The fall of the Roman Empire: a dynamic model based on EROEI

By Ugo Bardi

ASPO ITALIA

Marcus Aurelius 120-181

Though thou shouldst be going to live three thousand years, and as many times ten thousand years, still remember that no man loses any other life than this which he now lives, nor lives any other than this which he now loses. (*Memoirs, book I*l)#

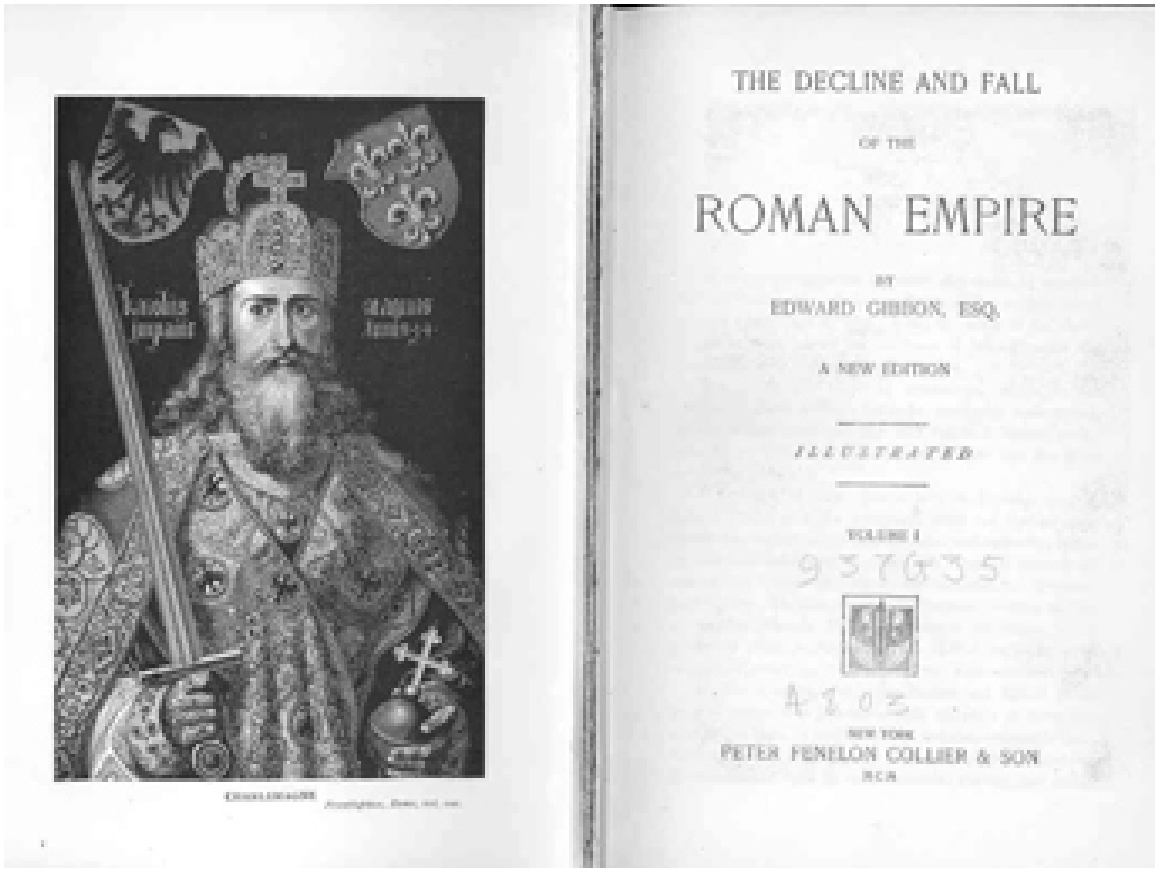
De Rebus Bellicis – mid 4th century.

“In primis sciendum est quod imperium romanum circumlatrantium ubique nationum perstringat insania et omne latus limitum tecta naturalibus locis appetat dolosa barbaries.

Rutilius Namatianus – early 5th century

I have chosen the sea, since roads by land, if on the level, are flooded by rivers; if on higher ground, are beset with rocks. Since Tuscany and since the Aurelian highway, after suffering the outrages of Goths with fire or sword, can no longer control forest with homestead or river with bridge, it is better to entrust my sails to the wayward

Edward Gibbon: 1737-1794



THE DECLINE AND FALL

OF THE

ROMAN EMPIRE

BY

EDWARD GIBBON, ESQ.

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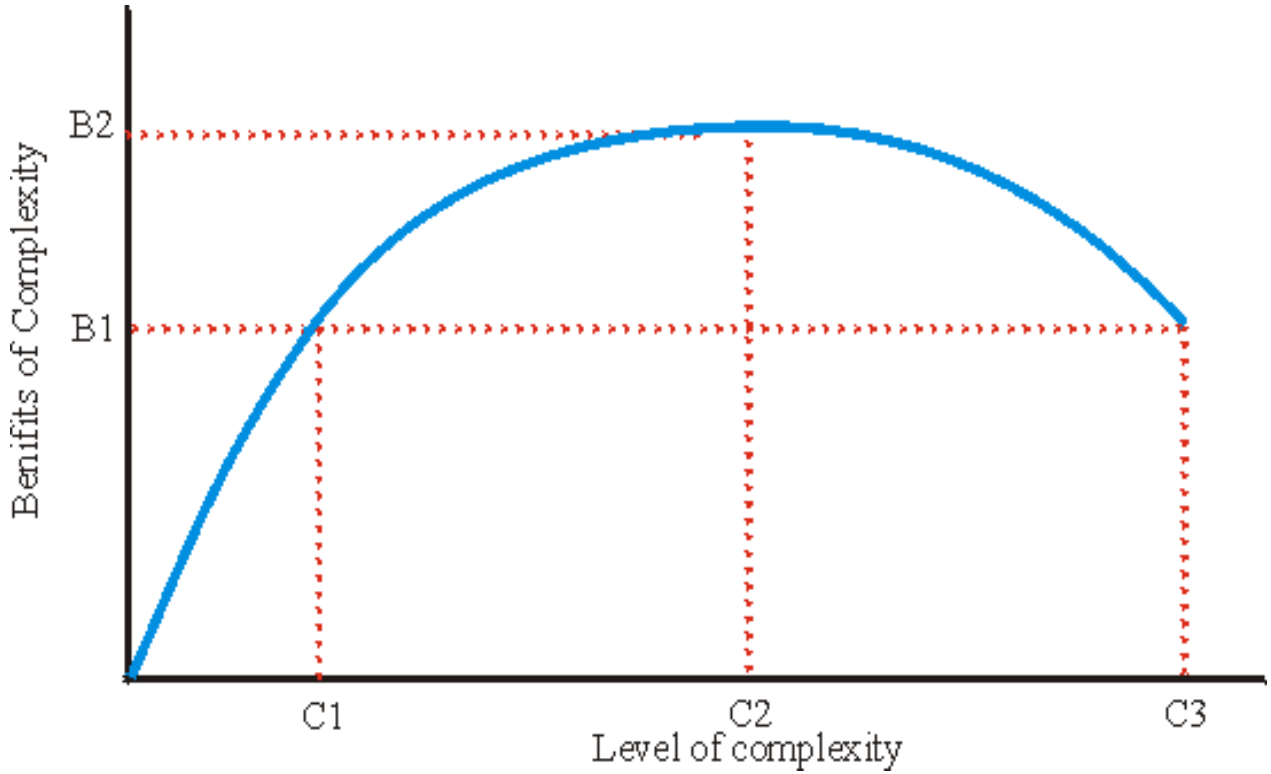
The rage ofthe Donatists was inflamed by a frenzy of a very extraordinary kind; and which, if it really prevailed among them in so extravagant a degree, cannot surely be paralleled in any country or in any age. Many of these fanatics were possessed with the horror of life, and the desire of martyrdom; and they deemed it of little moment by what means, or by what hands, they perished.

Joseph Tainter: The collapse of complex societies, 1996

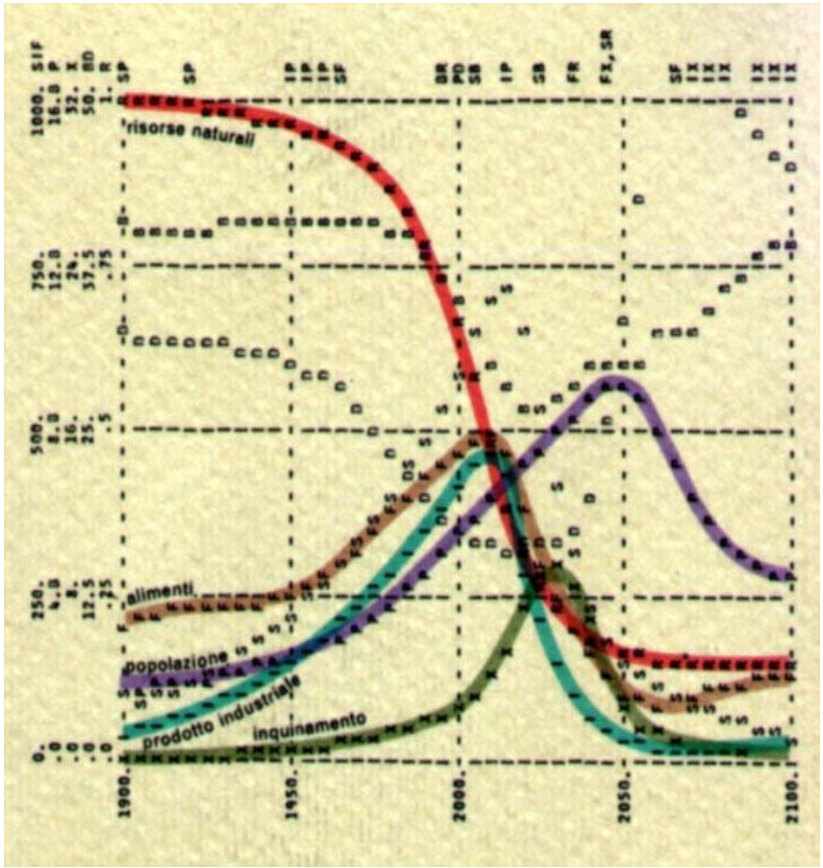


In ancient societies that I studied, for example the Roman Empire, the great problem that they faced was when they would have to incur very high costs just to maintain the status quo. Invest very high amounts in solving problems that don't yield a net positive return, but instead simply allowed them to maintain what they already got. This decreases the net benefit of being a complex society.

“Catabolic Collapse” (John Greer, 2005)

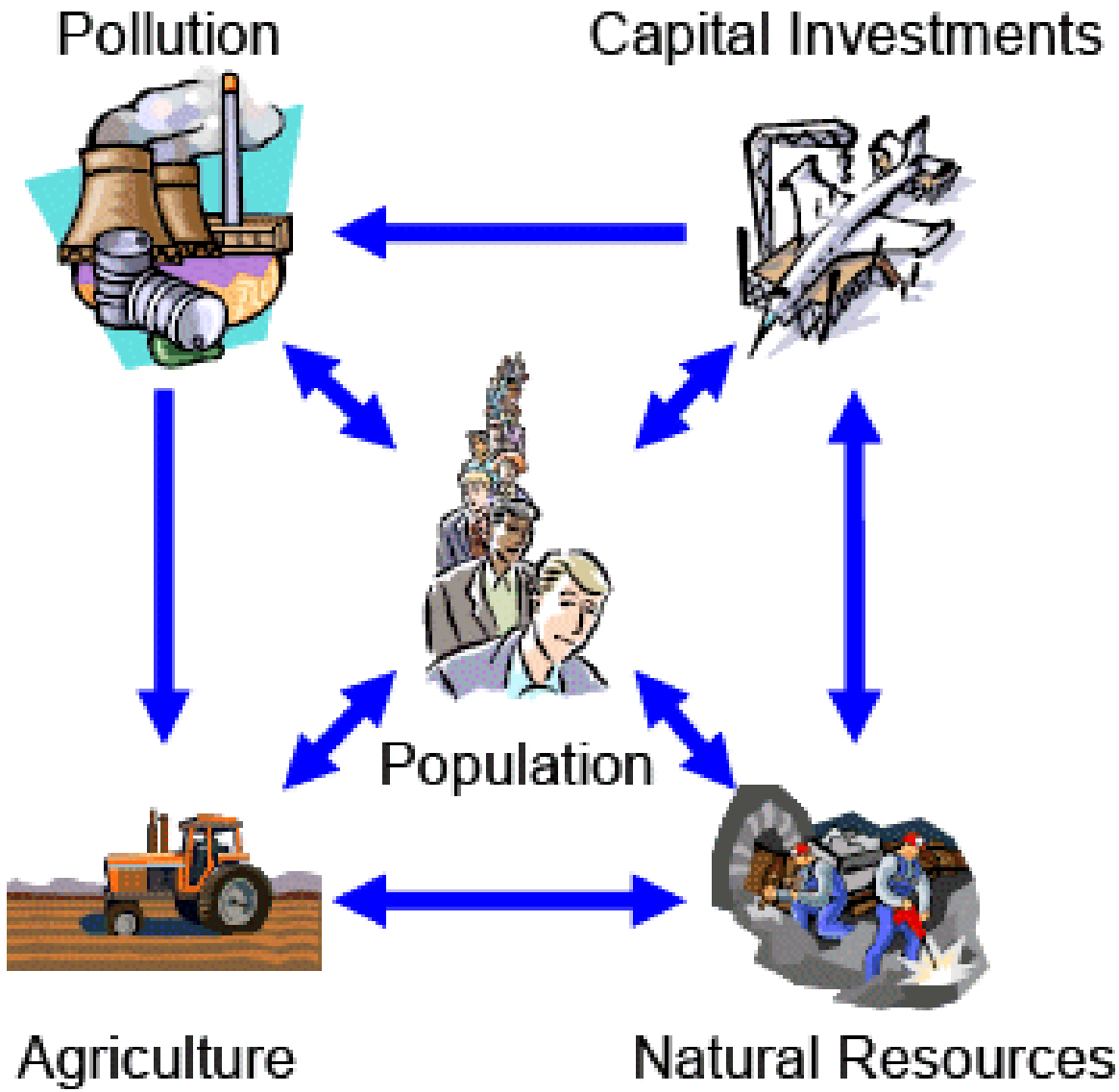
Since depletion requires progressively greater investments of capital in production, the loss of capital affects production more seriously than in an equivalent maintenance crisis. Meanwhile further production, even at a diminished rate, requires further use of depleted resources, exacerbating the impact of depletion and the need for increased capital to maintain production. With demand for capital rising as the supply of capital falls, C(p) tends to decrease faster than M(p) and perpetuate the crisis. The result is a catabolic cycle.

The Limits to Growth – Meadows et al. (1972)#



The industrial capital stock grows to a level that requires an enormous input of resources. In the very process of that growth it depletes a large fraction of the resource reserves available. As resource prices rise and mines are depleted, more and more capital must be used for obtaining resources, leaving less to be invested for future growth. Finally investment cannot keep up with depreciation, and the industrial base collapses, taking with it the service and agricultural systems, which have become dependent on industrial inputs.

The Limits to Growth (1972), World model

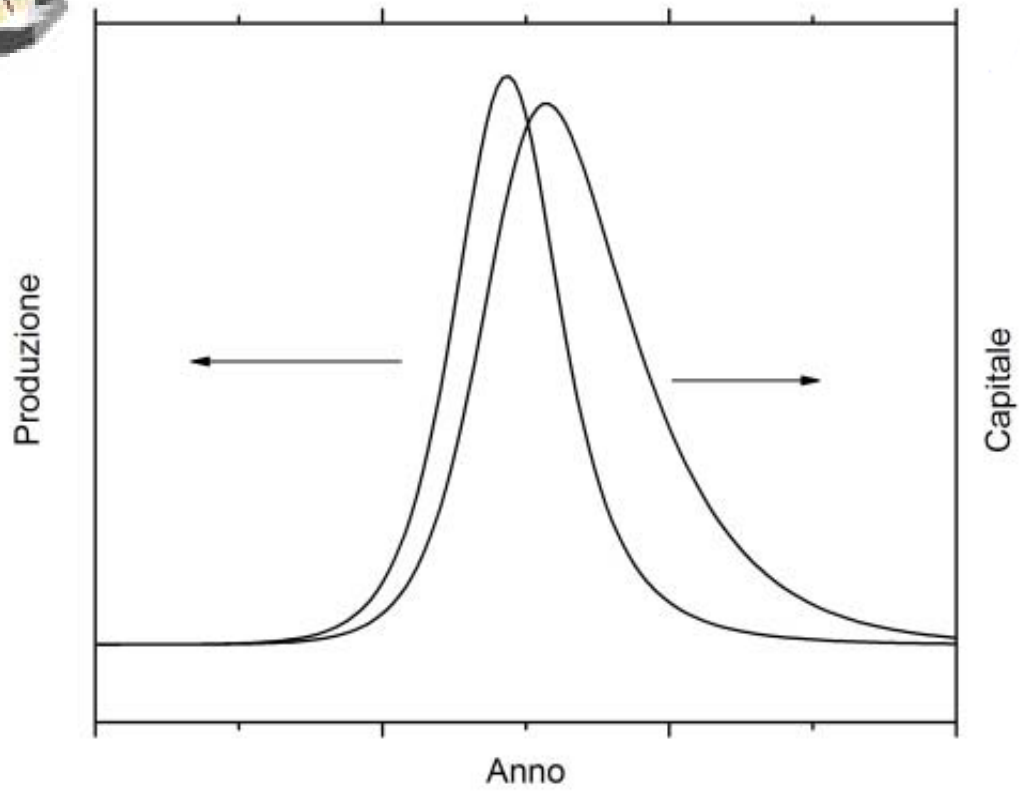


Myrtveit 2006

Simple Dynamic Modeling

$$p = -k_1 CR$$

$$g = k_2 CR - k_3 C$$

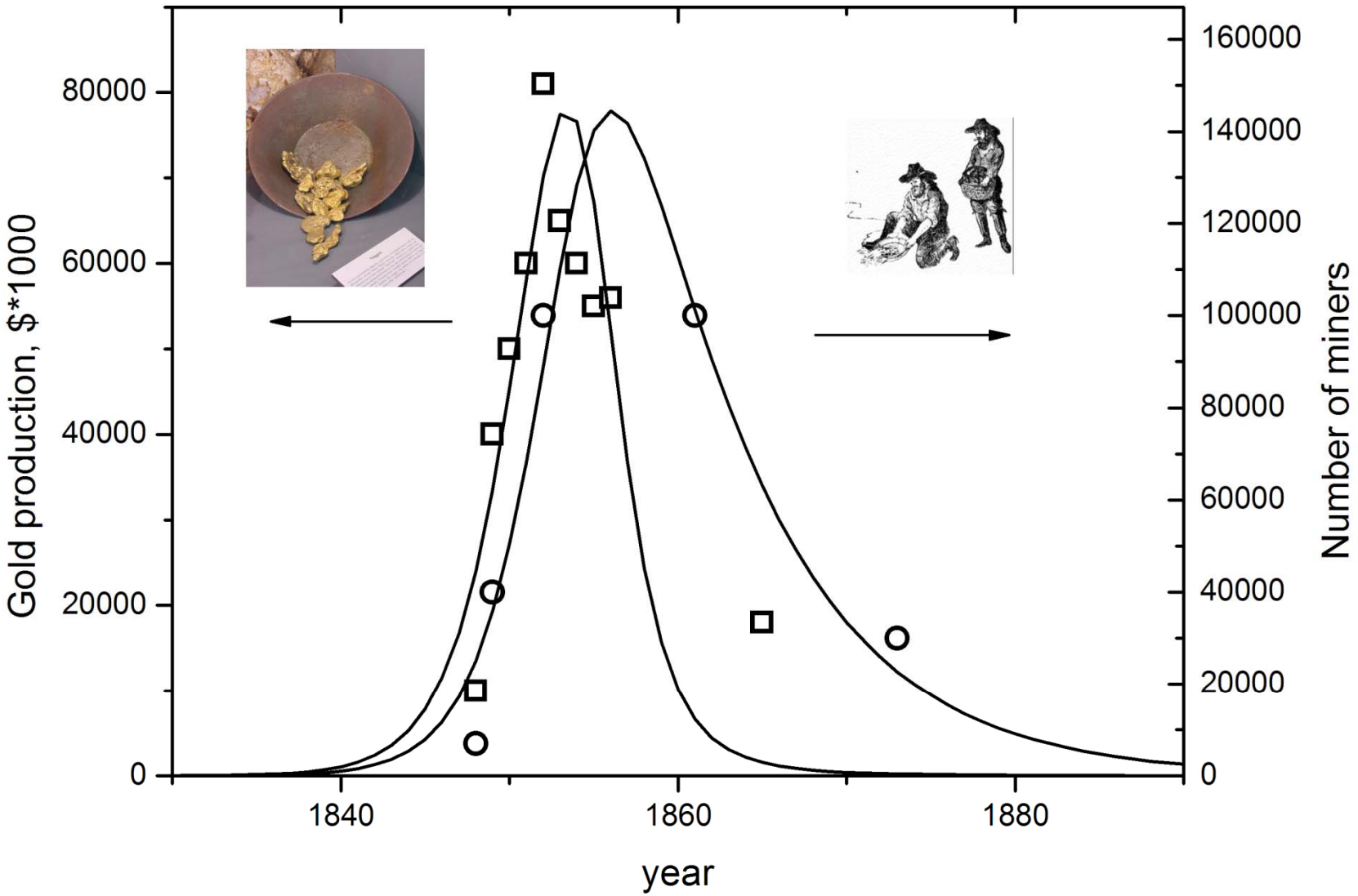


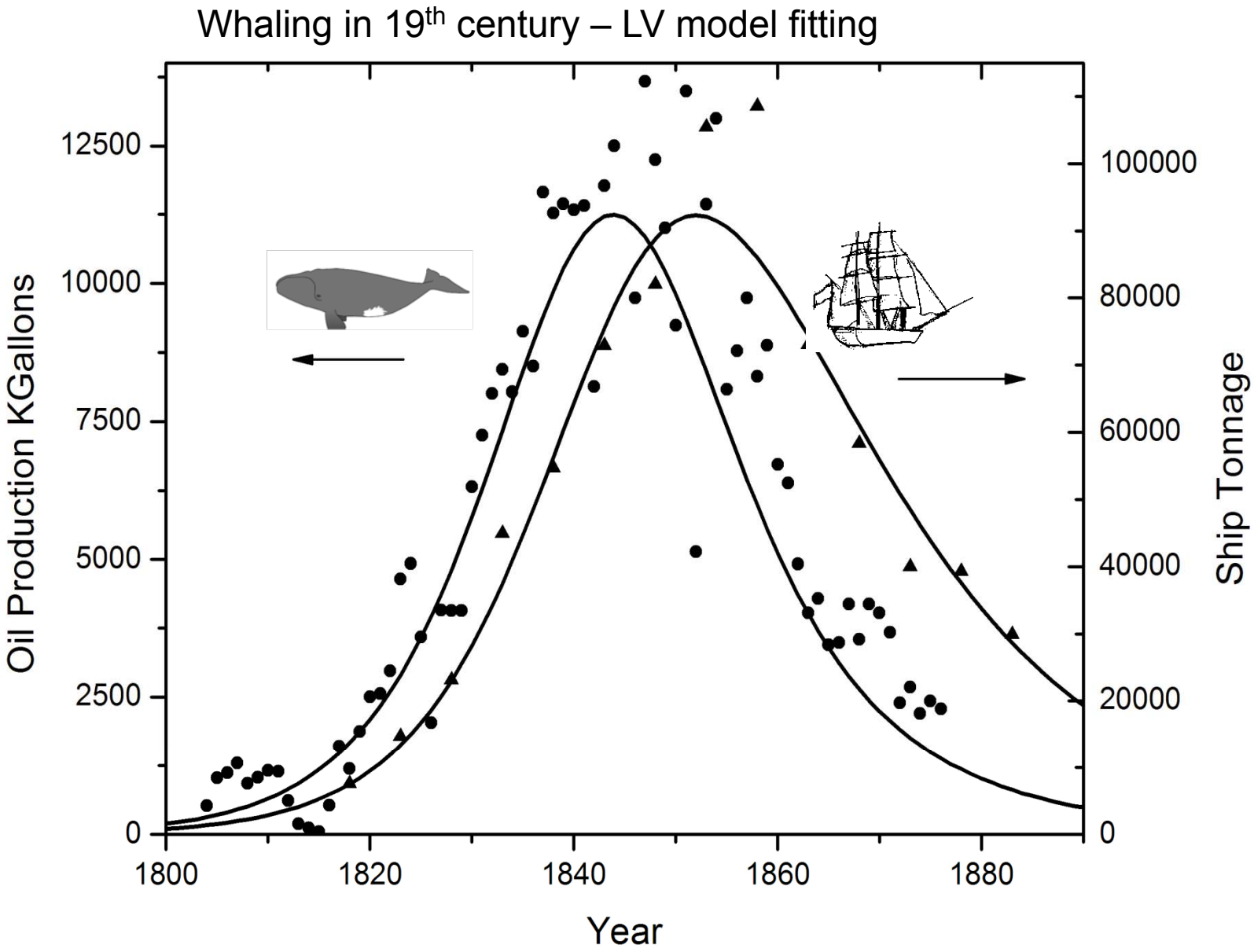
p = production
g = capital growth

C = Capital
R = Resources

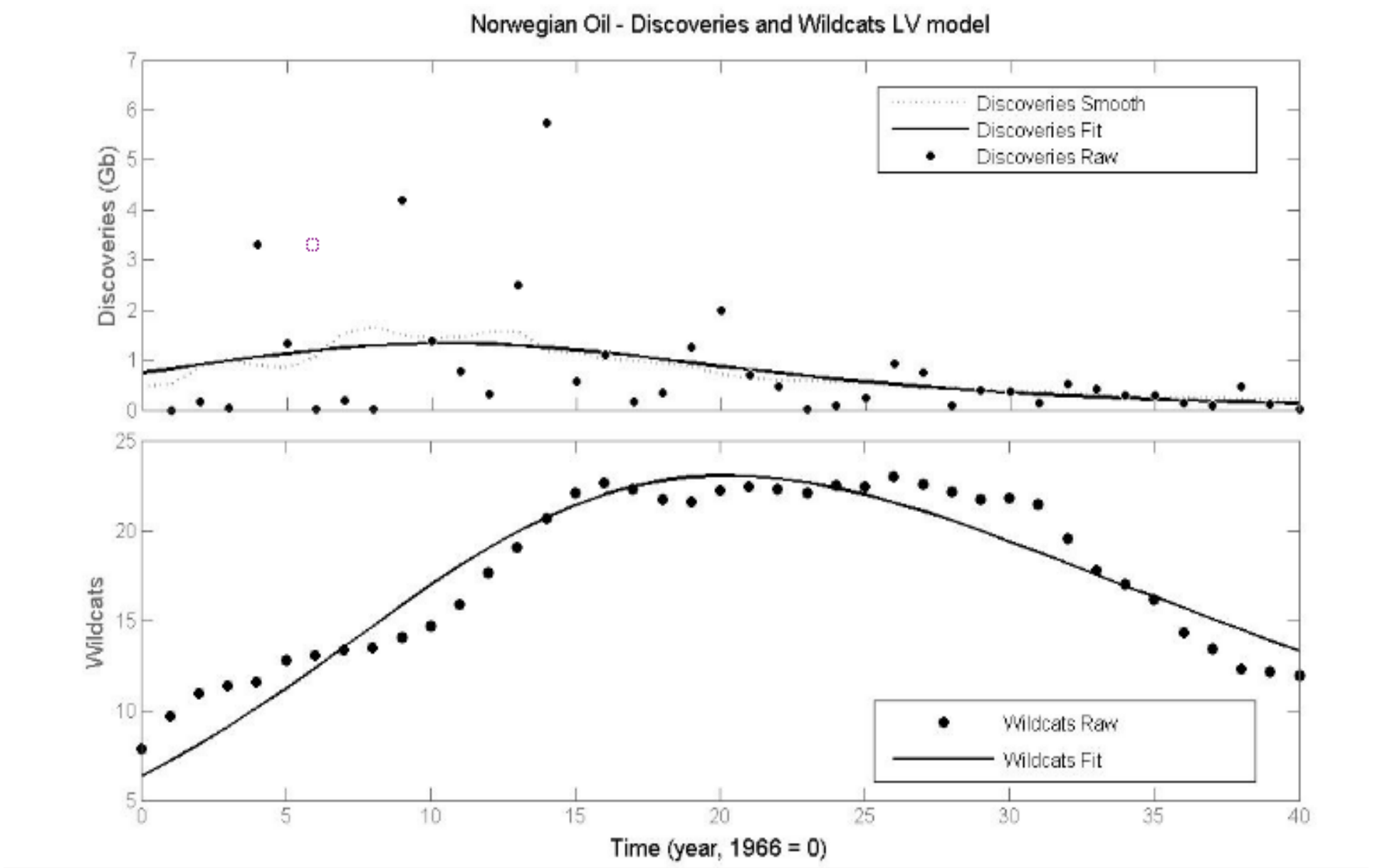
k_1 = efficiency of transformation of capital into resources
k_2 = efficiency of transformation of resources into capital
k_3 = capital depreciation

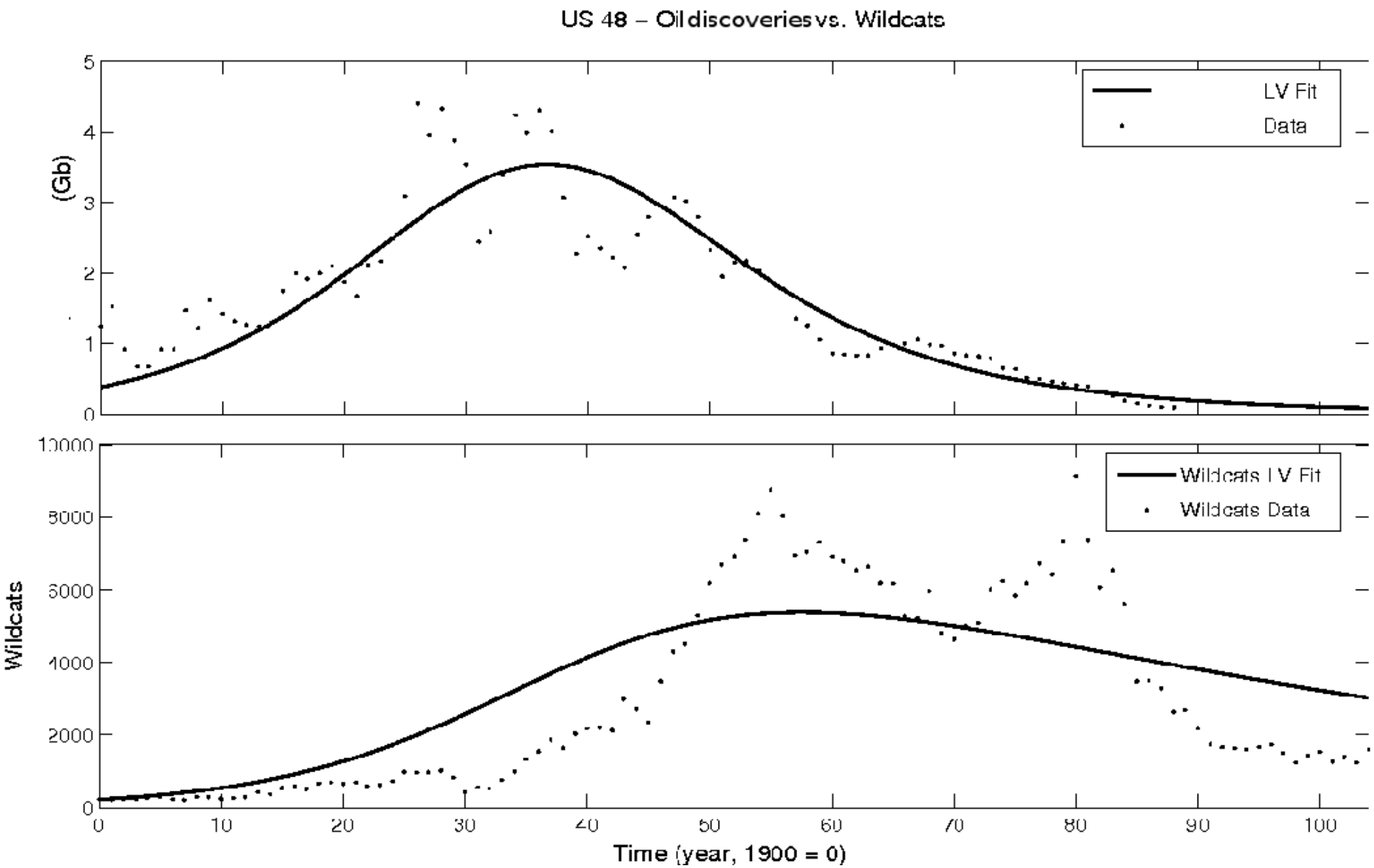
California gold rush,1848



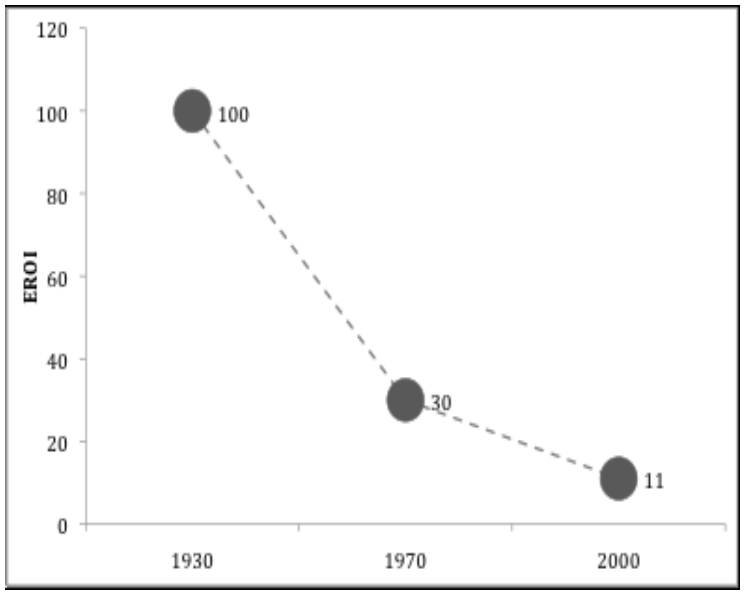


Bardi, to be published

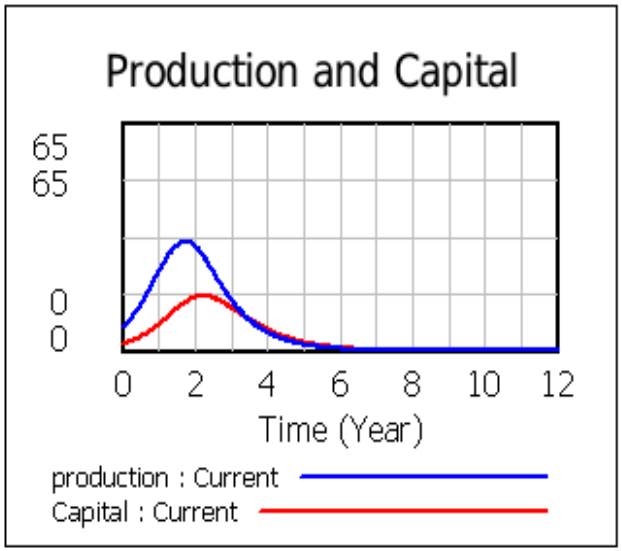

Norwegian Oil - Discoveries and Wildcats LV model
Discoveries (Gb)
Discoveries Smooth
Discoveries Fit
Discoveries Raw
Wildcats
Wildcats Raw
Wildcats Fit
Time (year, 1966 = 0)

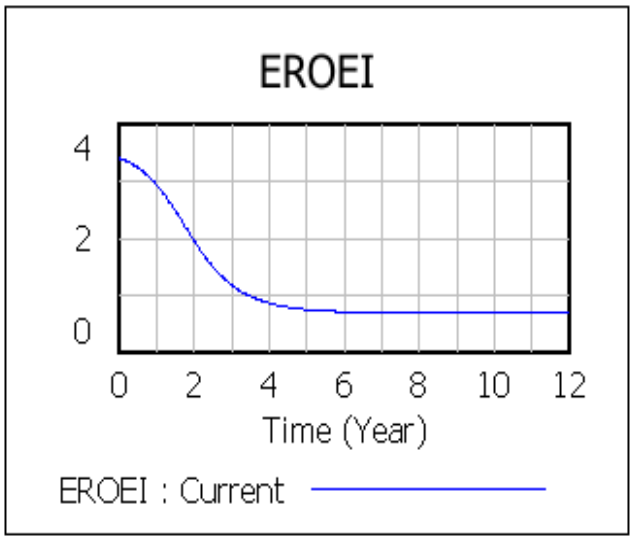

US 48 – Oil discoveries vs. Wildcats
(Gb)
LV Fit
Data
Wildcats
Wildcats LV Fit
Wildcats Data
Time (year, 1900 = 0)

Plot of the EROEI of oil extraction in the US.



(D. Murphy, TOD, from data of Cutler Cleveland)#





EROEI=p/C= k1R

LV model

The collapse of Easter Island

M. Bologna and J. C. Flores

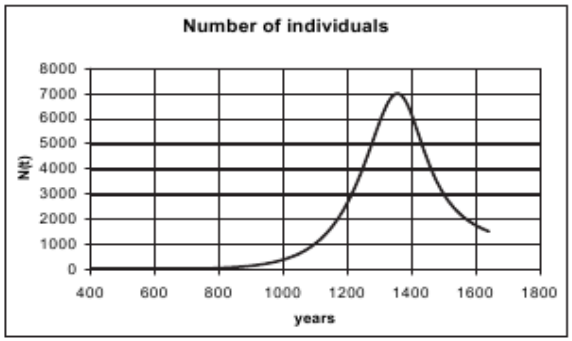


Fig. 1: Number of inhabitants *vs.* time inspired by the model (13) and (14). The maximum size of the population, $N_M \approx 7000$ inhabitants, and the equilibrium size of the population, $N_F \approx 2000$, is in very good agreement with the archeological data.

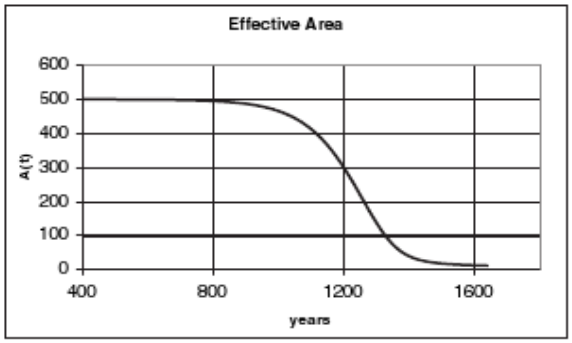
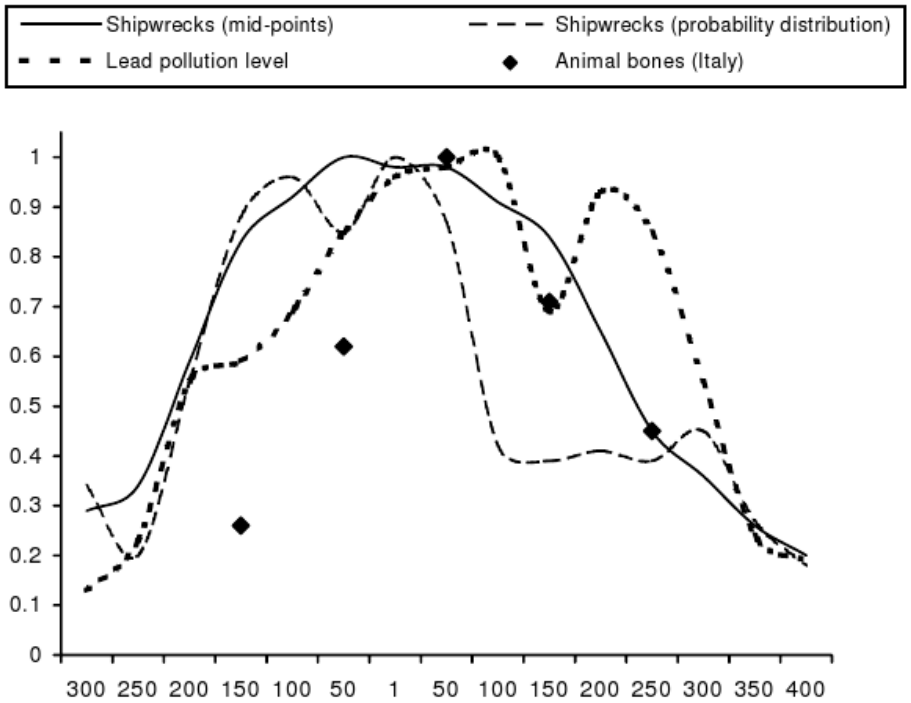


Fig. 2: Resources (effective area) *vs.* time inspired by the model (13) and (14).

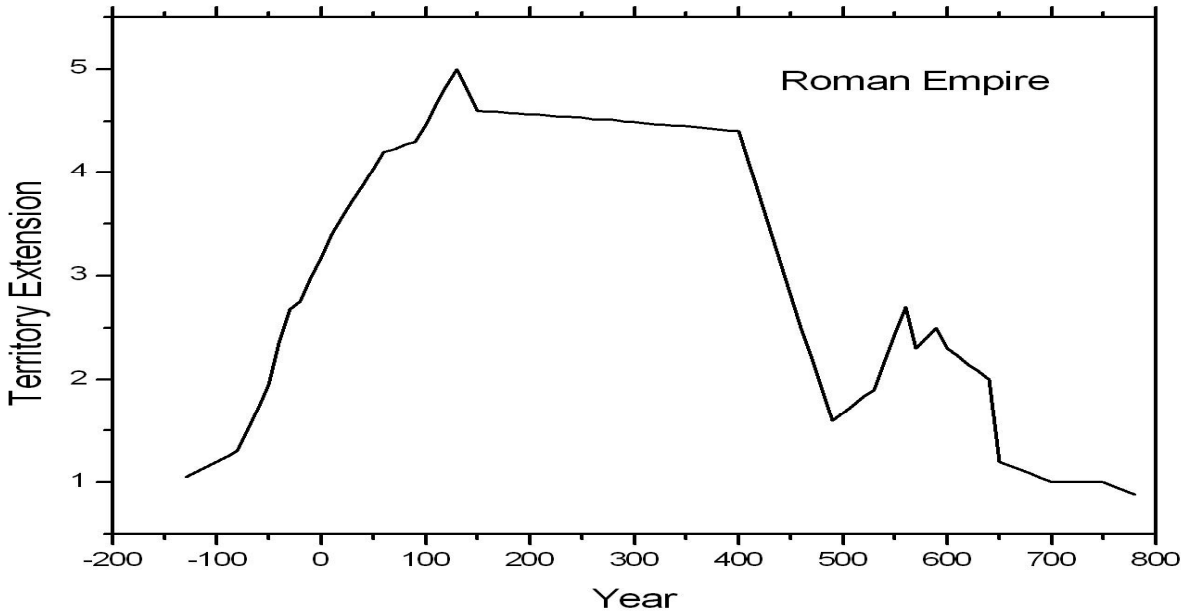
Bologna and Flores
EPL, 81 (2008) 48006

The fall of the Roman Empire

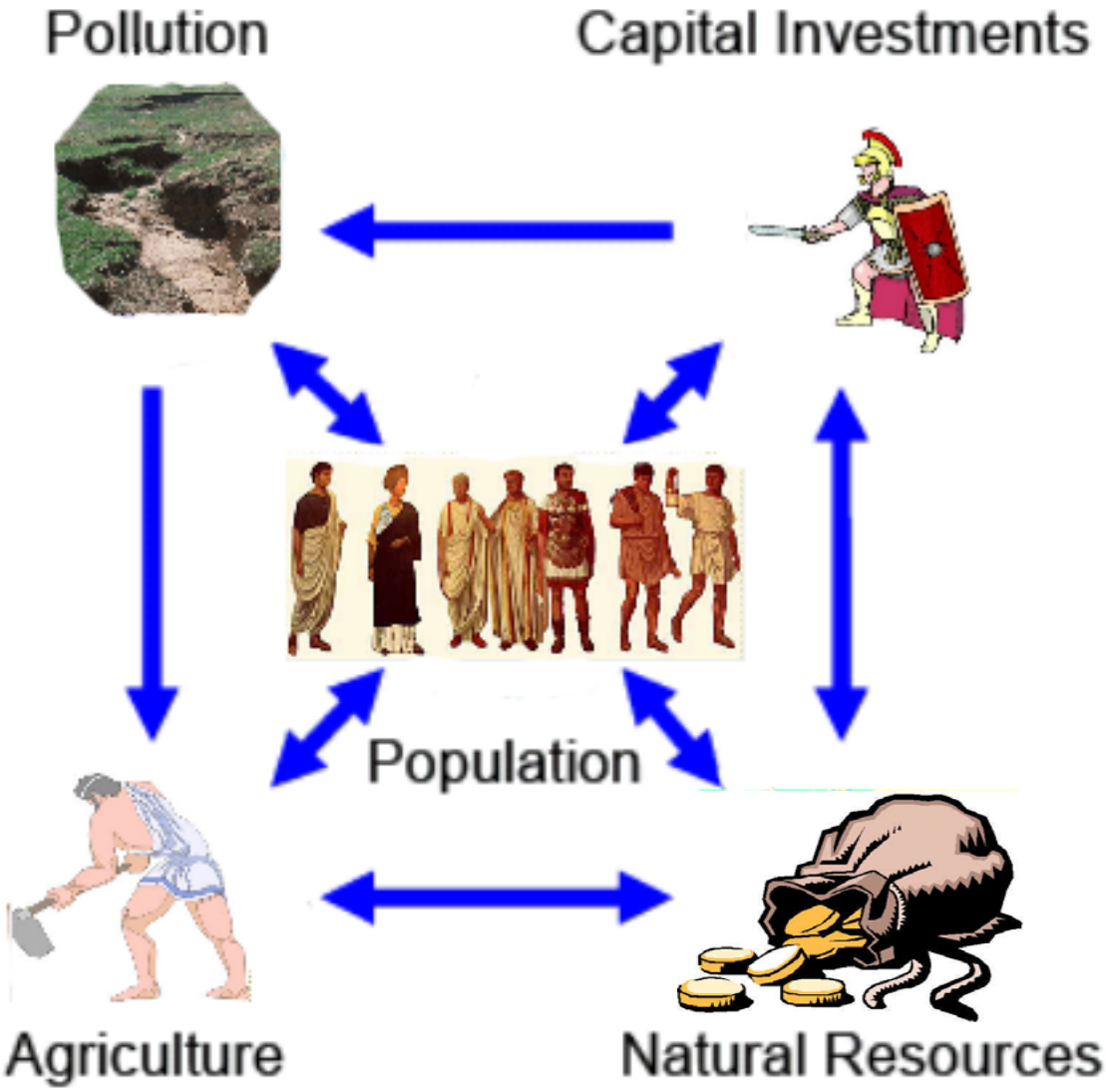
In search of Roman economic growth, W. Scheidel, 2008



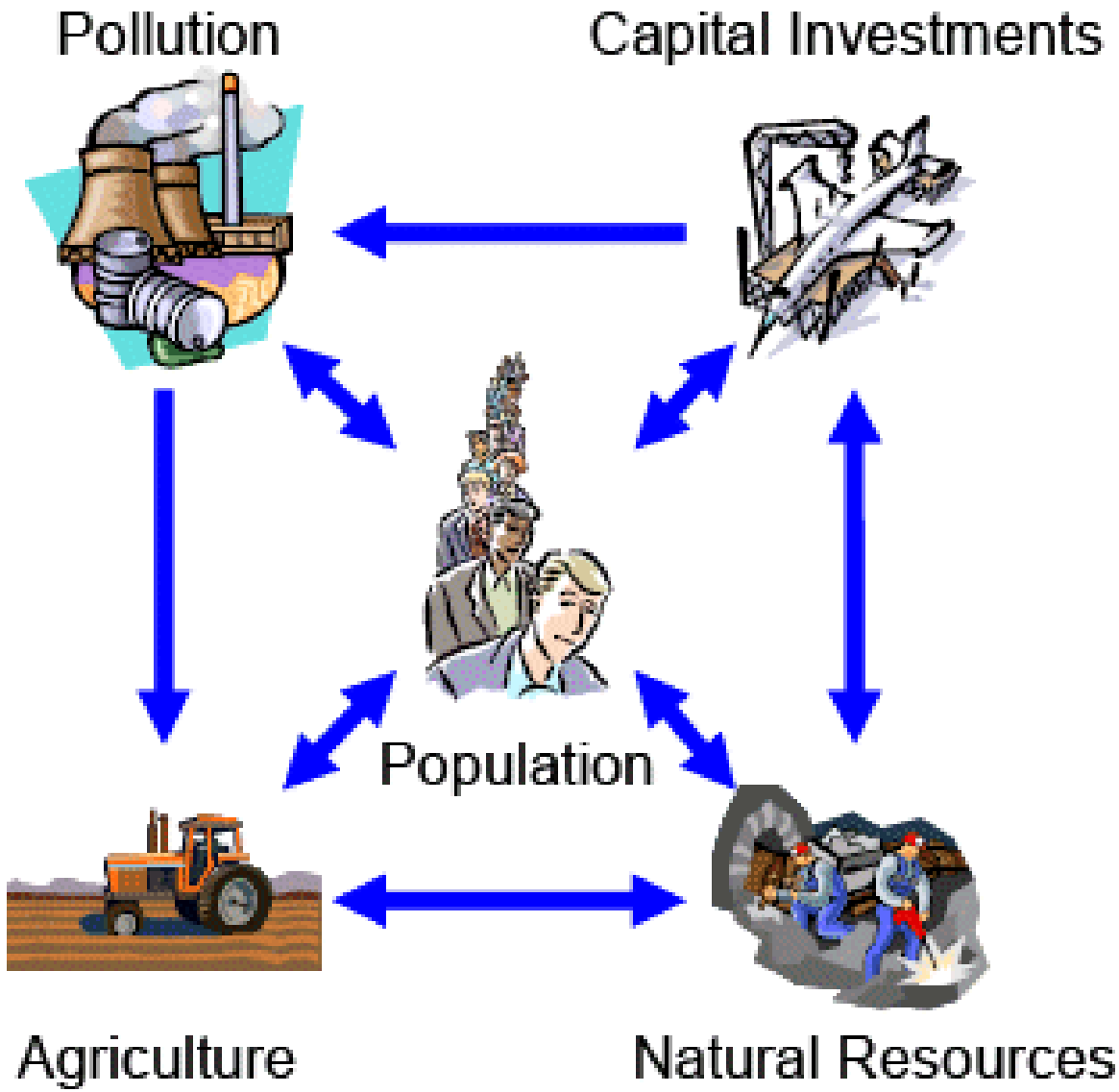
Taagenpere, 1968



Roman World Model



The Limits to Growth (1972), World model



Myrtveit 2006

Teutoburg, Sep 11, 9 A.D.

An army unrivaled in bravery, the flower of the Roman troops in discipline, vigor and military experience, was thus brought through supine leadership, the perfidy of the foe, and a cruel Fortune into an utterly desperate situation. The troops did not even have the opportunity of fighting, as they wished . . . and hemmed in by woods, lakes and the bands of ambushed enemies, were entirely cut off by those foes, whom they had used to slaughter like cattle. (Velleius Patroclus)#