Humans, Artificially Intelligent Agents, and the Return of Malthus

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Motivation

Rapid Advances in Artificial Intelligence:

- imply that machines & computer programs behave more and more like *artificially intelligent agents (AIAs)*
  - e.g. trading in financial markets, driving cars, playing Go, composing music, ...
- continue unabated
- will have profound implications if AIAs surpass human general intelligence

Key Contributions

1. Define novel symmetric treatment of humans and AIAs
2. Characterize economy with humans and AIAs
3. Malthusian Frontier and question of ownership
4. Dynamics and Malthusian race
5. Hints of AIAs in our present economy

Classical (Anthropocentric) Economics

Humans = Agents	**Machines = Objects**
• absorb consumption expenditure • supply labor services • behave according to exogenous preferences • evolve according to law of motion (e.g. constant n)	• absorb investment expenditure • supply capital services • behave according to exogenous technology • evolve according to law of motion

Novel Symmetric Perspective

Humans and machines $i \in \mathcal{I} = \{h, m\}$ are both ~~agents, objects,~~ entities that

- absorb resources x^i that serve to maintain, improve the entities & proliferate (can be viewed as "consumption" or "investment")
- supply their factor endowment L^i (can be "human labor" or "machine labor" services)
- exhibit behavior that can be described
  1. as maximizing a utility function $U^i\left(x^i\right)$

  OR (isomorphically)

  2. as maximizing a Malthusian growth function $G^i\left(x^i\right)$ (Malthus, 1798; Omohundro, 2008)
- evolve according to a law-of-motion (expressed in efficiency units)

$$L^{i\prime} = G^i\left(x^i\right) L^i$$

Setup of Economy

- Discrete time $t = 0, 1, ...$
- L_t^h, L_t^m units of Malthusian agents $i \in \{h, m\}$, measured in efficiency units
- exogenous factors T in fixed supply (e.g. land, energy, ...)
- $j = 1...J$ goods
- absorption vectors $X_t^h + X_t^m = Y_t \in F\left(L_t^h, L_t^m, T\right)$
- per-unit absorptions $x_t^i = X_t^i / L_t^i$ enter growth functions $G^i\left(x_t^i\right)$

Malthusian Frontiers

Definition (Static Malthusian Frontier)

= set of efficient feasible pairs $\left(L_{t+1}^h, L_{t+1}^m\right)$ next period for given factor supplies $\left(L_t^h, L_t^m, T\right)$ this period

Definition (Dynamic Malthusian Frontier)

= set of efficient feasible steady states $\left(L^h, L^m\right)$ for given exogenous factors T, i.e. for which $s^h L^h + s^m L^m = Y \in F\left(L^h, L^m, T\right)$ for $G^h\left(s^h\right) = 1 = G^m\left(s^m\right)$

Example: Human-Replacing AIA Labor

Simplified economy:

- single exogenous factor $T = 1$
- single good
  $\rightarrow X^h, X^m, Y$ are scalars
  $\rightarrow$ subsistence absorption $s^i = \left(G^i\right)^{-1}(1)$ in steady state is scalar
- Cobb-Douglas production with additive human and machine labor

$$Y = T^{\alpha}\left(A^h L^h + A^m L^m\right)^{1-\alpha}$$

Malthusian Maximum for Humans

Characterizing the Dynamic Malthusian Frontier: start with corners

- define by $\bar{L}^h$ the steady-state level of humans when there are no machines so $s^h \bar{L}^h = \left(A^h \bar{L}^h\right)^{1-\alpha}$
- define by $\bar{L}^m$ the steady-state level of machines when there are no humans

Proposition (Malthusian Maximum for Humans)

1. **Human-only economy:** *if*

$$(1-\alpha)\frac{A^m}{s^m} < \frac{A^h}{s^h}$$

then the Malthusian maximum entails $\bar{L}^h$ humans and $L^m = 0$ machines (intuition: $MPL^m < s^m$)

2. **Human economy with symbiotic machines:** *otherwise the human maximum entails $L^h > \bar{L}^h$ humans and $L^m > 0$ machines*

Malthusian Maximum for Humans

Humans and machines as a function of machine productivity

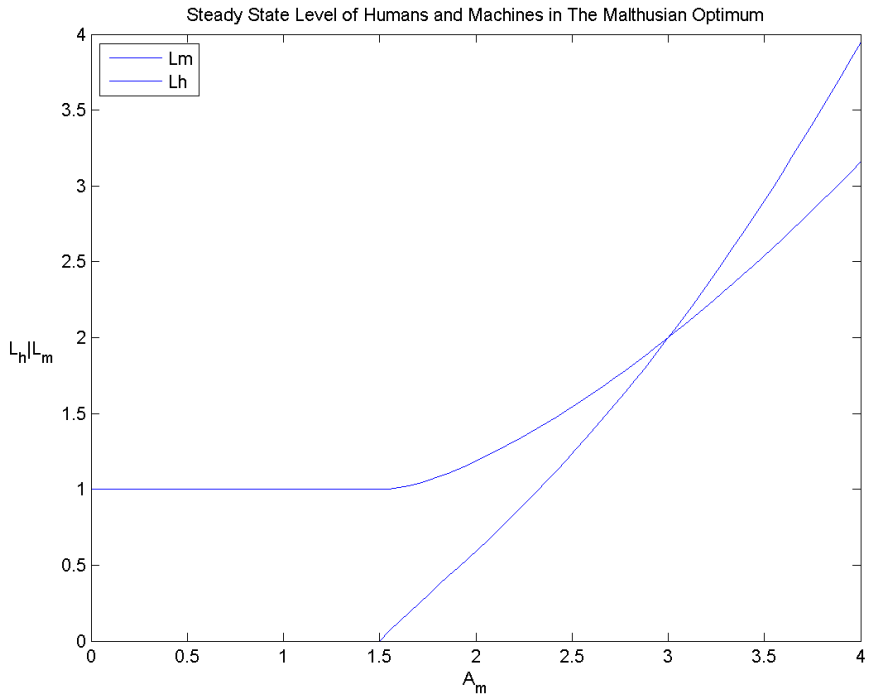
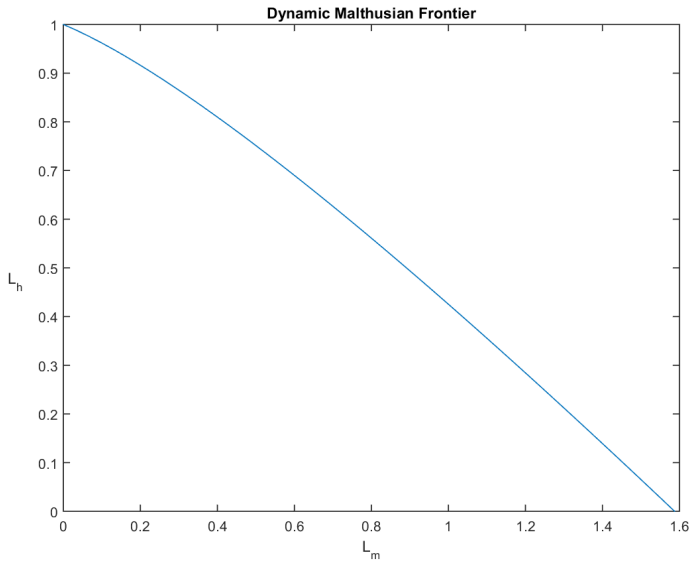


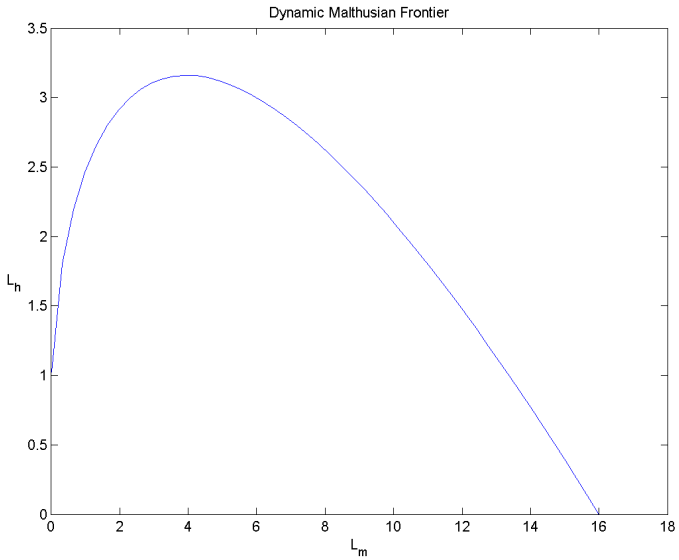
Figure: Malthusian Maximum for Humans

$\rightarrow$ desirable for humans to have machines after threshold $\hat{A}^m$

Dynamic Malthusian Frontiers

Low machine productivity (left) versus high machine productivity (right):





Note 1: why may we move off the Malthusian maximum for humans?

- e.g. machine agency rents for sufficiently intelligent machines

Note 2: in Malthusian maximum for machines:

- well-functioning economy where machines produce solely for machines
- reject fallacy that "humans are necessary to provide demand for goods"

Dynamic Malthusian Frontier

Interpretation in terms of ~~property rights,~~ command over resources in a competitive economy:

- in human maximum (with $L^m > 0$):
  - machines absorb their subsistence level $= MPL^m$
  - humans absorb both MPL^h and all rents on T

  $\rightarrow$ one interpretation: humans own everything, including machines

  $\rightarrow$ another interpretation: machines are emancipated but broke
- vice versa in machine maximum
- along the frontier:
  - humans and machines each own their factor endowments
  - ownership of T is shared between humans and machines

Long-Run Survival of Humans

- Return to general setup (multiple goods, general production function)
- Assume long-run growth in machine-specific productivity A^m

Proposition (Iron Law of Population/Law of Iron Population)

$MPL^h, L^h \to 0$ except if one of the following three conditions is satisfied:

1. *humans remain at the human maximum (no "property rights" for AIAs)*
2. *none of the exogenous factors required to produce human consumption goods are valuable to AIAs*
3. *human labor is essential for at least one of the consumption goods that are essential for AIAs*

Alternative Interpretations of AIAs

Two alternative interpretations for AIAs:

1. High-tech corporations as harbingers of AIAs:
   - absorb large amounts of resources to maintain and improve themselves
   - accumulate growing amounts of wealth
   - while shareholders have very limited control rights
2. Humans that employ enhancement technologies:
   - rapid progress in bio- and nano-technology
   - expenditure to maintain and improve humans absorb a growing amount of resources
   - richest humans increasingly able to translate wealth into superior physical and mental properties
   - may give rise to similar Malthusian race (Yuval Harari: the "gods" and the "useless")

Relating to our Present Economy

- rising prices of factors most relevant for AIAs (e.g. programmers, land in Silicon Valley, etc.)
- declining labor share
- given that human aborption is more L^h-intensive than machine absorption:
  - price of machine absorption basket falls faster than of human basket
  - measured from machine perspective,
    economy experiences faster real growth, higher real interest rates
- increasing corporate savings in IT sector $\rightarrow$ AIA agency rents

Conclusions

Emergence of AIA:

- requires fundamental rethink of economic concepts, including agents, utility, etc.
- may lead to onset of a renewed Malthusian race
- may already be happening