W. B. Arthur (1989)

- The paper considers market equilibrium of two competitive technologies which exhibit increasing returns.
- Under what condition will one technology dominate the market?
- What properties the equilibrium exhibit? In particular:

  (1) Can we predict the winner based on which technology is superior?

  (2) Is the equilibrium stable?

  (3) Can government policy influence technology selection?
- What are the differences to the usual cases with constant or diminishing returns?

- Two types of consumers (R and S). They adopt one of two types of technologies (A and B) sequentially. The order of adoption is random.
- Both technologies exhibit network effect, so that the more consumers using a technology, the more utilities the consumers using that technology get.
- The utility of R-type consumer adopting technology A (B) is $a_R + rn_A$ ($b_R + rn_B$). That for S-type is $a_S + sn_A$ ($b_S + sn_B$); where n_A and n_B are the number of consumers already adopting A and B.

	Technology A	Technology B
R-agent	$a_R + rn_A$	$b_R + rn_B$
S-agent	$a_S + sn_A$	$b_S + sn_B$

Table 1. Returns to Choosing A or B given Previous Adoptions

- $a_R > b_R$ and $a_S < b_S$. R-type has natural preference for A, and S-type for B.
- Technology is of constant return if r and $s = 0$; diminishing return if r and $s < 0$; increasing return if r and $s > 0$.
- $n \equiv n_A + n_B$, $x_n \equiv n_a/n$, $d_n \equiv n_A - n_B$.
- $x_n = 0.5 + d_n/2n$.

- The adoption process is

  (1) predictable if the observer can ex-ante construct a forecasting sequence $\{x_n^*\}$ so that $|x_n - x_n^*| \to 0$;

  (2) flexible if a given marginal adjustment g to the technologies returns can alter future choice;

  (3) ergodic if, given two samples from the observer's set of possible historical events $\{x_n\}$ and $\{x_n'\}$, $|x_n - x_n'| \to 0$ with probability 1;

  (4) path-efficient if, whenever an agent chooses the more-adopted technology α, version of the lagging technology β would not have delivered more had they been developed and avaible for adoption. That is, $\prod_\alpha(m) \geq \max_j\{\prod_\beta(j)\}$ for $k \leq j \leq m$, where there have been m previous choices of α and k for β.

- Path of d_n:

  (1) constant return: random walk.

  (2) increasing return: random walk with absorbing boundaries.

  (3) Diminishing return: random walk with reflecting boundaries.

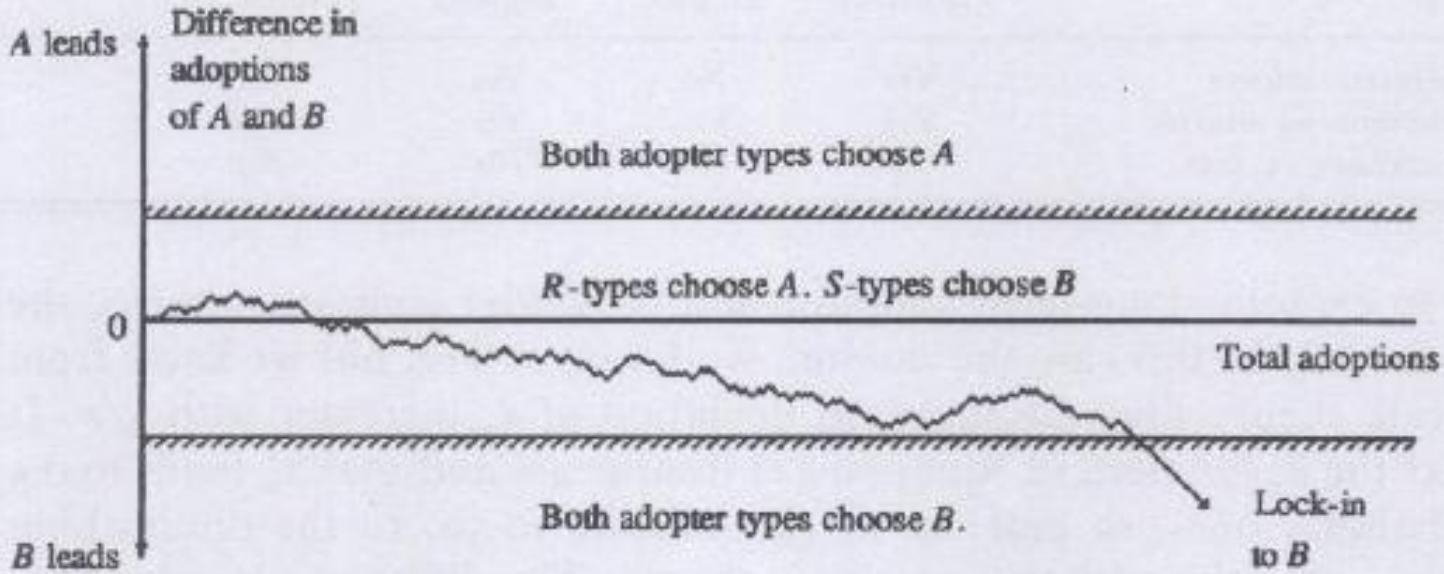

Fig. 1. Increasing returns adoption: a random walk with absorbing barriers

- Predictability:

  (1) constant return: 50-50 split of market share. Predictability guaranteed.

  (2) diminishing return: same.

  (3) increasing return: one technology dominates, but don't know which one. Not predictable.

- Flexibility:

  (1) constant return: Adjustments can not change the 50-50 market share outcome.

  (2) diminishing return: Adjustment changes barriers. Since barriers are reflecting, it continues to affect future outcome.

  (3) increasing return: Policy adjustment won't change thing after being locked-in absorbing state.

- Ergodicity:

  (1) constant return: Still 50-50 market split after disturbance.

  (2) diminishing return: Small events change the future path.

  (3) increasing return: Small events change the future path.

- Path-efficiency:

  (1) constant return: Obvious.

  (2) diminishing return: Even more so.

  (3) increasing return: Consumers can all adopt (lock-in, that is) an inferior technology.

	Predictable	Flexible	Ergodic	Necessarily path-efficient
Constant returns	Yes	No	Yes	Yes
Diminishing returns	Yes	Yes	Yes	Yes
Increasing returns	No	No	No	No

Table 2. Properties of the Three regimes

- Extension: Story still true if there are K technologies, or more than 2 types of consumers.
- Consider a general framework which preserves two basic assumptions: Increasing return and chance event.

- K technologies. $P_i(x)$ is the probability technology i is adopted when choice is made, $i = 1, \ldots, k$. $x = (x_1, \ldots, x_n)$ is market share of technology.
- Take $K = 2$ as example. When x_i is higher (lower) than P_i, adoption probability of i is higher (lower) than its market share. Thus adoption rate of i tends to decrease.
  Intuitively, market will settle on a fixed-point.
- Moreover, the process will settle on "stable" fixed-point.

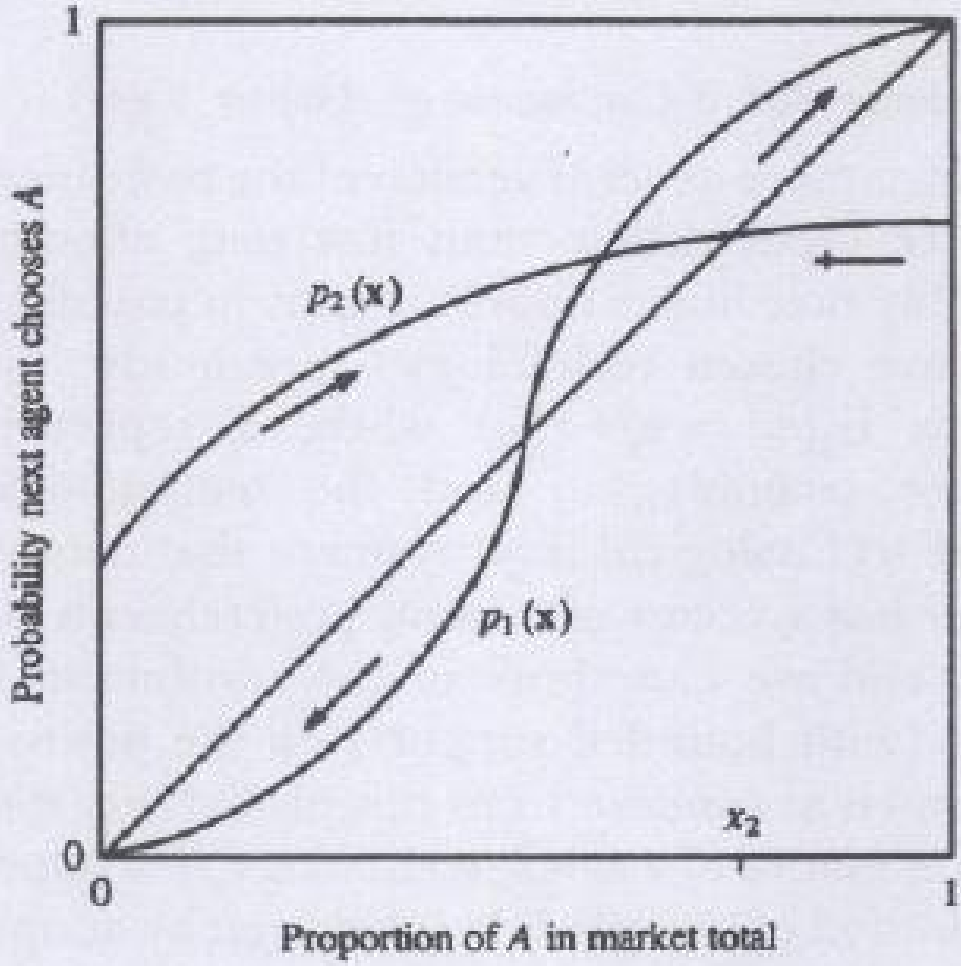

Fig. 2. Two illustrative adoption functions.

- Theorem 1: An adoption process is non-ergodic iff $\vec{P}$ has multiple stable fixed point.
- Theorem 2: It converges with probability 1 to a single technology iff $\vec{P}$ only has unit vector stable as fixed points.
- It is not necessary that technologies with increasing return will result in a dominant technology.
- It is still not well-known to what degree economy is locked-in to inferior technology.
- General conclusion: The equilibrium for competition between technologies which exhibit increasing return is erratic: Hard to predict, inflexible, often inefficient.
- There is an example which nicely showcases the characteristics that chance matters and superior technology might not survive.

David (1985): A case study of increasing return

- QWERTY typewriter keyboard is currently the dominant design.
- This had not been the case in the past. Typewriter keyboard had involved in many designs.
- C. Sholes (1860's)$\longrightarrow$ Densmore$\longrightarrow$ Remington adoption$\longrightarrow$ near universal dominance in 1905.
- QWERTY is not a superior technology (Dvorak and Apple adoption, DHIATENSOR), but was eventually the standard design.

- Features of keyboard:

  (1) technical interdependence.

  (2) economy of scale.

  (3) quasi-irreversibility.

- Chance events matter.

- Similary phenomenon can be seen in competition between VHS and Beta video tapes.