Low Level Equilibrium and Fractional Poverty Traps

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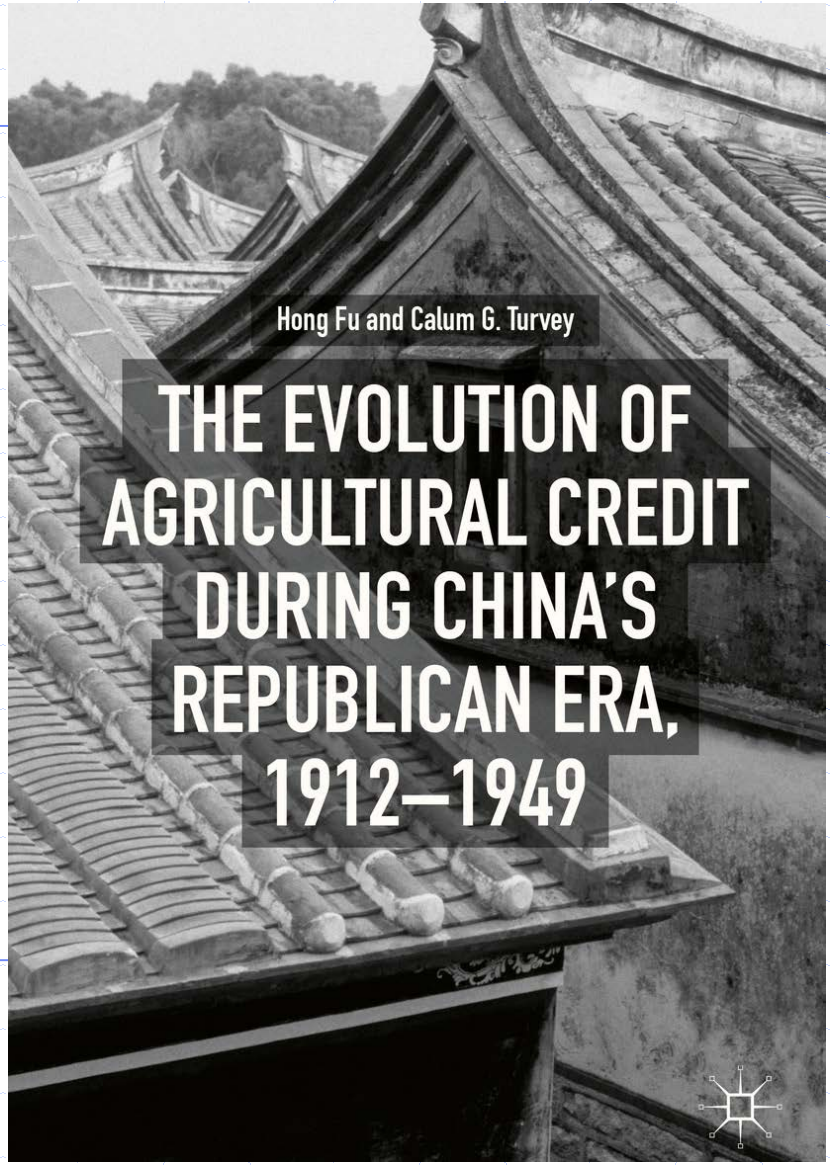


Overall Purpose and Objective

- To understand China's agricultural economy of the present we must understand her agricultural economy in the pasts
- By Republican era agricultural productivity was low and the peasant population impoverished.
- Institutions began to change with the International China Famine Relief Commission in 1921 and a push towards agricultural reconstruction following the Northern Expedition in 1927/1928
- But how did agricultural conditions in China get so bad and why did they not improve along with Western agricultural development?

Purpose

- This paper explores 2000 years of China history
  - Flood, drought and famine
  - The tyranny of dynasties
- We explore this history through the lens of a Malthusian Trap and low level; equilibrium traps
  - Precursors to modern era poverty traps
- We propose that history evolves fractionally but random
  - Fractionally persistent through hysteresis or memory across dynasties
  - Random in terms of drought and floods
  - This can be describes by an autoregressive process

Malthusian Trap

- Factors shaping the Agricultural Economy
  1. dynamic relationship between land cultivation and population growth
  2. agricultural output and population growth

Malthus; Drivers of Economic Surplus

1. An accumulation of capital as will lower the profits of stock (meaning that the next bundle of surplus invested in newer uncultivated lands or improvements to existing lands may reduce profits at the margin, but increase profits to the whole.),
2. An increase in population that will lower the wages of labor,
3. Such agricultural improvements, or such increase of exertion, as will diminish the number of laborers necessary to produce a given effect (output), and
4. An increase in the price of agricultural produce, from increased demand, as without nominally lowering the expense of production.

Malthus 1798 on Agricultural Productivity and Population Growth

- "*But as, by the law of our nature which makes food necessary to the life of man, population can never actually increase beyond the lowest nourishment capable of supporting it, a strong check on population, from the difficulty of acquiring food, must be constantly in operation. This difficulty must fall somewhere, and must necessarily be severely felt in some or other of the various forms of misery, or the fear of misery, by a large portion of mankind*" .....
- "*Yet still the power of population being in every period so much superior, the increase of the human species can only be kept down to the level of the means of subsistence by the constant operation of the strong law of necessity acting as a check upon the greater power*"

John Lossing Buck (1930)

- “But because of the dense population, the Chinese farmer is doomed and all that can be done is to make the most out of an unfortunate situation” , and later “The remedies for this too small size of farm business are difficult to find...As China become modernized, it is inevitable that industries will develop and a certain number of the country people be absorbed into them. Yet it can scarcely be hoped that sufficient numbers of them be absorbed as to relive the present agricultural situation very much. The best future solution of the problem seems to be in some method of population control, and the best immediate solution, more intensive methods of raising crops and the growing of crops that produce more food per unit of land. Such productivity, however, will also be useless if population continues to grow”

Equilibrium Traps

- Several economic models have been presented to explain population, growth and agricultural output in a Malthusian or neo-Malthusian context
  - Elvin (1973), Boserup (1975), Darity (1980) High-level equilibrium Traps
  - Nurske (1952), Nelson (1956), low-level equilibrium traps
  - Huang (1985), Tang (1979), Lin (1995) (more of a critique of models)
- We see merit in all of these models and critiques and attempt here to provide a dynamic model of agricultural productivity and population growth that gives rise to frequent poverty traps,

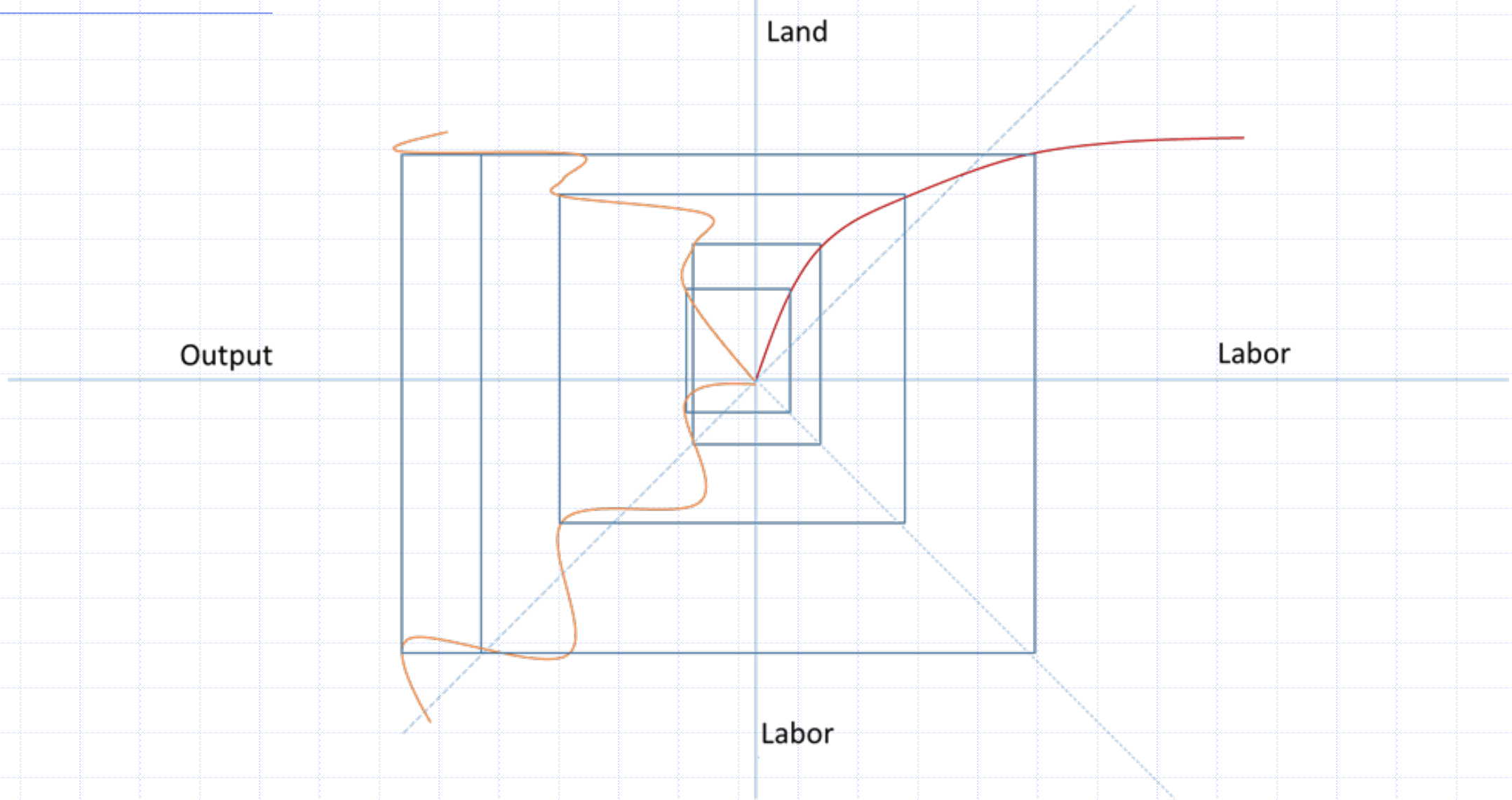
Low Level Equilibrium Traps

- A low-level equilibrium trap is diagnosed by a stable equilibrium level of per capita income at or close to subsistence. (Nelson 1956)
- difference from the Malthusian trap is the degree of aggregation of output (aggregate versus agricultural) and the pathway to equilibrium.
- If agricultural output is highly related or contributory to aggregate output then Malthusian and low level equilibrium trap are near equivalent

We develop model consolidating this literature

- We account for diminishing productivity of new lands vis Malthus and Ricardo
- We place maximum on land in line with maximum capital formation in Nelson
- We avoid the problem of involution raised by Philip Huang
- We allow correlation between innovation and population as suggested by Justin Y Lin
- We allow for low and high productivity to evolve randomly
- We allow for population to evolve randomly in a mean-reverting way

The Malthusian Poverty Trap



Relationship to Poverty Traps (Barrett, Carter, Swallow)

- In the poverty trap literature a dynamic equilibrium exists when a unit of well-being (income, assets) neither increases nor decreases in real terms between one period and the next.
- An equilibrium exists as an attractor in which economic forces, good or bad, will move a household away from that initial equilibrium into an alternative state.
- How long the household remains in that state depends on degrees of resilience and asset dynamics.

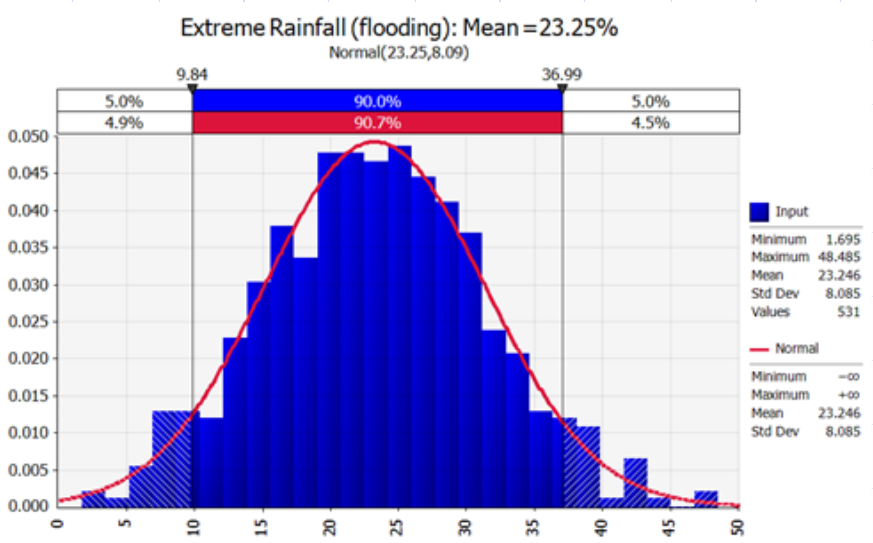
Fractional Poverty Traps

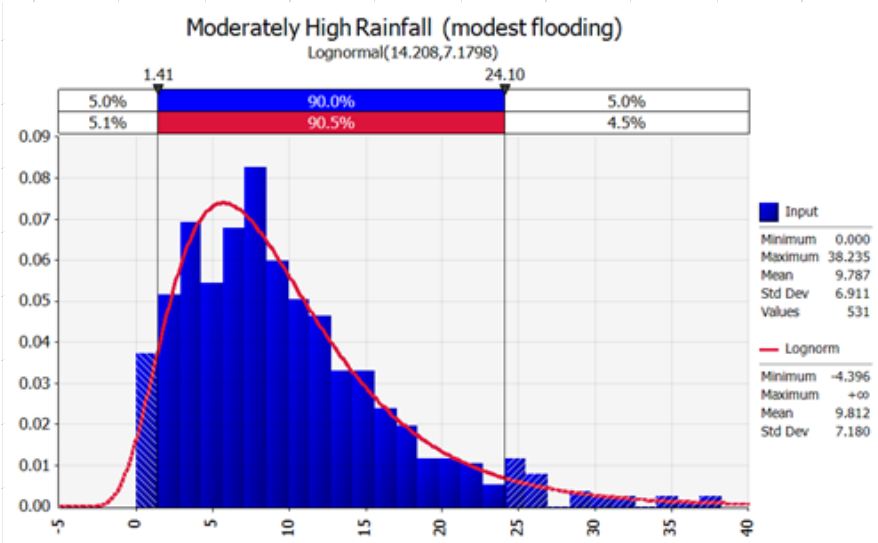
- Stealing from Swallow and Barrett
  - fractal poverty traps can exist simultaneously at multiple scales (micro, meso and/or macro) and are self-reinforcing through feedback effects.
  - The essential element of a fractal poverty trap is that the pattern repeats at all scales of aggregation;
  - Forces which drive farm households into poverty by a particular dynamic, are the same forces that drive a county into poverty, and are the same forces that drive a country into poverty.
  - The forces are endogenous to each other and are self-reinforcing.
- Fractional Poverty Traps is different: it is based on feedback rules and path dependency over time. With memory.

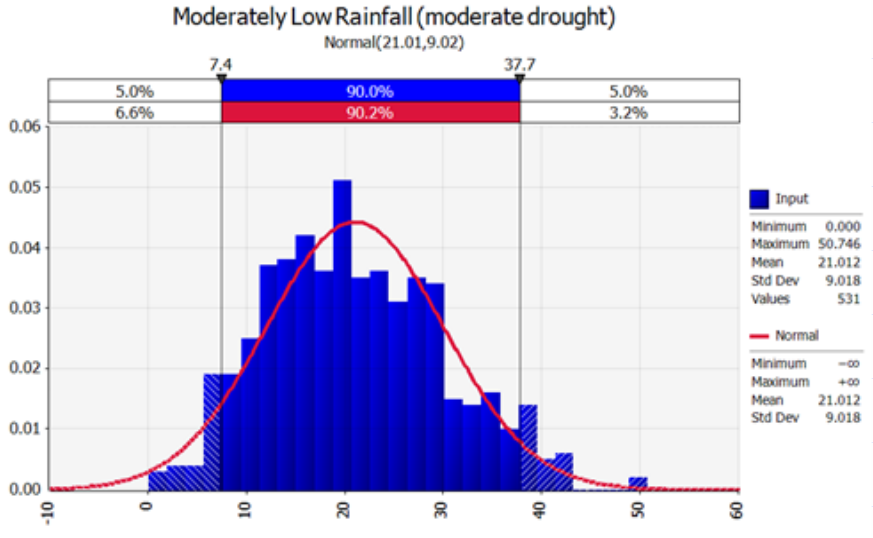
Ecological and Political Risks

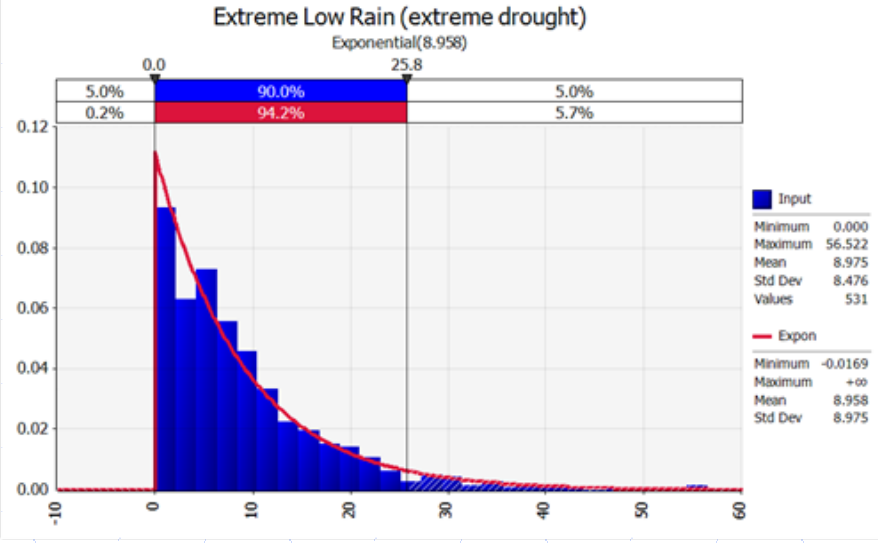
2000 years of history in a few graphs

Frequency distributions of rainfall-related risk events, China 1470-2000

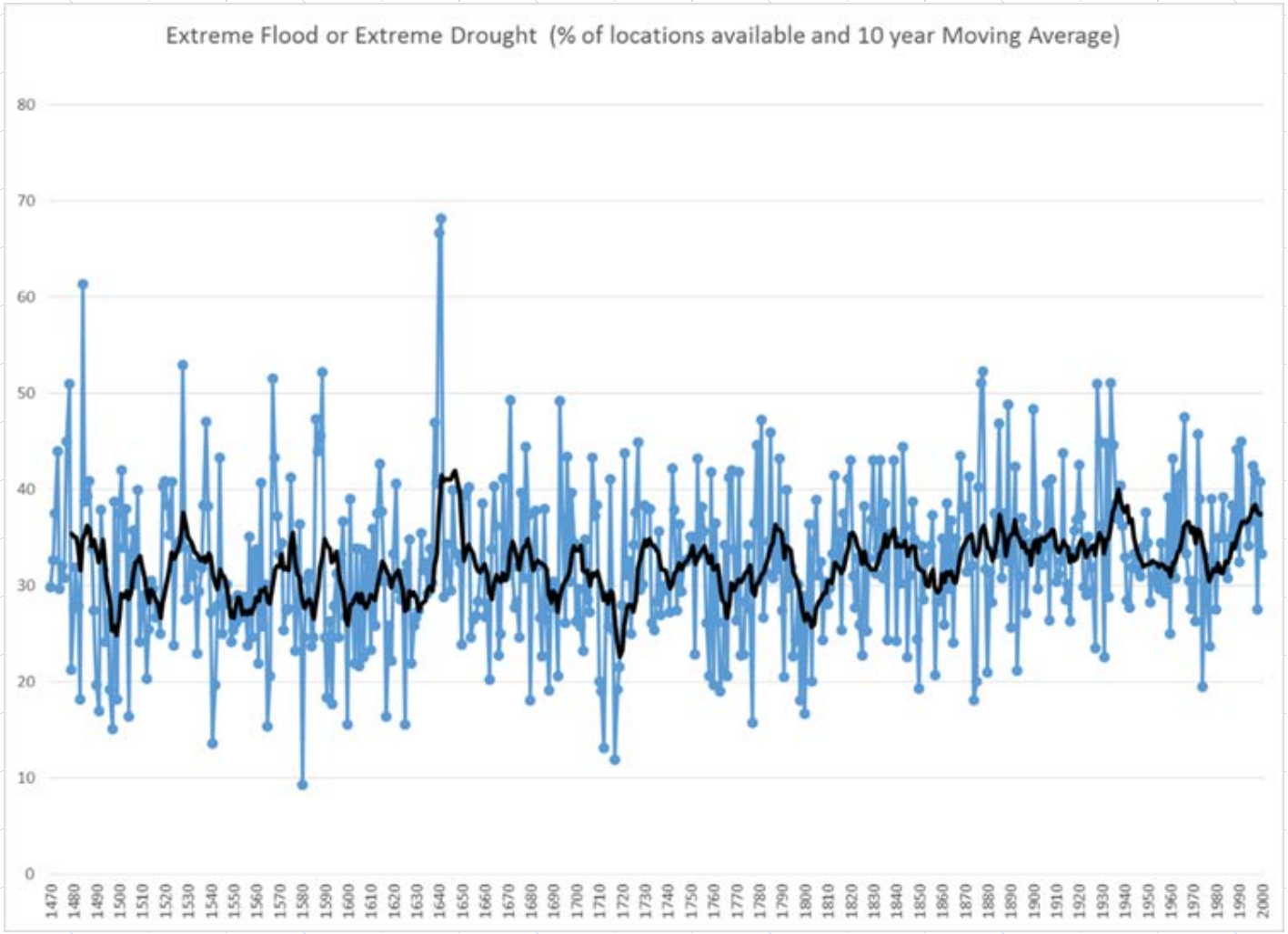








Extreme Flooding or Drought (% of locations available and 10 year Moving Average)



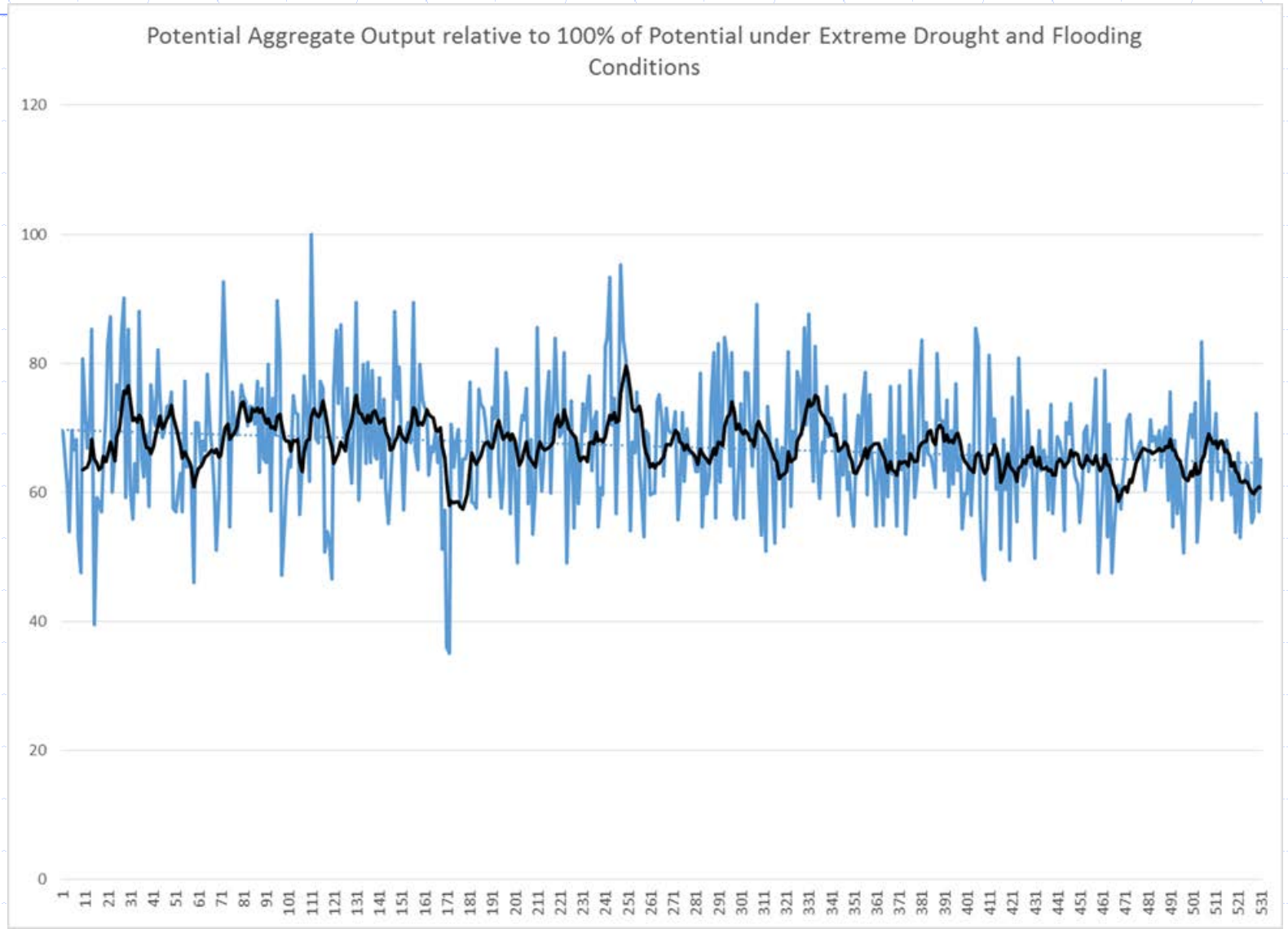
Output Decay and Weather Events

assume that aggregate output decays from the maximum of 100% to 35% exponentially so that

$$Y_t = 100e^{\left(-0.017788*\left(W_t - 9.259\right)\right)}$$

and W is the recorded percent of affected locations in year t

Potential Aggregate Output with Rainfall Sensitive Exponential Decay



Dynasties and Emperors: The Good....

- The 2nd emperor Chin Nong promoted increased productivity and production of food. He invented basic implements for cultivation and established the idea of a central market place for trade. He explored biology and sought out plants with certain poisonous qualities that could be used for medicines and the cures for many ailments of the day
- Kao Tsou Ven Ti, the first ruler of the Souy dynasty built granaries in all towns and ordered that each family according to their level of subsistence to contribute to the granaries so that rice and corn could be distributed in years of famine

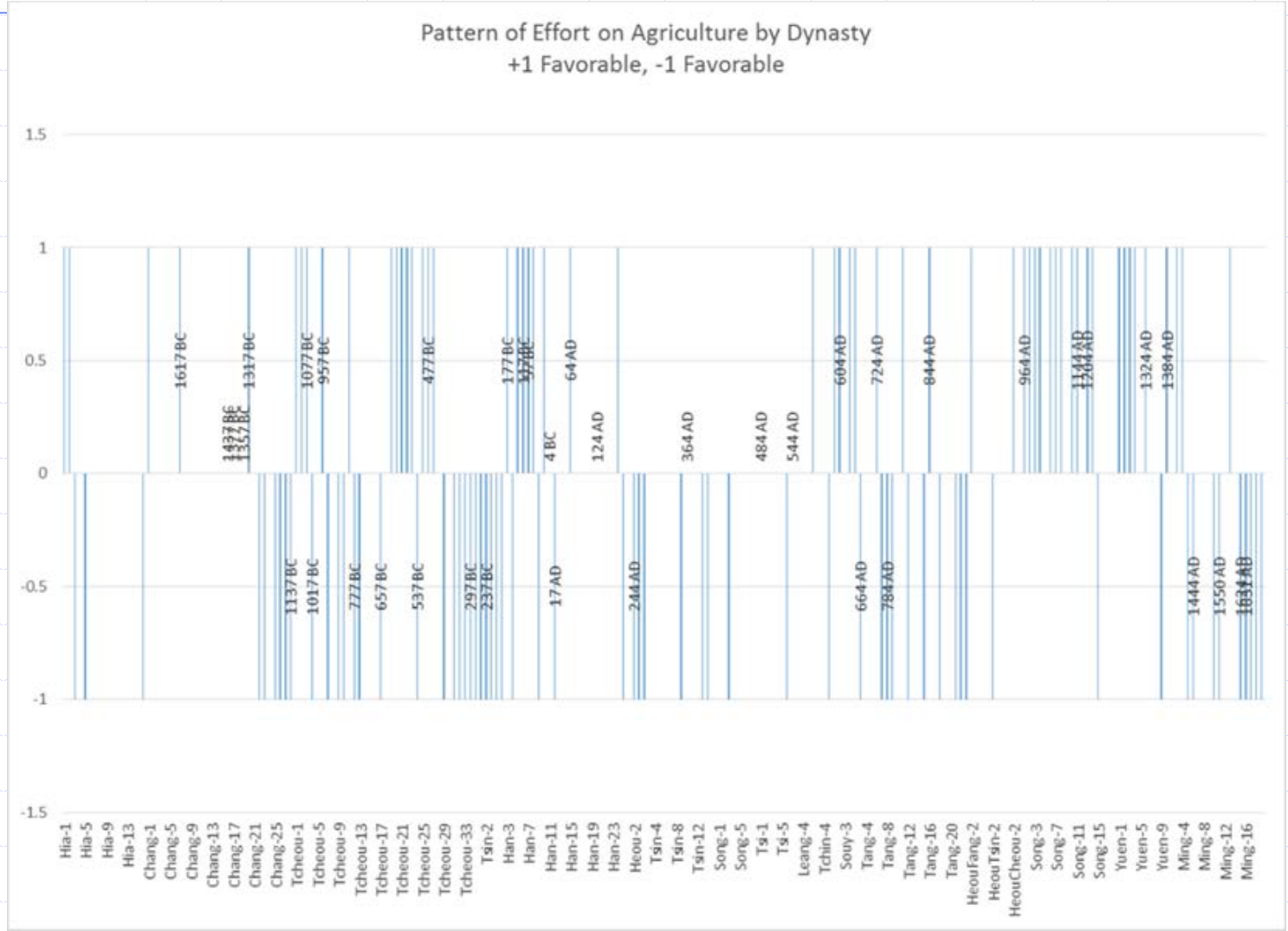
Dynasties and Emperors: The Bad....

- Tai Kan, the 3rd emperor was so absorbed with horses and women that he gave no concern to agricultural land and would without concern trample harvests for the hunt
- Emperors who undertook warring with the Tartars or other groups, would likely have taxed farmers for grain, and paid more attention to geo-political power received a score of -1

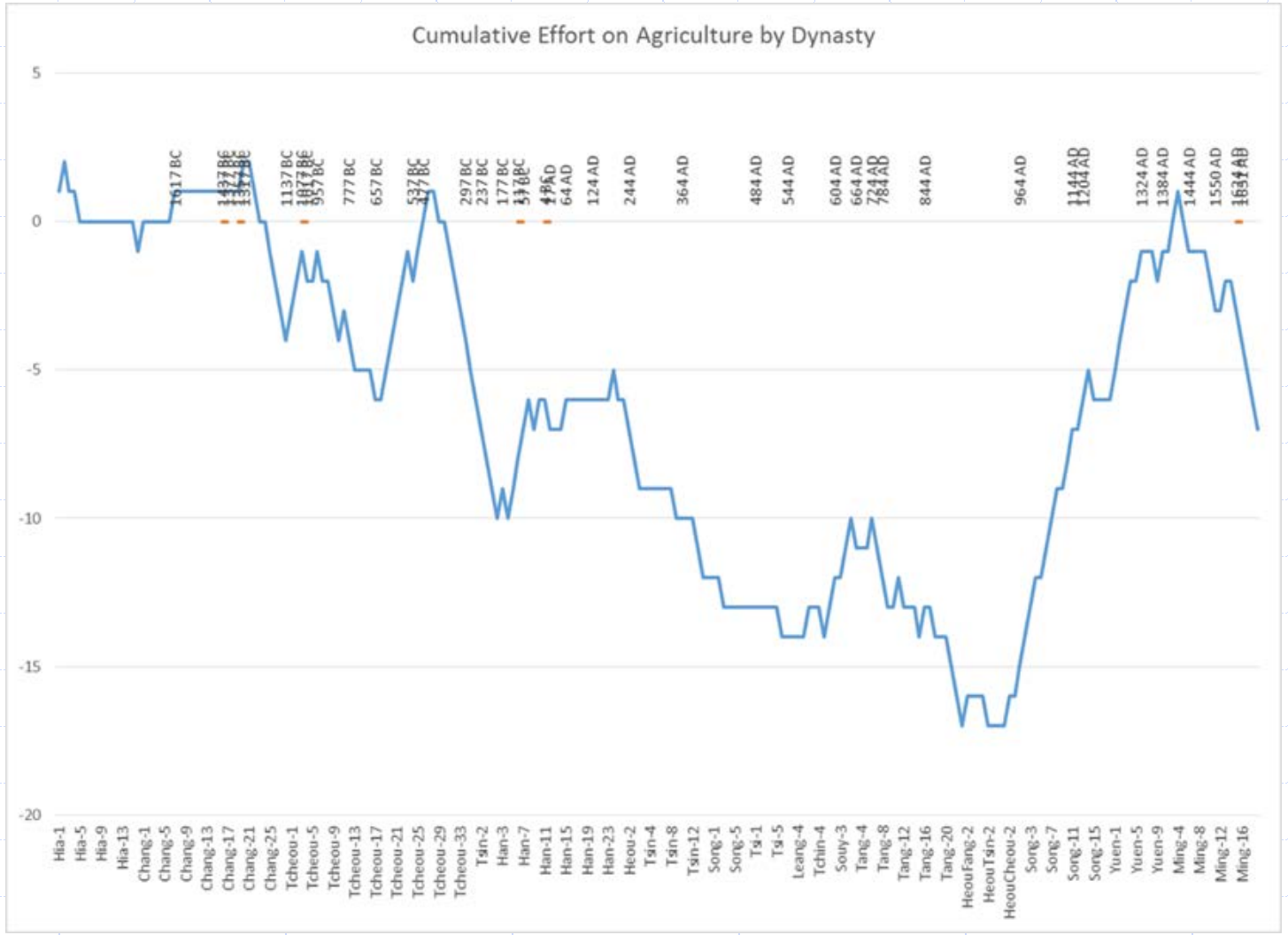
Dynasties and Emperors: And the Ugly

- the 7th emperor of the Hia dynasty married a woman so cruel, and so uncaring that she built a large lake out of agricultural lands, filled it with wine and ordered 3,000 persons to throw themselves in it

Depiction of Dynasty and Effort on Agriculture (+1,0,-1)



Cumulative Effort on Agriculture across Dynasties



Dynamics and the Malthusian Trap: Population Dynamics

$$\frac{dP}{P} = g\left(1 - \phi\frac{P}{P^*}\right)dt + \sigma_P dZ_P$$

Exogenous populations shocks independently distributed (Wiener process)

Natural population growth rate

Degree of resilience: 1= no resilience, 0= resilient

P* is population capacity Population can be supported by output

$$P_t^* = \frac{Y_t}{c}$$

Aggregate Output

Per capita requirement

Dynamics and the Malthusian Trap: Output and Innovation

$$Y = AP^{(\alpha+\lambda_P L)} L^{(\beta-\lambda_L L)}$$

As more land is brought into production its output elasticity diminishes

As population increases there is a gain in human capital – needed to offset reduced productivity of new lands. AVOIDS 'involution' trap suggested by Phillip Huang when $\lambda_P \geq \lambda_L$

$$\frac{dA}{A} = \mu_A dt + \sigma_A dZ_A$$

Innovation in aggregate output increases randomly over time.

Output faces independent random shocks over time (Brownian motion)

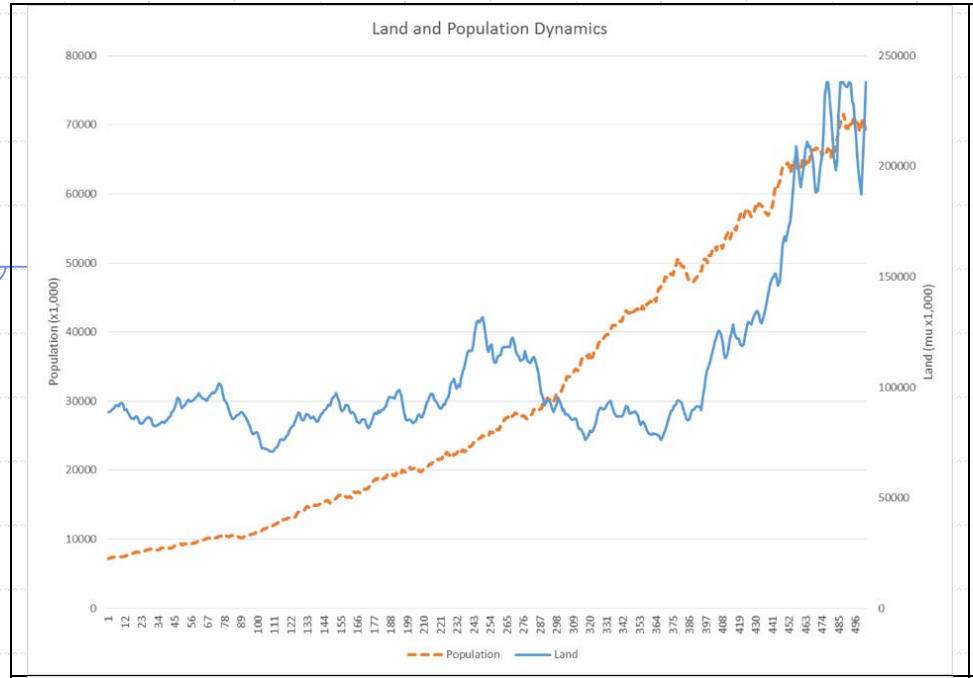
Output Dynamics (% change) by Ito's Lemma follows a (fractional) random walk

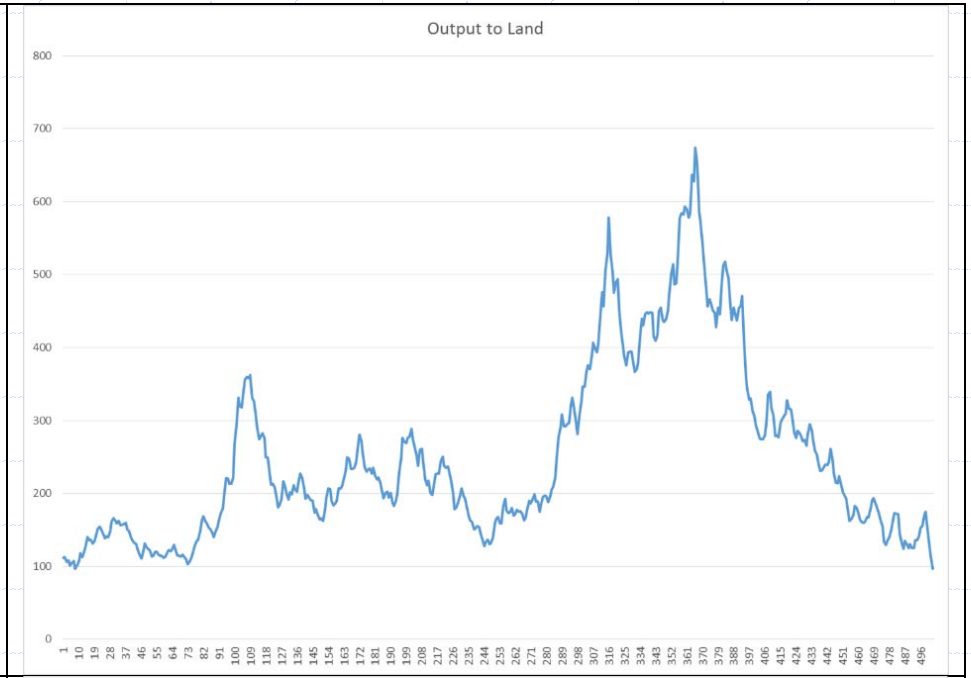
Growth part determined by population , land, innovation, human capital, risk

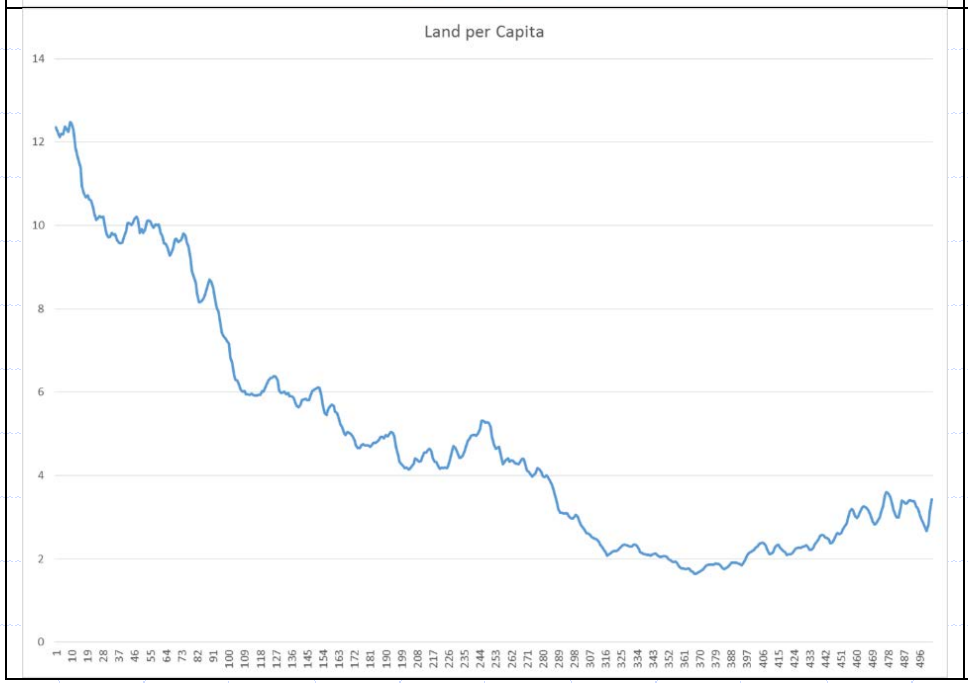
$$\frac{dY}{Y} = \left(\mu_A + \left(\hat{\alpha} + L\left(\lambda_P Log(P) - \lambda_L Log(L) + \frac{\hat{\beta}}{L} \right) \right) \mu_P + \frac{1}{2} \left(\left(\hat{\alpha}(\hat{\alpha}-1) + L^2 \left(\left(\lambda_P Log(P) - \lambda_L Log(L) + \frac{\hat{\beta}}{L} \right)^2 - \frac{(2\lambda_L L - \beta)}{L^2} \right) \right) \sigma_P^2 + \left(+2L\left(\lambda_P + \hat{\alpha}\left(\lambda_P Log(P) - \lambda_L Log(L) + \frac{\hat{\beta}}{L} \right) \right) + 2\left(L\left(\lambda_P Log(P) - \lambda_L Log(L) + \frac{\hat{\beta}}{L} \right) + \hat{\alpha} \right) \rho_{AP} \sigma_A \sigma_P \right) \right) dt + \left(\sigma_A dZ_A + \sigma_P dZ_P \right)$$

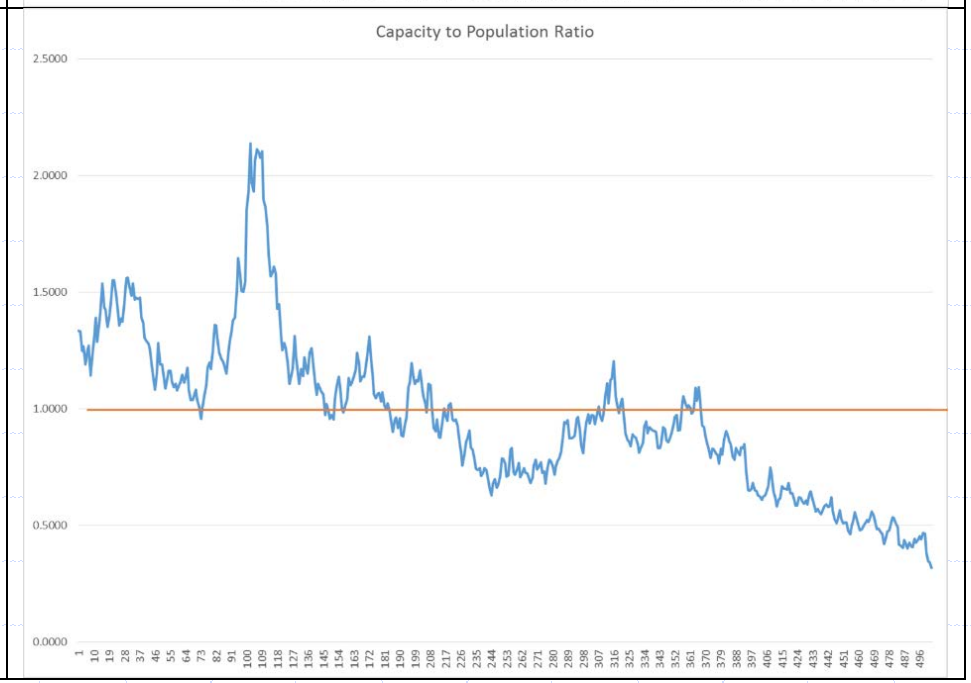
Randomness

Innovation and population assumed correlated as suggested by Justin Y. Lin

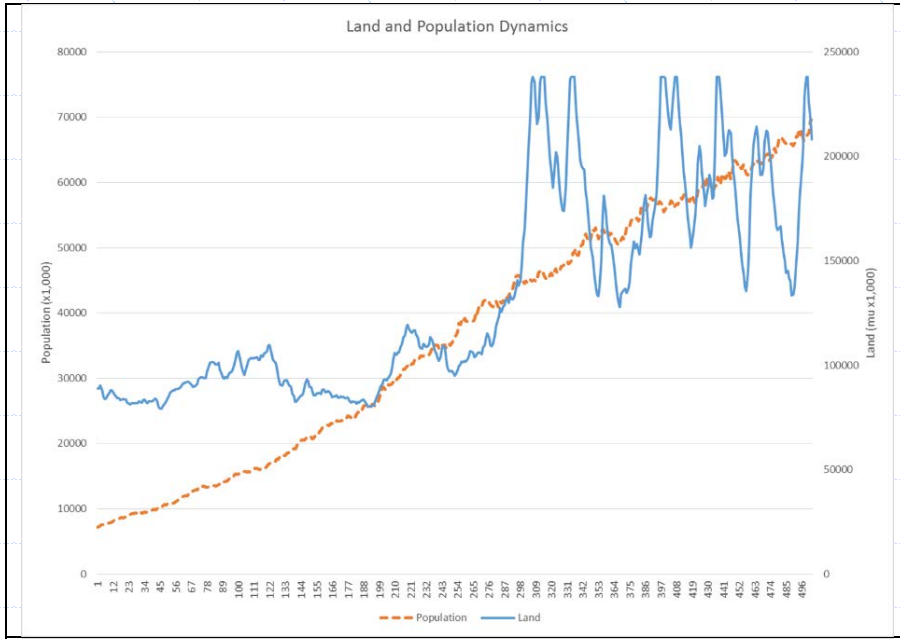


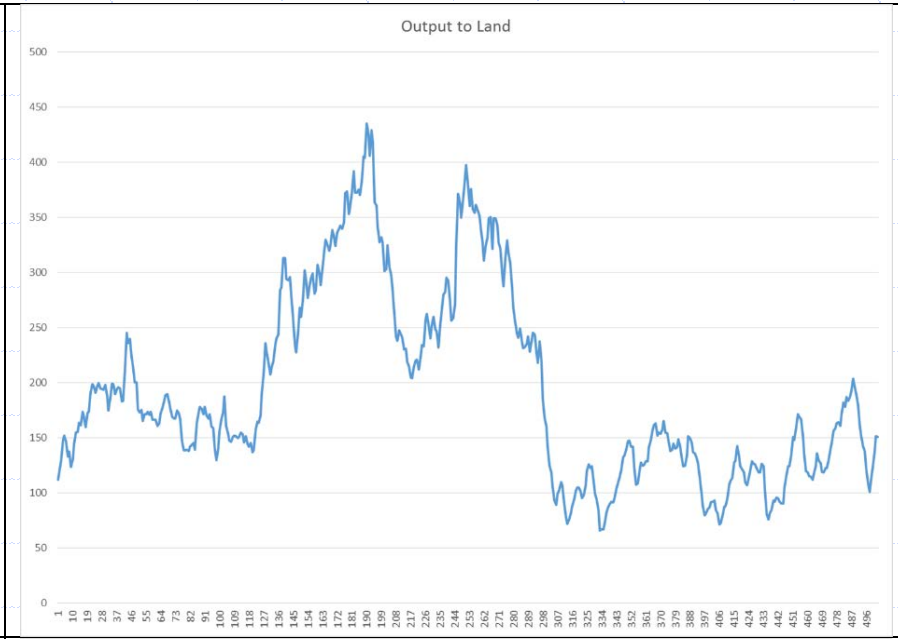


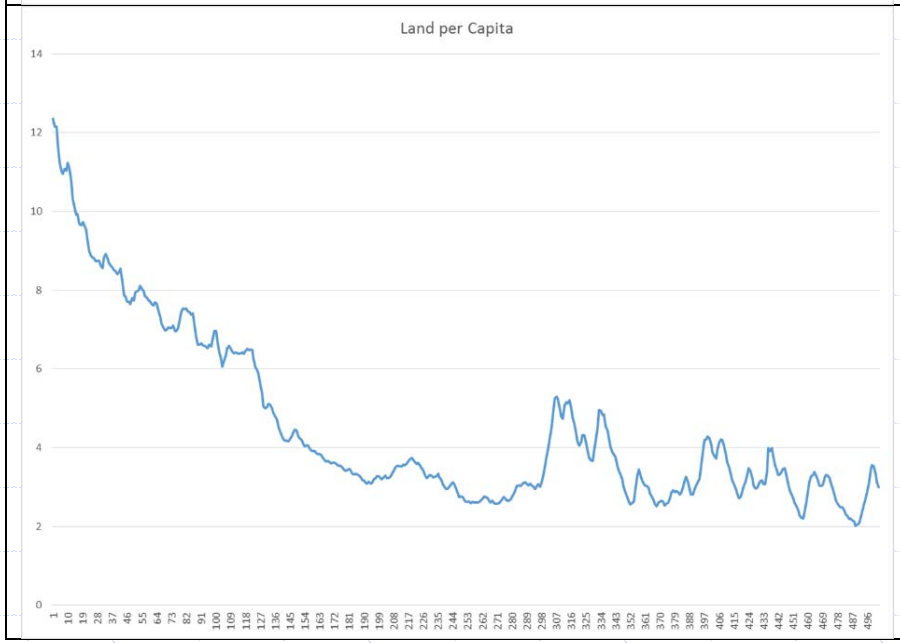


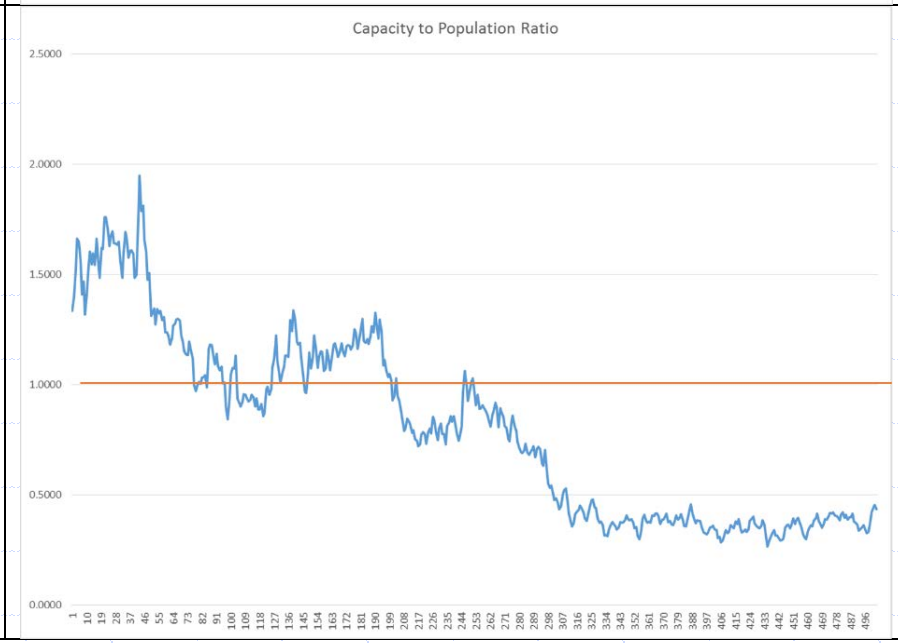


Monte Carlo Simulation: 500 years Hebei and Shandong, Initial conditions at 1400 and conditions in 1900 match. This is one path

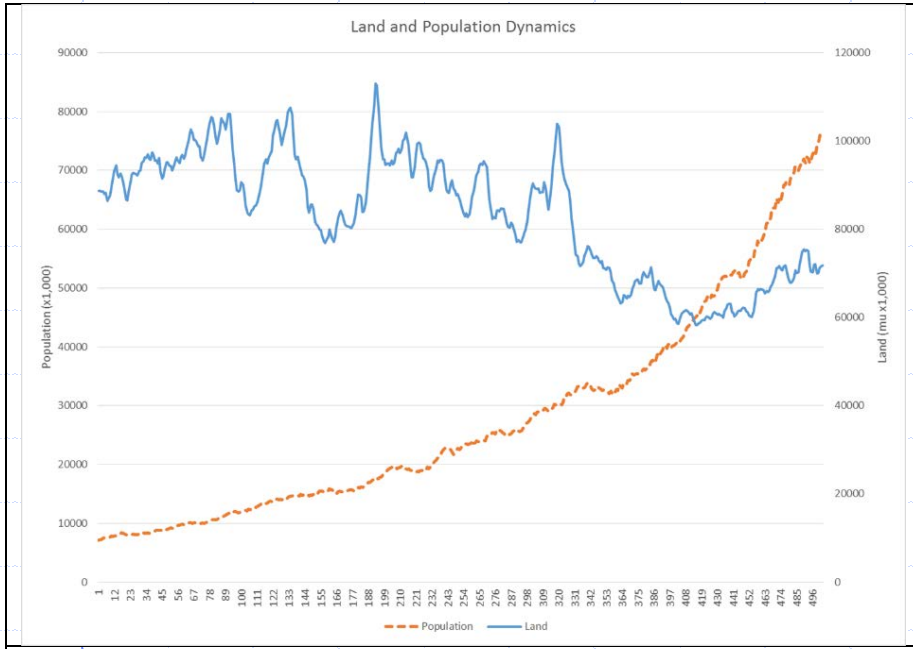


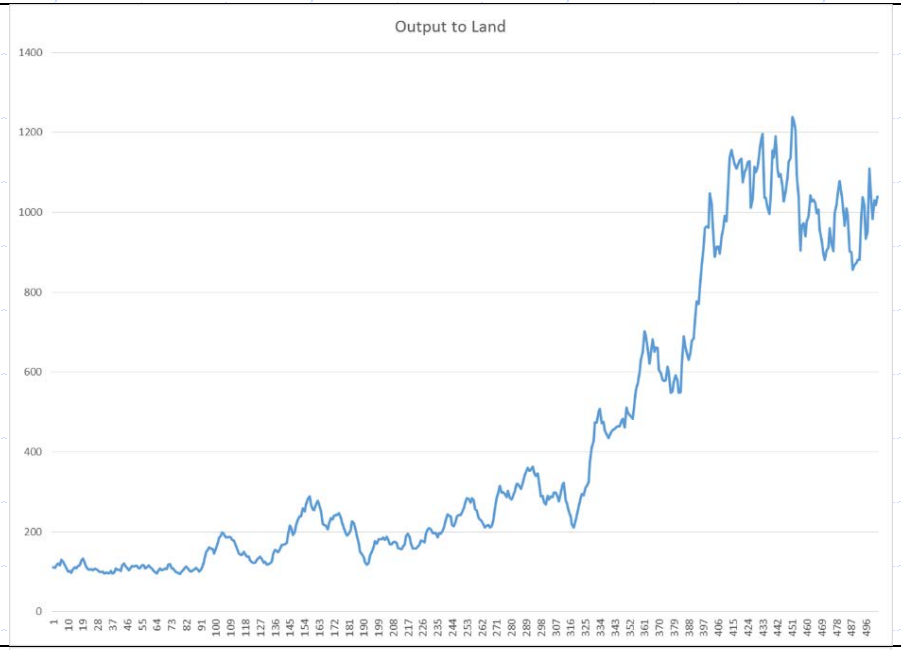


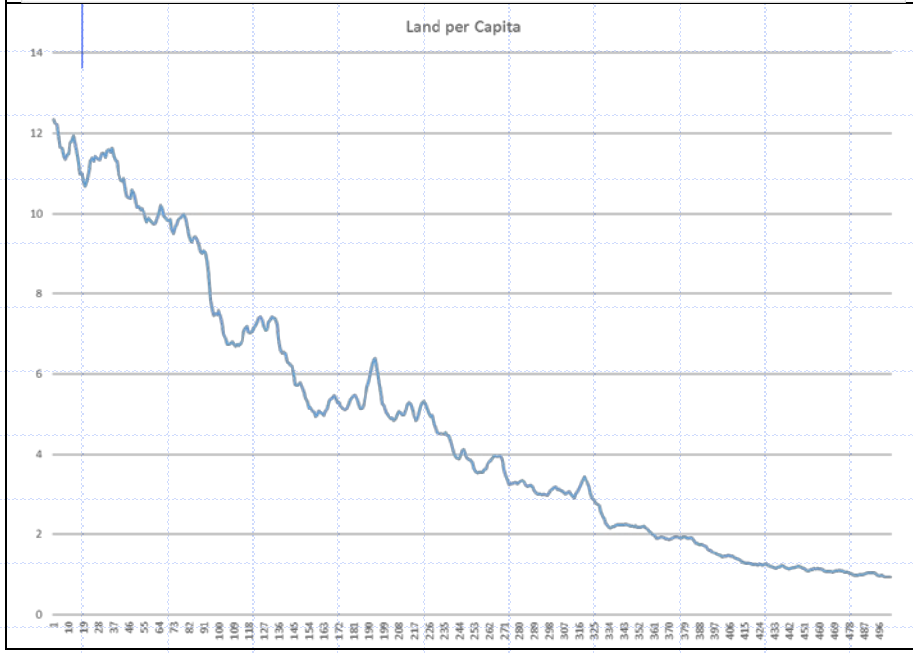


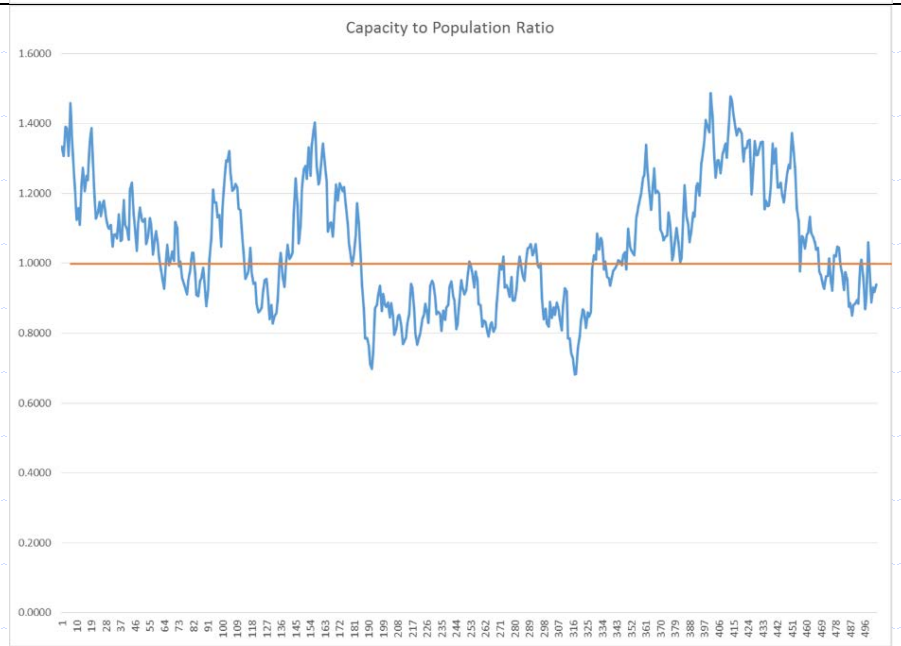


Monte Carlo Simulation: 500 years Hebei and Shandong, Initial conditions at 1400 and conditions in 1900 match. This is another path









Monte Carlo Simulation: 500 years Hebei and Shandong, Initial conditions at 1400 and conditions in 1900 DO NOT match. This is an alternative path

Are these fractional?

- See text for development
- We can use simulation to calculate the Hurst coefficient
- H<0.5 is a mean reverting system (negative memory)
- H=0.5 is a memoryless random system
- H>0.5 is a persistent dynamic (positive memory)

Computed Hurst Coefficients showing fractional dynamics

Population	0.701	Persistent
Capacity/Population	0.368	Mean reverting
Output	0.512	Slight persistence
Innovation	0.50	No correlation
Land	0.603	Persistent
Output to Land	0.535	Slight persistence
Output/Population	0.368	Mean reverting
Land/Population	0.654	Persistent

Conclusions

- We are not sure
- Agricultural development, through a historical lens, provides some hints as to how poverty traps can emerge, evolve and persist
- We believe that the evolutionary theory is rooted in fractional dynamic processes with long term memory peppered by randomness
- China’s agricultural history is replete with natural and man made hazards and tragedies consistent with a fractional theory..... But more is needed to be done including more than anecdotal evidence