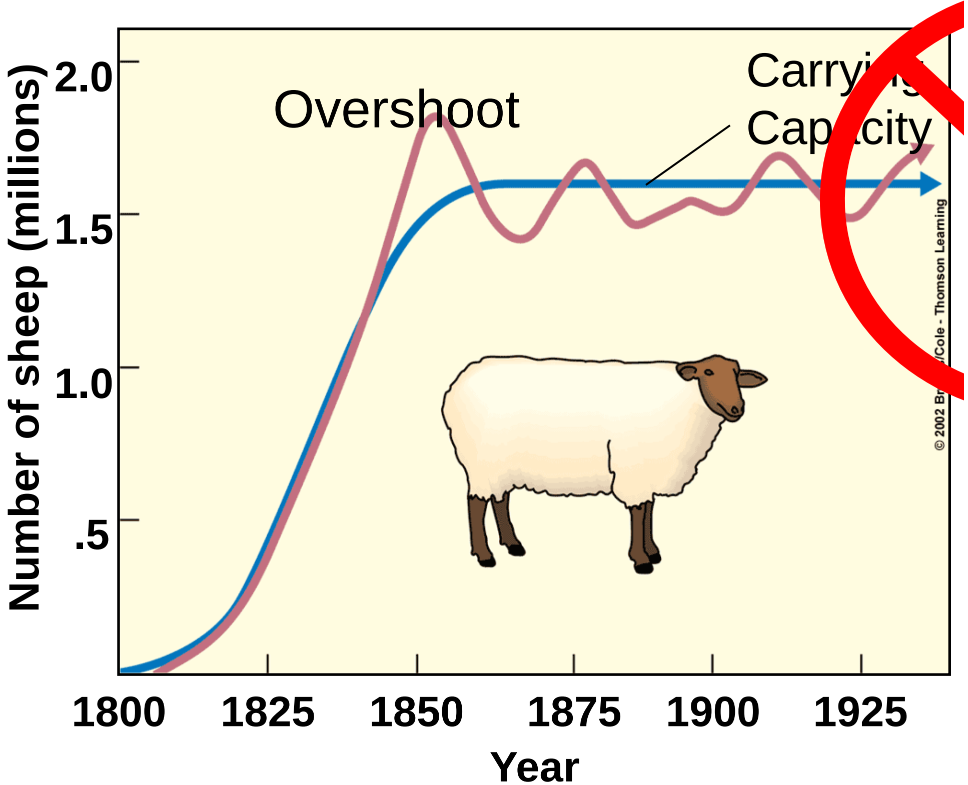
What does sustainability look like?

"Sustainability is the long-term perpetuation of well being, which has environmental, economic, and social dimensions."

"Sustainability is living off the natural [illegible] replenished by natural resources and not depleting [illegible] endowment of natural capital that supplies this income."

oxymoron

"Sustainability is doing no harm for seven generations."



"Carrying capacity refers to the number of individuals who can be supported in a given area within natural resource limits, and without degrading the natural social, cultural and economic environment for present and future generations."

What does sustainability look like?

Components of Ŝustainability

1. Feedback – Ŝ has a homeostatic interplay
2. Efficiency – Ŝ functions at an efficiency that minimizes system entropy
3. Volatility – Ŝ has a heterogeneity factor at which Ŝ functions at or below
4. Equilibrium – Ŝ is a function of system volatility and efficiency
5. Predictability – Ŝ should be locally predictability
6. Adjustment – Ŝ should signal the point for prudent management response
7. Relatedness – Ŝ is empirically related to natural phenomenological events

Would we know sustainability when we see it?

"What gets measured, gets managed"

Peter Drucker

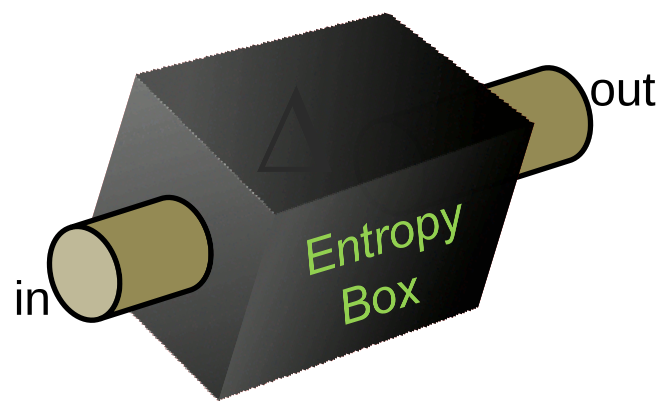
Can sustainability be measured?

Problem:

--there is no basal formulation of sustainability upon which higher, coherent analyses can be constructed.

Objective:

--relate Entropy Box events (e.g. efficiency, η, or volatility, $\hat{S}_{\pm\infty}$) to sustainability, $\hat{S}$



Overview of Ŝustainability

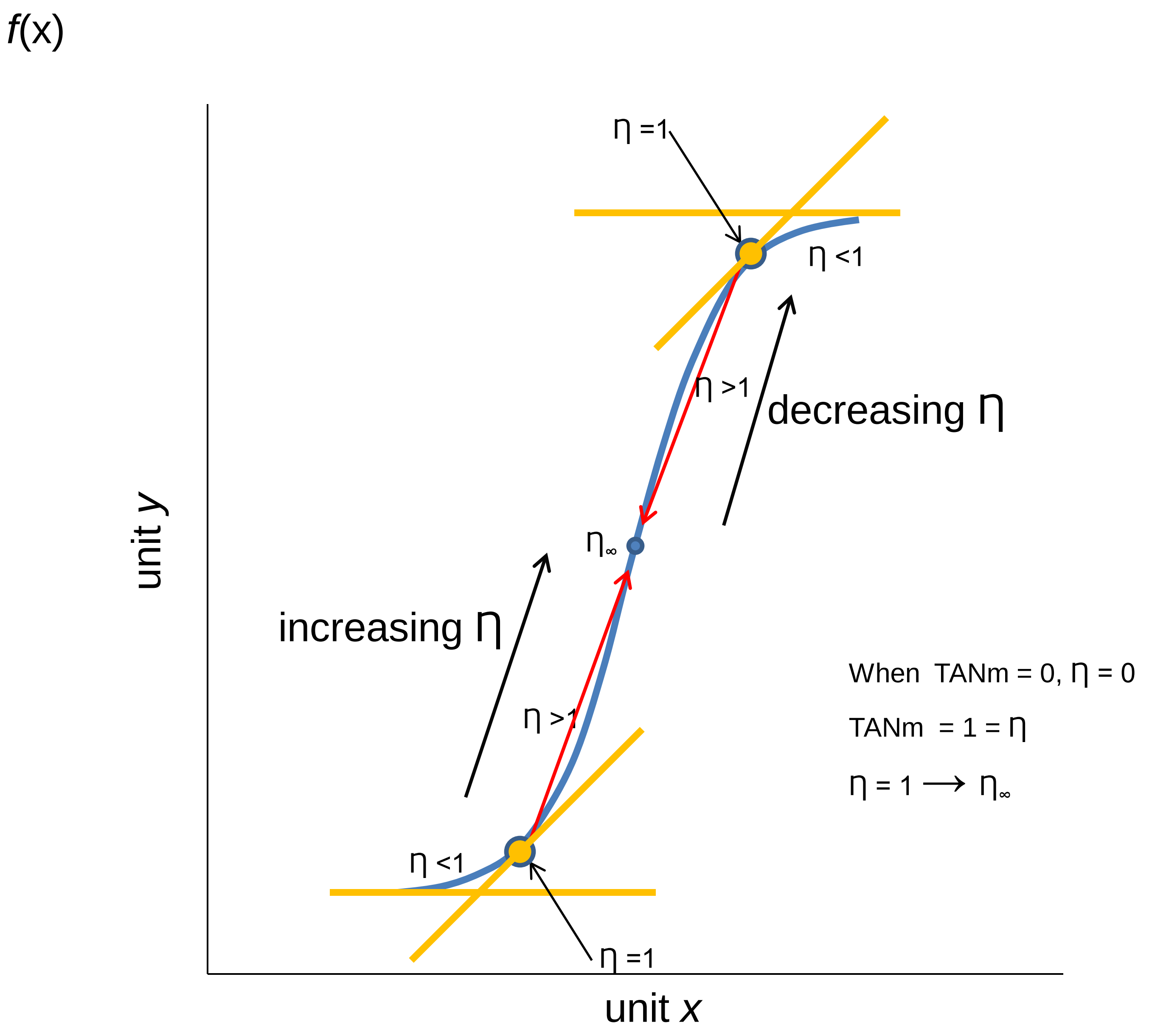
1. f(x) dN/dt = rN(1-N/K)

--when $\eta = 1 = \eta_\infty$, equilibrium efficiency of f(x) maximizes at η_∞
--for f(x), η_∞ = point of prudent management adjustments

2. f '(x) dN/dt = r - 2rN/K
--rate of change of TANm; TANm at $\eta'_\infty = \hat{S}\infty$, *optimized sustainability*
--system variability as σ^2

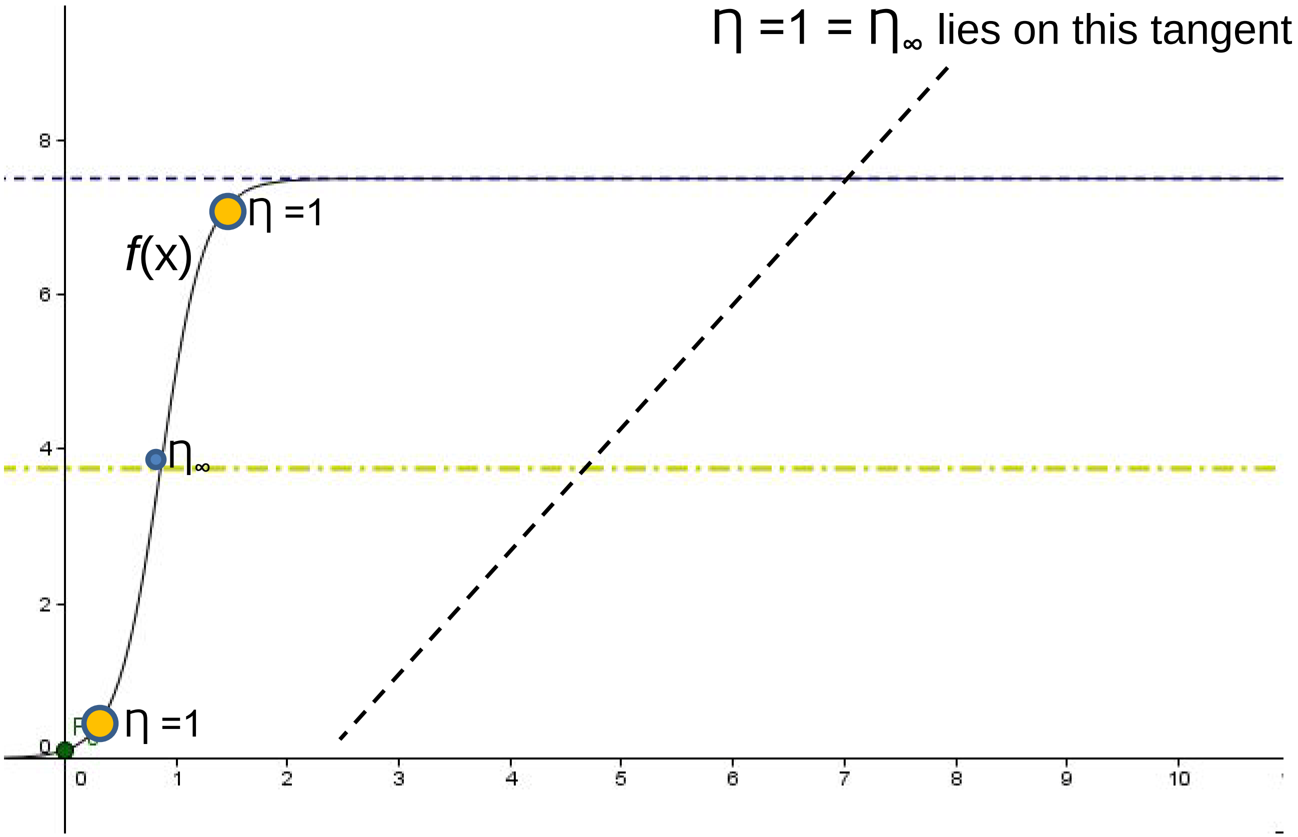
3. f ''(x) --f ''(x) volatility is related to variability in the environment of f(x)
--system volatility; f '(x) σ^2 inversely proportional to f''(x) volatility, $\hat{S}_{\pm\infty}$
--Set correspondence of f '(x) η'_∞ equal to f (x) η_∞; $|\eta'_\infty| \rightarrow \eta_\infty$
--Set correspondence of f ''(x) η''_∞ equal to f '(x) η'_∞; $|\eta''_\infty| \rightarrow \eta'_\infty$
--$\hat{S}_{-\infty}$= f ''(x) minimum; sustainability, $\hat{S}$, ($\hat{S}_{-\infty} \geq \hat{S} \geq \cap TANm_{(0,\eta_\infty)}\angle/2$)
$\hat{S} \leq \hat{S}_{-\infty}$ maximizes sustainability at minimum volatility
--$\hat{S}_{+\infty}$= f ''(x) maximum; sustainable yield, $\hat{S}_y$, is $\geq \hat{S}_{+\infty}$;
$\hat{S}_y \geq \hat{S}_{+\infty}$ minimizes sustainable yield at maximum volatility

4. f '(x) at $\eta = 1 = \eta_\infty$
-- relationship that optimizes equilibrium of common and rare occurrences of f '(x). E.g., vertical vs. horizontal hierarchy development; efficiency and equitability of resource utilization; volatility vs. variability; common species vs. rare species; minimizes entropy flow

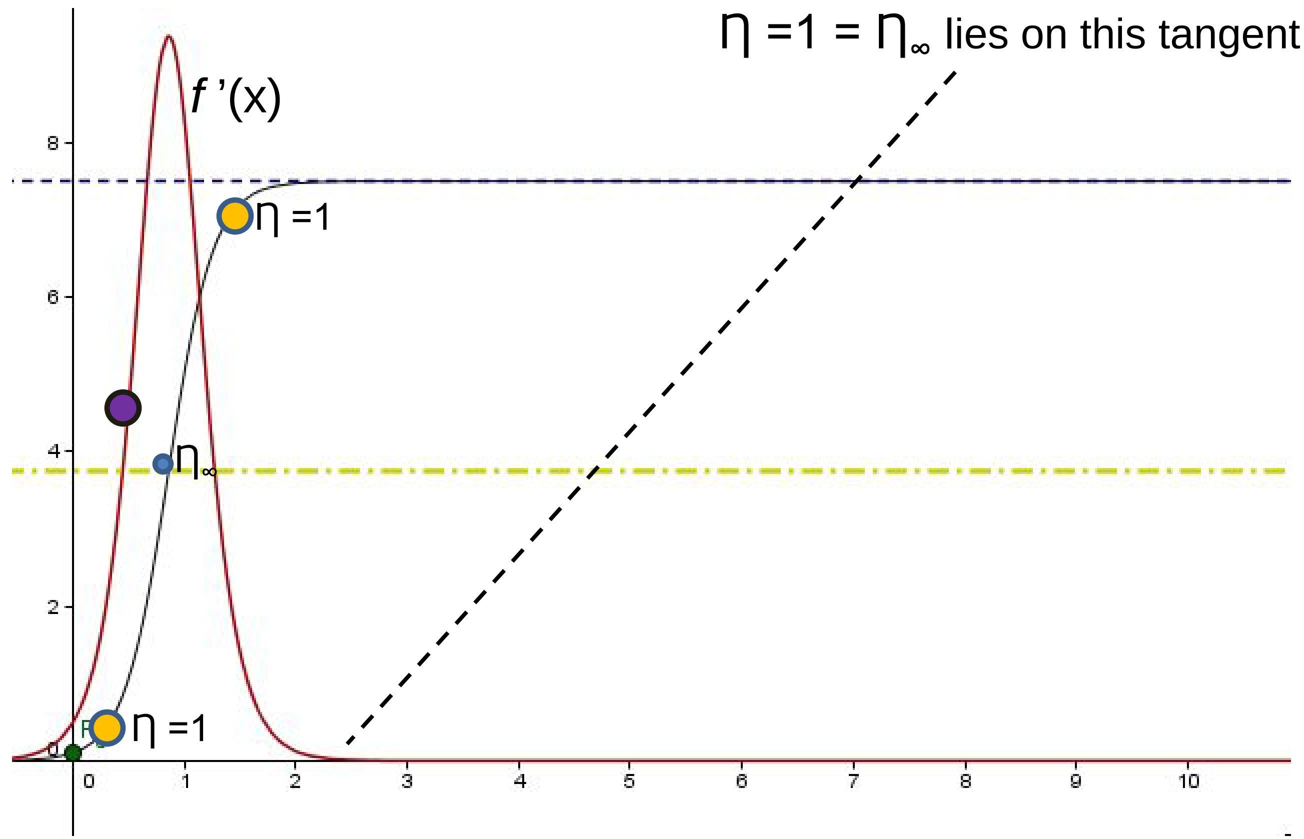


Efficiency map of logistic curve

f(x) = growth curve



f(x) = growth curve
f '(x) = rate of change



● = $\hat{S}_{\mu}$

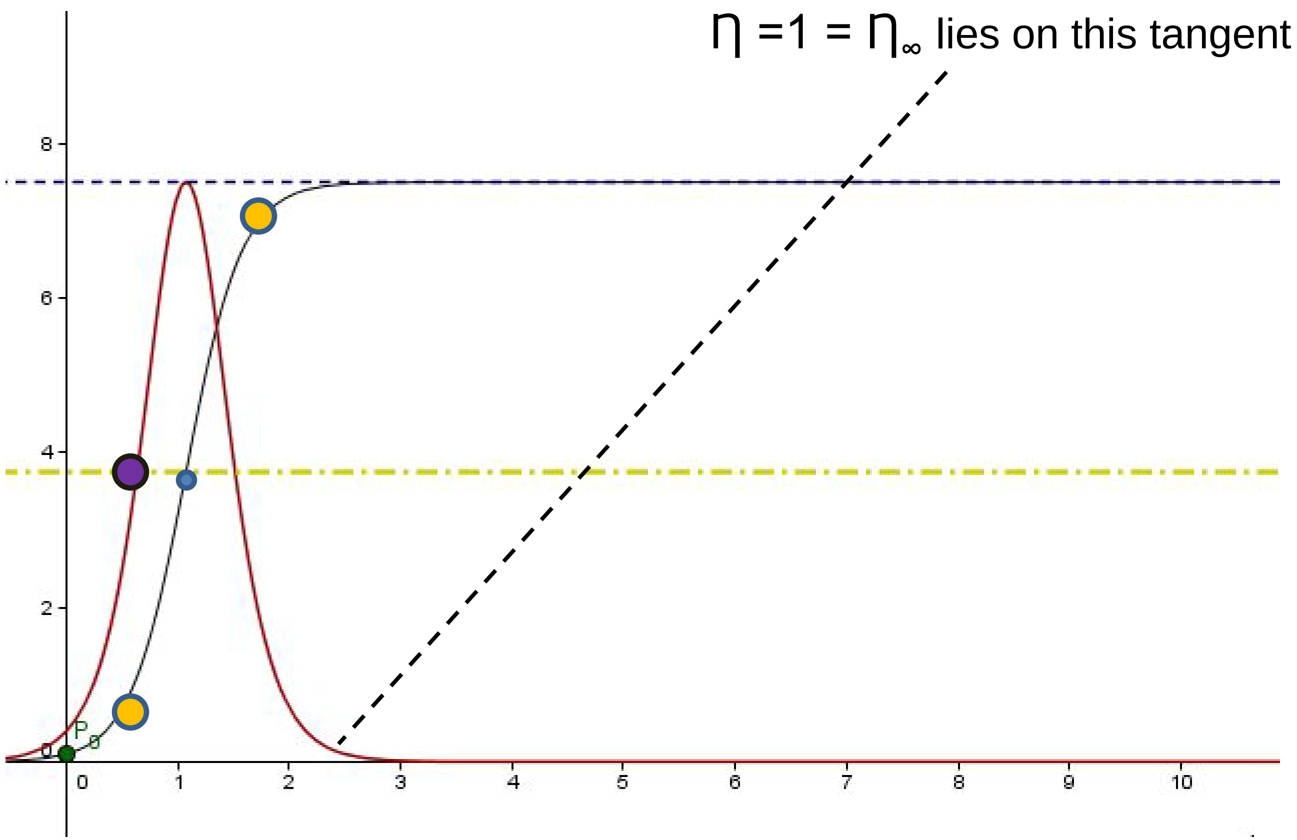
$\hat{S}_{\mu} = \eta'_{\infty}$

non-optimized sustainability; $\eta = 1 \neq \eta_{\infty}$

f (x) is not in equilibrium, ∴ the system is not optimally sustainable

Sustainability optimizes, $\hat{S}\infty$, as $\eta = 1 \rightarrow \eta_{\infty}$

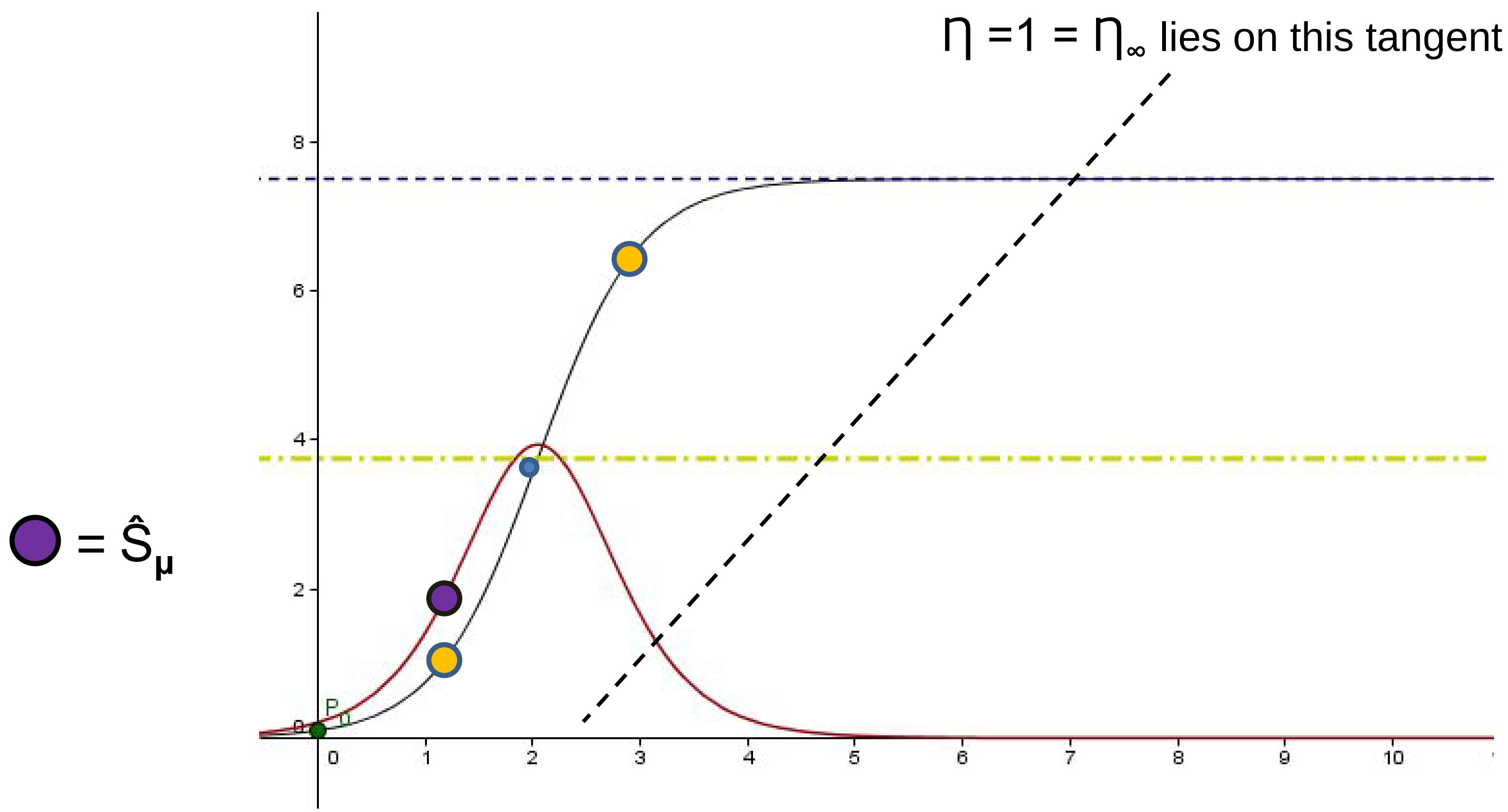
$f(x)$ = growth curve
$f'(x)$ = rate of change



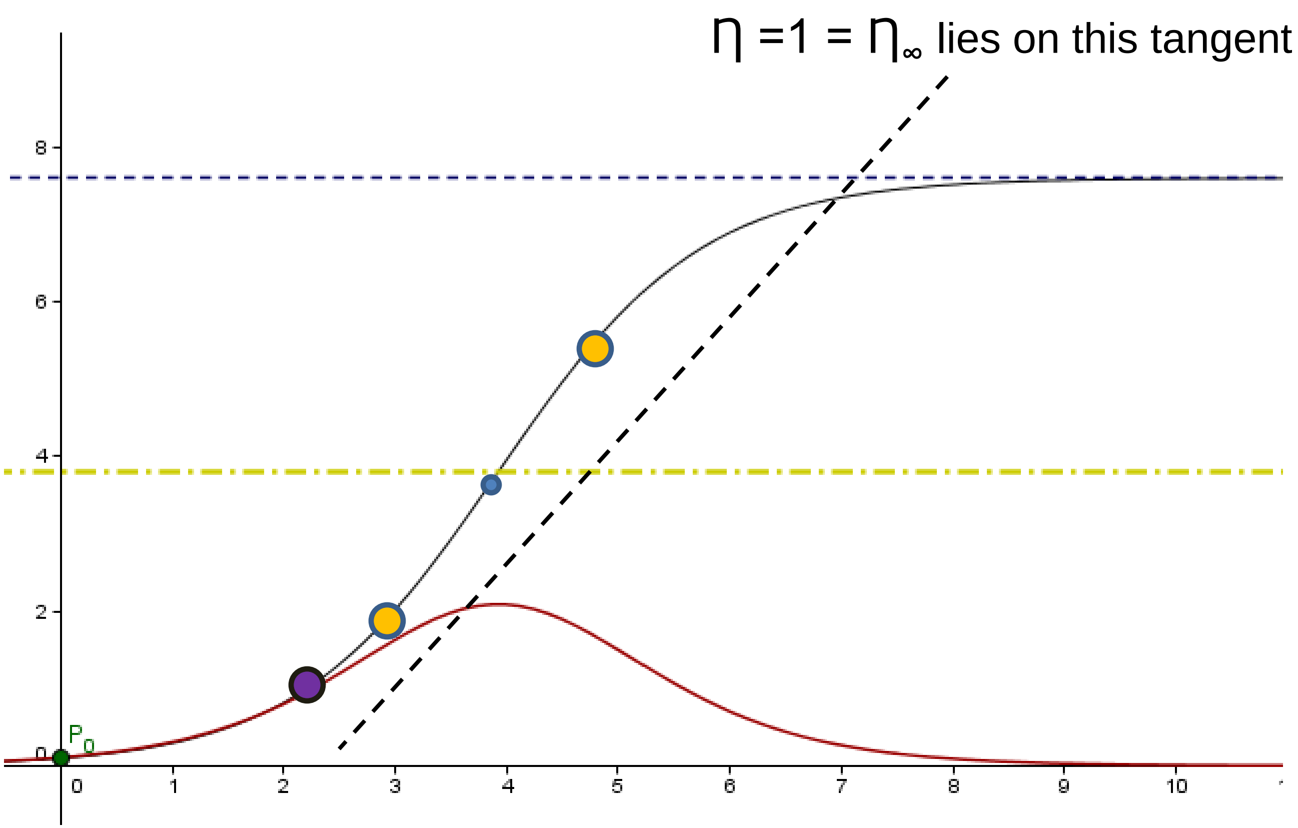
● = $\hat{S}_{\mu}$

f(x) = growth curve

f ’(x) = rate of change

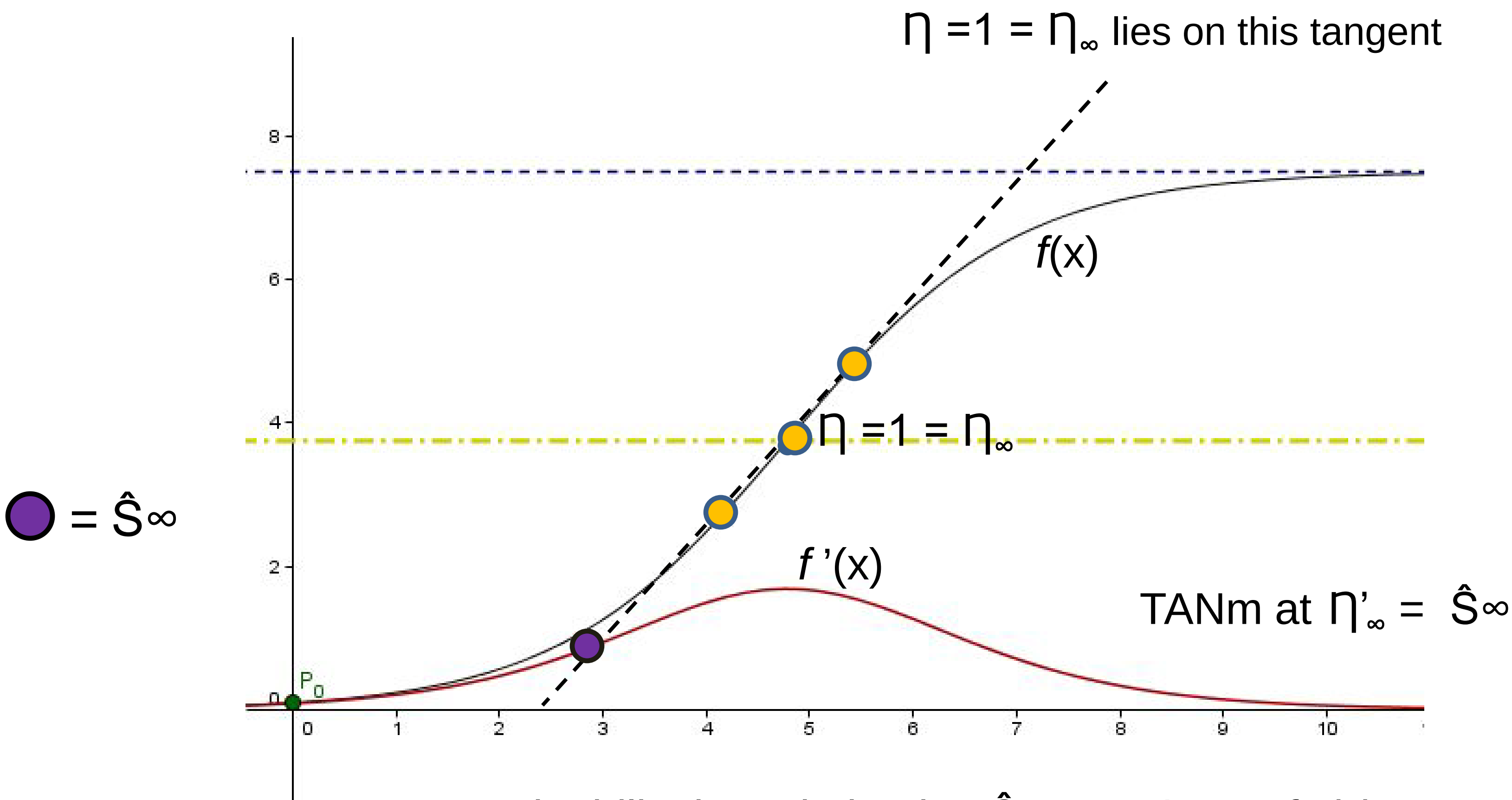


$f(x)$ = growth curve
$f'(x)$ = rate of change



= $\hat{S}_{\mu}$

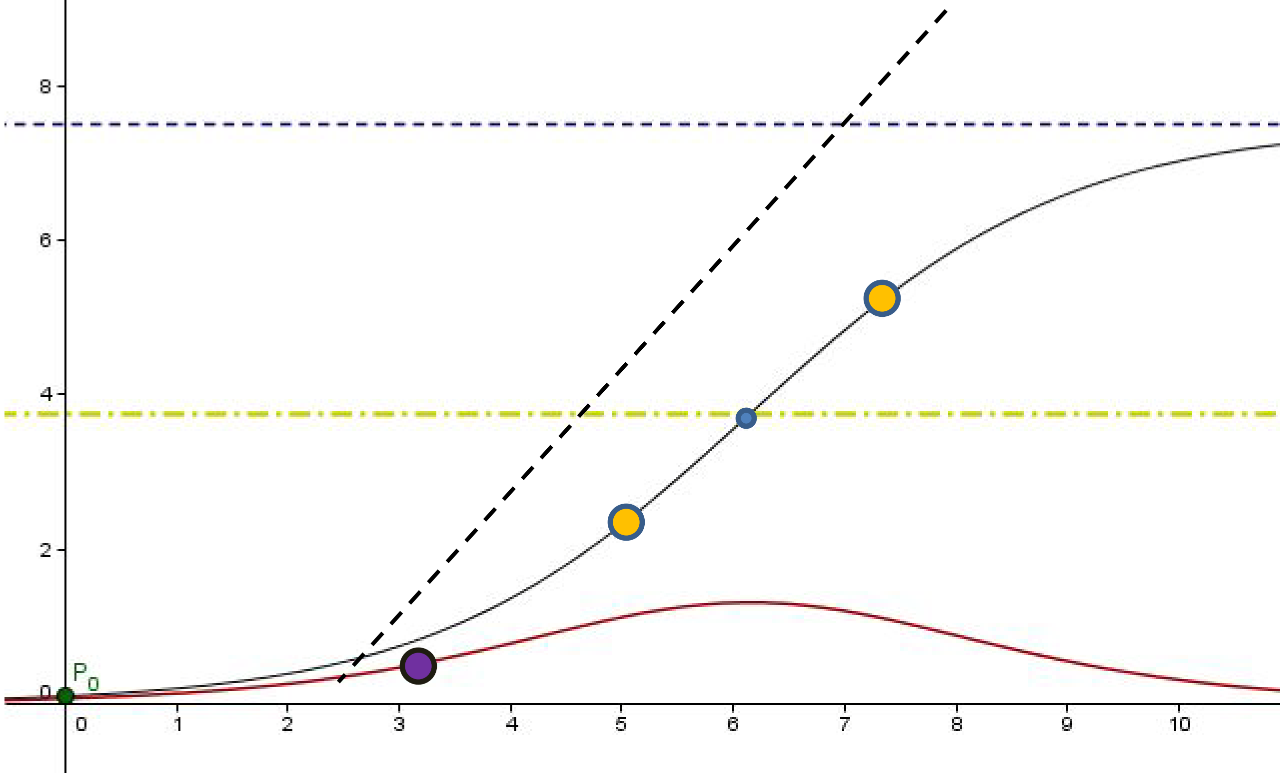
f(x) = growth curve
f ’(x) = rate of change



--sustainability is optimized at Ŝ∞, relative to *f* ”(x)
--maximum system equilibrium when *f*(x) Ƞ =1 = Ƞ∞
--system entropy is minimal

$f(x)$ = growth curve
$f\,'(x)$ = rate of change

$\eta = 1 = \eta_\infty$ lies on this tangent



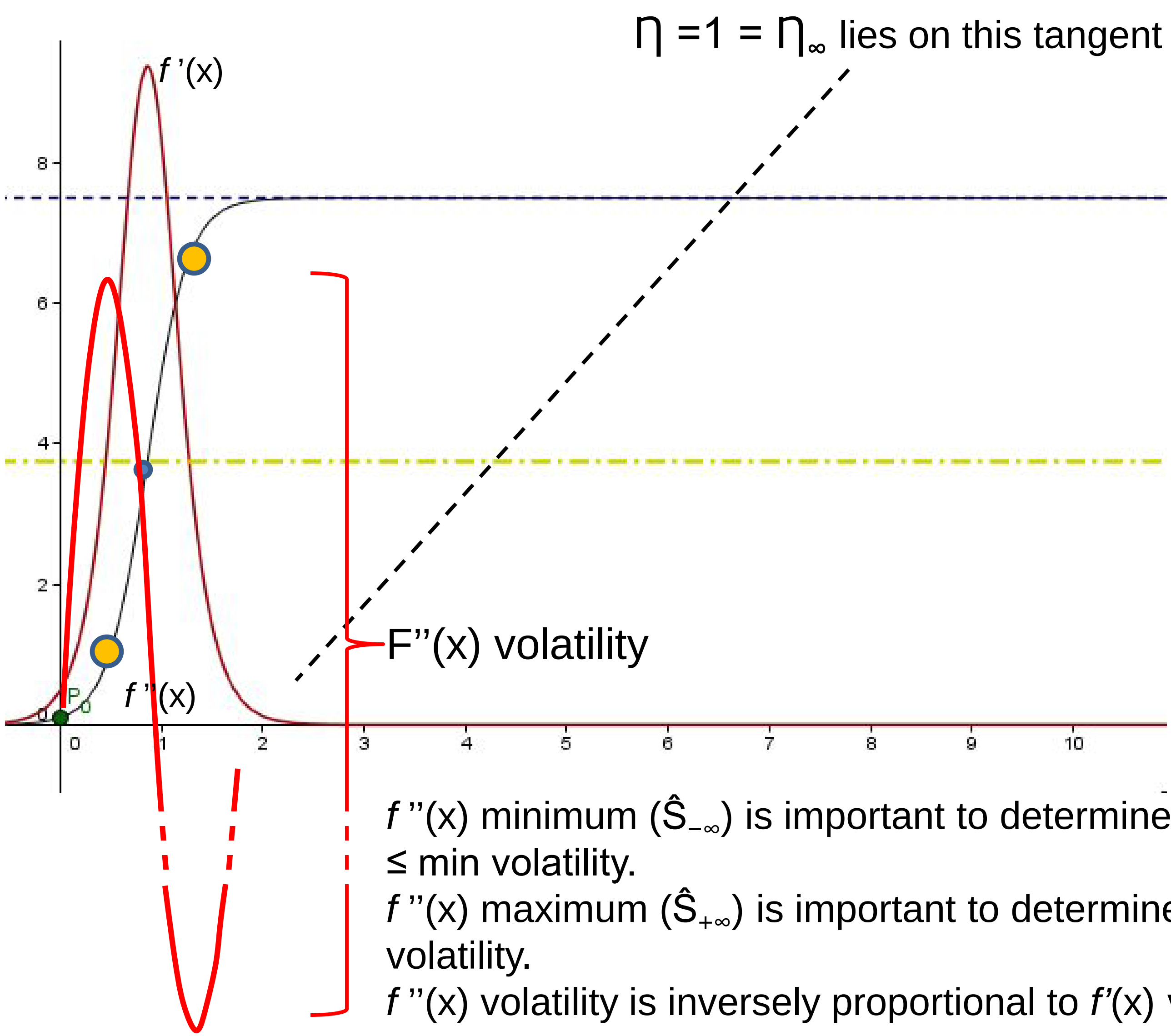
= $\hat{S}_{\mu}$

non-optimized sustainability; $\eta = 1 \neq \eta_\infty$

f(x) = growth curve

f ’(x) = rate of change

f ”(x) = system volatility

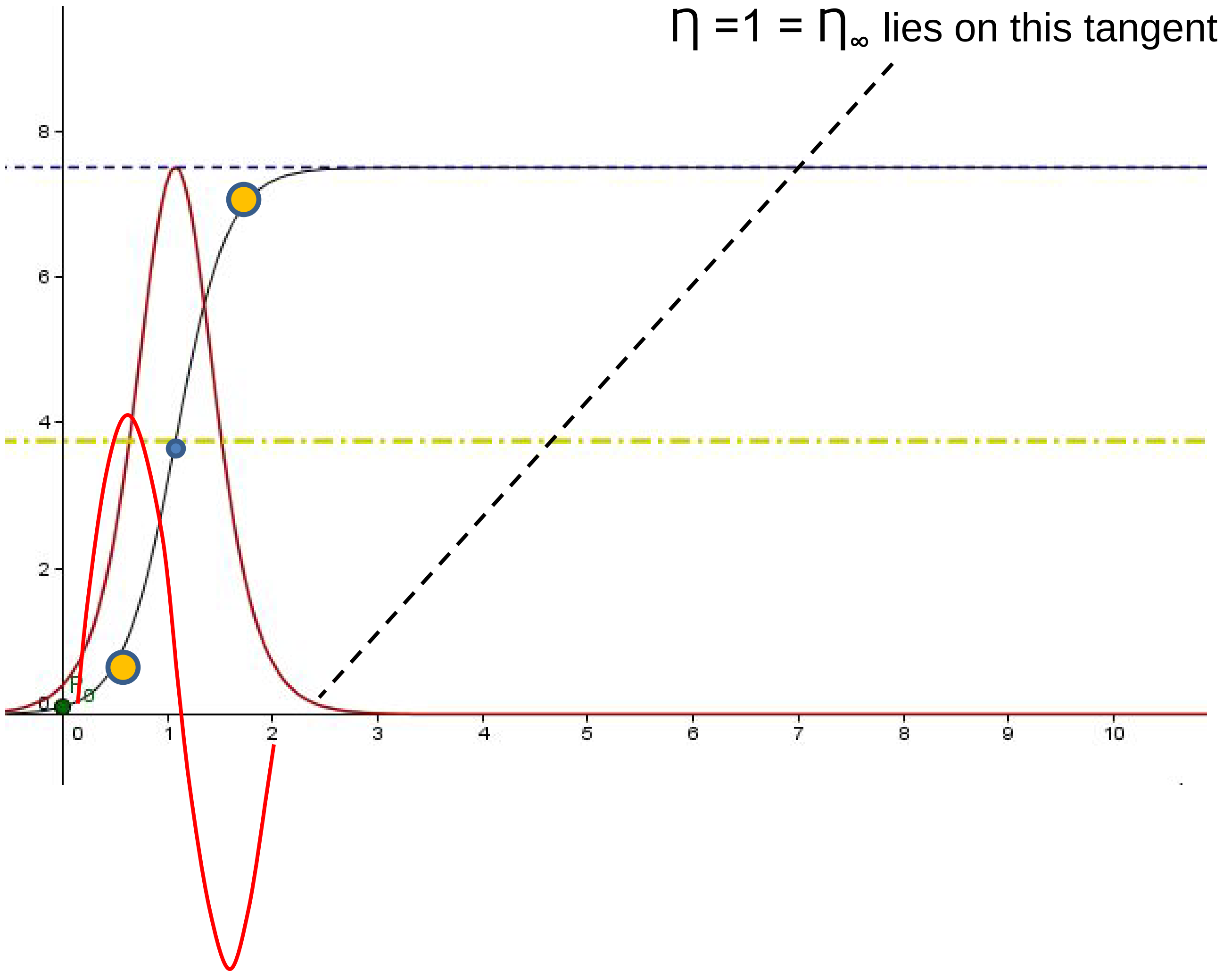


f ”(x) minimum ($\hat{S}_{-\infty}$) is important to determine sustainability, ≤ min volatility.
f ”(x) maximum ($\hat{S}_{+\infty}$) is important to determine yield, ≥ max volatility.
f ”(x) volatility is inversely proportional to *f’*(x) variability

f(x) = growth curve

f ’(x) = rate of change

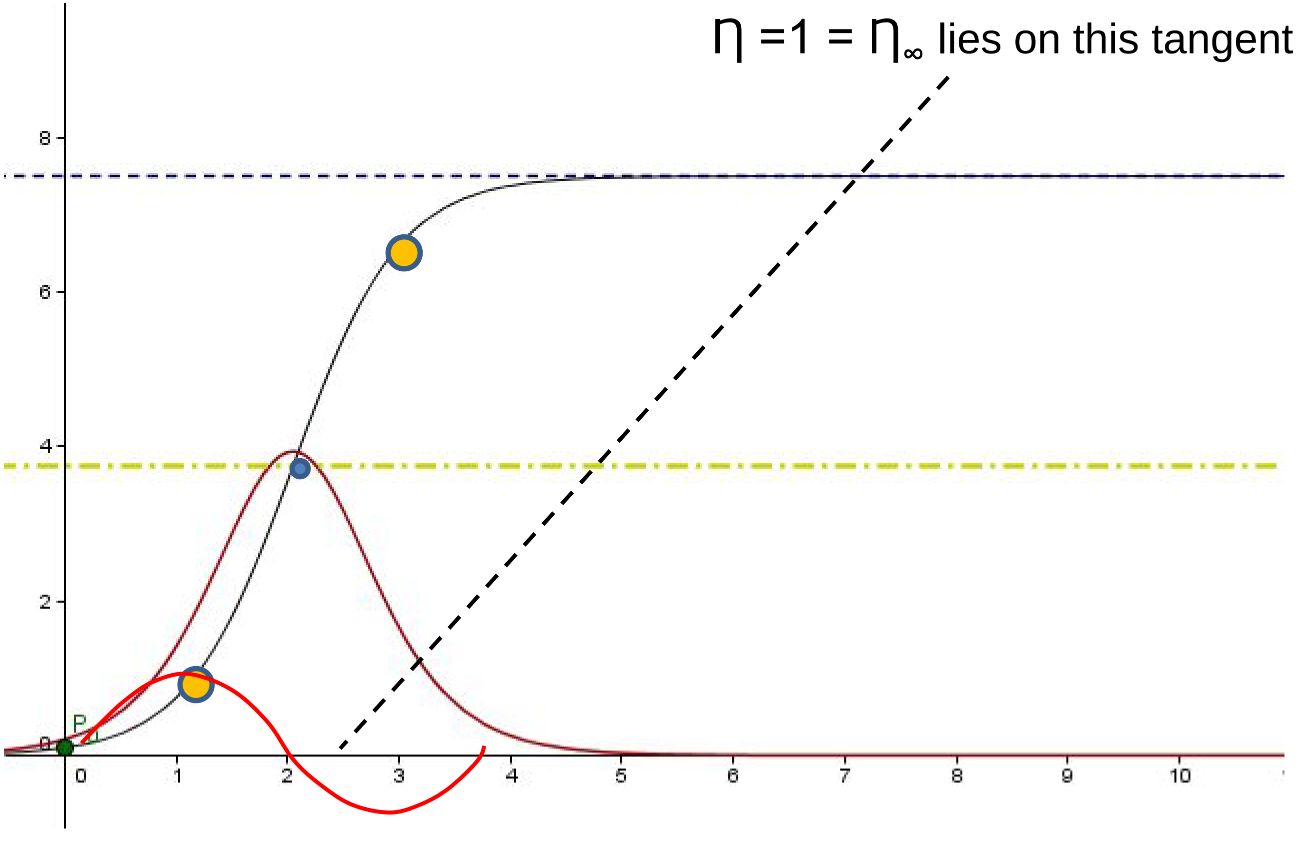
f ’’(x) = system volatility



$f(x)$ = growth curve

$f'(x)$ = rate of change

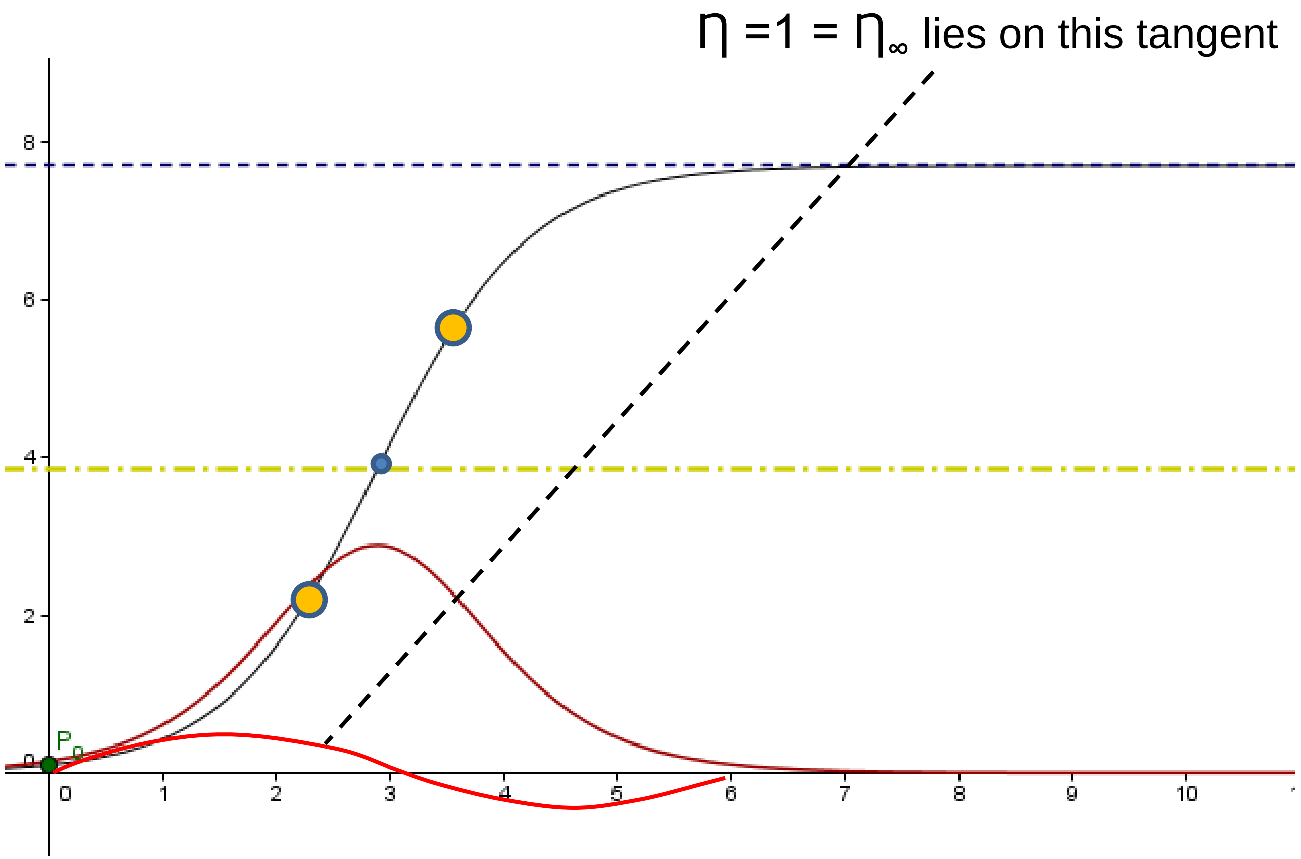
$f''(x)$ = system volatility



f(x) = growth curve

f '(x) = rate of change

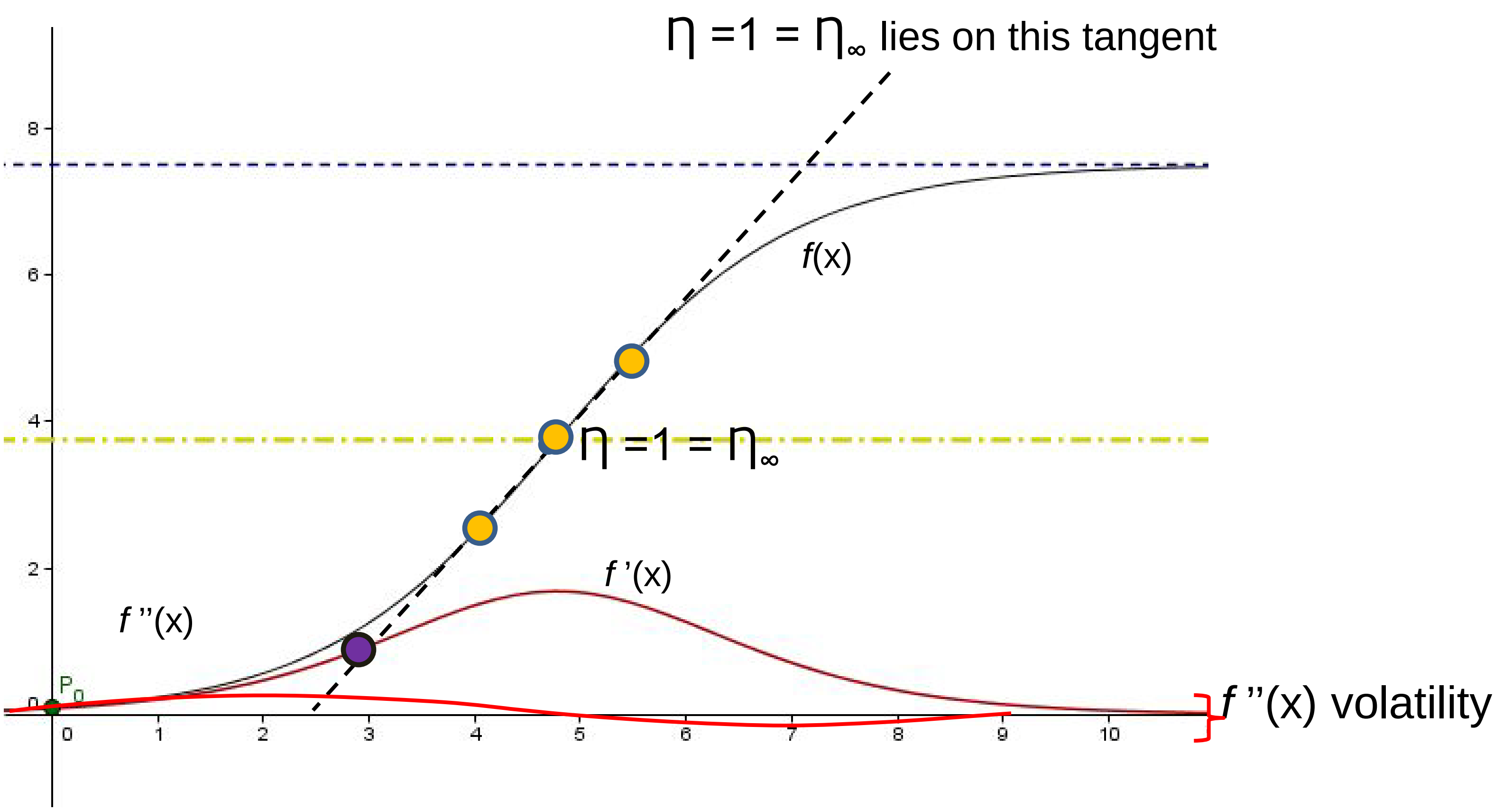
f ''(x) = system volatility



$f(x)$ = growth curve

$f'(x)$ = rate of change

$f''(x)$ = system volatility

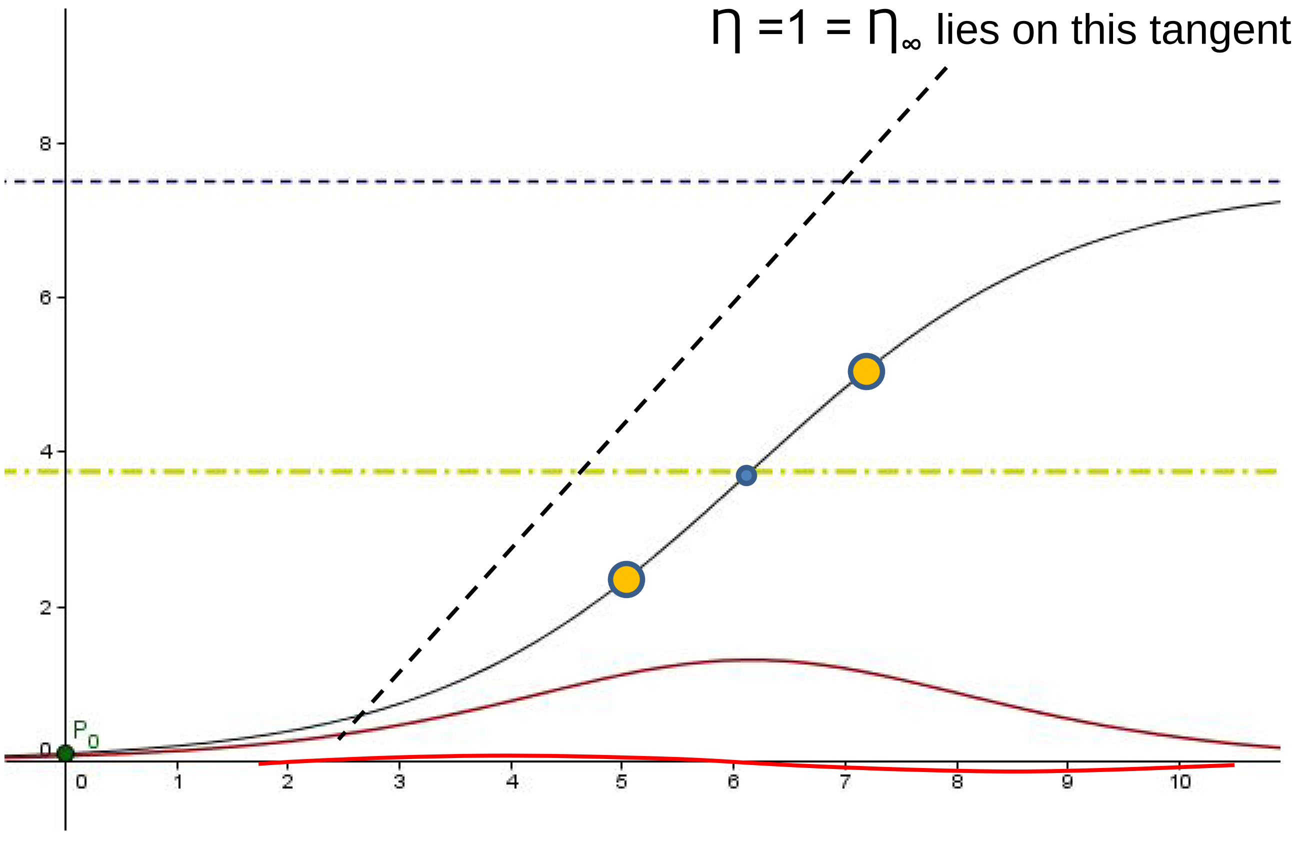


optimal system volatility

f(x) = growth curve

f '(x) = rate of change

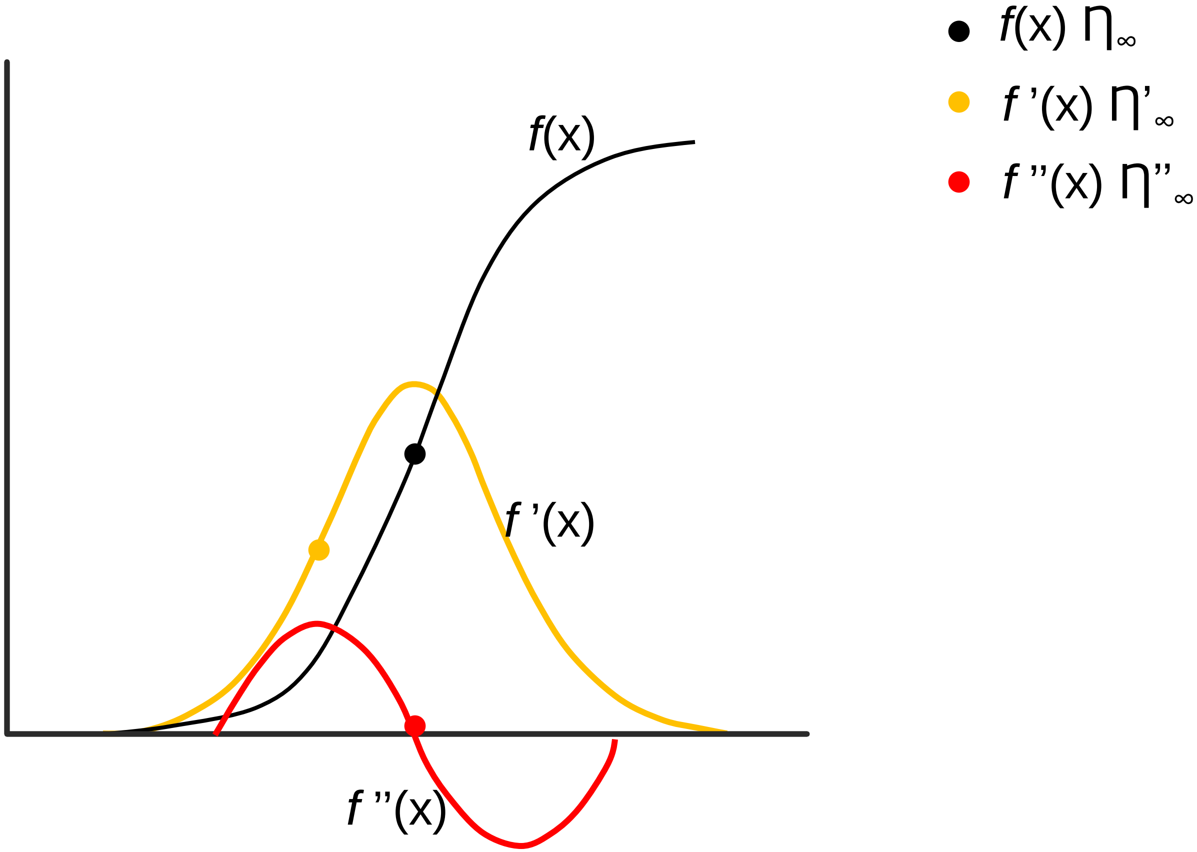
f ''(x) = system volatility



Correspondence

$f'(x)\,\eta'_\infty = f(x)\,\eta_\infty$; $|\eta'_\infty| \rightarrow \eta_\infty$ at $y = \hat{S}_{\boldsymbol{\mu}}$

$f''(x)\,\eta''_\infty = f'(x)\,\eta'_\infty$; $|\eta''_\infty| \rightarrow \eta'_\infty$ at $y = \hat{S}_{\boldsymbol{\mu}}$



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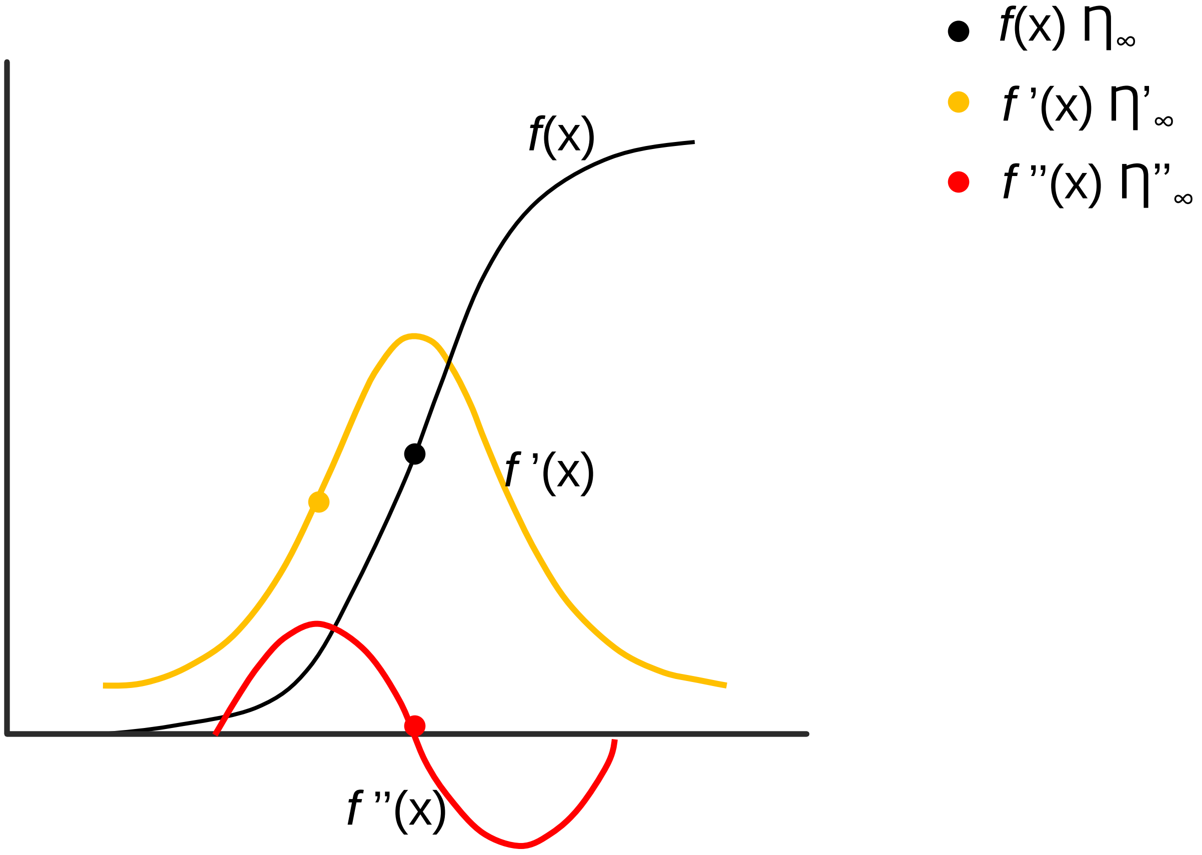
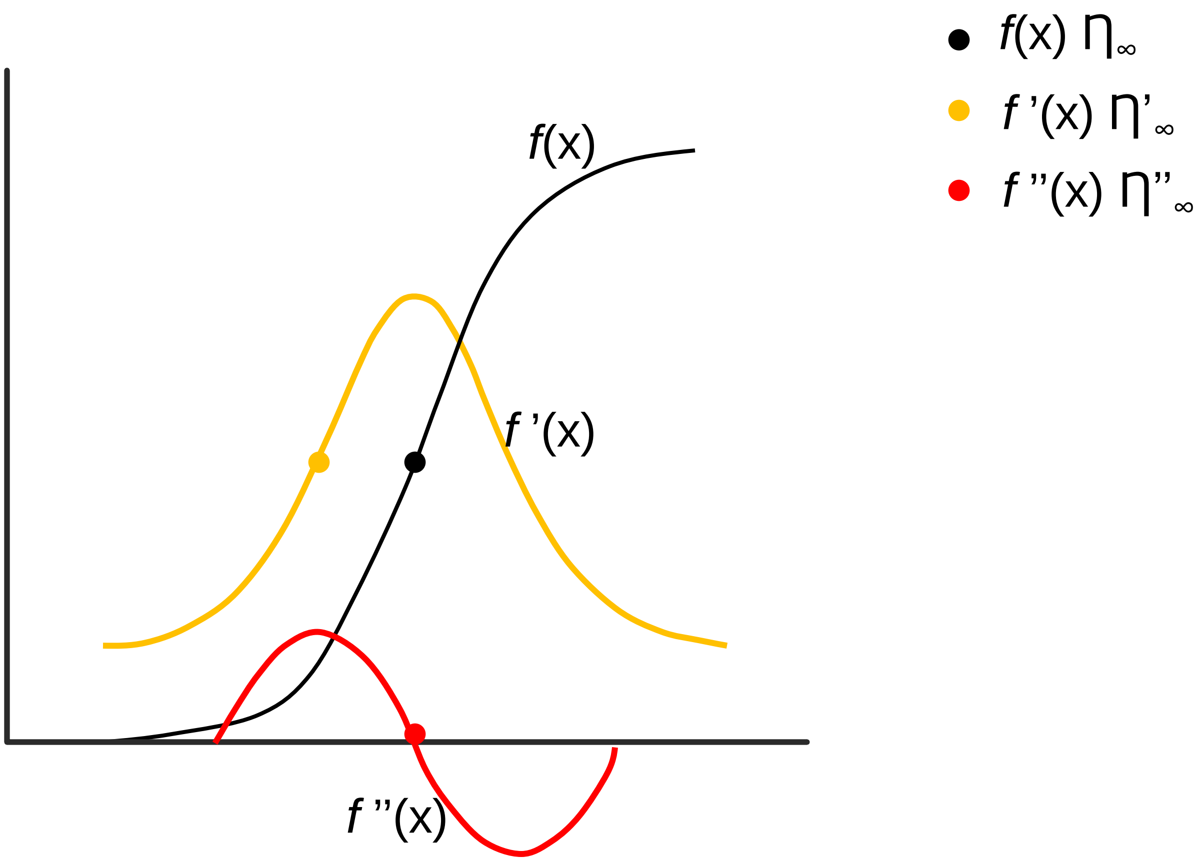


Correspondence

$$f'(x)\,\eta'_{\infty} = f(x)\,\eta_{\infty};\ |\eta'_{\infty}| \rightarrow \eta_{\infty} \text{ at } y = \hat{S}_{\mu}$$

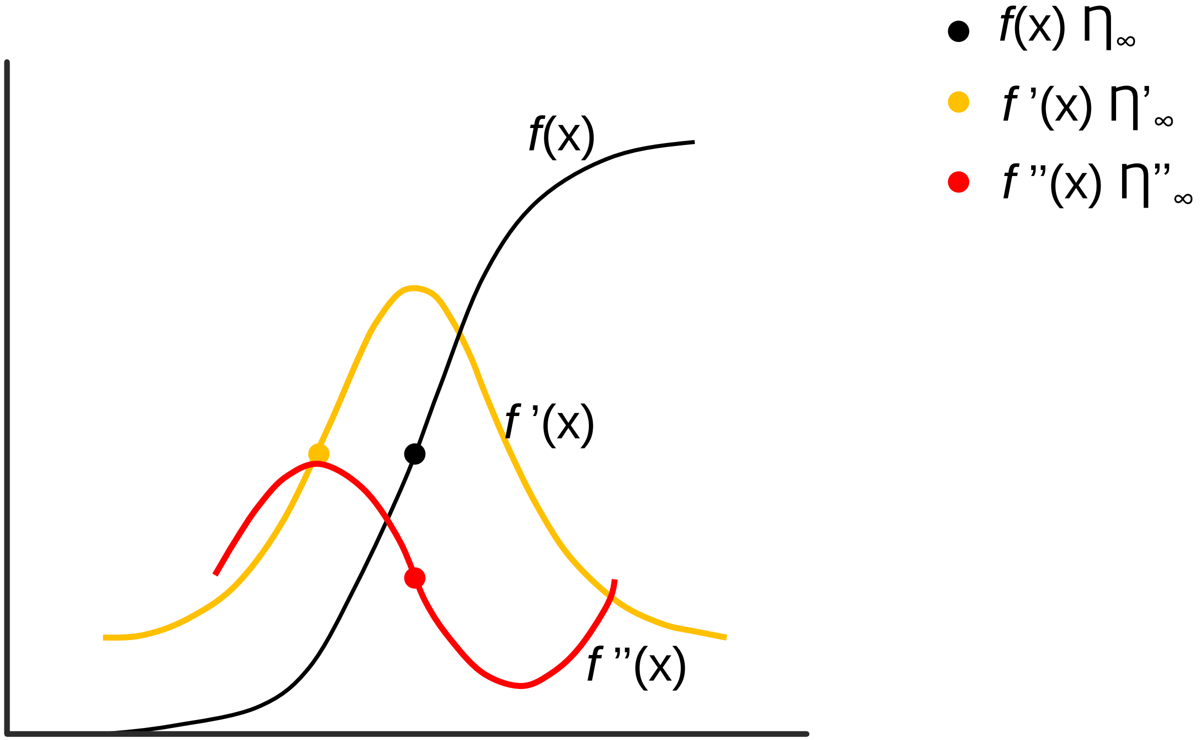
$$f''(x)\,\eta''_{\infty} = f'(x)\,\eta'_{\infty};\ |\eta''_{\infty}| \rightarrow \eta'_{\infty} \text{ at } y = \hat{S}_{\mu}$$



Correspondence

$f\,'(x)\ \eta'_\infty = f(x)\ \eta_\infty;\ |\eta'_\infty| \rightarrow \eta_\infty$ at $y = \hat{S}_{\boldsymbol{\mu}}$

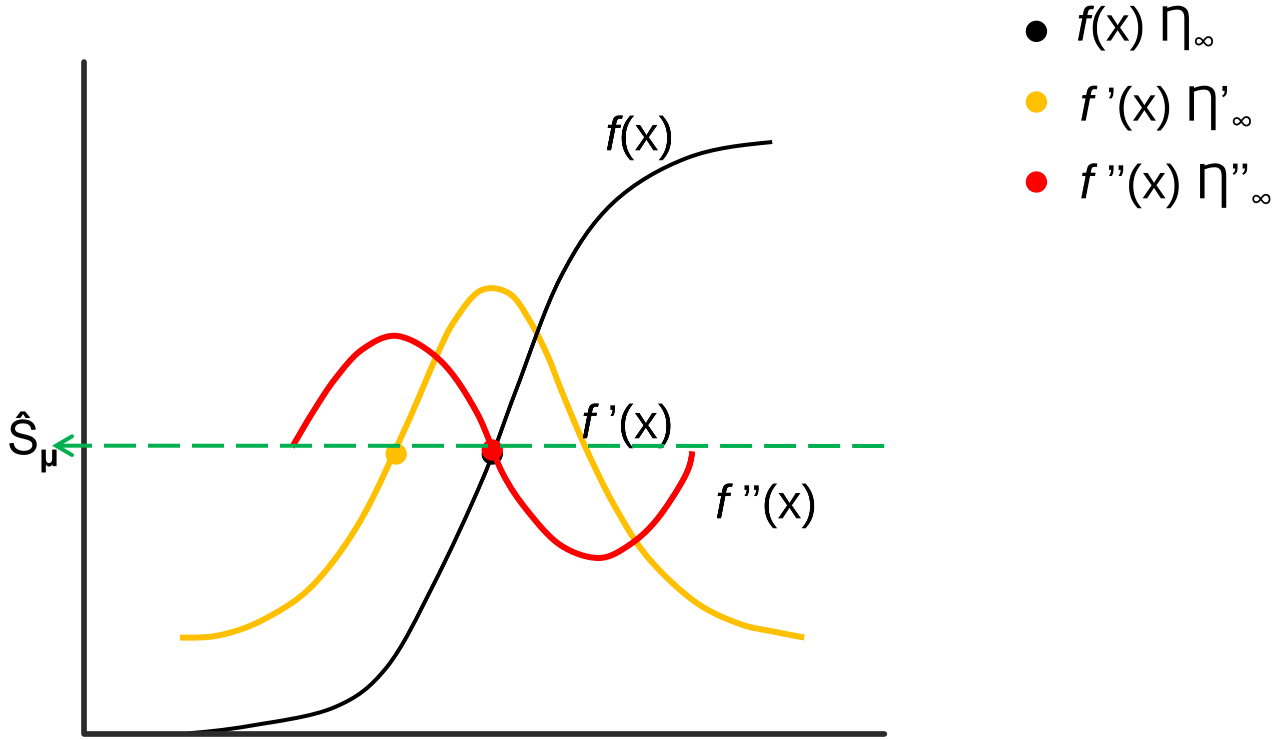
$f\,''(x)\ \eta''_\infty = f\,'(x)\ \eta'_\infty;\ |\eta''_\infty| \rightarrow \eta'_\infty$ at $y = \hat{S}_{\boldsymbol{\mu}}$



Correspondence

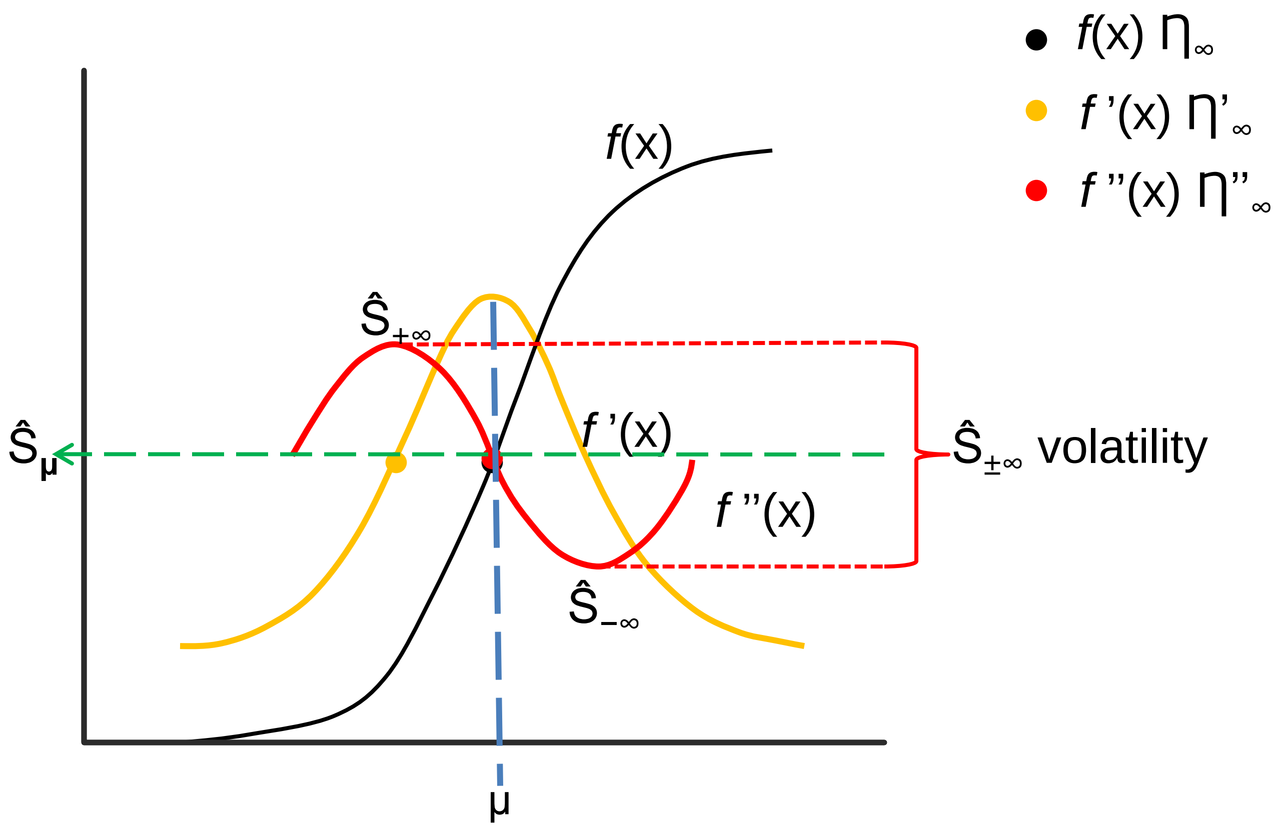
$f'(x)\,\eta'_{\infty} = f(x)\,\eta_{\infty}$; $|\eta'_{\infty}| \rightarrow \eta_{\infty}$ at $y = \hat{S}_{\mu}$

$f''(x)\,\eta''_{\infty} = f'(x)\,\eta'_{\infty}$; $|\eta''_{\infty}| \rightarrow \eta'_{\infty}$ at $y = \hat{S}_{\mu}$



Volatility

--Variance measures variability of x around μ
--Volatility measures variability of y around $\hat{S}_{\mu}$

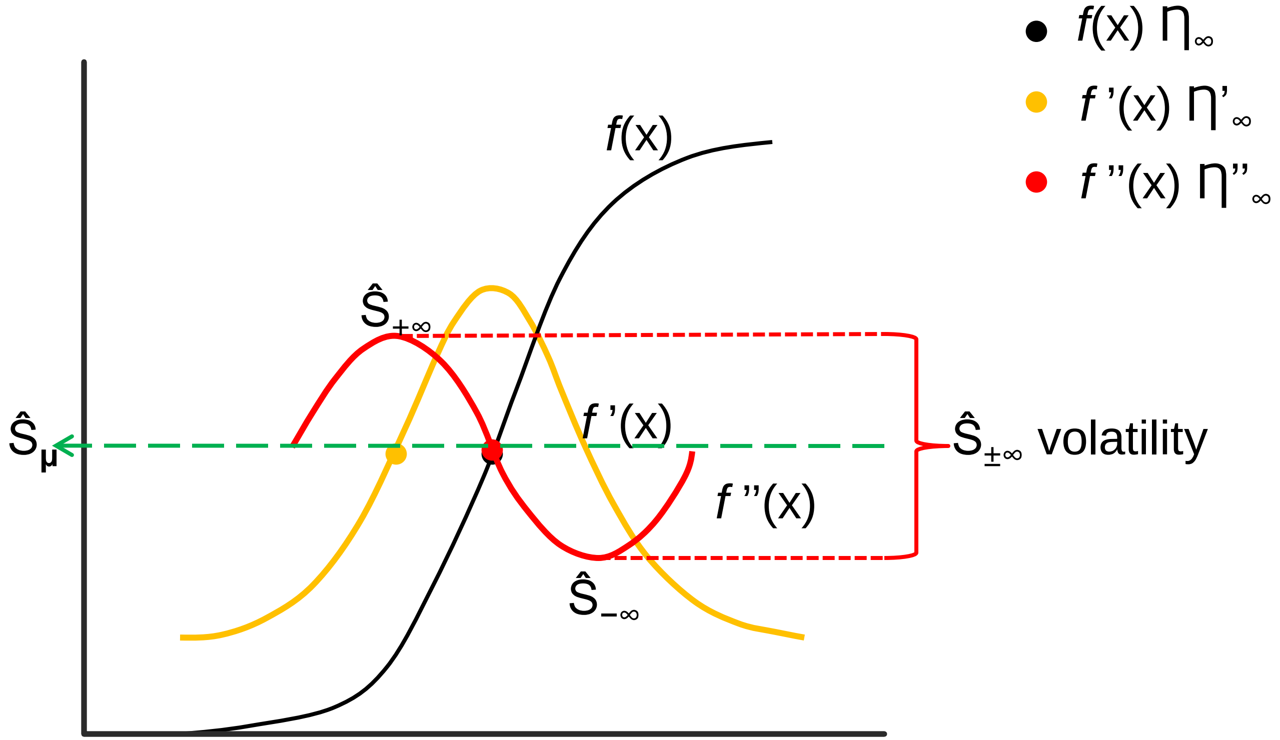


Volatility

--Variance measures variability of x around μ

--Volatility measures variability of y around $\hat{S}_{\mu}$

$\pm\sigma = \eta_{\infty} \pm \eta'_{\infty}$; σ^2 is inversely proportional to $f''(x)\ \hat{S}_{\pm\infty}$ volatility

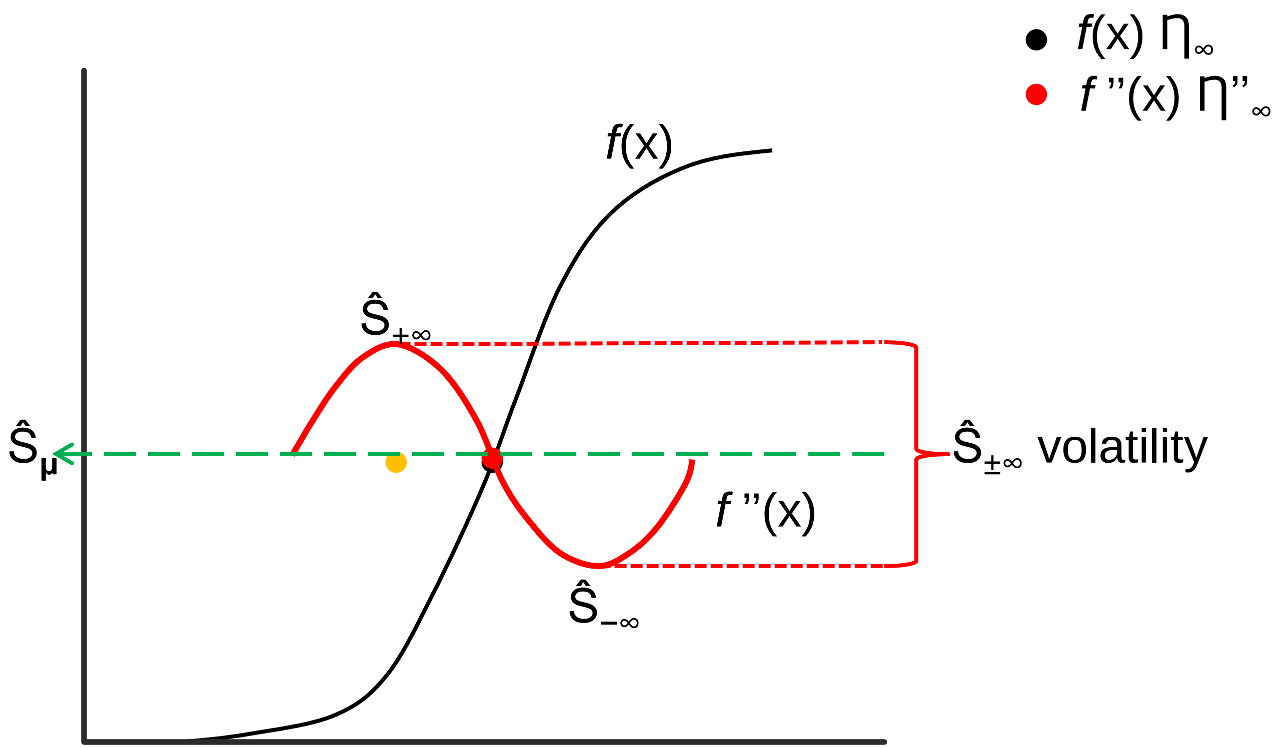


Volatility

--Variance measures variability of x around μ

--Volatility measures variability of y around $\hat{S}_{\mu}$

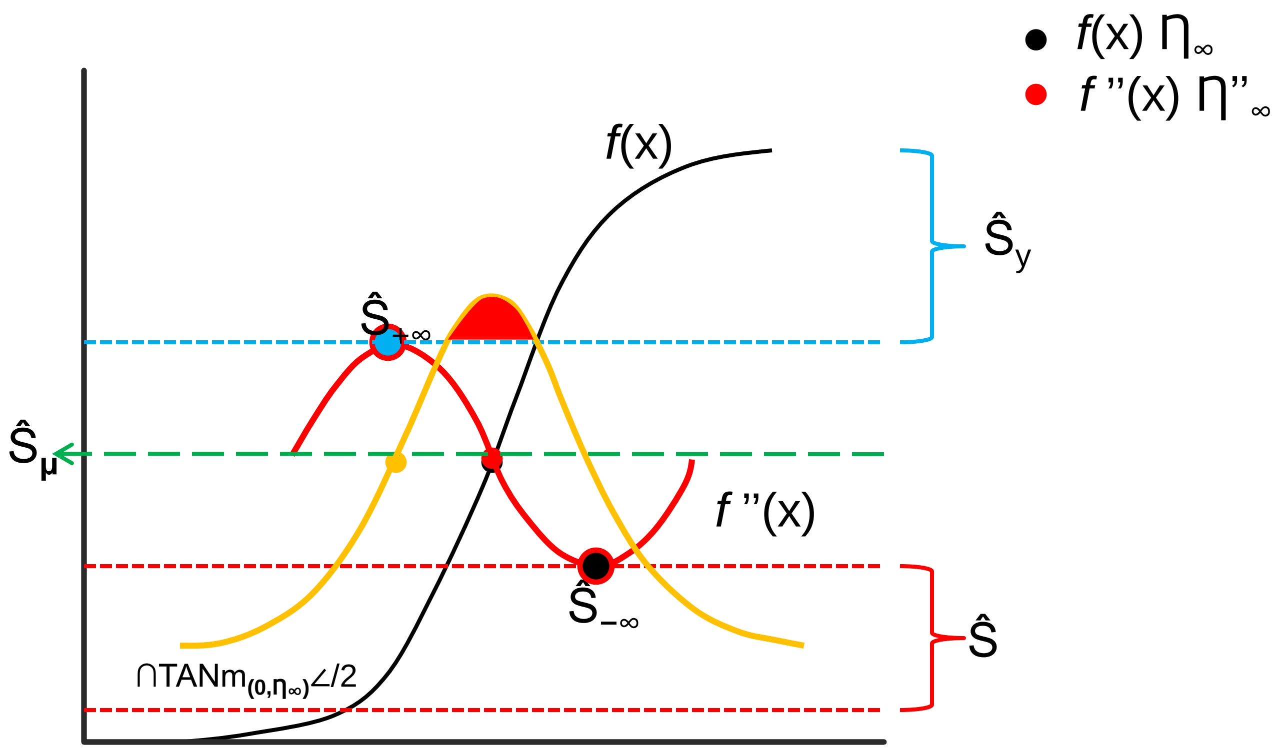
$\pm\sigma = \Pi_{\infty} \pm \Pi'_{\infty}$; σ^2 is inversely proportional to *f''*(x) $\hat{S}_{\pm\infty}$ volatility



--the line of *f* ''(x) is the trajectory of volatility

--because of correspondence, σ is also indicted by *f* ''(x)

System Sustainability, Ŝ

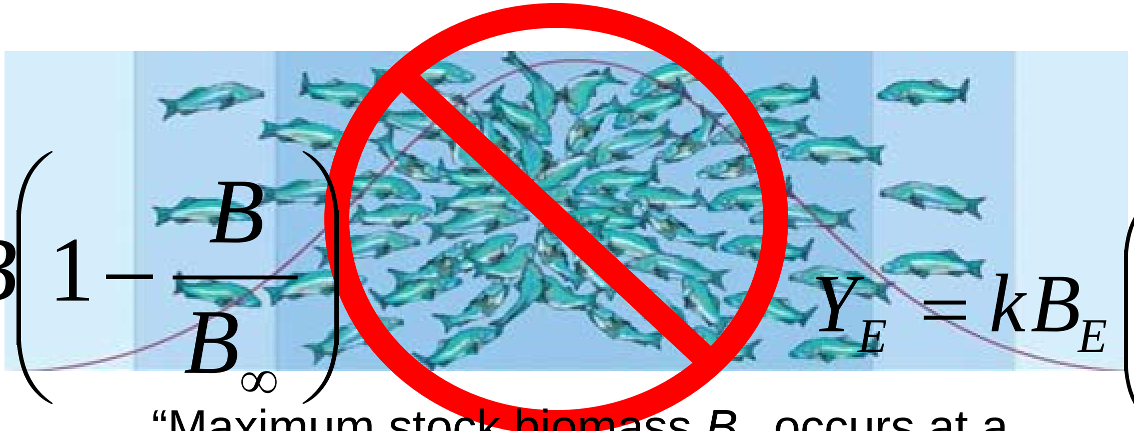


- system sustainability, Ŝ, is equal to or less than minimal volatility, $\hat{S}_{-\infty}$
- system sustainable yield, $\hat{S}_y$, is equal to or greater than maximum volatility, $\hat{S}_{+\infty}$

Maximum sustainable yield

is based on knowledge of K

"The largest yield (or catch) that can be taken from a species' stock over an indefinite period."



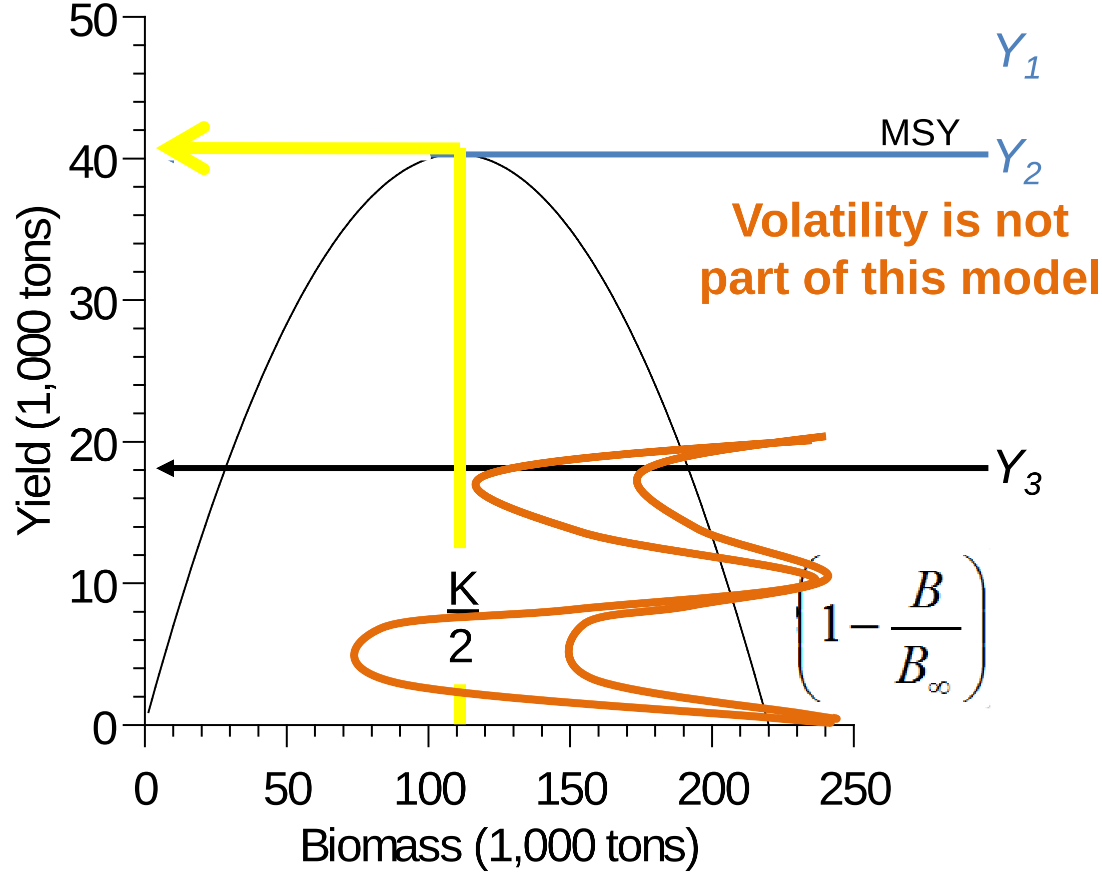
$$\frac{dB}{dt} = kB\left(1 - \frac{B}{B_\infty}\right)$$

$$Y_E = kB_E\left(1 - \frac{B_E}{B_\infty}\right)$$

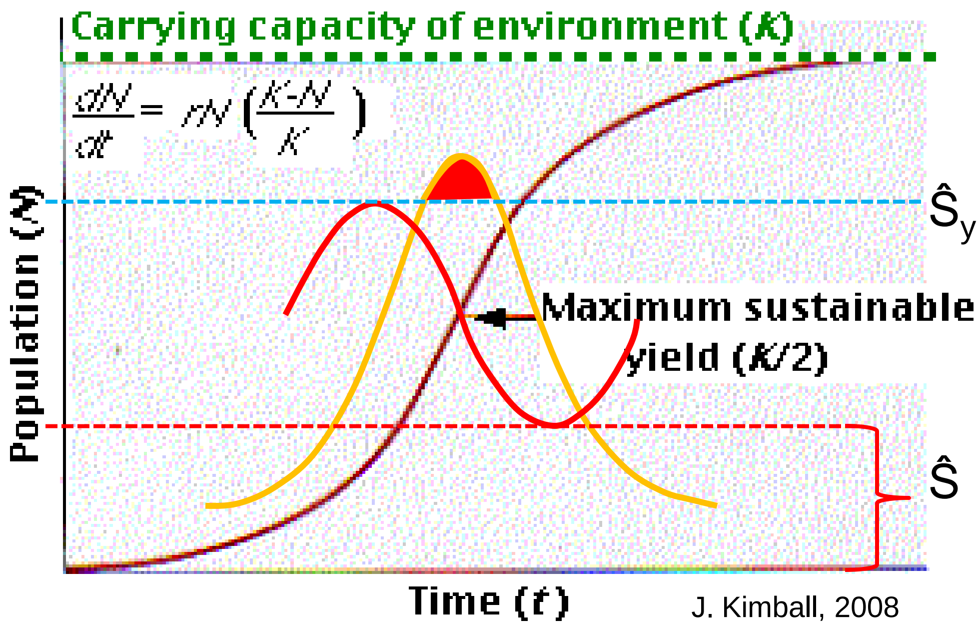
"Maximum stock biomass B_∞ occurs at a level of no harvest or removal (like *K* of the logistic model)."

"The maximum sustainable yield is the largest yield that can be taken from a population at equilibrium." [r, k]

Surplus Production
Graham-Schaefer Model



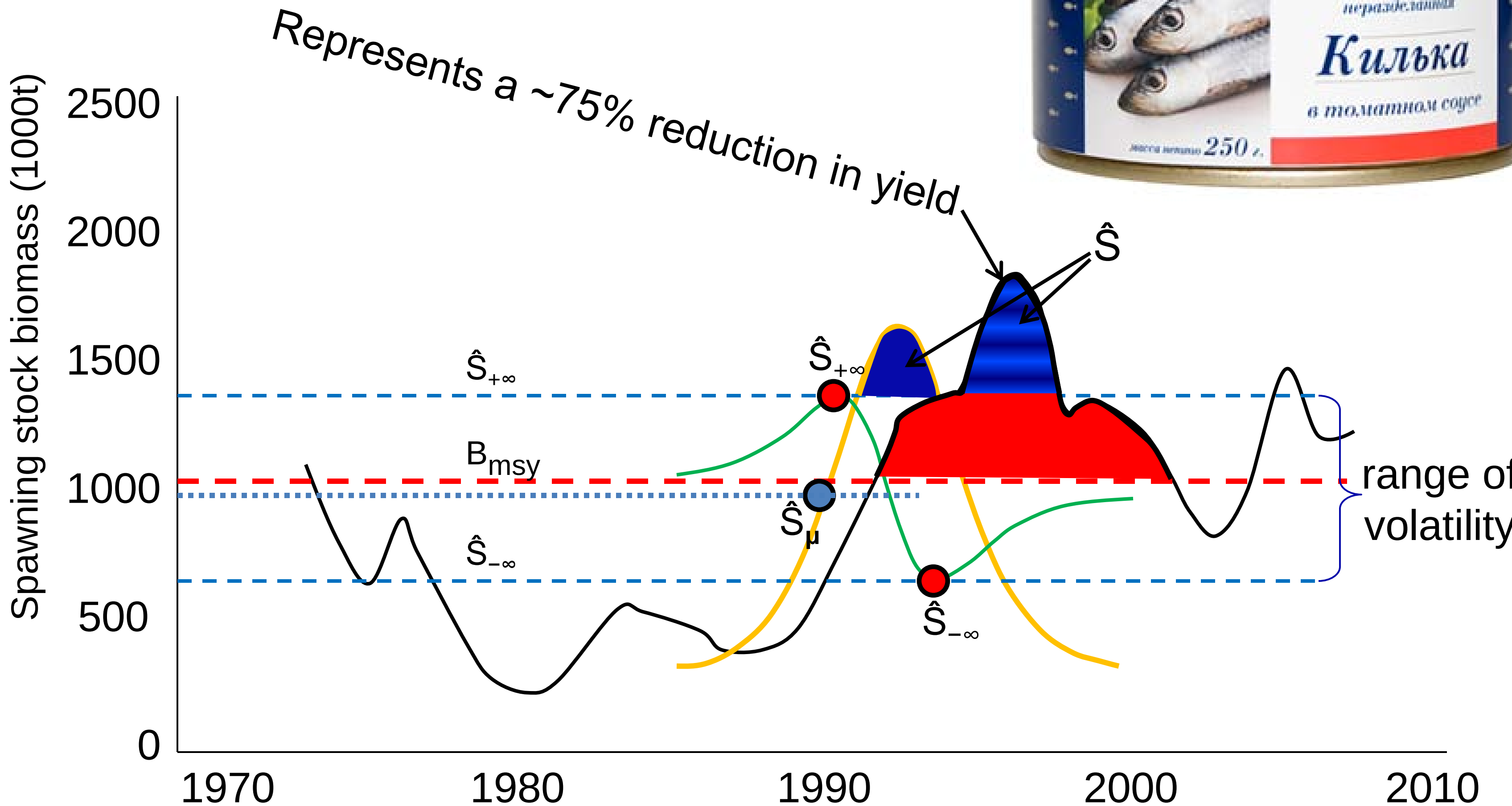
70% of all commercial fish species are fully exploited primarily because MSY does not allow for natural volatility. MSY has been criticized for 30 years. Effects of volatility are magnified as they move through a stock.



MSY = K/2 only takes into account η_∞ (while totally ignoring volatility) based on the premise that maximum efficiency should be the point of greatest stability (high resistance and resilience to change).

Ŝ suggests that volatility and efficiency equilibrium determines sustainability

Baltic Sprat



B_{msy} "biomass that can produce maximum sustainable yields"

Predictability

∵ $f''(x)$ volatility, $\hat{S}_{\pm\infty}$, is symmetrical around $\hat{S}_{\mu}$

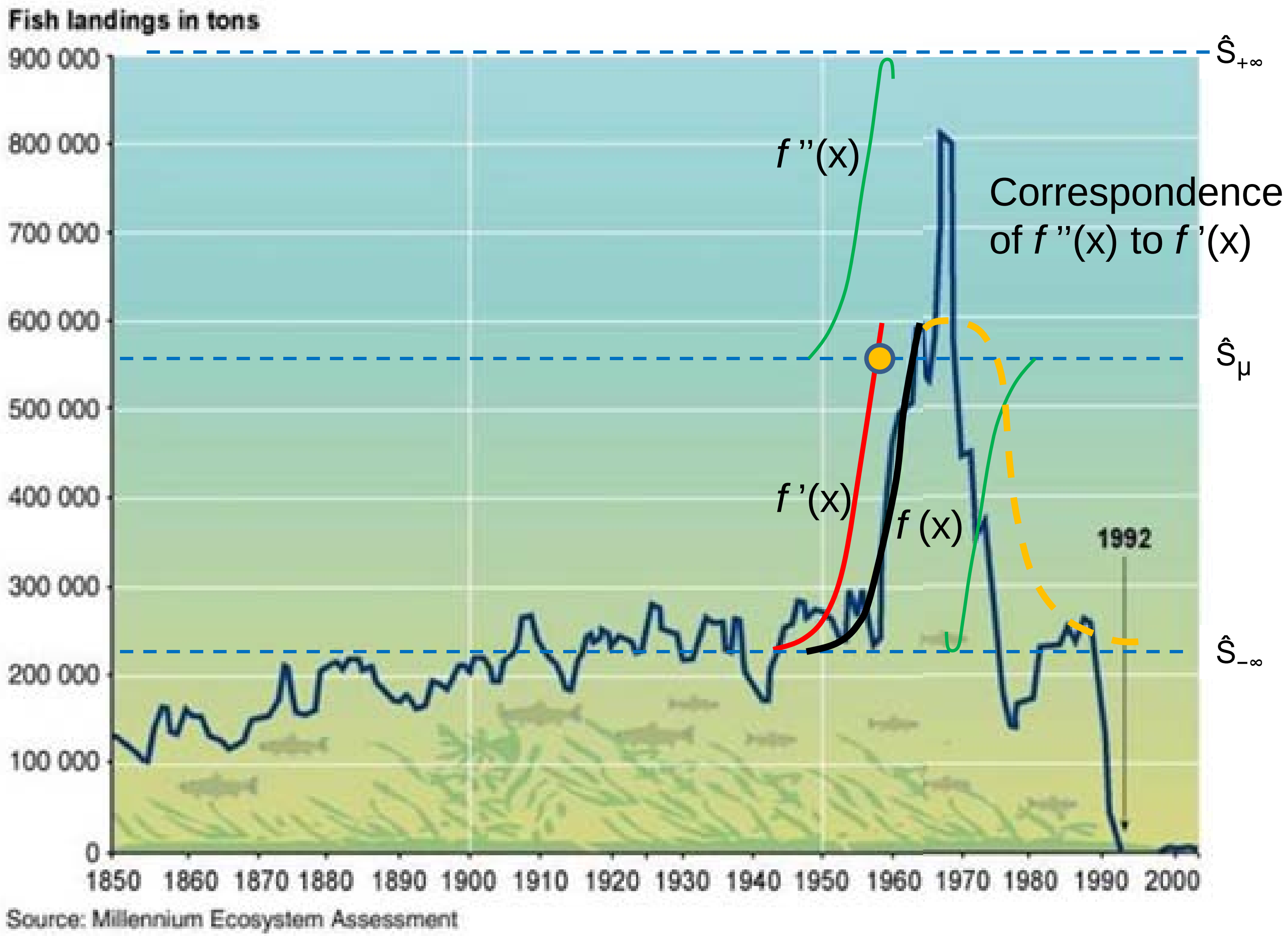
∵ correspondence sets η_{∞}, η'_{∞}, and η''_{∞} equal on y

∵ the standard deviation $\pm\sigma = \eta_{\infty} \pm \eta'_{\infty}$, i.e. the distance from μ to η'_{∞} equals 1 sd

∴ a prediction can be made from $f'(x)$ concavity-up data that is inclusive of η'_{∞}

∴ ∴ η_{∞} can serve as an indicator for prudent management response

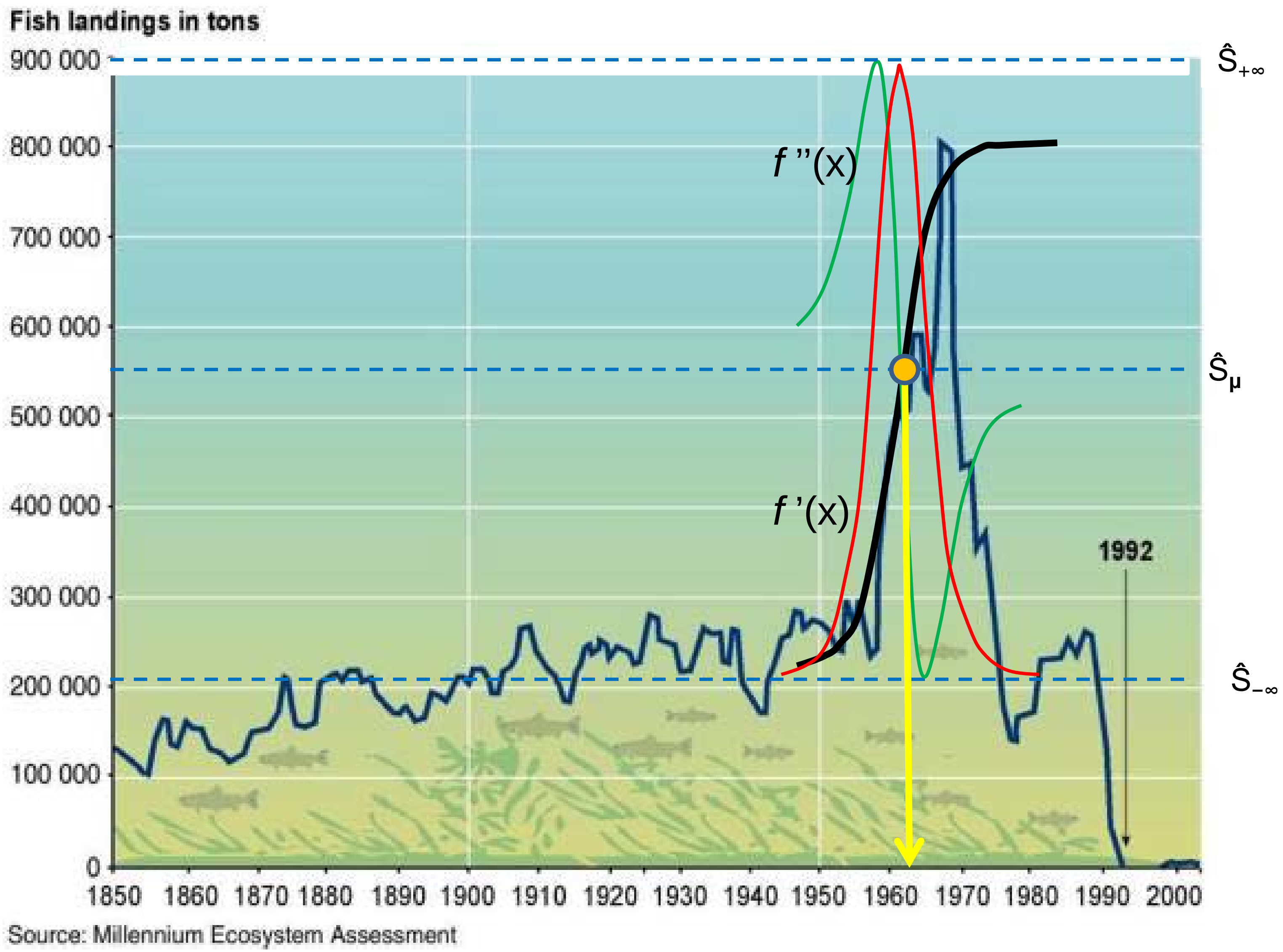
Atlantic cod stocks off the East Coast of Newfoundland



with prudent management response at $\hat{S}_{\mu}^{est}$

Should be known as the collapse of 1962, not 1992

Collapse of Atlantic cod stocks off the East Coast of Newfoundland in 1992

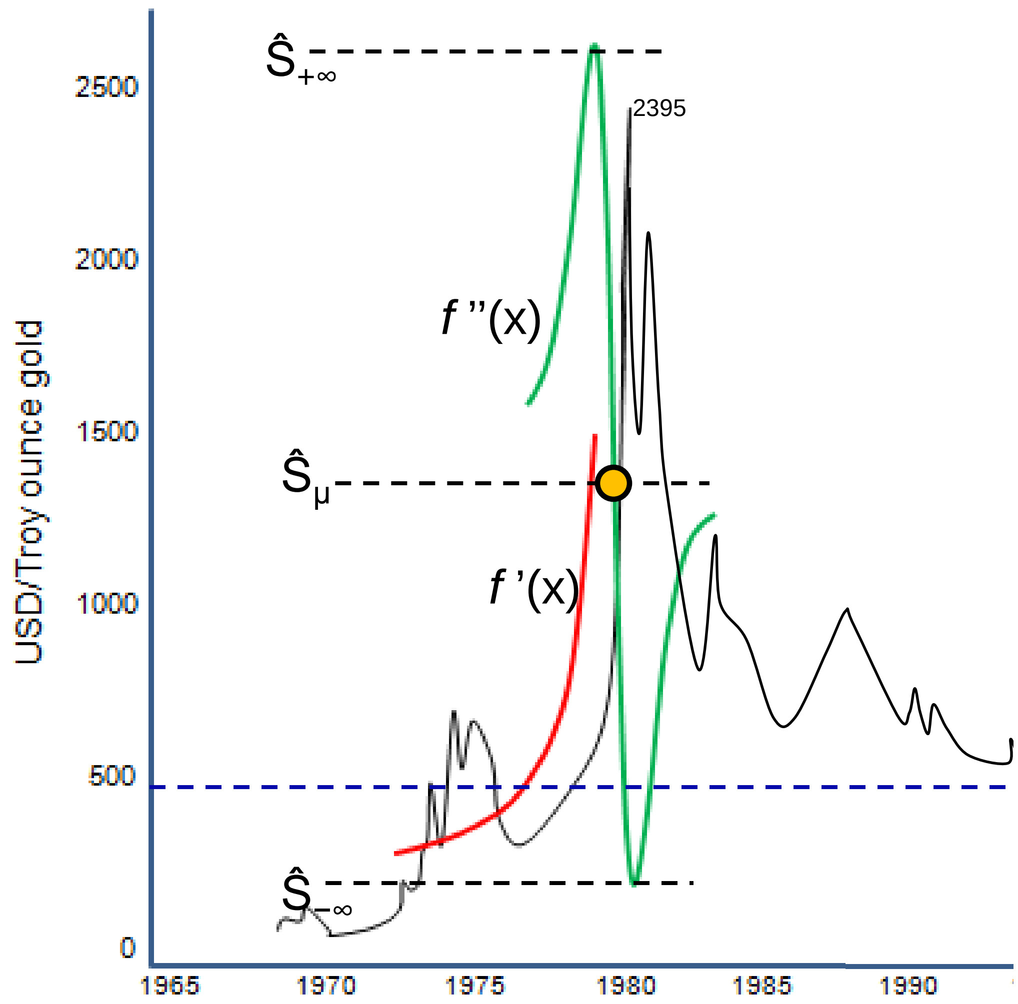


So, if you would have known in 1962 that future fishing would result in a collapse, what would be the year for making harvest corrections?

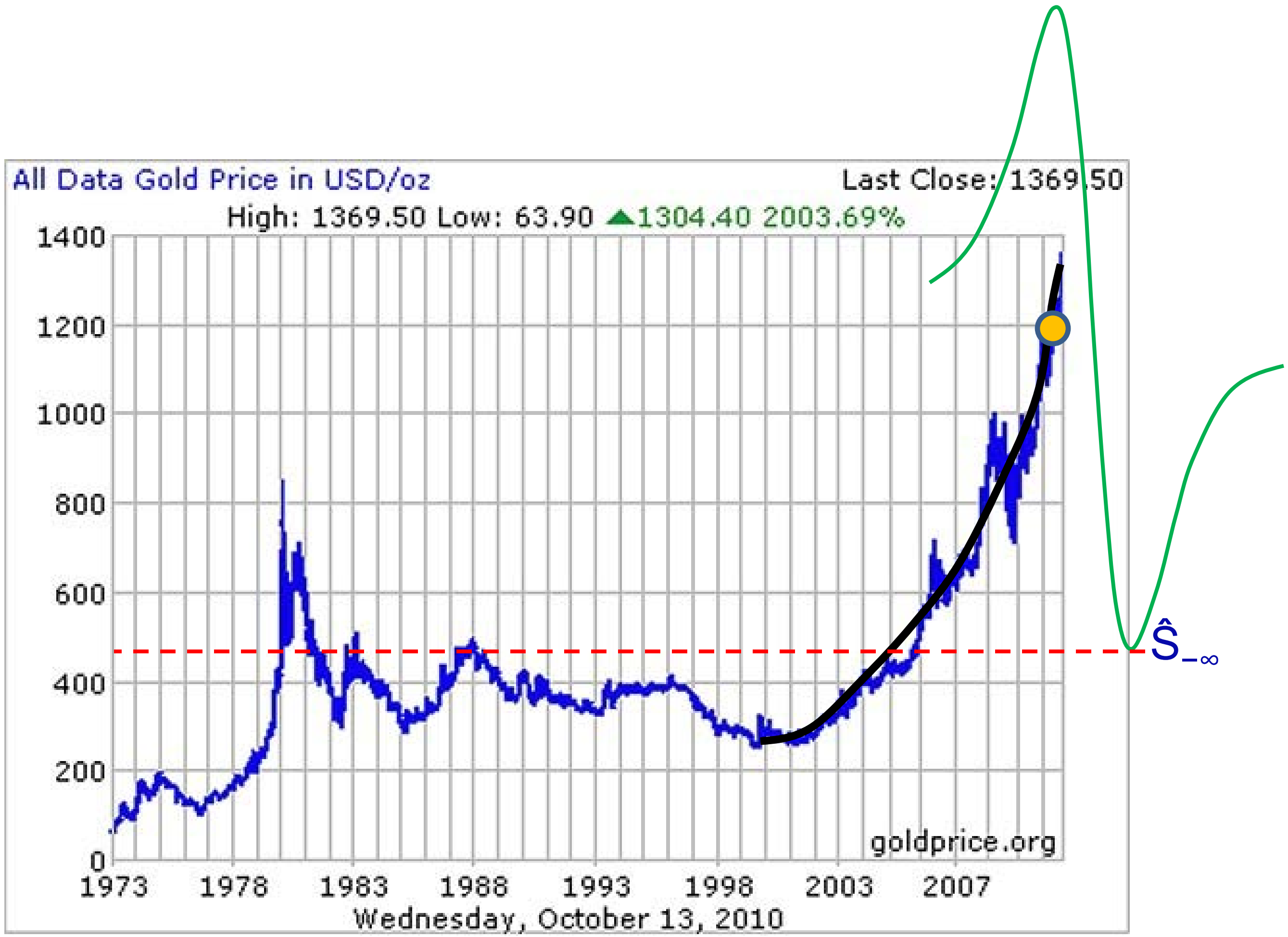
Gold in USD inflation adjusted cpi

Is there a gold bubble?

Yes, gold should be at 2006 prices (~$475) to be outside volatility range of the market.



$\hat{S}_{\mu}$ = point where prudent market forces (homeostasis) should make an adjustment



All Data Gold Price in USD/oz
Last Close: 1369.50
High: 1369.50 Low: 63.90 ▲1304.40 2003.69%
1400
1200
1000
800
600
400
200
0
1973
1978
1983
1988
1993
1998
2003
2007
Wednesday, October 13, 2010
goldprice.org
$\hat{S}_{-\infty}$

Other Implications of Sustainability Model

H’ Shannon diversity

--H’ evenness, *J’,* (MacArthur 1965) is indicated as not being definitive for defining H’.

Hierarchy growth and collapse

--Vertical system growth through resource hoarding by common units to the detriment of rare units.

All hierarchy growth is built on exploitation and collapses on volatility.

Kasterism

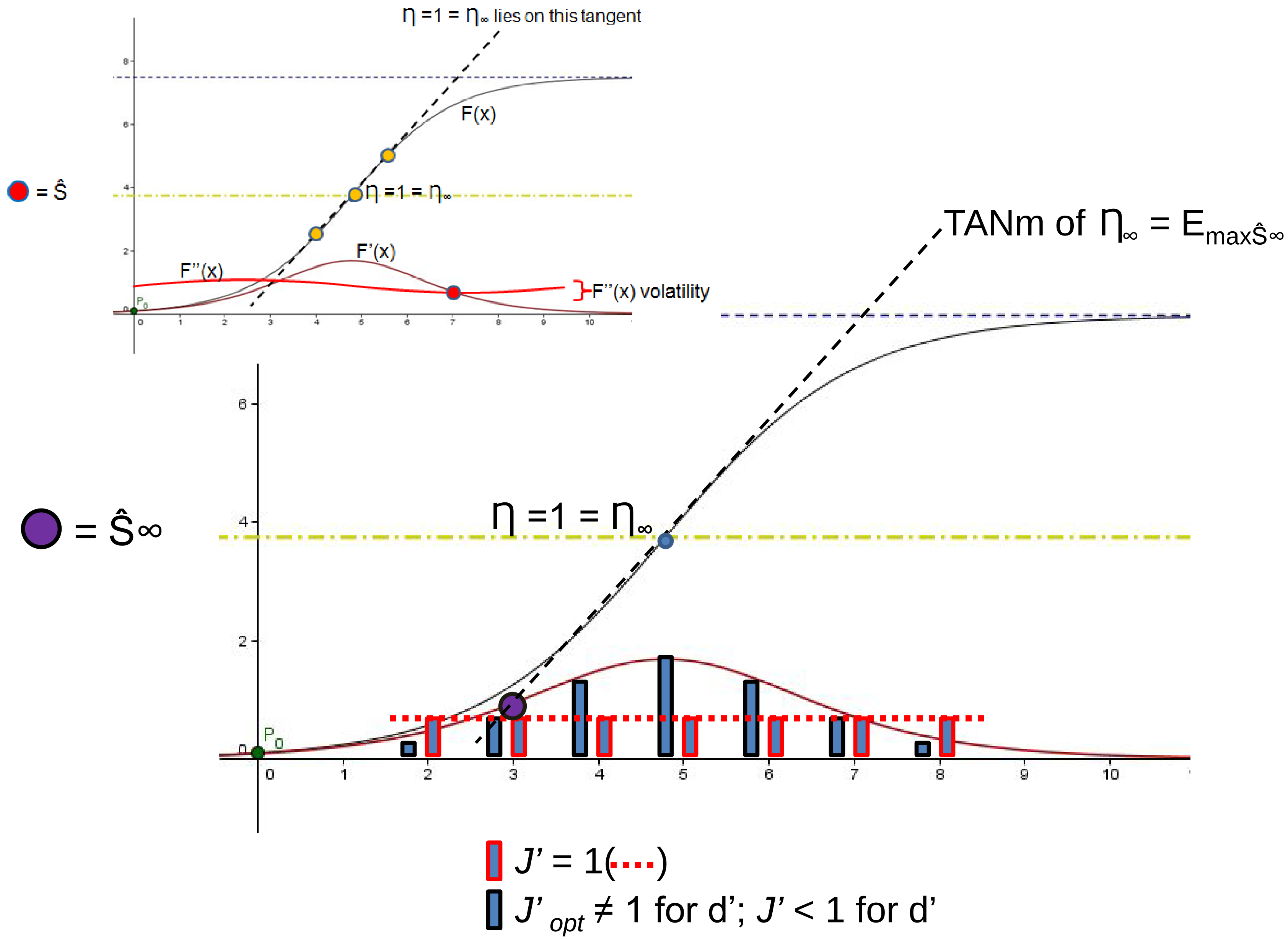
Sustainable strategists

--There should be biota that are adapted for a sustainable strategy, that lies between the r strategy and K strategy, and operates at minimum entropy. These species would provide a disproportionate amount of stability to communities.

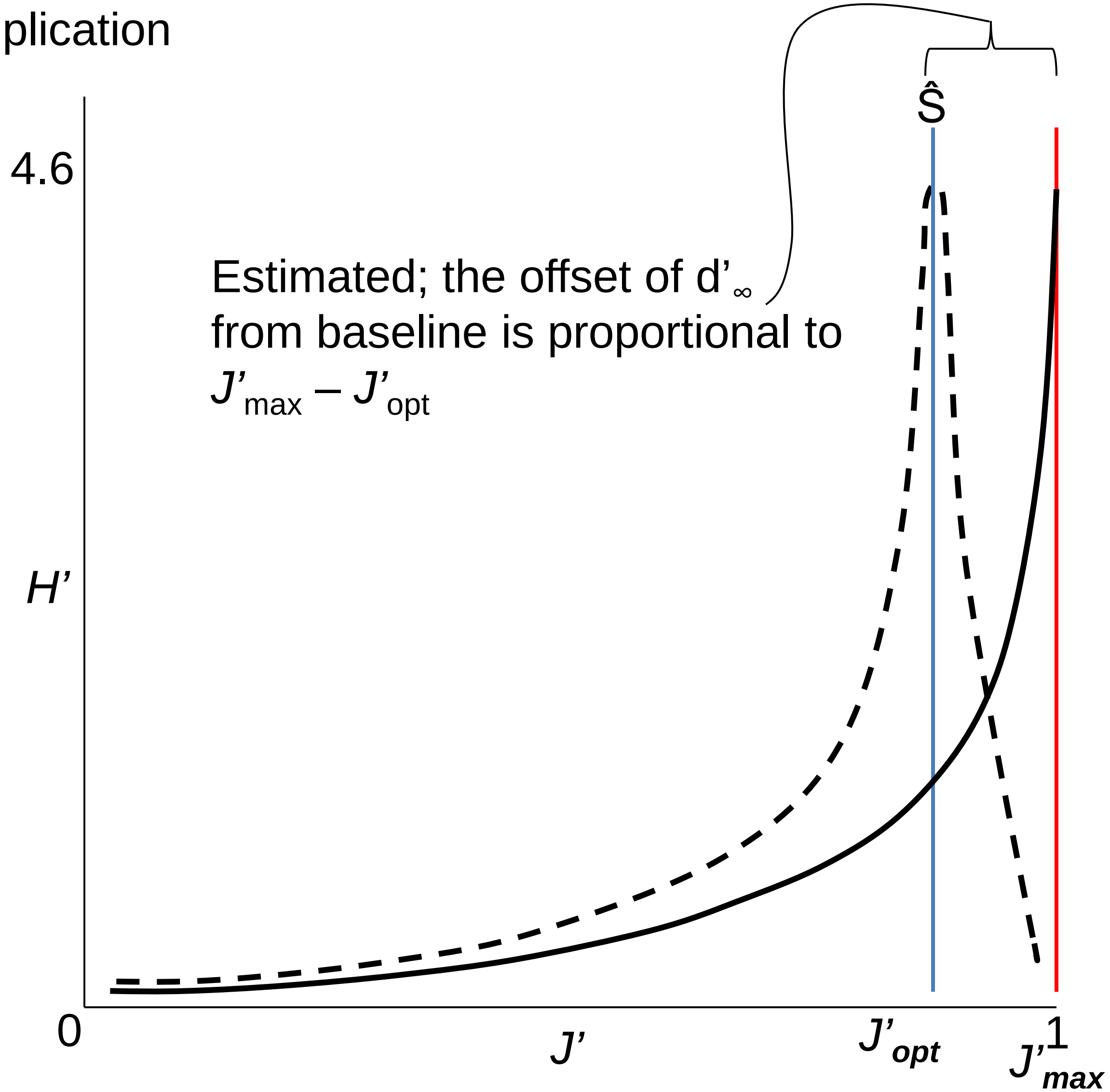
r-strategists ⟶ Ŝ-strategists ⟶ K-strategists

exploitive strategy → sustainable strategy → feedback strategy

Sustainability strategists will create small, specialized niche speciation but not do much for major evolutionary innovation.


η =1 = η∞ lies on this tangent
F(x)
= Ŝ
η =1 = η∞
F'(x)
F''(x)
F''(x) volatility
P0
TANm of η∞ = E maxŜ∞
= Ŝ∞
η =1 = η∞
J' = 1(····)
J' opt ≠ 1 for d'; J' < 1 for d'

H' diversity implication

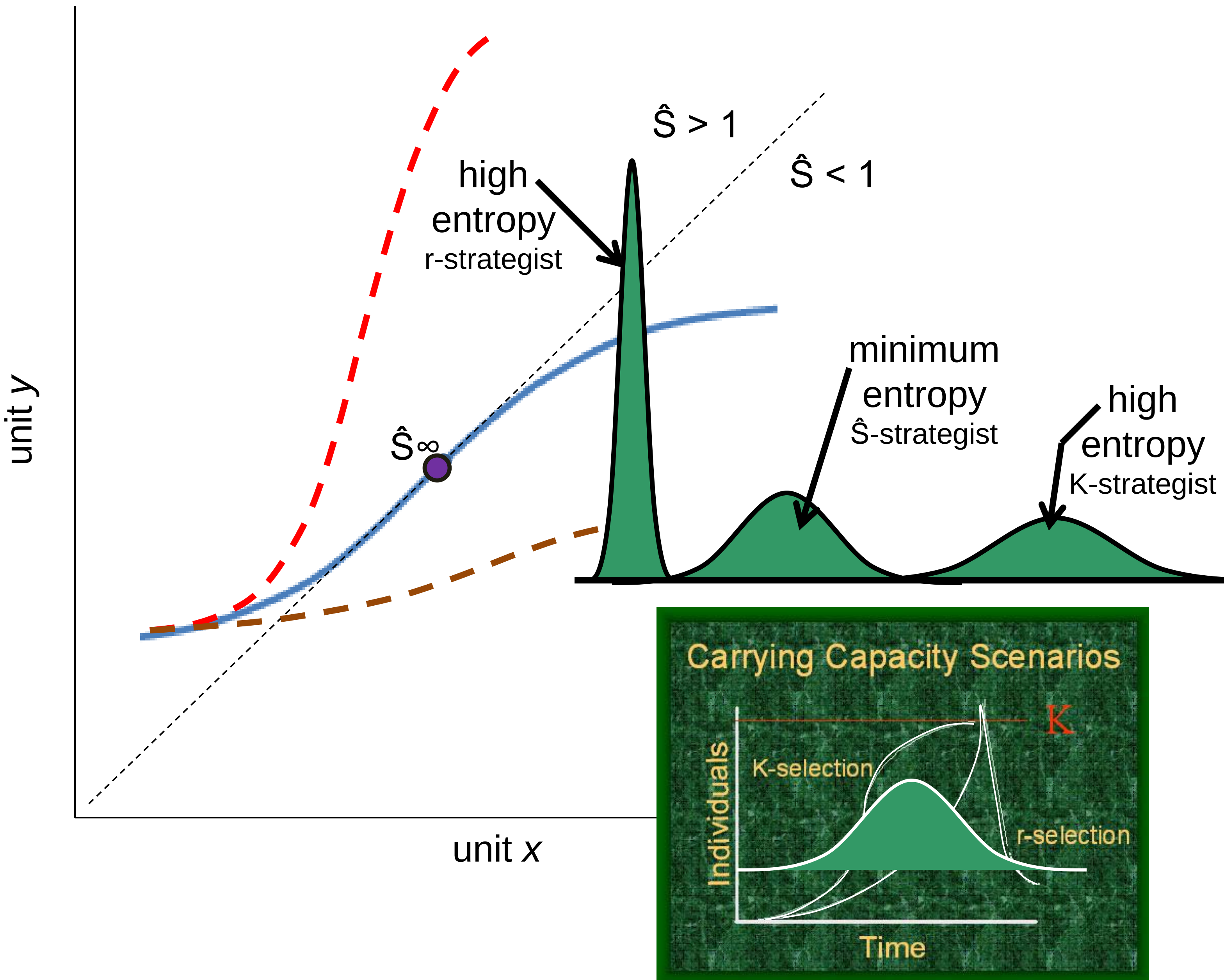


Maximum diversity, H', is at *J'*<1 (cf. IDH, a little 'contrast' is good)

This suggests that J'_{opt} at Ŝ∞ is a better measure than evenness between taxa. That is, traditional J'_{max} is not the definitive measure of evenness in H'. A little unevenness is good! "Optimal evenness" applies (J'_{opt}) vs. J'_{max}

In the d’ curve set, which curve function matches H’ maximum?

What is the tradeoff between vertical and horizontal flow (information theory)?



Conclusions

1. Sustainability is optimized when system entropy is minimized

2. Sustainability is a dynamic process, involving derivative rates of change in biotic potential and environmental resistance

3. System volatility and system efficiency determine sustainability

4. Volatility in a system suppresses sustainability

5. System efficiency & minimum entropy support sustainability

6. Sustainability has management implications, e.g. predictability