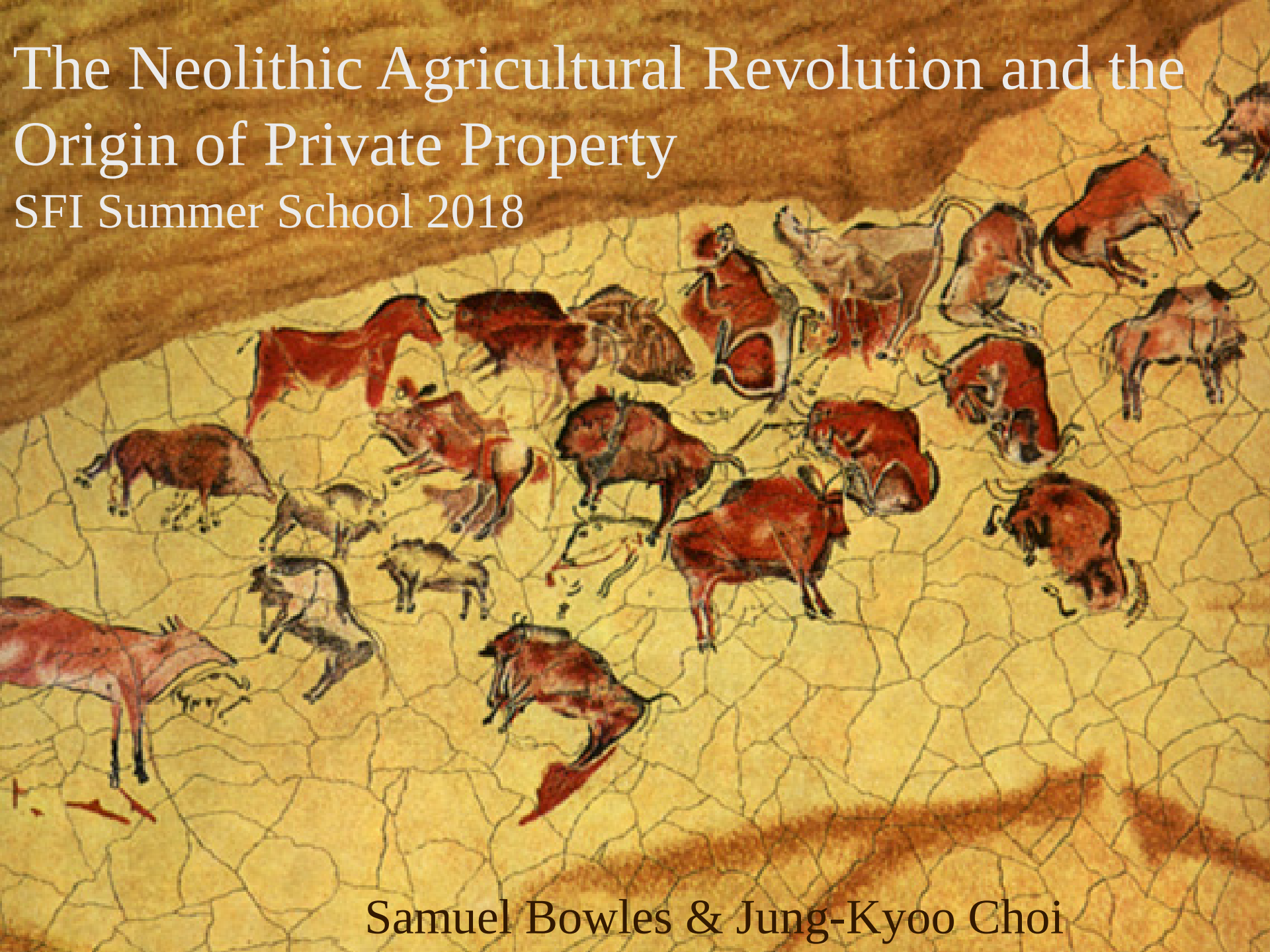
The Neolithic Agricultural Revolution and the Origin of Private Property

SFI Summer School 2018



Samuel Bowles & Jung-Kyoo Choi

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Jung Kyoo Choi (SFI)

U of Siena, Yale, Oxford, LSE,
Cape Town, Umass at SFI

Technology and institutions as influences on social dynamics

- Technology, *the manner in which people interact with their natural environment to produce their livelihoods*, highlights the importance of the nature of the goods and services on which a population lives and reproduces, and the manner in which they are acquired in the particular ecology of a society.
- *The hand mill gives you society with the feudal lord; the steam mill, society with the industrial capitalist.* Karl Marx, *The Poverty of Philosophy*, 1847
- Institutions, *the manner in which people relate to one another in producing and distributing their livelihoods (including reproduction),* highlights the importance of political influences.
- *Knaves will tell you that it is because you have no property, you are unrepresented. I tell you on the contrary, it is because you are unrepresented that you have no property*. . . Chartist leader James Bonterre O'Brien, 1848.

The influences – technology, institutions -- are not mutually exclusive.

- A circumscribed natural environment - the Nile Valley for example - may favor the emergence and success of coercive states which in turn may support high levels of wealth inequality (Carneiro (1970).
- Similarly, egalitarian institutions -- the convention that upon being acquired, food should be widely shared beyond the immediate family, for example – may influence the choice of technology, discouraging farming and storage even where both would contribute substantially to individuals' livelihoods under different institutions (Bowles and Choi, 2013, Woodburn 1982.)
- But explanations of societal differences in inequality often favor one class of explanation over another…
- Behavioral ecologists (e.g. Vehrencamp (1983)) and economists in the Walrasian tradition (e.g. Ferguson (1968), Samuelson 1957, early Solow), for example, favoring what might be called the technology-ecology view, while
- Historians in the Marxian tradition (Brenner (1976)) and the "conflict" school of sociology (e.g. Dahrendorf (1959)) favor the institutions-politics view.

Echoes of this institutions vs technology debate in recent works on growth and stagnation

- Jared Diamond's *Guns Germs and Steel* and Jeffrey Sachs on the importance of geography
- Ken Pomeranz's *The Great Divergence* and Daron Acemoglu and James Robinson *Why Nations Fail* on the importance of politics and institutions.
- *Conflict of interest statement*: My previous work has placed me entirely in the second camp (e.g. the pre-historic agricultural revolution was led by institutional change, not a new technology, Bowles & Choi, 2013)

Technology and institutions: Big history

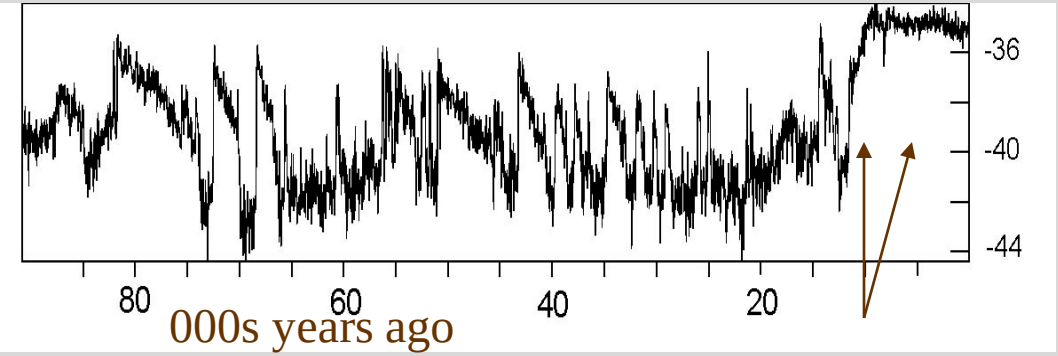
- Exogenous shocks: A standard view (Demsetz, North, Marx, Childe): institutions such as property rights systems or forms of governance change in response to exogenous changes (in technology, increased population, climate change, epidemics).
- A common variant of this view is that new technologies are adopted because they are efficient, inducing institutional change as a result
- Marx: "forces of production" → "social relations of production"
- technology → institutions
- This works in many cases: the horse on the U.S. Great Plains, the sweet potato in PNG highlands.

Exogenous technical change as the driver of institutional innovation?

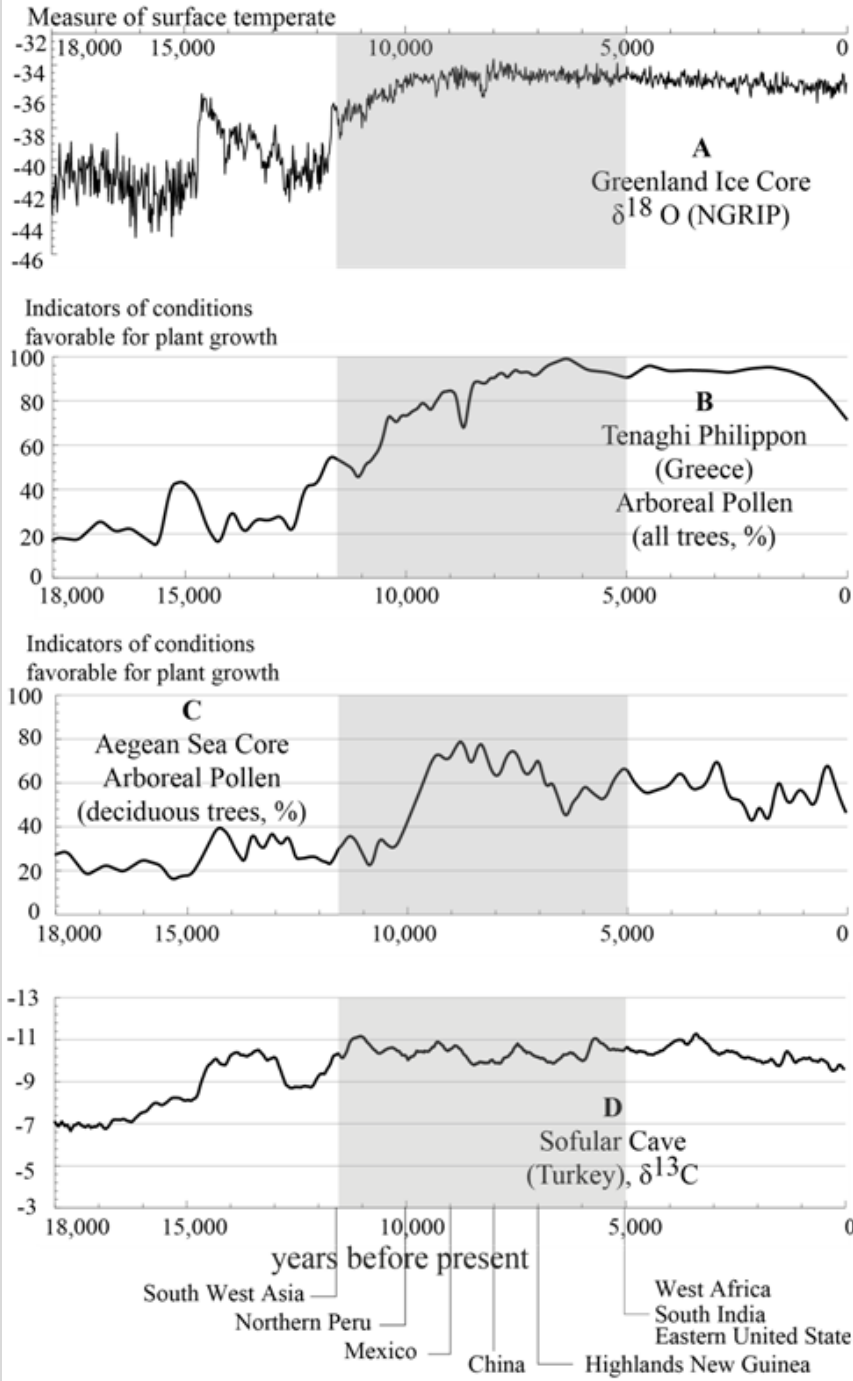
- This view has been proposed, too, for the Holocene revolution: climate amelioration → agriculture → private property
- "Agriculture was impossible prior to the Holocene and mandatory during the Holocene" (Bettinger, Richerson and Boyd, 2001)
- Also: Bowles and Choi 2002, Bowles 2004 etc.
- Variants on this explanation stressing population pressure or climate adversity (North and Thomas1977, Vernon Smith 1975) share the view that the introduction of farming raised the (marginal and average) productivity of labor (or averted a fall in productivity)
- But while the climate change is part of the story, empirically the *exogenous technical improvement* explanation seems unlikely in light of recent archaeological research (Bowles 2013).

The climate amelioration part of the story works

- Warmer and less variable climates during the Holocene (NB: ice core data (Ditlevsen et al, 1996, Bettinger et al 2002) from 90ka to the present)



Domestication of plants and animals

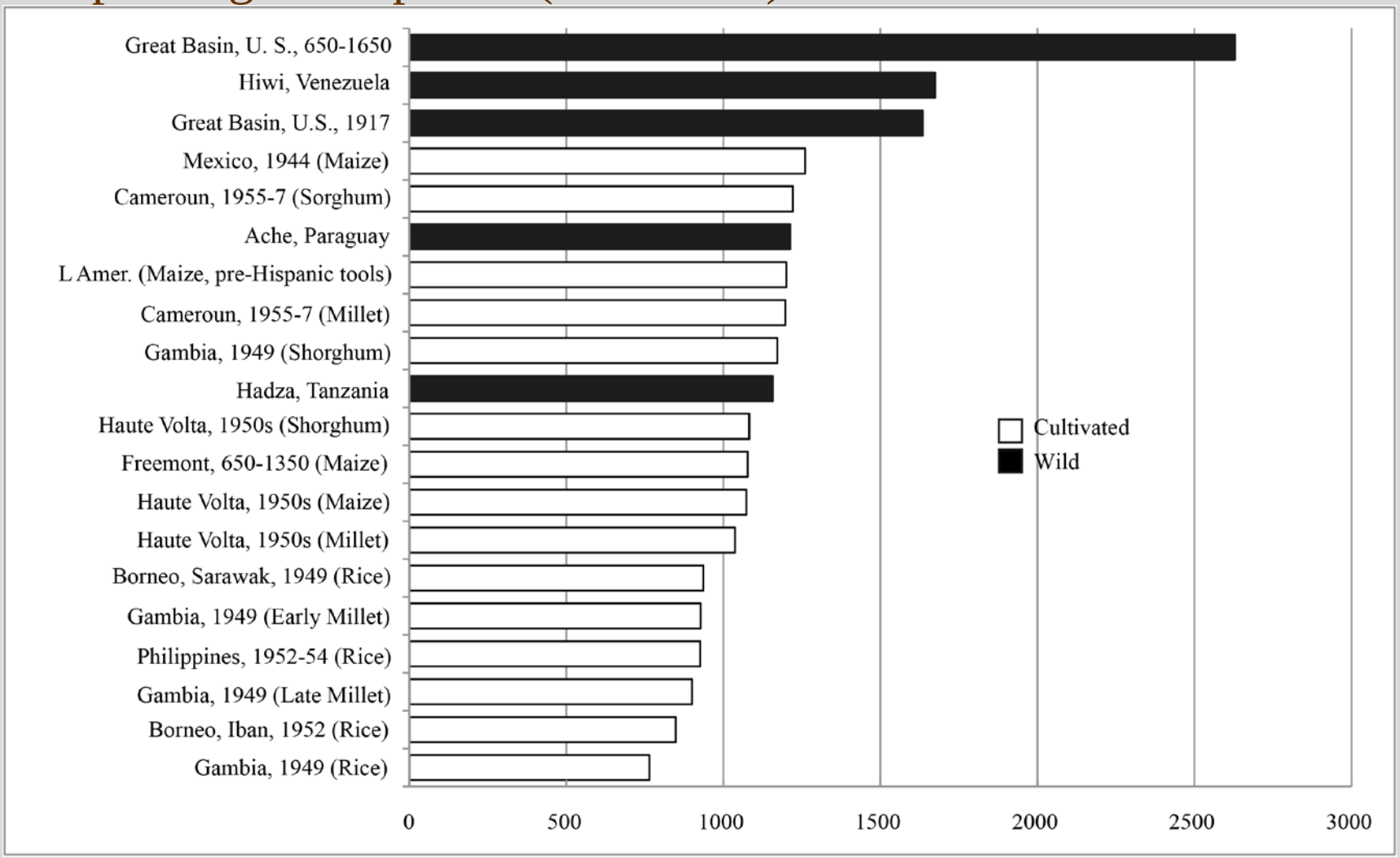


– Holocene climate amelioration and the advent of farming.

But the rest of the exogenous technical improvement story does not work: *Farming was not more (labor) productive*.

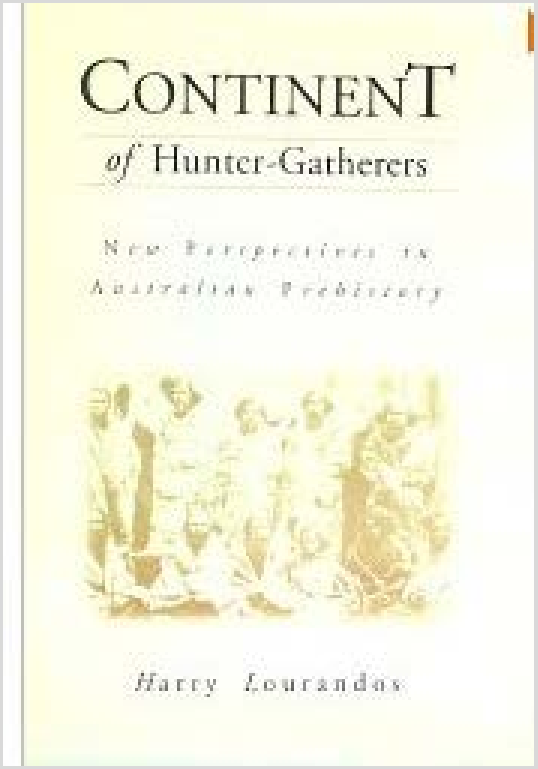
- The first farmers were much smaller and on average in much less good health than the foragers that they replaced.
- The early domesticates (wheat, millet, corn) had limited food value, and extraordinary processing costs.
- Cultivation involves significant delay (between production and consumption) which is subjectively and reproductively costly, and which entails storage losses (predation by humans and other animals).
- Cultivators of 1or 2 crops are more risk-exposed than foragers (who rely on dozens of species): certainty equivalents of farmers' output are well below the mean
- Ethnographic foragers were/are highly productive (calories per hour of labor), even if displaced to unfavorable habitats.
- Farming could spread even if it was a worse way to make a living (sedentism and the Neolithic demographic transition).

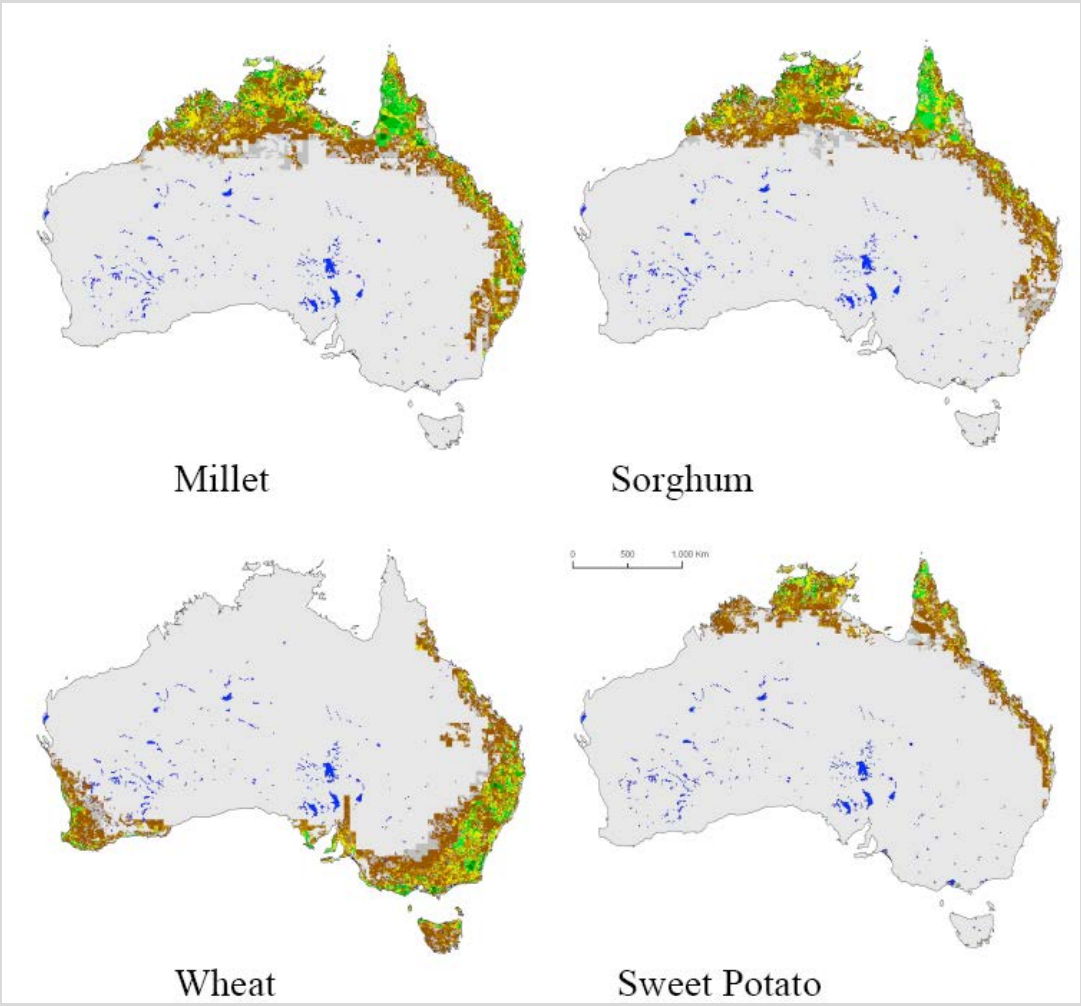
Puzzles: When it emerged, farming (white bars) was not more productive than exploiting wild species (black bars)



Kcalories produced (net of storage and processing losses) per hour of direct and indirect labor for wild and cultivated species based on ethnographic and archaeological data (Bowles 2010)

The puzzle deepens: even under farming friendly early Holocene climate conditions, foraging persisted even in many locations ideally suited for food production.





Also: California, Western Cape, (probably) much of Argentina

Soil and climate suitable for some of the first farmer's cultivars (FAO data). NB Australia did not lack cultivatable plants (contra Jared Diamond).

The puzzle restated: Why would a land saving, labor using technology be adopted in a land abundant labor scarce economy?

Acemoglu & Robinson: foragers were "forced to settle down" by elite mobilization of "extractive institutions."

Archaeological evidence makes this political explanation quite unlikely.

Region (contemporary geographic designations)	*First domestications before the present, in years BP (crop) BP = "before present"*	*First state BP(name of earliest state or proto state in region)*
Southwest Asia	11,500 (Einkorn, emmer, barley)	5,500 (Late Uruk)
China	8,000 (Millet, rice)	4,300 (Erlitou)
Mexico	9,000 (Pepo squash)	2,400 (Teotihuacan)
Northern Peru	10,000 Arrowroot	2,200 (Moche)
Highland New Guinea	>7,000 (Yam, banana, taro)	European (Aust.) colonization
West Africa (Sahel)	5,000 (Sorghum, animals 9000)	1,500 (Ghana, possibly Tichitt)
South India (Karnataka)	5,000 (Millet)	3,200 (evidence of elite burials)
Eastern United States	5,000 (Pepo squash, sunflower)	European colonization

Puzzles for the standard view (continued)

- Population pressure? Where farming and private property emerged, this occurred following long periods of population decline.
- Mandatory? The independent emergence of farming mostly *did not happen.*
- Were it not for the military and demograhic advantages of those farming populations that did emerge, the world today would look more like the image on the left, than the one on the right.

Clues: Institutional barriers to technical change:

- *The traditional Batek* [Malaysian forager] *notions that all natural resources are unowned until collected and that any food obtained in excess of the needs of the procurer's family must be shared with other families seem well suited to a nomadic foraging life, but wholly unsuited to ... peasant farming... giving up that set of ideas and practices would be psychologically very difficult for them to do as the obligation to share food is one of the fundamental components of Batek self-identity and one of the main bonds that link Batek families together as a society*. (Endicott)
- *For storage to develop* [among California Native Americans]… *there must first be a shared tenet that stored food -- and more generally all harvested food -- is restricted (private or family) property*. (Bettinger)
- The result was a chicken and egg problem: for farming to be individually advantageous one had to be able to exclude others from the fruits of ones labor so property rights were required; but
- …ownership of dispersed and mobile wild species was difficult to delimit and defend, so property rights were difficult to establish before farming

How could the chicken and egg problem be overcome? The appearance of private property (storage, dwellings, fishing gear) early in the Neolithic transition and in some cases well before.

Fishing sites (privately held) on the Columbia River

- Huaca Prieta (coastal Peru): Sedentary off shore fishers from 13kya (kya = thousand of years ago) later developed irrigated farming
- Storage among California Native Americans (pinyon, acorn), mammoth hunters on the Russian Plain (20kya), wild grain collectors and hunters at Abu Hureyra (Iraq.11kya)
- In many cases we can identify a shift from public to private storage

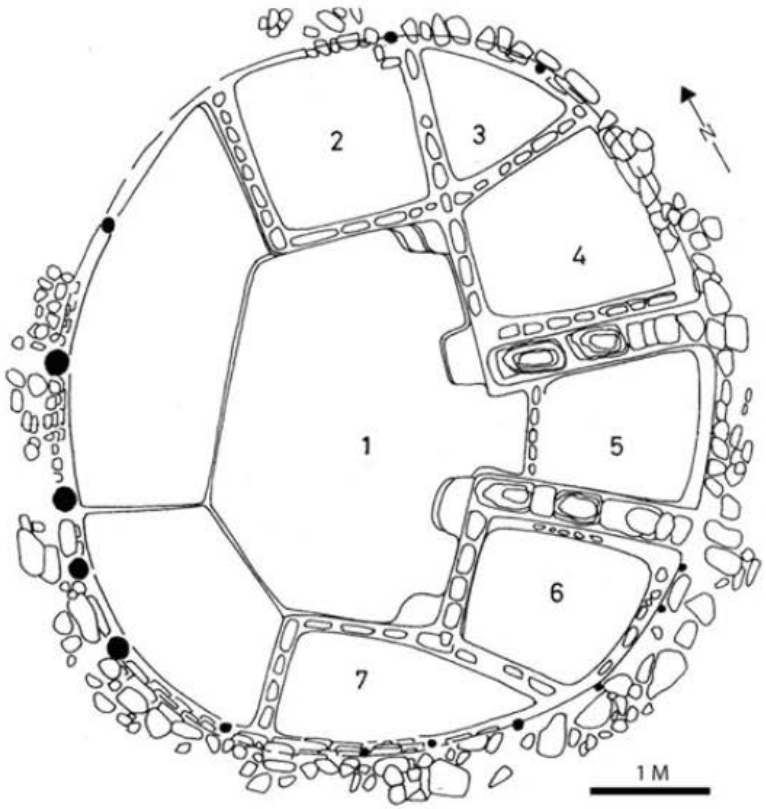
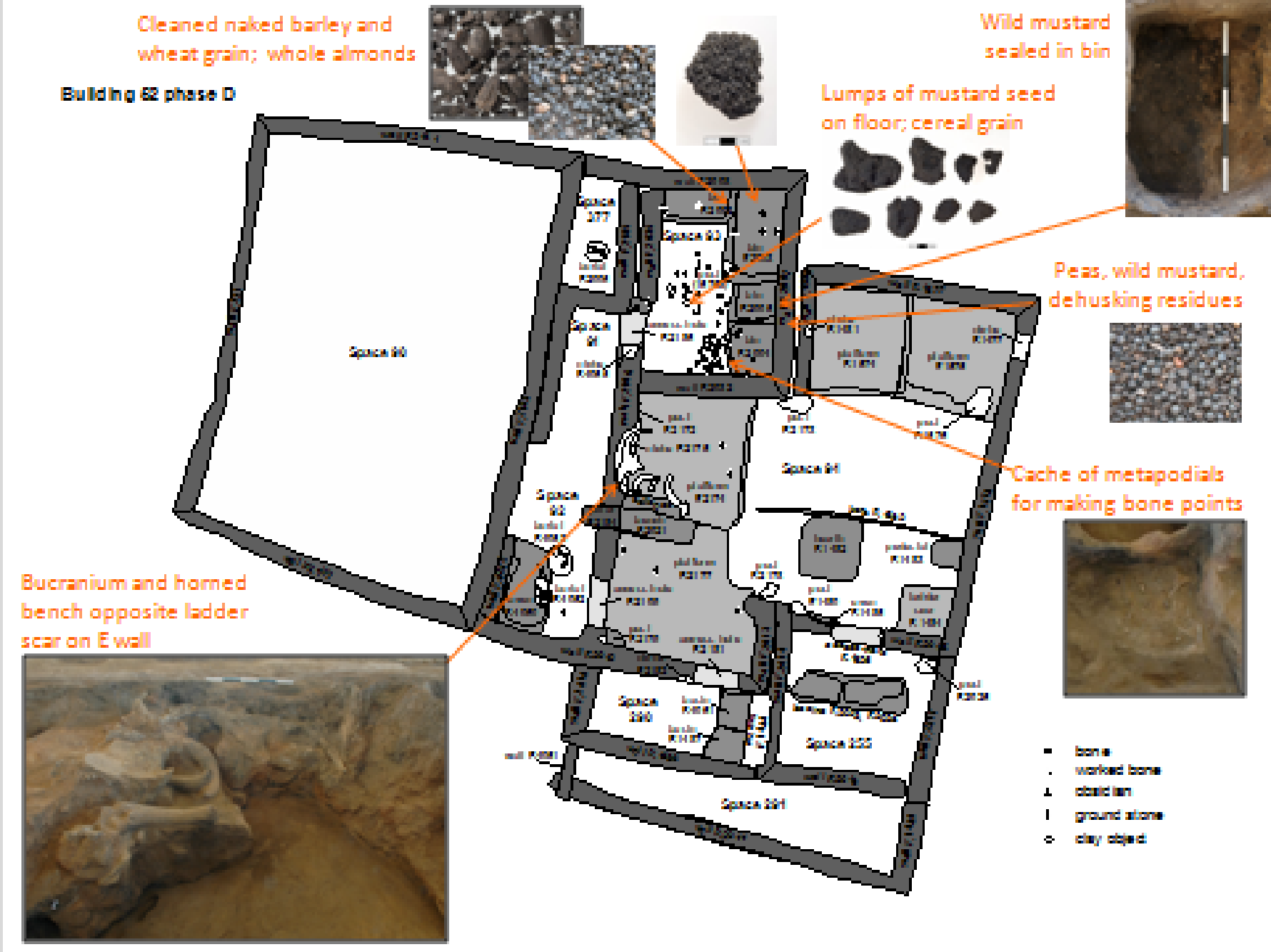


Figure 8. Communal building 30 was semi-subterranean and divided into cells. It was surrounded by habitation structures such as houses 10 and 54. The cells are interpreted as being communal storage structures. The photograph shows the opening into one of the storage structures, used to remove grain.

Communal storage wilox 2012

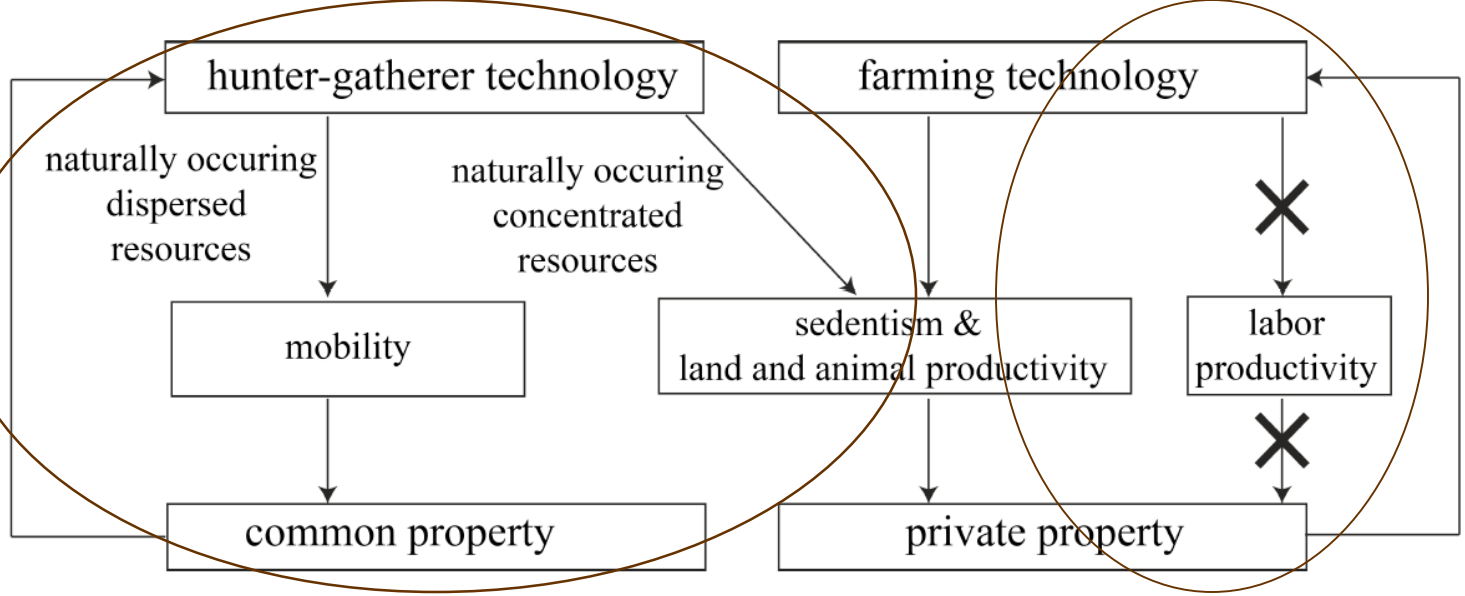


Private storage (Amy Bogaard, personal communication)

An alternative explanation: not exogenous ‘drivers of history” but a co-evolutionary process (to be modeled as a phase transition in a *stochastic Markov process* with multiple stationary states).

- A reduction of climatic volatility allowed a more sedentary livelihood,
- …contributing to conditions for an evolutionarily stable private property regime (defensible wealth) prior to farming.
- This could have occurred among groups of hunter-gatherers occupying sites with highly productive concentrated resources which could be delimited and defended.
- If some of these sites were suitable for food production, the emergence of farming would then have been possible even without a productivity advantage.
- This could occur if the private property with farming package limited the costs that farmers incurred in their conflicts with others.

the coevolution of technology and institutions



- The puzzle restated: A land-saving labor intensive technology(farming) proliferated in a land-abundant economy
- ….because by making small parcels of land, stores, and groups of animals valuable enough to demarcate and defend it facilitated the spread of private property rights,
- …which in turn facilitated the spread of farming
- ..which in turn facilitated the spread of private property
- Modeling this co-evolutionary process …

To explore the alternative explanation:

- This occurred before states: the model needs to represent a substantially un-coordinated process (evolutionary game theory in large populations, not classical game theory with a few hypothetical "collective" actors)..
- ..of individual perturbed myopic best response adoption of behaviors representing alternative institutions and technologies
- Due to strategic complementarities, the resulting stochastic Markov process may have multiple stationary states, termed institutional-technology conventions…
- … that might have characterized both the forager economy and social system and the farming economy that would eventually replace it.
- … phase transitions among which due to idiosyncratic play may have been facilitated by climatic change shrinking the basin of attraction of the convention of the the forager economy and society.
- To do this we need a model of technology and institutions and their coevolution.

Civics and bourgeois/Foragers and Farmers

- Adaptation of Maynard Smith's Hawk Dove Bourgeois game
- Two behavioral strategies for dividing output: Civic and Bourgeois
  - Bourgeois: claim full ownership (play Hawk) if in possession of the output; do not contest possession of another (play Dove) unless possession is ambiguous).
  - Civic conditions his action not on possession but on the reputation of the other, who may bear a stigma if in the past he has not shared: share (play Dove) unless the other bears the stigma, otherwise contest (Hawk)

Row payoffs in the Hawk Dove Game v-c < 0

	H	D
H	$\frac{v-c}{2}$	v
D	0	$\frac{v}{2}$

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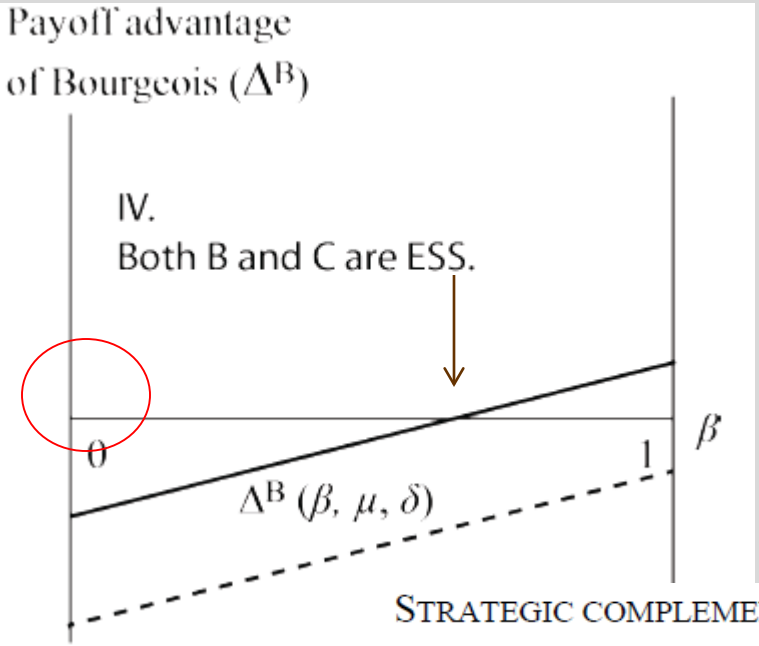
- Two technologies: Foraging and Farming
- Farming differs from foraging in that
  - possession of farmed goods is less ambiguous and therefore less likely to be contested, and
  - farming requires a prior investment which is lost in an unsuccessful contest, making farming more dependent on the recognition of possession based property by the fraction Bourgeois in the population.

Impediments to a transition: the evolutionary stability of the forager economy and society.

- Two recurrent classes: Civic Foragers and Bourgeois Farmers
- In social science terms these are technology-institutional conventions.
- Transition from the former must pass two critical points
  - B_a* the minimum number of Bourgeois such that the expected payoffs to farming exceed the payoffs to foraging.
  - B_B* the minimum number of Bourgeois such that the expected payoffs to Bourgeois exceed the expected payoffs to Civic
- Where the number of B's is less than the critical points, the deterministic (best response) dynamic reduces the number of farmers and bourgeois; for numbers greater, the opposite.
- Our results concern the process by which the first passage time to these two critical points could have been reduced

The Problem: Strategic complementarities

β = fraction Bourgeois in the population



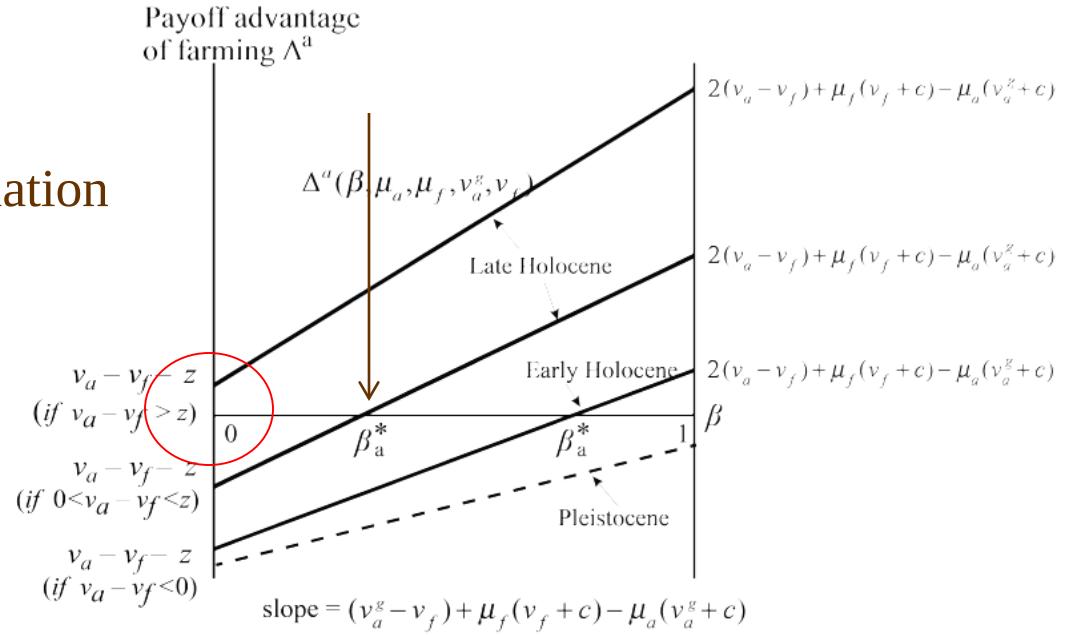


FIGURE 7 –. Why institutional innovation was a precondition for the Neolithic agricultural revolution.

STRATEGIC COMPLEMENTARITIES IMPEDING THE NEOLITHIC AGRICULTURAL REVOLUTION

Complementarity	*Economics*	*Result*
Bourgeois strategies are strategic complements	Payoffs to Bourgeois increasing in β	If Proposition 1 holds, then $\delta > \mu/(1+\mu)$ so from Eq. (4): $\partial\Delta^B(\beta,\delta,\mu)/\partial\beta > 0$
Farming and Bourgeois are strategic complements, I	Relative payoffs to farming increasing in β	If Proposition 2 holds: $\partial\Delta^a(\beta,\mu_a,\mu_f,v_a^g,v_f)/\partial\beta > 0$
Farming and Bourgeois are strategic complements, II	Relative payoffs to Bourgeois decreasing in μ	Given A2, from Eq (4) & (7): $\partial\Delta^B(\beta,\mu,\delta)/\partial\mu > 0$.

Transitions

$$\psi(\Delta^B(\beta,\delta,\mu),\phi) = \frac{1}{1+e^{\phi\Delta^B(\beta,\delta,\mu)}}$$

- Idiosyncratic (non-best response) play by the logit rule (Blume, 2003, etc, more costly deviations are less likely).
- Climate amelioration reduces the number of idiosyncratic plays of Bourgeois sufficient to “escape” the basin of attraction of the all Civic (forager) stationary state.
- And it also reduces the cost of playing idiosyncratically, hence increases the rate of idiosyncratic play.
- The result is a reduction in the first passage time to the two critical values.
- Given the two (interior) stationary points there are four passages – from civic foraging to bourgeois farming -- that could and did take place.

Four transitions away from the forager institutional-technology convention: model mechanisms and archaeological evidence.

- I. Natufian proto farming and return to hunting-gathering (SW Asia, 15kya)
- II. Coastal adaptation (Marean, 2015, e.g. Huaca Preita, Peru 7+kya).
- III. California native American populations (Bettinger, 2015)
- IV. Abu Hureyra (SW Asia, 11kya and subsequently)

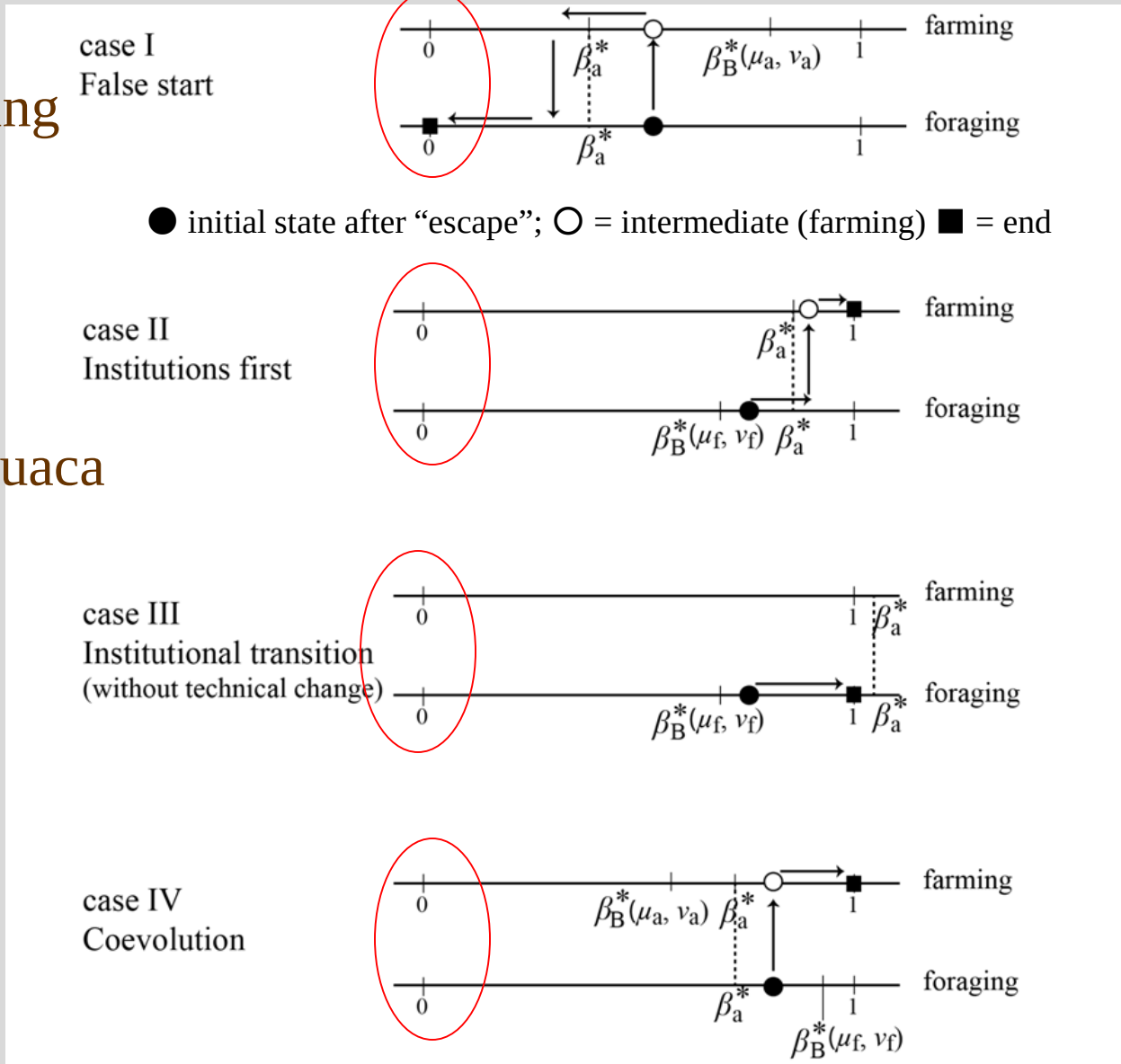
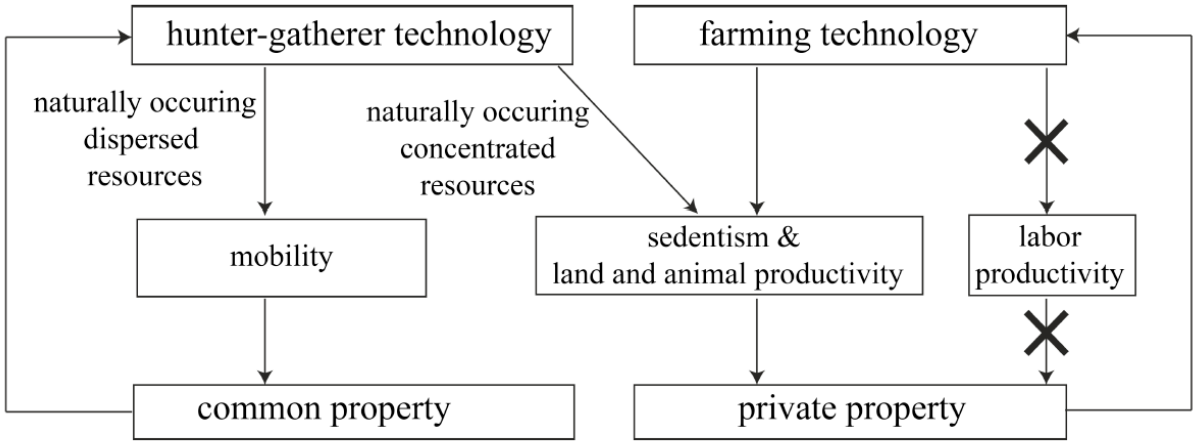


FIGURE 8 –. Technological and institutional transitions in the Neolithic revolution.

Take home:



- It was not its labor productivity properties that accounts for farming's early success, but instead the fact that it facilitated the adoption of private property because of its land and animal productivity attributes (allowing the demarcation and defense of private ownership), and this reduced within group costly conflicts.
- Private property emerged independently of the advent of farming largely in response to the sedentism made possible by climate amelioration.
- If technical change was involved it was in foraging, not farming (gazelle traps in Abu Hureyra, bow and arrow in California).

Institutions and technology, again

- Did the *the steam mill, give you society with the industrial capitalist ?*
- Or was it the other way around: factories before the industrial revolution. (Marglin)?
- Applications to the current trend towards an knowledge intensive economy
- Is a new software app or a hit song like a cow (private ownership is evolutionary stable and efficient) or like a kudu?

Our project: to explore the implications of recent research in contract theory, evolutionary economics and behavioral economics for standard questions in economic history, labor economics, international trade, public economics, and other fields of economics as well as law and political philosophy.


Park


Oh


Belloc


Naidu

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Bogaard

Hwang

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- Today: The co-evolution of technology and institutions

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The coevolution of institutions and preferences working group at SFI

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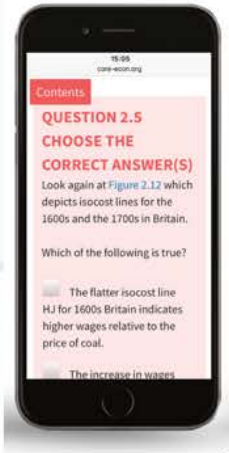

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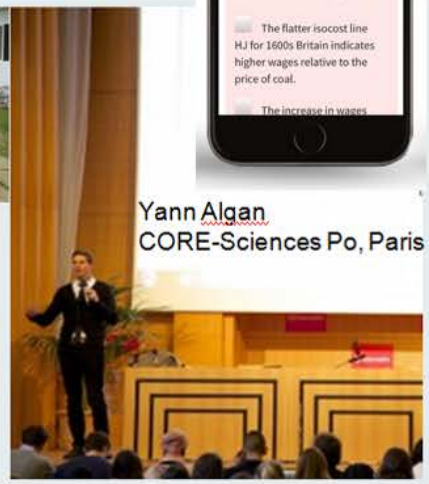

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Samuel Bowles
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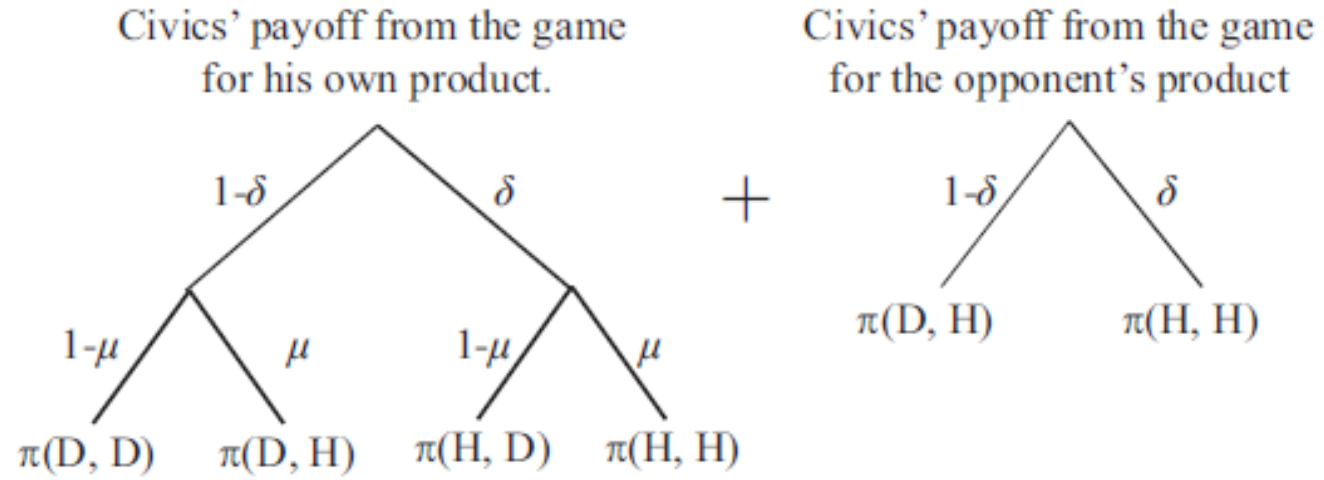

	H	D
H	$\frac{v-c}{2}$	v
D	0	$\frac{v}{2}$

$$
\begin{aligned}
r(C,C|\delta,\mu) &= [\pi(D,D)] + [\pi(D,D)] \\
r(C,B|\delta,\mu) &= [(1-\delta)\left((1-\mu)\pi(D,D) + \mu\pi(D,H)\right) + \delta\left((1-\mu)\pi(H,D) + \mu\pi(H,H)\right)] \\
&\quad + [(1-\delta)\pi(D,H) + \delta\pi(H,H)] \\
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&\quad + [(1-\delta)\left((1-\mu)\pi(D,D) + \mu\pi(H,D)\right) + \delta\left((1-\mu)\pi(D,H) + \mu\pi(H,H)\right)] \\
r(B,B|\delta,\mu) &= [(1-\mu)\pi(H,D) + \mu\pi(H,H)] + [(1-\mu)\pi(D,H) + \mu\pi(H,H)]\,.
\end{aligned}
$$

Evolutionary Dynamics of the Fraction Bourgeois

Proposition 1

For $\delta > \frac{v+\mu v}{2v+c+\mu c}$ *and* $\mu < \frac{(c-2v)\delta+v}{(2-\delta)c-v}$ *there exists*

$$\beta_B^* = \frac{\delta\left((1-\mu)v + (1+\mu)(v+c)\right) - (1+\mu)v}{2c(\delta + \delta\mu - \mu)}$$

in (0,1), such that under a deterministic payoff-monotonic updating process β *increases if* $\beta > \beta_B^*$ *and decreases if* $\beta < \beta_B^*$.

Payoff Advantage to Farmers

Proposition 2

Given that $v_a - v_f < 0$, *there exists*

$$\begin{aligned}\beta_a^* &= -\frac{\left((v_a^g - z) - v_f\right) - z}{(v_a^g - v_f) + \mu_f(v_f + c) - \mu_a(v_a^g + c)} \\ &= -\frac{v_a - v_f - z}{v_a - v_f + z + \mu_f(v_f + c) - \mu_a(v_a + z + c)}\end{aligned}$$

in (0,1), if and only if $\mu_a \leq \frac{2(v_a - v_f) + \mu_f(v_f + c)}{v_a + z + c}$.