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Slavery and Other Property Rights[1]

NILS-PETTER LAGERLÖF
York University

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The institution of slavery is found mostly at intermediate stages of agricultural development and less often among hunter-gatherers and advanced agrarian societies. We explain this pattern in a growth model with land and labour as inputs in production and an endogenously determined property rights institution. The economy endogenously transits from an egalitarian state with equal property rights to a despotic slave society where the elite own both people and land; thereafter, it endogenously transits into a free labour society, where the elite own the land but people are free.

1. INTRODUCTION

One of the most significant institutional transformations of human societies involves property rights in man: slavery. It was not commonly practiced among hunter-gatherers, or in the most advanced agrarian societies. Rather, it has shown up mostly in societies at intermediate stages of pre-industrial development. We explain this pattern by linking slavery to property rights in another important production factor: land.

The basic idea is that the political institution of most historical societies can be characterized by the property rights of its political elite to land and to people, that is: to land only, to both, or to none. We argue that distinct patterns in the long-term evolution of property rights can be discerned throughout human history. Most human societies started off in a relatively egalitarian state as low-level technology and an abundance of land provided few incentives to enclose land. Over time, many of these societies transformed first into a state of despotism and slavery, with a political elite owning both people and land. Later, a transition was made into a free labour society, where the elite owned the land but people were much more free. We seek to set up a model that can replicate this three-stage process and other trajectories of institutional transformation. More precisely, we want to model these transitions *endogenously*, and using a setting where the factors driving them, growth in population and technology, are endogenous as well.

The starting point of our model is that a society's property rights institution at a given stage of development is chosen by its elite. There are two production factors, land and labour. How these are owned defines the institution. Under slavery, the elite own both the land and their subjects' labour. This not only carries the cost of keeping some agents as non-productive guards but also enables the elite to pay workers less than their marginal product. Another institution is that of free labour, where the elite own the land but the subjects supply their labour on a free market, being paid their marginal product. The third institution is an egalitarian society where the elite and the subjects divide land (or output) equally.

The elite's preferred institution depends on two state variables: land productivity and population size. Slavery dominates when land productivity is high enough and population density is at intermediate levels: not too high, not too low. For densely populated societies, where free

1. Previous versions of this paper have circulated under the titles "The Roads To and From Serfdom" and "Slavery".

workers are relatively cheap, free labour pays better than slavery. In sparsely populated societies, the opportunity cost of workers is high, and an egalitarian structure dominates. Our model thus suggests that population growth has played different roles in history. It is initially a factor transforming egalitarian societies into slave societies, and later, a factor driving the transition from slavery to free labour.

This brings us to the dynamic component of our model: the joint evolution of agricultural technology and population. First, consistent with the type of pre-industrial societies we are describing, we let children be a normal good. This gives the model the *Malthusian* feature that higher *per capita* incomes induce higher fertility and faster population growth. Second, we also allow for a *Boserupian* effect: population pressure spurs agricultural technological progress (cf. Boserup, 1965).

The result is a feedback loop in which the economy moves endogenously from a state of low population density and simple agricultural technology towards increasingly dense population and more productive ways to use of land. In this process, the institution changes endogenously from egalitarianism, to slavery, and to free labour, similar to long-run trends described above.

The model seems broadly consistent with many other historical observations. For example, under slavery, reproductive success (fertility) is more unequally distributed across agents than under egalitarianism and free labour. This is consistent with slave societies being more polygynous than both hunter-gatherer societies and the type of free labour societies that we live in today (Betzig, 1986; Wright, 1994; Lagerlöf, 2005). Another result is that if an initially densely populated group of societies colonizes a sparsely populated land mass, it may switch from free labour to slavery, as happened when Europeans discovered the Americas.

However, the theory described so far has one shortcoming: if the economy were to experience a slowdown in population growth and/or an acceleration in technological progress (an industrial revolution and a demographic transition), it would re-enter (or never leave) the slavery regime. This is avoided in an extended setting where guarding costs rise with the level of development (technology).

The rest of this paper is organized as follows. This section continues by discussing some previous literature (Section 1.1) and long-run property rights trends (Section 1.2). Section 2 sets up the model. We first derive the payoffs to the elite when choosing each of the three institutions and then compare these payoffs to analyse what institution is chosen at any given levels of agricultural technology and population. In Section 3, the dynamics of population and agricultural technology are derived, showing how these state variables evolve over time and generate transitions from one type of institution to another. Section 4 discusses how the model fits with some other historical evidence, and—when it does not—sketches possible extensions. Section 5 concludes.

1.1. *Previous literature*

Existing theories of very long-run social evolution are often crafted outside the discipline of economics. These do not make use of explicit models and typically do not focus on slavery as such (*e.g.* Flannery, 1972; Diamond, 1997). One theory specifically about slavery is that of Domar (1970). In his reasoning, population density was a force behind the downfall of slavery, as it is in our model. Different from us, however, Domar treats population as exogenous. In reality, as in our model, rising population density seems to be due to improved technologies in food production, and technological change may in and by itself impact the viability of a slave institution, as suggested by, for example Fenoaltea (1984). Abstracting from this, Domar is not able to explain the rise of slavery, or why sparsely populated hunter-gatherer societies so rarely use slavery (cf. the critique in Patterson, 1977). However, all this is accounted for in our model.

Aside from the general theories of Domar (1970) and Fenoaltea (1984), many economic historians have studied plantation slavery in the U.S. South,[2] and the rest of the Americas.[3] Our aim was to model the rise and fall of slavery in world history, and over time spans stretching back before the invention of agriculture.

There is also work on the micro-economics of slavery. Bergstrom (1971) and Findlay (1975) analyse, *inter alia*, slaves' incentives to work when they can buy their freedom. Genicot (2002) analyses bound labour as an *ex ante* voluntary choice. These papers take the slave system as given and do not attempt any macro-economic explanation of its rise or fall. Conning (2007) uses a general-equilibrium framework, formalizing many of the mechanisms discussed by Domar (1970). The model of Conning (2007) is in many ways much richer than ours, but the framework is static, and fertility and population are treated as exogenous. In that sense, it is complementary to ours. (See also Conning, 2003.)

Contractual relationships between land and labour in agricultural economies is the subject of a large literature (see, *e.g.* Banerjee, Gertler and Ghatak, 2002; Conning and Robinson, 2007; and further references therein). However, this literature does not share our very long-run perspective, going back to pre-agricultural times, and typically abstracts from property rights in humans (slavery) and how demographic and technological change can cause transitions from one institution to another.[4]

Theories on the origin of property rights include Demsetz (1967), who proposes that property rights arise when the costs associated with their establishment are outweighed by the tragedy-of-the-commons problems in their absence. As illustration, he suggests the Montagnes Indian tribe in Quebec, who developed property rights to hunting territory when game became susceptible to overhunting following the rise of the fur trade. Our explanation rather focuses on the redistributive role of property rights.

Our paper also relates to a recent literature on long-run economic and demographic development. We share some single components with this literature, like the focus on land and agriculture (Kögel and Prskawetz, 2001; Gollin, Parente and Rogerson, 2002; Hansen and Prescott, 2002; Lucas, 2002), fertility (Galor and Weil, 2000; Jones, 2001; Tamura, 2001; Galor and Moav, 2002; Lagerlöf 2003*a*, 2003*b*, 2005; Galor and Mountford, 2006), and institutions (Acemoglu, Johnson and Robinson, 2001, 2002, 2005; Acemoglu and Robinson, 2006). However, none of these papers models endogenous institutional transformations of human societies.

In that regard, our modelling approach is conceptually closer to a literature on the origin of property rights. (See, *e.g.* Skaperdas, 1992; Hirshleifer, 1995; Grossman, 2001; Piccione and Rubinstein, 2007; and Hafer, 2006.) The central theme that we share with these papers is that the exogenous component is not the property rights institution itself but rather the technologies used in appropriation and production. Appropriation in our model amounts to enslaving an agent (*i.e.* stealing his labour), which requires an input of guards who do not produce food but still need to be fed.

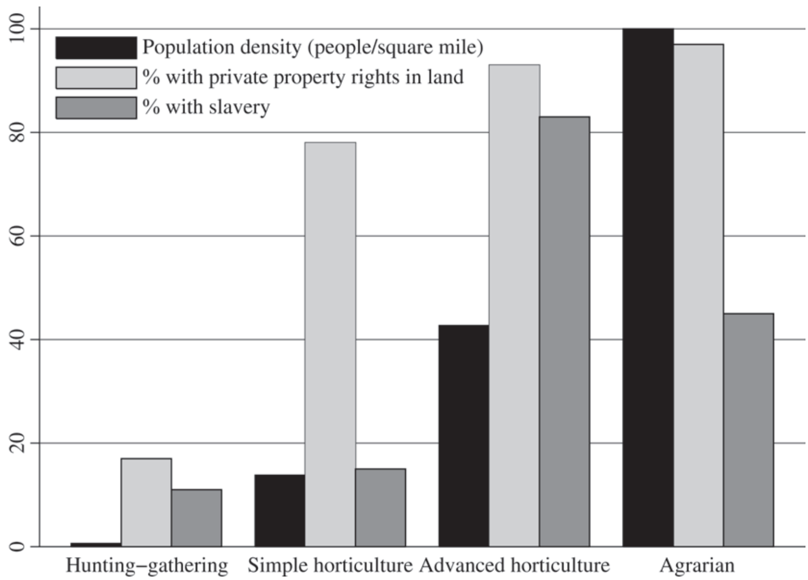
1.2. *Evidence*

Over the very long run, human societies have developed increasingly productive food procurement techniques: from hunting and gathering, via different stages of horticulture (farming

2. Some classic works are Conrad and Meyer (1958) and Fogel and Engerman (1974). For an overview, see Hughes and Cain (1998, ch. 10).

3. See, for example Curtin (1998). Sokoloff and Engerman (2000) discuss slavery in the context of Latin America's post-colonial growth experience.

4. See, however, Baker (2002) and Marceau and Myers (2006) for models of landownership in pre-agricultural environments.



Source: Nolan and Lenski (1999, pp. 107, 125, 144).

FIGURE 1

Population density and private property rights in land and people at different stages of long-run development

without ploughs, like "slash-and-burn" cultivation), to agriculture (plough-based farming). As food production has evolved, so have other features of human societies. Population has become denser and more stratified; gender roles in food production have changed; and we have seen several technological innovations, for example the use of metal weapons and tools. All these changes do not happen at exactly the same stage of agricultural development across societies and regions, but the trend tends to go in the same direction when going from one stage to the next, for example from low population density to higher (see Diamond, 1997; Flannery, 1972; Nolan and Lenski, 1999; Wright, 2000).

Slavery seems to be an exception. It was rarely practised among hunter-gatherers,[5] and often not among some very advanced agrarian societies: in Western Europe, serfdom (which can be thought of as a mild form of slavery) had been replaced by free labour several centuries before the industrial revolution. It is rather at intermediate levels of development that slavery shows up.

Consider some descriptive numbers based on the so-called Ethnographic Atlas, a data set consisting of some thousand human societies, both historic and present. Figure 1 shows how average population density, private property rights in land, and slavery vary across societies at different stages of agricultural development.[6] As seen, when transiting from hunting and gathering to agriculture, population density rises. This is not surprising: the more productive is agricultural technology, the more mouths can be fed. Figure 1 also shows that the percentage of societies in which private ownership in land is present increases in the process of agricultural development.

5. In the first chapter of "Time On the Cross", Fogel and Engerman (1974, p. 12) note that slavery "came into being at the dawn of civilization, when mankind passed from hunting and nomadic pastoral life into primitive agriculture".

6. The Ethnographic Atlas consists of some thousand human societies, both historic and present, and was compiled by Murdock (1967, see pp. 3–6 for details). The numbers cited here are from Nolan and Lenski (1999). Simple horticultural societies in Figure 1 are distinguished from advanced by the use of metallurgy in the latter.

Different from the case with private ownership in land, however, slavery, which essentially amounts to ownership of people, is most common among advanced horticultural societies and less common among both hunter-gatherers and agrarian societies.

The pattern for slavery in Figure 1 would be even clearer if we introduced a final industrial stage, at which slavery had vanished altogether. One could then describe the facts so that slavery *began* its decline in the agrarian stage, and ended it in the industrial stage. (The extension presented in Section 4.3 could be interpreted as capturing the transition into an industrial stage.)

With some simplification, one may thus describe this long-run process as passing through three stages. The first is an egalitarian stage, without private property rights in land or people. The second stage is a slave society where both humans and land are held as private property. At the final stage, land is owned but ownership to humans (slavery) is not practised. In the next section, we set up one unified growth model that can replicate the transition through each of these three stages.

2. THE MODEL

There are several land areas, or societies, each populated in period t by a continuum of (adult) agents of mass P_t, referred to by the male pronoun. A finite number of these agents belong to an internal elite, who do not work. The remainder are referred to as non-elite agents. Both internal elite and non-elite agents live in overlapping generations for two periods, adulthood and childhood. Children make no decisions but carry a cost q to rear.

Outside each society lives an "external" elite of mass 1, who may be thought of as a foreign power. These agents are identical to the internal elite (*e.g.* they do not work), except that they are infinitely lived (which serves to simplify the analysis of the population dynamics later). The external elite also lack influence over the choice of institution; that choice rests solely with the internal elite. However, the internal elite need the help of the external elite to seize ownership of the land and must in that event share profits with them. One interpretation is that the internal elite supply local knowledge, and/or some measure of legitimacy, needed to exploit the non-elite agents. The external elite, although more numerous than the internal elite, cannot wield power over the internal elite and non-elite agents if they are united.[7]

The distinction between an internal and an external elite is not important for the results, but it will be seen later to simplify the analysis. Because the external elite carry mass 1, and the internal elite are a finite number of agents and thus carry zero mass, we can think of these as one single-elite group that changes size (from 0 to unit mass) at the moment they seize ownership of the land. Put another way, the cost to the internal elite of expropriating the land from the non-elite agents is that they must share the profits with an external elite.

Adult agents spend income on own consumption and child rearing. For the moment, denote this income by w_t. We can then write an agent's budget constraint as:

$$c_t = w_t - qn_t, \tag{1}$$

where c_t is his consumption and n_t is his number of children.

Labour supply is indivisible, so that a (non-elite) agent supplies either one unit of labour, or none. Work requires energy: the agent must eat a certain amount of food, $\overline{c}$, to be able to work. We call $\overline{c}$ subsistence consumption. To capture this, we let preferences take this form:

$$V_t^{\text{work}} = \begin{cases} (1-\beta)\ln c_t + \beta \ln n_t & \text{if } c_t \geq \overline{c}, \\ -\infty & \text{if } c_t < \overline{c}. \end{cases} \tag{2}$$

7. The Parthian empire, ruling Mesopotamia over a few centuries BC and AD, let the regions it occupied be administrated by the local elite (see, *e.g.* Colledge, 1967, ch. 4). A more recent example is the reliance of European colonial powers on local elites and tax collection networks in many of their colonies (see, *e.g.* Acemoglu *et al.*, 2002).

Solving the utility maximization problem amounts to maximizing the first line in equation (2), subject to the constraint that $c_t \geq \overline{c}$ (and whatever other constraints are relevant).

For an agent who is not working (which would here be the internal and external elites) the first line in equation (2) extends to the case when $c_t < \overline{c}$:[8]

$$V_t^{\text{no work}} = (1-\beta)\ln c_t + \beta \ln n_t. \tag{3}$$

2.1. *The three institutions*

The internal elite in each society choose one of three institutions. Under an *egalitarian institution*, output (or land) is divided equally among non-elite agents and the internal elite; the external elite get nothing.[9] The other two institutions amount to the internal elite joining the external elite to enclose (seize exclusive ownership of) the land. Under a *slavery institution*, they own *both* the land *and* the non-elite agents' labour, making the non-elite agents slaves. These must be paid subsistence to be able to work, as must a fixed number of guards per slave. Under a *free labour institution*, the non-elite agents own their own labour and can migrate to work in other societies, thus earning the marginal product of labour.

2.2. *Production and the timing of events*

Total output in period t, Y_t, depends on the society's total amount of land, M; agricultural productivity, $\widetilde{A}_t$; and the amount of labour working the land, L_t:

$$Y_t = (M\widetilde{A}_t)^{\alpha} L_t^{1-\alpha} \equiv A_t^{\alpha} L_t^{1-\alpha}, \tag{4}$$

where $\alpha \in (0,1)$ is the land share of output and $A_t = M\widetilde{A}_t$ denotes the productivity-augmented size of the land. In other words, A_t can increase either due to a rise in the productivity of land or due to an increase in the amount of available land (*e.g.* the discovery of new continents). In what follows, we shall refer to A_t as technology for short.

In each period and in each society, events unfold as follows. Taking as given A_t and P_t, the internal elite first decide whether or not to enclose the land. Enclosing the land requires the help of the external elite, who share the profits, thus imposing a cost of the enclosure. After the enclosure, the internal elite choose either slavery or free labour. If the internal elite choose no enclosure (egalitarianism), they share output equally with the non-elite agents; the external elite get nothing. Given their incomes, non-elite agents and the internal and external elite make consumption and fertility decisions. Fertility decisions update population to P_{t+1}, and a technology production function updates technology to A_{t+1}.

In what follows, unless otherwise stated, the term "elite" refers to the internal elite if the institution is egalitarianism and to the internal and external elite collectively if the institution is slavery or free labour. By "agents", we shall mean non-elite agents when there is no risk of confusion.

2.3. *The elite's payoff*

Denote the (internal) elite's payoff by π_t^i, where i indicates the institution: egalitarianism ($i = E$), free labour ($i = F$), and slavery ($i = S$).

8. The distinction between working and non-working agents' utilities is not crucial for any of our results but simplifies the algebra when comparing payoffs later. In particular, as long as the non-working agent earns an income above $\overline{c}/(1-\beta)$, this distinction will not matter.

9. We can interpret the model so that the internal elite can work under the egalitarian institution, which can then be thought of as equal division of land, rather than output.

To make these payoffs easy to derive, we impose assumptions that imply that agents can migrate only between free labour societies. Migration is not allowed into egalitarian societies because (as is seen) all agents in those societies have an interest in preventing immigration, as it makes them all worse off. Likewise, agents have no incentives to migrate out of an egalitarian society into a free labour or slave society, where they would earn less. Migration out of slave societies is not allowed by definition, and no agent would want to migrate into a slave society either.

Since there is no migration into or out of egalitarian and slave societies, those payoffs can be derived as if the society were autarchic. To calculate the payoff under free labour, we let the elite take as given a wage rate that is determined on an inter-society free labour market.

2.3.1. Payoff in a free labour society. Consider first the free labour institution. Here, the (internal and external) elite own all land. Agents are landless but can migrate across societies. As a result, the elite hire labour on a competitive market taking the wage rate, w_t, as given.[10] Their payoff is thus given by:

$$\pi_t^F = \max_{L_t \geq 0}\{A_t^{\alpha} L_t^{1-\alpha} - w_t L_t\}. \tag{5}$$

Solving this maximization problem, demand for free labour becomes:

$$L_t = \left(\frac{1-\alpha}{w_t}\right)^{\frac{1}{\alpha}} A_t. \tag{6}$$

Substituting back into equation (5) gives the payoff as a function of the equilibrium wage, w_t:

$$\pi_t^F = \alpha \left(\frac{1-\alpha}{w_t}\right)^{\frac{1-\alpha}{\alpha}} A_t. \tag{7}$$

Recall that an agent must eat $\overline{c}$ to be able to work, so supply of labour (from each free labour society) is given by:

$$L_t = \begin{cases} P_t & \text{if } w_t \geq \overline{c}, \\ 0 & \text{if } w_t < \overline{c}. \end{cases} \tag{8}$$

There are two cases to consider. Let *Case A* refer to a situation where the wage rate covers subsistence consumption, $w_t \geq \overline{c}$. In this case, P_t agents from each free labour society supply labour. Denoting the number of societies choosing free labour by N_t, total supply of free labour equals $N_t P_t$. Labour demand in each free labour society is given by equation (6), and there are N_t such societies. Thus, aggregate labour demand across all societies becomes $N_t[(1-\alpha)/w_t]^{1/\alpha} A_t$. Equalizing supply and demand (*i.e.* setting $N_t P_t = N_t[(1-\alpha)/w_t]^{1/\alpha} A_t$), the N_ts cancel, and we get the wage rate as $w_t = (1-\alpha)(A_t/P_t)^{\alpha}$. Together with equation (7), this gives:

$$\pi_t^F = \alpha A_t^{\alpha} P_t^{1-\alpha}. \tag{9}$$

In *Case B*, the wage rate is constrained to subsistence, $w_t = \overline{c}$, so it follows directly from equation (7) that:

$$\pi_t^F = \alpha \left(\frac{1-\alpha}{\overline{c}}\right)^{\frac{1-\alpha}{\alpha}} A_t. \tag{10}$$

10. The free labour institution is here modelled as each member of the elite running a farm as his own estate. Equivalently, given the constant-returns-to-scale production function, agents could rent land from the elite.

Using $w_t = (1-\alpha)(A_t/P_t)^\alpha$, it is seen that $w_t > (=)\bar{c}$ when $A_t > (\leq)[\bar{c}/(1-\alpha)]^{1/\alpha} P_t$. If $A_t \leq [\bar{c}/(1-\alpha)]^{1/\alpha} P_t$, then π_t^F is given by equation (10); else π_t^F is given by equation (9). We can thus write:

$$\pi_t^F = \begin{cases} \alpha A_t^\alpha P_t^{1-\alpha} & \text{if } A_t > \left[\frac{\bar{c}}{1-\alpha}\right]^{\frac{1}{\alpha}} P_t, \\ \alpha \left[\frac{1-\alpha}{\bar{c}}\right]^{\frac{1-\alpha}{\alpha}} A_t & \text{if } A_t \leq \left[\frac{\bar{c}}{1-\alpha}\right]^{\frac{1}{\alpha}} P_t. \end{cases} \tag{11}$$

Note that this payoff does not depend on the number of elites choosing free labour, N_t. Intuitively, when the elite in one society let their agents free, this increases the total labour supply from which other elites hire their workers. At the same time, when choosing the free labour institution, the elite automatically enters the labour market as a buyer, thus increasing demand. Since all societies are identical, the net effect on prices and profits is zero.

2.3.2. Payoff in a slave society. Consider next the slavery institution. Like under free labour, the (internal and external) elite own all land, but now non-elite agents are slaves. Each slave is paid the minimal amount required to keep him productive, $\bar{c}$. To prevent slaves from running away requires γ agents to guard each slave. We let each guard's consumption be kept to the same level as that of the slaves, $\bar{c}$.[11] Then the cost of keeping S_t slaves equals $(1+\gamma)\bar{c}S_t$.

As is seen, to ensure that slavery can ever dominate the other two institutions, we must assume that the guarding cost is not too high.

Assumption 1. $\alpha(1+\gamma)^{1-\alpha} < 1$.

Under slavery, the elite can dispose freely of agents, and not all need to be held as slaves or guards; some may be abandoned or left to starve. The maximum number of slaves is restricted by the number of agents, P_t, minus the guards needed to watch over them (which, recall, amounts to γ per slave). Therefore, the number of slaves cannot exceed $P_t/(1+\gamma)$, so the payoff under slavery is given by:

$$\pi_t^S = \max_{S_t \leq P_t/(1+\gamma)} \{A_t^\alpha S_t^{1-\alpha} - (1+\gamma)\bar{c}S_t\}. \tag{12}$$

Let S_t^* denote the unconstrained choice of S_t in equation (12) above, given by $(1-\alpha) A_t^\alpha S_t^{-\alpha} - (1+\gamma)\bar{c} = 0$, that is:

$$S_t^* = \left[\frac{1-\alpha}{(1+\gamma)\bar{c}}\right]^{\frac{1}{\alpha}} A_t. \tag{13}$$

The elite are unconstrained if the desired number of slaves, plus the γS_t^* guards needed to guard them, are fewer than the total population.[12] This holds if $S_t^*(1+\gamma) \leq P_t$, or:

$$A_t \leq \left(\frac{1}{1+\gamma}\right)\left[\frac{\bar{c}(1+\gamma)}{1-\alpha}\right]^{\frac{1}{\alpha}} P_t \equiv \Gamma(P_t;\gamma). \tag{14}$$

11. We thus assume that guards are slaves too and that they (like workers) must be watched over by other guards. More precisely, let $\tilde{\gamma} < 1$ be the number of guards needed to watch each slave (guard or worker). The cost of keeping S_t working slaves then becomes:

$$\bar{c}S_t + \bar{c}\tilde{\gamma}S_t + \bar{c}\tilde{\gamma}^2 S_t + \ldots = \bar{c}S_t/(1-\tilde{\gamma}),$$

which is equivalent to our formulation, if $\gamma = \tilde{\gamma}/(1-\tilde{\gamma})$.

12. It can be seen that in this case, slavery will be dominated by free labour.

Call this *Case 1*. This amounts to keeping S_t^* agents as slaves and γS_t^* guarding the slaves; the remainder are not used as either guards or workers. The payoff is then given by $A_t^{\alpha} S_t^{*1-\alpha} - (1+\gamma)\overline{c}S_t^*$, which together with equation (13) and some algebra gives:

$$\pi_t^S = \alpha \left[\frac{1-\alpha}{(1+\gamma)\overline{c}} \right]^{\frac{1-\alpha}{\alpha}} A_t. \tag{15}$$

Next, consider *Case 2*, where the elite are constrained (*i.e.* $A_t > \Gamma(P_t;\gamma)$]. Thus, $P_t/(1+\gamma)$ agents are kept as slaves and the remainder used for guarding the slaves. The payoff is thus given by:

$$\pi_t^S = A_t^{\alpha} \left(\frac{P_t}{1+\gamma} \right)^{1-\alpha} - \overline{c}P_t. \tag{16}$$

We can thus write:[13]

$$\pi_t^S = \begin{cases} A_t^{\alpha} \left(\frac{P_t}{1+\gamma} \right)^{1-\alpha} - \overline{c}P_t & \text{if } A_t > \Gamma(P_t;\gamma), \\ \alpha \left[\frac{1-\alpha}{(1+\gamma)\overline{c}} \right]^{\frac{1-\alpha}{\alpha}} A_t & \text{if } A_t \leq \Gamma(P_t;\gamma). \end{cases} \tag{17}$$

2.3.3. Payoff in an egalitarian society. Consider finally the egalitarian institution. Here, each agent consumes the average product, and the (internal) elite's payoff is the same as that of the non-elite agents, and given by:[14]

$$\pi_t^E = A_t^{\alpha} P_t^{-\alpha}. \tag{18}$$

We implicitly assume that agents are able to work earning the average product ($A_t^{\alpha} P_t^{-\alpha} \geq \overline{c}$). We can indeed choose initial conditions, (A_0, P_0), to ensure that this holds along the whole path (see Section 3.3 below).

As long as $A_t > [\overline{c}/(1-\alpha)]^{1/\alpha} P_t$ (and thus $w_t > \overline{c}$), total output equals $A_t^{\alpha} P_t^{1-\alpha}$ under both egalitarianism and free labour. There are no efficiency gains from the enclosure of the land, only redistribution of resources from non-elite agents to the elite.[15] As a corollary, workers are always better off under egalitarianism than under free labour: the average product, $(A_t/P_t)^{\alpha}$, always exceeds the marginal product, $(1-\alpha)(A_t/P_t)^{\alpha}$.[16] Thus, no agent would want to migrate from an egalitarian society to a free labour society (and obviously not to a society where they would become slaves and earn only $\overline{c}$).

Note also that the payoff in equation (18) is decreasing in P_t, due to a standard land-dilution effect. Thus, both non-elite agents and the internal elite have an incentive to prevent immigration of agents from other societies, as we assumed earlier that they did.

13. An alternative way to derive the payoff in eqaution (17) is to let slaves be traded on a market at an endogenously given slave price. The slave price being positive in equilibrium can then be seen to be equivalent to $A_t > \Gamma(P_t;\gamma)$ (see Lagerlöf, 2006).

14. This can be derived by dividing total output, $A_t^{\alpha} P_t^{1-\alpha}$, equally across all P_t agents (the internal elite and non-elite agents). Alternatively, each agent may be allocated property over a share $1/P_t$ of the (productivity augmented) land, A_t. With his unit time endowment he then produces $[(1/P_t)A_t]^{\alpha}(1)^{1-\alpha} = A_t^{\alpha} P_t^{-\alpha}$. The latter interpretation assumes that the (internal) elite can work under egalitarianism.

15. If $A_t < [\overline{c}/(1-\alpha)]^{1/\alpha} P_t$, output is in fact lower under free labour because not all agents can survive and work with a competitive wage; an enclosure is then associated with an efficiency loss.

16. This result relates to Samuelson's (1974) negative reply to the question "Is the Rent-Collector Worthy of His Full Hire?"

2.4. *Comparing payoffs*

The next step is to examine what payoff is larger: π_t^E, π_t^F, or π_t^S, as given by equations (11), (17), and (18), respectively.

Distinguishing between internal and external elites has served to make these payoff comparisons technically correct. Intuitively, the internal elite are a finite number of agents and thus vanishingly small compared to the non-elite population, so under egalitarianism, their share of the pie is also vanishingly small and always less than the non-negligible fractions taken under slavery and free labour. However, π_t^F and π_t^S in equations (11) and (17) are divided among a continuum of agents of mass 1, making them of the same order as π_t^E in equation (18). The elite effectively erupts onto the stage (changes size from zero to unit mass) when the society leaves the egalitarian institution and moves into slavery or free labour. The interpretation is that the internal elite decide what group to share output with: either the domestic non-elite agents (egalitarianism) or an external elite (landownership).[17]

The payoffs all depend on agricultural technology, A_t, and population size, P_t (and exogenous parameters), which thus determine what institution dominates the other two. Begin by defining:

$$\Psi(P) = \left[\frac{\bar{c}(1+\gamma)^{1-\alpha}}{1-\alpha(1+\gamma)^{1-\alpha}}\right]^{\frac{1}{\alpha}} P, \tag{19}$$

where $1-\alpha(1+\gamma)^{1-\alpha} > 0$ follows from Assumption 1;

$$\Omega(P) = \left[\frac{\bar{c}(1+\gamma)^{1-\alpha} P^{1+\alpha}}{P-(1+\gamma)^{1-\alpha}}\right]^{\frac{1}{\alpha}}; \tag{20}$$

and

$$\Phi(P) = \left(\frac{1}{\alpha}\right)^{\frac{1}{1-\alpha}} \left[\frac{\bar{c}}{1-\alpha}\right]^{\frac{1}{\alpha}} P^{-\left(\frac{\alpha}{1-\alpha}\right)}. \tag{21}$$

These functions separate the state space into three sets:

$$\begin{aligned} \mathcal{S}^S &= \{(A,P) \in \mathbb{R}_+^2 : A \geq \max\{\Psi(P), \Omega(P)\} \text{ and } P > (1+\gamma)^{1-\alpha}\}, \\ \mathcal{S}^F &= \{(A,P) \in \mathbb{R}_+^2 : P \geq 1/\alpha \text{ and } \Phi(P) \leq A \leq \Psi(P)\}, \\ \mathcal{S}^E &= \{(A,P) \in \mathbb{R}_+^2 : (A,P) \notin \mathcal{S}^S \cup \mathcal{S}^F\}. \end{aligned} \tag{22}$$

We can now state the following (proven in the Appendix):

Proposition 1. *The payoffs associated with slavery, egalitarianism, and free labour are ordered as follows:*

(a) *Slavery (weakly) dominates when*

$$\pi_t^S \geq \max\{\pi_t^F, \pi_t^E\} \Longleftrightarrow (A_t, P_t) \in \mathcal{S}^S. \tag{23}$$

17. Alternatively, we could let there be only one elite carrying unit mass. If this elite can work under egalitarianism, total output equals $A_t^\alpha(1+P_t)^{1-\alpha}$ and the elite's payoff under egalitarianism becomes $\pi_t^E = A_t^\alpha(1+P_t)^{-\alpha}$. In such a setting, the qualitative results in Proposition 1 below still hold, but the analysis is more complicated. See Lagerlöf (2006).

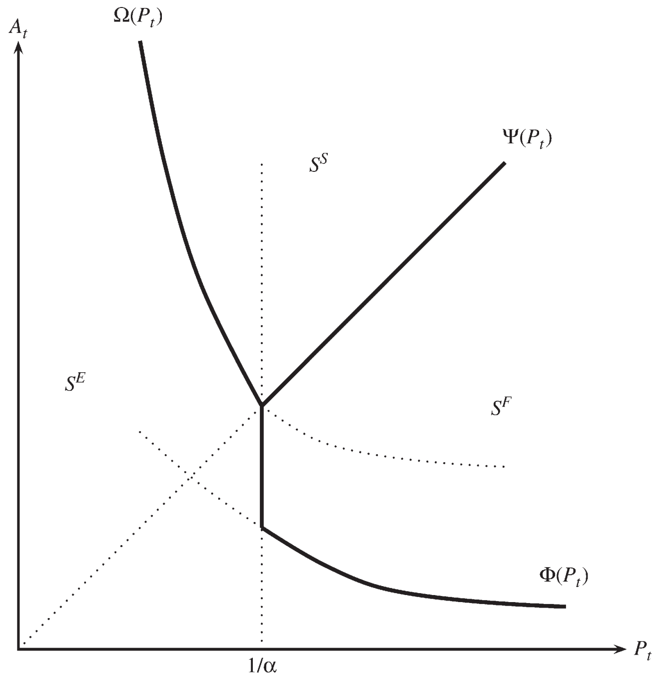


FIGURE 2
Institutional regions

(b) *Free labour (weakly) dominates when*

$$\pi_t^F \geq \max\{\pi_t^S, \pi_t^E\} \iff (A_t, P_t) \in \mathcal{S}^F. \tag{24}$$

(c) *Egalitarianism (strictly) dominates otherwise, that is when* $(A_t, P_t) \in \mathcal{S}^E$.

This is illustrated in Figure 2. The institutional borders are straightforward to derive when we know the relevant payoffs to compare. As shown in the Appendix, these are (with one exception): $\pi_t^S = A_t^\alpha[P_t/(1+\gamma)]^{1-\alpha} - \bar{c}P_t$, $\pi_t^F = \alpha A_t^\alpha P_t^{1-\alpha}$, and $\pi_t^E = A_t^\alpha P_t^{-\alpha}$. Some algebra then easily verifies that $\pi_t^S \geq \pi_t^F$ when $A_t \geq \Psi(P_t)$, $\pi_t^S \geq \pi_t^E$ when $A_t \geq \Omega(P_t)$ (if the denominator in equation (20) is positive; else $\pi_t^S < \pi_t^E$), and $\pi_t^F \geq \pi_t^E$ when $P_t \geq 1/\alpha$.[18]

Slavery thus dominates the other two institutions when $A_t \geq \Psi(P_t)$ and $A_t \geq \Omega(P_t)$, that is at high enough levels of land productivity, A_t, and intermediate population levels, P_t. The productivity of land determines the size of the pie to be split; the larger the pie, the greater is the reward to taking a larger fraction of it at the cost of diminishing its size a little, which is what slavery amounts to doing.

The impact of population size works through the marginal product of labour. If labour is scarce, keeping workers as unproductive guards is costly, so slavery is not an attractive option. Scarce labour also implies high wages and a low payoff to free labour. The internal elite may therefore prefer egalitarianism, that is sharing output communally with the non-elite agents.

18. When comparing the last pair of payoffs, the exception shows up: for free labour to dominate egalitarianism, $P_t \geq 1/\alpha$ is not sufficient. If the competitive wage rate is so low that it does not cover the subsistence consumption of free workers, the relevant payoff under free labour is given by the second line in equation (11). Egalitarianism then turns out to dominate free labour if $A_t \leq \Phi(P_t)$.

Abundant labour, by contrast, makes it attractive to own land. If labour is sufficiently abundant, free labour dominates slavery because of the low competitive price of free workers.

3. DYNAMICS

Having determined how the equilibrium institution depends on population and agricultural technology, we next examine how these evolve over time.

3.1. *Agricultural technology*

We let A_t evolve according to:

$$A_{t+1} = \overline{A} + D(A_t - \overline{A})^{1-\theta} P_t^{\theta}, \tag{25}$$

where $D > 0$, $\theta \in (0, 1)$, and $\overline{A} > 0$ is a minimum level of agricultural technology imposed to ensure the existence of steady states with non-growing levels of A_t and P_t.

The Boserupian feature of this relationship is that A_t grows faster the higher is population pressure, that is when P_t is large relative to A_t. One example could be the very birth of farming, which may have followed the extinction of big mammals, like the mammoth (Smith, 1975, 1992). Other examples could be intensified land use, or rising cropping frequency, in response to increasing population density in agricultural societies. It could also capture a scale effect from population density to technological progress (see, *e.g.* Kremer, 1993; Nestmann and Klasen, 2000; Lagerlöf, 2003*a*).

3.2. *Population*

The population dynamics are more complicated since fertility depends on total income, how it is allocated (*i.e.* the institution), and whether or not the subsistence consumption constraint binds for non-elite agents. However, we can impose a parametric restriction, which implies that when it does bind, population is falling (see Assumption 2 below).

3.2.1. Population dynamics in a free labour society. The landowning (internal and external) elite have $n_t^{\text{landowner}}$ children and the P_t workers have n_t^{worker} children. Population dynamics are thus given by:

$$P_{t+1} = n_t^{\text{worker}} P_t + n_t^{\text{landowner}}. \tag{26}$$

To interpret equation (26), recall that P_t denotes the mass of "domestic" non-elite agents in period t. They have n_t^{worker} children each. The internal and external elite together carry mass 1, each having $n_t^{\text{landowner}}$ children. (Recall that the internal elite carry zero mass.)

Note that the $n_t^{\text{landowner}}$ children reared by the external elite add to the P_{t+1} non-elite agents who in the next period enter the society where their parents were landowners. (Although this is a one-sex setting, this could perhaps be interpreted as foreign male rulers siring children with domestic women.) This is why we assumed that the external elite are infinitely lived; they are not replaced by any of the $n_t^{\text{landowner}}$ children, who all become non-elite agents.[19]

19. Alternatively, we could assume that the external elite die and that a unit-mass portion of their $n_t^{\text{landowner}}$ children replace them in the next period, the remainder becoming domestic non-elite agents. Then equation (26) would read:

$$P_{t+1} = n_t^{\text{worker}} P_t + n_t^{\text{landowner}} - 1.$$

This would not change the qualitative features of the dynamical system.

The next step is to derive expressions for these fertility rates. Consider first the elite's fertility, $n_t^{\text{landowner}}$. They do not work so the $(c_t \geq \bar{c})$-constraint is irrelevant, and fertility is given by maximizing equation (3), subject to equation (1), with π_t^F replacing w_t. This gives $n_t^{\text{landowner}} = \beta\pi_t^F/q$.

For workers, the $(c_t \geq \bar{c})$-constraint matters. Maximizing each worker's utility function in equation (2), subject to equation (1), gives the worker fertility rate as:

$$n_t^{\text{worker}} = \begin{cases} \frac{w_t - \bar{c}}{q} & \text{if } w_t < \frac{\bar{c}}{1-\beta}, \\ \frac{\beta w_t}{q} & \text{if } w_t \geq \frac{\bar{c}}{1-\beta}. \end{cases} \tag{27}$$

The case when $w_t < \bar{c}/(1-\beta)$ is analytically complicated but simplified by the following assumption:

Assumption 2. $\frac{\beta\bar{c}}{(1-\beta)q} < 1-\alpha$.

We can now state the following:

Proposition 2. *In a free labour society, population evolves as follows:*

(a) *If $w_t \geq \bar{c}/(1-\beta)$, then*

$$P_{t+1} = \frac{\beta A_t^{\alpha} P_t^{1-\alpha}}{q}. \tag{28}$$

(b) *If $w_t < \bar{c}/(1-\beta)$, then population is falling: $P_{t+1} < P_t$.*

The proof is given in the Appendix. Part (b) hinges on Assumption 2.

3.2.2. Population dynamics in an egalitarian society. In an egalitarian society, all agents have the same income, which (recall) is given by $\pi_t^E = (A_t/P_t)^{\alpha}$ (see equation (18)). Let fertility be denoted n_t^{egal}, which is given by maximizing equation (2) subject to $c_t = \pi_t^E - qn_t$. Fertility thus takes the same form as in the free labour case in (27) above:

$$n_t^{\text{egal}} = \begin{cases} \frac{\pi_t^E - \bar{c}}{q} & \text{if } \pi_t^E < \frac{\bar{c}}{1-\beta}, \\ \frac{\beta\pi_t^E}{q} & \text{if } \pi_t^E \geq \frac{\bar{c}}{1-\beta}. \end{cases}$$

Since all P_t agents have the same fertility, it must hold that $P_{t+1} = P_t n_t^{\text{egal}}$. (The external elite have no income and thus zero fertility.) We can now state the following:

Proposition 3. *In an egalitarian society, population evolves as follows:*

(a) *If $\pi_t^E \geq \bar{c}/(1-\beta)$, then P_{t+1} is given by equation* (28).

(b) *If $\pi_t^E < \bar{c}/(1-\beta)$, then population is falling: $P_{t+1} < P_t$.*

The proof is given in the Appendix. Again, part (b) uses Assumption 2.

3.2.3. Population dynamics in a slave society. In a slave society, the consumption of slaves is constrained to subsistence. Given the way we have formulated preferences in equation

(2), slave fertility is thus zero, and all children are fathered by the (internal and external) elite.[20] This seems broadly consistent with the historical evidence. In despotic societies (corresponding to slave societies here), elites have been strongly polygynous in both mating and marriage, with rich rulers having more wives and offspring than their subjects. Hunter-gatherer societies, and free labour societies (like the one we live in today), have been more monogamous, that is they have displayed a more equal distribution of women and fertility (Betzig, 1986; Wright, 1994).[21]

Thus, population in period $t+1$ is given by the (internal and external) elite's fertility in period t, here denoted $n_t^{\text{slaveowner}}$.[22] Maximizing equation (3), subject to equation (1), with π_t^S replacing w_t, gives $n_t^{\text{slaveowner}} = \beta\pi_t^S/q$. We can now state the following:

Proposition 4. *In a slave society, population evolves as follows:*

(a) *If $A_t > \Gamma(P_t;\gamma)$, then*

$$P_{t+1} = \frac{\beta}{q}\left[A_t^{\alpha}\left(\frac{P_t}{1+\gamma}\right)^{1-\alpha} - \overline{c}P_t\right]. \tag{29}$$

(b) *If $A_t \le \Gamma(P_t;\gamma)$, then population is falling: $P_{t+1} < P_t$.*

The proof is given in the Appendix. Again, part (b) uses Assumption 2.

3.3. *The phase diagram*

To analyse the dynamics of A_t and P_t in a phase diagram, we begin by deriving expressions for the loci along which A_t and P_t are constant.

Proposition 5.

(a) *Population is constant ($P_{t+1} = P_t$) when*

$$A_t = \begin{cases} \left(\frac{q}{\beta}\right)^{\frac{1}{\alpha}} P_t \equiv \mathbf{L}^{E/F}(P_t) & \text{if } (A_t, P_t) \in \mathcal{S}^E \cup \mathcal{S}^F, \\ (1+\gamma)^{\frac{1-\alpha}{\alpha}}\left(\frac{q}{\beta}+\overline{c}\right)^{\frac{1}{\alpha}} P_t \equiv \mathbf{L}^S(P_t) & \text{if } (A_t, P_t) \in \mathcal{S}^S. \end{cases} \tag{30}$$

(b) *Technology is constant ($A_{t+1} = A_t$) when either $A_t = \overline{A}$, or*

$$A_t = \overline{A} + D^{\frac{1}{\theta}} P_t \equiv \mathbf{L}^A(P_t). \tag{31}$$

Proof. Part (a) follows from Propositions 2, 3, and 4. Part (b) follows from equation (25). ||

20. Introducing, for example a subsistence level for fertility in equation (2), as we have for consumption, slaves too would have some offspring.

21. Polygynous mating habits were widespread among the elites of all early human civilizations in Mesopotamia, Egypt, China, India, and Middle and South America (Betzig, 1993), and in the Roman Empire (Betzig, 1992). The Mongolian Empire is another example: geneticists have estimated that across a large region of Asia from the Pacific to the Caspian Sea, approximately 8% of the male population (16 million men) are descendants of Genghis Kahn (Zerjal *et al.*, 2003). See also Lagerlöf (2005).

22. Like for a free labour society, the children of the external elite become non-elite agents. If the external elite had finite lives, and a unit mass portion of their $n_t^{\text{slaveowner}}$ children thus replaced them in the next period, population dynamics would instead read $P_{t+1} = n_t^{\text{slaveowner}} - 1$. This would not change the qualitative features of the dynamical system.

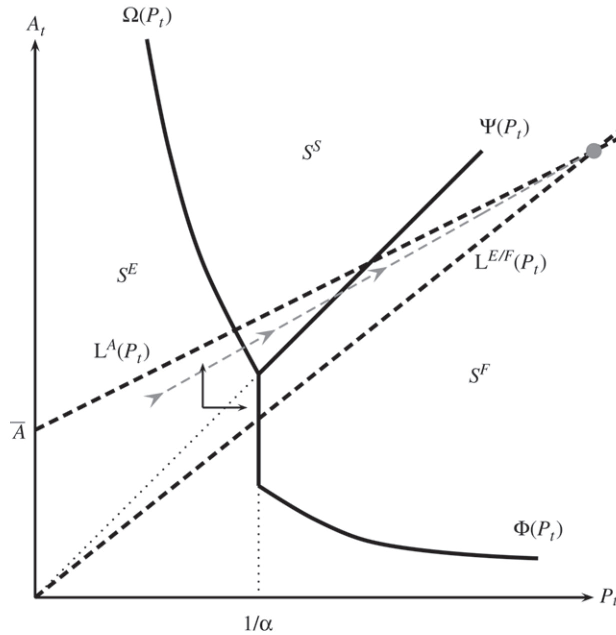


FIGURE 3
A transition through all three institutions

Examples of these loci are shown in Figures 3 and 4. A steady state is given by an intersection of the functions in equations (30) and (31). The motion arrows show how the state variables evolve off the loci. Exogenous parameters determine the shape of the loci, and in what institutional regions the steady state(s) lie (if any steady state exists at all). Initial conditions, (A_0, P_0), determine what regions the economy passes in the transition.

It can be seen from equations (18) and (30) and Assumption 2 that for any economy starting off in the egalitarian region above $\mathbf{L}^{E/F}(P_t)$, it must hold that $\pi_t^E > \overline{c}$ along the path throughout the egalitarian region.

The following proposition tells us when a steady state with free labour or egalitarianism may exist.

Proposition 6.

(a) *If and only if*

$$\left(\frac{q}{\beta}\right)^{\frac{1}{\alpha}} > D^{\frac{1}{\theta}}, \tag{32}$$

$$\frac{q}{\beta} \leq \frac{\overline{c}(1+\gamma)^{1-\alpha}}{1-\alpha(1+\gamma)^{1-\alpha}}, \tag{33}$$

then there exists a finite $\overline{A}^F > 0$*, such that for any* $\overline{A} \geq \overline{A}^F$*, there exists a steady state in the free labour region,* $\mathcal{S}^F$*.*

(b) *If and only if equation* (32) *holds, then for some (sufficiently small)* $\overline{A} > 0$*, there exists a steady state in the egalitarian region,* $\mathcal{S}^E$*.*

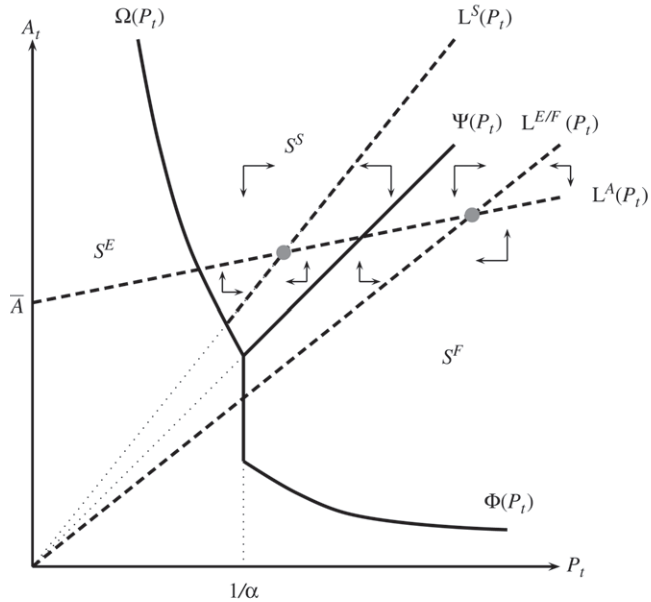


FIGURE 4

Phase diagram with both a slavery and free labour steady state

The proof is given in the Appendix. Intuitively, the condition in equation (32) ensures that the mutually reinforcing Boserupian and Malthusian forces are weak enough so that, under the free labour/egalitarian population dynamics in equation (28), population and technology converge in levels. The condition in equation (33) ensures that the cost of children (q) is low enough and the utility weight on children (β) is high enough, so that population is not falling throughout the free labour region; in terms of Figure 3, equation (33) ensures that $\mathbf{L}^{E/F}(P_t)$ is flatter than $\Psi(P_t)$. We can then choose $\overline{A}$ to make $\mathbf{L}^A(P_t)$ intersect $\mathbf{L}^{E/F}(P_t)$ in either the free labour or the egalitarian, region (but not in both).[23]

Next we examine when a steady state with slavery may exist.

Proposition 7. *If and only if*

$$(1+\gamma)^{\frac{1-\alpha}{\alpha}}\left(\frac{q}{\beta}+\overline{c}\right)^{\frac{1}{\alpha}} > D^{\frac{1}{\theta}}, \tag{34}$$

$$\frac{q}{\beta} \geq \frac{\alpha\overline{c}(1+\gamma)^{1-\alpha}}{1-\alpha(1+\gamma)^{1-\alpha}}, \tag{35}$$

then there exists a finite $\overline{A}^S > 0$, *such that for any* $\overline{A} \geq \overline{A}^S$, *there exists a steady state in the slavery region,* $\mathcal{S}^S$.

The proof is given in the Appendix. The intuition resembles that behind Proposition 6. If equation (34) holds, population and technology converge in levels. This condition is weaker than

23. From equations (30) and (31), the levels of A_t and P_t in a steady state with free labour or egalitarianism are $P^* = \overline{A}/[(\beta/q)^{\frac{1}{\alpha}} - D^{\frac{1}{\theta}}]$, and $A^* = (\beta/q)^{\frac{1}{\alpha}}\overline{A}/[(\beta/q)^{\frac{1}{\alpha}} - D^{\frac{1}{\theta}}]$.

equation (32) because for any given (A_t, P_t), population growth is slower under slavery than under the other two institutions (cf. equations (28) and (29)); this follows from total income under slavery being lower because agents are used as non-productive guards. The condition in equation (35) implies that the child cost and preference parameters (q and β) are such that population is not growing throughout the slavery region, that is $\mathbf{L}^S(P_t)$ is steeper than $\Psi(P_t)$ (cf. Figure 4). We can then choose $\overline{A}$ to make $\mathbf{L}^A(P_t)$ intersect $\mathbf{L}^S(P_t)$ in the slavery region.[24]

3.3.1. A full transition. Figure 3 illustrates the case when a steady state with free labour exists but none with slavery (or egalitarianism). That is, the conditions in Proposition 6 (a) hold but not those in Proposition 7,[25] and $\overline{A}$ exceeds $\overline{A}^F$. We can now choose initial conditions so that the economy passes all three institutional regions. To see this, let the economy start off within the egalitarian region, above $\overline{A}$. (Note from equation (25) that A_t cannot fall below $\overline{A}$.) If this initial point is close to the slavery region, the path goes through the slavery region before converging to the steady state in the free labour region. Such a trajectory is illustrated in Figure 3.[26]

In this transition, population and technology grow in tandem through mutual reinforcement: advances in agricultural technology raise incomes and thus generate population growth in a Malthusian fashion; this feeds back into more technological progress through the Boserupian effect. This is broadly consistent with the type of long-run growth in agricultural technology and population density described in Section 1.2. The institutional transitions fit with the long-run trends captured in Figure 1: an initial egalitarian stage, with communal rather than private property rights, is followed by a slavery stage where the elite own both their subjects and the land; then follows a free labour stage where the elite own land but not people.

3.3.2. Multiple steady states. As illustrated in Figure 4, a steady state in the free labour region may coexist with one in the slavery region.[27] This requires that the conditions in both Propositions 6 (a) and 7 hold and that $\overline{A}$ exceeds both $\overline{A}^F$ and $\overline{A}^S$. That is, q/β lies on the interval defined by the R.H.S. of equations (35) and (33). Both steady states can be seen to be locally stable, so that an economy that enters the slavery region never exits, and likewise for an economy that enters the free labour region (absent shocks to population, technology, or exogenous parameters). Initial conditions thus determine what steady state the economy converges to. The slavery steady state is a stagnant trap in the sense that it has relatively low levels of both population and technology.

Figure 4 illustrates how two groups of societies (two empires, if you wish) may coexist: one in the slavery trap and one in the free labour region. The free labour society has larger

24. From equations (30) and (31), the levels of A_t and P_t in a steady state with slavery are:

$$P^* = \frac{\overline{A}}{(1+\gamma)^{\frac{1-\alpha}{\alpha}}(\beta/q+\overline{c})^{\frac{1}{\alpha}} - D^{\frac{1}{\theta}}},$$

$$A^* = \frac{(1+\gamma)^{\frac{1-\alpha}{\alpha}}(\beta/q+\overline{c})^{\frac{1}{\alpha}}\overline{A}}{(1+\gamma)^{\frac{1-\alpha}{\alpha}}(\beta/q+\overline{c})^{\frac{1}{\alpha}} - D^{\frac{1}{\theta}}}.$$

25. More precisely, equation (35) does not hold, and therefore $\mathbf{L}^S(P_t)$ does not pass through $\mathcal{S}^S$. However, because equation (32) holds, so does equation (34).

26. In fact, the trajectory will not be a straight line; its path changes slope as the economy enters the slavery region, where it starts to evolve according to equation (29) instead of equation (28).

27. However, a steady state in the free labour region cannot coexist with one in the egalitarian region since $\mathbf{L}^{E/F}(P_t)$ cannot intersect $\mathbf{L}^A(P_t)$ more than once.

population and higher levels of technology. Note that initial positions to the "northwest" (high technology, low population) lead to the slavery trap, and positions to the "southeast" lead to the free labour steady state. Interestingly, if two societies start off in the egalitarian region with identical population but different levels of technology, the one with higher initial technology may converge to a slavery trap and the one with lower initial technology to free labour. (Note, however, that transitions from egalitarianism to free labour technically cannot happen the way Figure 4 is drawn since technology cannot fall below $\overline{A}$.) One can thus imagine a scenario where one society initially leads but stagnates in a slavery trap and is overtaken by the previous laggard. Such changing leadership may capture something about Western Europe's overtaking of other (more despotic, less free) Eurasian regions in the centuries leading up to the industrial revolution (cf. Landes, 1999).

4. DISCUSSION, EVIDENCE, AND EXTENSIONS

4.1. *Changes in the supply of land and technology*

Recall from equation (4) that a rise in the amount of land, at a given level of technology, amounts to an upward jump on the A_t-axis. In Figures 3 and 4, this may cause a (reversed) transition from free labour to slavery. Domar (1970) provides two examples of such scenarios. First, the discovery of the Americas, at the time when serfdom and slavery had died out in most of Europe, led to the re-introduction of slavery on a large scale. The other example is the Russian 16th-century military land conquests, which expanded Russian territory and made peasants migrate to these new lands. Landowners (by lobbying the central government) then imposed restrictions on the peasants' freedom of movement, thus introducing serfdom.

In this model, a land-augmenting rise in productivity has the same effect as an increase in the amount of land: a rise in the marginal product of labour. This implies that (all else equal) slavery is more likely to dominate over free labour in societies with more advanced agricultural technology. This may fit with some examples: the U.S. South during the slave era was more technologically advanced than Western Europe when serfdom ended there; Prussian serfdom was technologically superior to the free labour system that preceded it. The same argument can be applied to differences in land productivity driven by geography. Slavery in the Americas was used mostly where the marginal product of labour was high, that is in regions where valuable commodities could be grown (Sokoloff and Engerman, 2000).

However, this feature of the model also implies that accelerating growth in technology—in particular if coupled with declining population growth, thus making the marginal product of labour rise even more—would push the world back into slavery, contradicting the evidence. Section 4.3 below discusses an extension where such a reversal would not occur.

4.2. *Changes in population*

The model also predicts that low population density (all else equal) makes slavery more likely compared to free labour. This may fit with the observation that slavery was less common in those parts of the Americas where Europeans migrated, that is to regions with a temperate climate and low (European settler) mortality (cf. Coelho and McGuire, 1997; Acemoglu *et al.*, 2001, 2002; Mitchener and Mclean, 2003, p. 93). (Of course, a warm climate may also be associated with high agricultural productivity, as discussed above.)

Indenture of European migrants (by which the ticket across the Atlantic was paid for by committing to a work contract) was practised in, for example the sparsely populated Canada but absent in Latin America, where native labour was more abundant (Emmer, 1986).

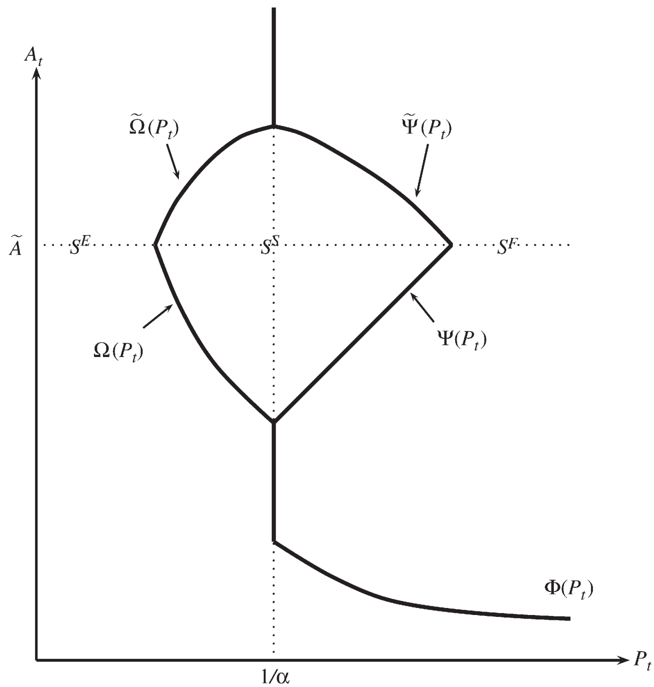


FIGURE 5

Institutional regions with increasing guarding costs

4.2.1. The Black Death. The Black Death poses a challenge for this model. Some would argue that the fast population growth in the centuries leading up to the Black Death in Europe caused a decline of serfdom in this period (Domar, 1970, pp. 27–28). This would be consistent with our model. However, the population reduction in the wake of the Black Death did not lead to a transition back to slavery, or serfdom, as our model would suggest. Some even propose that the Black Death *caused* the decline in serfdom (North and Thomas, 1971, 1973).

However, a fall in population in our model will always make workers better off as long as the economy does not transit back into slavery. This is perfectly consistent with the rise in living standards in Western Europe following the Black Death.

In another sense, this model is consistent with the effects of the Black Death in Europe: landowners often responded to the labour shortage by attempting to reintroduce serfdom. These attempts failed in Western Europe due to a lack of central authority able to control peasants' movements but succeeded in Eastern Europe.[28] Such changes in the power structure are not captured in our model, where the elite have all power at every stage of development.

4.3. *Increasing guarding costs*

The discussion of the Black Death above suggests that our model may lack an element of changing power structures as the economy develops. A very crude and *ad hoc* way to introduce this is to let the guards-per-slave ratio, γ, rise with the level of technology. Here, we postulate that

28. This argument is associated with Robert Brenner, and what has become known as the "Brenner Debates". See Conning (2007, section 1.1) for an excellent overview and further references.

γ begins to increase in A_t, once A_t exceeds some threshold, $\widetilde{A}$ (see Figure 5).[29] We would generate similar results by assuming, for example that γ increases with the free labour wage rate, $(1-\alpha)(A_t/P_t)^\alpha$, or the number of periods that workers have been free.

For $A_t \le \widetilde{A}$, the diagram in Figure 5 is identical to that in Figure 2. For $A_t \ge \widetilde{A}$, the new institutional borders are denoted $\widetilde{\Omega}(P_t)$ and $\widetilde{\Psi}(P_t)$. Compared to Figure 2, the free labour and egalitarian regions are larger at the expense of the slavery region, reflecting that slavery is more expensive in terms of supervision. For A_t high enough, slavery never dominates. Thus, slavery must eventually die out if either population or technology exhibit sustained growth. This extension may capture the ideas of Fenoaltea (1984), who suggested that slavery died out with the arrival of industrial production modes, involving a larger number of work tasks.[30]

5. CONCLUSIONS

We have presented a unified growth model, which captures some broad features of long-run demographic and institutional development, from hunter-gatherer times up until recently. An economy starting off in an egalitarian state with communal property rights transits endogenously into a despotic slave society, where the elite own both people and land. Thereafter, it may transit endogenously into a free labour society, where the elite own the land but people are free.

The society's elite choose the institution that maximizes their income. Two state variables, land productivity (or agricultural technology) and population, evolve endogenously over time. The economy may follow a path where, at an initial state with low levels of technology and small population, an egalitarian regime dominates; as population and technology expand a slave regime arises; and further population expansion can push the economy into free labour, by lowering the marginal product of labour and thus the wage rate.

As a potentially countervailing force, however, growth in technology may keep the marginal product of labour from declining, thus making the economy either re-enter a slavery state or never leave it. One way to eliminate that result is to postulate that the cost of guarding slaves increases with the level of technology; then slavery must always die out if population and/or technology keep growing.

There are many possible extensions of this model. Transitions from one institution to another here do not involve conflicts because all societies are identical: if the elite in one society prefer slavery, so do others. To relax this assumption, we could assume that slave labour is relatively more productive in some societies compared to others. For example, climate may determine which crops can be grown, and some crops (like cotton, tobacco, and sugar) can be more suitable for slave labour than others (Sokoloff and Engerman, 2000). Then, elites in regions where free labour is relatively profitable would want other elites to free their slaves (or not prevent them from running away) to reduce equilibrium wages. This may describe conflicts between U.S. states in the 19th century.

29. Figure 5 is drawn letting the number of guards per slave be given by

$$\gamma(A_t) = \begin{cases} \overline{\gamma} & \text{if } A_t \le \widetilde{A}, \\ (1+\overline{\gamma})(A_t/\widetilde{A})^\theta - 1 & \text{if } A_t \ge \widetilde{A}, \end{cases}$$

where $\overline{\gamma} > 0$, and $\widetilde{A} > 0$. It can be seen that a slavery region exists for large enough $\widetilde{A}$. See Lagerlöf (2006) for details.

30. To model this in more detail, one may allow for asymmetric information about the quality of the work done. For example, Aghion and Tirole (1997) set up a principal–agent model where the principal (here a slave-owning elite) may under some conditions find it in his interest to transfer formal authority (freedom) to the agent (the slave). See also Banerjee *et al.* (2002). Alternatively, in a setting where agents own some land, rising productivity of that land may weaken the market power of the elite (cf. Conning, 2007).

APPENDIX

Proof of Proposition 1. The proof is done by first finding conditions for $\pi_t^S \geq \pi_t^E$, $\pi_t^F \geq \pi_t^E$, and $\pi_t^F \geq \pi_t^S$, and then deriving conditions for $\pi_t^S \geq \max\{\pi_t^F, \pi_t^E\}$, $\pi_t^F \geq \max\{\pi_t^E, \pi_t^S\}$, and $\pi_t^E \geq \max\{\pi_t^F, \pi_t^S\}$.

Conditions for $\pi_t^S \geq \pi_t^E$: Here, we need to distinguish between two cases for calculating π_t^S. Consider first Case 1, which upon recalling equation (14) can be written as $A_t \leq \Gamma(P_t;\gamma)$. Using equation (18) and the second line of equation (17), we see that $\pi_t^S \geq \pi_t^E$ when $\alpha\{(1-\alpha)/[(1+\gamma)\overline{c}]\}^{\frac{1-\alpha}{\alpha}} A_t \geq A_t^\alpha P_t^{-\alpha}$, or:

$$A_t \geq \left(\frac{1}{\alpha}\right)^{\frac{1}{1-\alpha}} \left[\frac{\overline{c}(1+\gamma)}{1-\alpha}\right]^{\frac{1}{\alpha}} (P_t)^{-\left(\frac{\alpha}{1-\alpha}\right)} \equiv \Lambda(P_t). \tag{A.1}$$

Consider next Case 2: $A_t > \Gamma(P_t;\gamma)$. Using equation (18) and the first line of equation (17), we see that $\pi_t^S \geq \pi_t^E$ when $A_t^\alpha (P_t/[1+\gamma])^{1-\alpha} - \overline{c}P_t \geq A_t^\alpha P_t^{-\alpha}$. This requires both that $P_t > (1+\gamma)^{1-\alpha}$ and $A_t \geq \Omega(P_t)$, where $\Omega(P_t)$ is defined in equation (20). Considering both cases together we thus conclude:

$$\pi_t^S \geq \pi_t^E \iff \text{either } \Gamma(P_t;\gamma) \geq A_t \geq \Lambda(P_t) \text{ or } \left\{\begin{array}{c} A_t \geq \max\{\Omega(P_t), \Gamma(P_t;\gamma)\} \\ \text{and} \\ P_t > (1+\gamma)^{1-\alpha} \end{array}\right\}. \tag{A.2}$$

Conditions for $\pi_t^F \geq \pi_t^E$: Here, we need to distinguish between the two cases for calculating π_t^F. Consider first Case A: $A_t > [\overline{c}/(1-\alpha)]^{\frac{1}{\alpha}} P_t$. Using (18) and the first line in (11) we see that $\pi_t^F \geq \pi_t^E$ when $\alpha A_t^\alpha P_t^{1-\alpha} \geq A_t^\alpha P_t^{-\alpha}$, or

$$P_t \geq \frac{1}{\alpha}. \tag{A.3}$$

Consider next Case B: $A_t \leq [\overline{c}/(1-\alpha)]^{\frac{1}{\alpha}} P_t$. Using (18) and the second line in (11) we see that $\pi_t^F \geq \pi_t^E$ when $\alpha\left[(1-\alpha)/\overline{c}\right]^{\frac{1-\alpha}{\alpha}} A_t \geq A_t^\alpha P_t^{-\alpha}$. This gives $A_t \geq \Phi(P_t)$, where $\Phi(P_t)$ is defined in (21).

It can be seen that $[\overline{c}/(1-\alpha)]^{\frac{1}{\alpha}} P_t$ is always greater than $\Phi(P_t)$ when P_t exceeds $1/\alpha$. Considering both cases together we thus conclude:

$$\pi_t^F \geq \pi_t^E \iff P_t \geq \frac{1}{\alpha} \text{ and } A_t \geq \Phi(P_t). \tag{A.4}$$

Conditions for $\pi_t^F \geq \pi_t^S$: Here, the payoffs involve two cases each. Consider first the combination of Case A under free labour and Case 2 under slavery, which we shall name *Case I*. Because $\Gamma(P_t;\gamma) > [\overline{c}/(1-\alpha)]^{\frac{1}{\alpha}} P_t$ (see equation (14) and recall that $\gamma > 0$), this case prevails if $A_t \geq \Gamma(P_t;\gamma)$. Using the first lines in equations (11) and (17), we see that $\pi_t^F \geq \pi_t^S$ when $\alpha A_t^\alpha P_t^{1-\alpha} \geq A_t^\alpha[P_t/(1+\gamma)]^{1-\alpha} - \overline{c}P_t$. This can be written as $A_t \leq \Psi(P_t)$, where $\Psi(P_t)$ is defined in equation (19).

Consider next the combination of Case A under free labour and Case 1 under slavery, which we name *Case II*. This case prevails if $[\overline{c}/(1-\alpha)]^{\frac{1}{\alpha}} P_t < A_t < \Gamma(P_t;\gamma)$. Using the first line in equation (11) and the second line in equation (17), we see that $\pi_t^F \geq \pi_t^S$ when $\alpha A_t^\alpha P_t^{1-\alpha} \geq \alpha\{(1-\alpha)/[(1+\gamma)\overline{c}]\}^{\frac{1-\alpha}{\alpha}} A_t$, or:

$$A_t < \left[\frac{\overline{c}(1+\gamma)}{1-\alpha}\right]^{\frac{1}{\alpha}} P_t = (1+\gamma)\Gamma(P_t;\gamma), \tag{A.5}$$

which always holds in Case II since $A_t < \Gamma(P_t;\gamma)$.

Consider finally the combination of Case B under free labour and Case 1 under slavery, which we name *Case III*. This amounts to $A_t \leq [\overline{c}/(1-\alpha)]^{\frac{1}{\alpha}} P_t$. Using the lower rows of equations (11) and (17), we see that $\pi_t^F \geq \pi_t^S$ can be written $\alpha[(1-\alpha)/\overline{c}]^{\frac{1-\alpha}{\alpha}} A_t \geq \alpha\{(1-\alpha)/[(1+\gamma)\overline{c}]\}^{\frac{1-\alpha}{\alpha}} A_t$. This amounts to $(1+\gamma)^{\frac{1-\alpha}{\alpha}} > 1$, which always holds.

To sum up, in Cases II and III, $\pi_t^F \geq \pi_t^S$ always holds; in Case I, $\pi_t^F \geq \pi_t^S$ holds unless $A_t > \Psi(P_t)$. Note that $A_t > \Psi(P_t)$ can only hold in Case I since $\Psi(P_t) > \Gamma(P_t;\gamma)$. Considering all Cases I–III together, we thus conclude:

$$\pi_t^F \geq \pi_t^S \iff A_t \leq \Psi(P_t). \tag{A.6}$$

Conditions for $\pi_t^S \geq \max\{\pi_t^F, \pi_t^E\}$: This holds when both $\pi_t^S \geq \pi_t^F$ and $\pi_t^S \geq \pi_t^E$. Reversing equation (A.6), $\pi_t^S \geq \pi_t^F$ is equivalent to that $A_t \geq \Psi(P_t)$.

The condition for $\pi_t^S \geq \pi_t^E$ is given in equation (A.2). As long as $\pi_t^S \geq \pi_t^F$, and thus $A_t \geq \Psi(P_t)$, it must hold that $A_t > \Gamma(P_t;\gamma)$ because $\Psi(P_t) > \Gamma(P_t;\gamma)$. It is then straightforward to use (A.2) to see that $\pi_t^S \geq \max\{\pi_t^E, \pi_t^F\}$ when A_t is greater than both $\Psi(P_t)$ and $\Omega(P_t)$, and P_t is strictly greater than $(1+\gamma)^{1-\alpha}$, that is:

$$P_t > (1+\gamma)^{1-\alpha} \text{ and } A_t \geq \max\{\Psi(P_t), \Omega(P_t)\}, \tag{A.7}$$

which is equivalent to (A_t, P_t) being in $\mathcal{S}^S$, defined in equation (22). This proves part (a).

Conditions for $\pi_t^F \geq \max\left\{\pi_t^E, \pi_t^S\right\}$: This holds when both $\pi_t^F \geq \pi_t^E$ and $\pi_t^F \geq \pi_t^S$. As seen from equation (A.6), $\pi_t^F \geq \pi_t^S$ requires that $A_t \leq \Psi(P_t)$. The condition for $\pi_t^F \geq \pi_t^E$ is given in equation (A.4): both $P_t \geq 1/\alpha$ and $A_t \geq \Phi(P_t)$ must hold. Thus, $\pi_t^F \geq \max\{\pi_t^E, \pi_t^S\}$ holds when:

$$\Phi(P_t) \leq A_t \leq \Psi(P_t) \text{ and } P_t \geq \frac{1}{\alpha}, \tag{A.8}$$

which is equivalent to (A_t, P_t) being in $\mathcal{S}^F$, defined in equation (22). This proves part (b).

Conditions for $\pi_t^E \geq \max\{\pi_t^F, \pi_t^S\}$: This holds when both $\pi_t^F \geq \max\{\pi_t^E, \pi_t^S\}$ and $\pi_t^S \geq \max\{\pi_t^F, \pi_t^E\}$ fail to hold, that is when (A_t, P_t) is not in either $\mathcal{S}^F$ or $\mathcal{S}^S$. This proves part (c). ‖

Proof of Proposition 2. For part (a), note that $w_t \geq \bar{c}/(1-\beta)$ implies that $w_t > \bar{c}$, so all P_t agents work and the wage rate is given by $w_t = (1-\alpha)A_t^\alpha P_t^{-\alpha}$. Thus, $\pi_t^F = \alpha A_t^\alpha P_t^{1-\alpha}$, and $n_t^{\text{landowner}} = (\beta/q)\alpha A_t^\alpha P_t^{1-\alpha}$. Then, equation (26) gives equation (28). To show part (b), consider first the case when $A_t \leq [\bar{c}/(1-\alpha)]^{1/\alpha} P_t$ so that the labour force, L_t, adjusts so that the wage rate equals subsistence consumption: $w_t = \bar{c}$. Thus $n_t^{\text{worker}} = 0$, and equation (11) and $P_{t+1} = n_t^{\text{landowner}} = (\beta/q)\pi_t^F$ give:

$$P_{t+1} = \frac{\beta\alpha}{q}\left[\frac{1-\alpha}{\bar{c}}\right]^{\frac{1-\alpha}{\alpha}} A_t < \frac{\beta\alpha}{q}\left[\frac{1-\alpha}{\bar{c}}\right]^{\frac{1-\alpha}{\alpha}}\left[\frac{\bar{c}}{1-\alpha}\right]^{\frac{1}{\alpha}} P_t < P_t, \tag{A.9}$$

where we have used Assumption 2, $\alpha < 1$, and $1-\beta < 1$. Next, consider the case when $A_t > [\bar{c}/(1-\alpha)]^{1/\alpha} P_t$ and thus $w_t > \bar{c}$. This gives $n_t^{\text{worker}} = (w_t - \bar{c})/q > 0$, and $P_{t+1} = (\beta/q)\alpha A_t^\alpha P_t^{1-\alpha} + (w_t - \bar{c})P_t/q$. Since all P_t agents are working, it must hold that $w_t = (1-\alpha)A_t^\alpha P_t^{-\alpha}$. Using $w_t < \bar{c}/(1-\beta)$ and some algebra then shows that $P_{t+1} < \{\bar{c}\beta/[q(1-\alpha)(1-\beta)]\}P_t$. Assumption 2 demonstrates that $\bar{c}\beta/[q(1-\alpha)(1-\beta)] < 1$ and thus $P_{t+1} < P_t$. ‖

Proof of Proposition 3. Part (a) follows from $P_{t+1} = P_t n_t^{\text{egal}}$ and equation (18). Part (b) follows from noting that $n_t^{\text{egal}} = (\pi_t^E - \bar{c})/q < [\bar{c}/(1-\beta) - \bar{c}]/q = \beta\bar{c}/[q(1-\beta)] < 1-\alpha < 1$, where we have used $\pi_t^E < \bar{c}/(1-\beta)$ and Assumption 2. Since $P_{t+1} = P_t n_t^{\text{egal}}$, $n_t^{\text{egal}} < 1$ implies that $P_{t+1} < P_t$. ‖

Proof of Proposition 4. Part (a) follows from $A_t > \Gamma(P_t;\gamma)$, equation (17), and $P_{t+1} = n_t^{\text{slaveowner}} = (\beta/q)\pi_t^S$. To prove part (b), first use $A_t \leq \Gamma(P_t;\gamma)$ and equations (14) and (17), which together imply that:

$$\begin{aligned}\pi_t^S &= \left(\frac{\alpha A_t \bar{c}}{1-\alpha}\right)\left\{\left(\frac{1-\alpha}{\bar{c}}\right)^{\frac{1}{\alpha}}\left(\frac{1}{1+\gamma}\right)^{\frac{1-\alpha}{\alpha}}\right\} \\ &= \left(\frac{\alpha A_t \bar{c}}{1-\alpha}\right)\left\{\frac{P_t}{\Gamma(P_t;\gamma)}\right\} \leq \frac{\alpha\bar{c}P_t}{1-\alpha},\end{aligned} \tag{A.10}$$

where equation (14) verifies that the factors in curly brackets are equal, and the inequality follows from $A_t \leq \Gamma(P_t;\gamma)$. The inequality in equation (A.10) implies that $P_{t+1} = n_t^{\text{slaveowner}} = (\beta/q)\pi_t^S \leq \{\beta\alpha\bar{c}/[q(1-\alpha)]\}P_t \leq \alpha(1-\beta)P_t < P_t$, where the second inequality follows from Assumption 2, and the third from $\alpha < 1$ and $\beta > 0$. ‖

Proof of Proposition 6. Consider first part (a). First note from equations (30) and (31), and $\overline{A} > 0$, that equation (32) is a necessary and sufficient condition for $\mathbf{L}^{E/F}(P_t)$ and $\mathbf{L}^A(P_t)$ to intersect. A free labour steady state exists if $\mathbf{L}^A(P_t)$ and $\mathbf{L}^{E/F}(P_t)$ intersect in $\mathcal{S}^F$ (cf. Figure 3). From equations (19) and (30), it is seen that equation (33) is a necessary and sufficient condition for $\mathbf{L}^{E/F}(P_t)$ to pass through $\mathcal{S}^F$ (see equation (22)). Changing $\overline{A}$ shifts the intercept of $\mathbf{L}^A(P_t)$, and moves the intersection along $\mathbf{L}^{E/F}(P_t)$. Thus, if and only if equations (32) and (33) hold, for some $\overline{A}$ they intersect in $\mathcal{S}^F$. Let $\overline{A}^F$ be the lowest $\overline{A}$ such that they do. Then, a steady state exists in $\mathcal{S}^F$ for any $\overline{A} \geq \overline{A}^F$. Next, consider part (b). Recall that equation (32) is a necessary condition for $\mathbf{L}^{E/F}(P_t)$ and $\mathbf{L}^A(P_t)$ to intersect at all. The intersection must be in $\mathcal{S}^E$ if $\overline{A}$ is sufficiently small (see equation (22)). ‖

Proof of Proposition 7. Similar to the proof of Proposition 6, a steady state with slavery is given by an intersection of $\mathbf{L}^A(P_t)$ and $\mathbf{L}^S(P_t)$ in $\mathcal{S}^S$ (cf. Figures 3 and 4). From equations (19) and (31), if equation (35) holds, $\mathbf{L}^S(P_t)$ must pass through $\mathcal{S}^S$ (see equation (22)). If equation (34) holds, then $\mathbf{L}^S(P_t)$ slopes steeper than $\mathbf{L}^A(P_t)$, ensuring that $\mathbf{L}^A(P_t)$ and $\mathbf{L}^S(P_t)$ do intersect. Shifting $\overline{A}$ moves the intersection along $\mathbf{L}^S(P_t)$, ensuring that for some $\overline{A}$, sufficiently large they intersect in $\mathcal{S}^S$. Let $\overline{A}^S$ be the lowest $\overline{A}$ such that they do. Then, a steady state exists in $\mathcal{S}^S$ for any $\overline{A} \geq \overline{A}^S$. The "only if" part is seen from reversing either equation (34) or (35), or both; this rules out an intersection of $\mathbf{L}^A(P_t)$ and $\mathbf{L}^S(P_t)$ in $\mathcal{S}^S$ for any $\overline{A}$. ‖

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