The Roads To and From Serfdom

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Abstract:

The institution of slavery displays a puzzling historical pattern: it is found mostly at intermediate stages of agricultural development, in horticultural societies, and less frequently among hunter-gatherers and societies at more advanced agrarian stages. We explain this rise-and-fall pattern of slavery in a growth model with land and labor as inputs in production. The "organization" of society is determined endogenously, and depends on agricultural technology and population density, both of which also evolve endogenously over time, and depend on how society is organized. The model replicates the full transition of the economy from an egalitarian society with no property rights; to a slave society where a despotic ruler owns both land and people; and finally into a society with a free labor market, where the ruler owns all land but all agents own their labor. In this process, the role of population growth switches from being a force driving the transition into a slavery, to a force behind the transition from slavery to free labor. Our model also explains several other historical facts, e.g. why Europeans replaced free labor with slavery following the discovery of the Americas, and why those states in the 19th century US which had sparser population had a larger percentage slaves in the population.

1. Introduction

Since the birth of mankind we have come up with increasingly productive ways to use land for subsistence production. We have gone from *hunting and gathering*; via different stages of *horticulture*, i.e. farming without plows, like "slash-and-burn" cultivation; to *agriculture*, i.e. plow-based farming using harnessed animals (Nolan and Lenski 1999).

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, institutions like property rights have developed, and we have seen several technological innovations, e.g. 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, e.g. from low population density to higher (see Diamond 1999; Flannery 1972; Nolan and Lenski 1999; Wright 2000).

There is an exception to this rule: slavery, or serfdom, displays a non-monotonic pattern.[1] It was rarely practiced among hunter-gatherers. Neither did the most advanced agrarian societies use it: in Western Europe serfdom had vanished several centuries prior to the industrial revolution.[2] It is rather at intermediate levels of development that slavery shows up.

We set up a growth model which endogenously replicates this rise-and-fall pattern of slavery. Our results are driven by three components. Firstly, the way society is "organized" is determined endogenously. There are several identical tribes, or societies, each with one (potentially) dictatorial leader. There is also a king who rules over all these leaders and imposes on them a certain ownership structure, according to what maximizes each leader's payoff. (This could capture the idea that the king "represents" the tribal leaders' interests; or that each leader pays a fraction of his income in tribute to the king.)

The king can give each tribal leader ownership to both the tribe's total land estate and to the subjects' labor (making the leader a feudal lord, of sorts). With this system the tribal leader must feed unproductive guards to watch over the enslaved population. Another option is a free labor society, where the leader owns the land only, but his subjects are free and supply labor on a market, being paid their marginal product. Finally, there is the option of a fully egalitarian hunter-gatherer society, where there are no property rights at all, so the leader

[1]Throughout this paper, we shall let slavery and serfdom mean the same thing. This is not the complete truth, at least when considering Western Europe, where the lord-serf relationship was more of a contract than a form of ownership, but this is more a matter of degree. See also Section 2.3.1.

[2]According to North and Thomas (1971, p. 780) serfdom in Western Europe was "in an advanced state of decay by the end of the fifteenth century." See also Eltis (2000, Ch. 1).

and his subjects share all output equally.[3]

For slavery to dominate, first of all agricultural technology must be sufficiently advanced, so that a surplus can be generated to feed both slaves and non-working guards. Moreover, since guards are unproductive, slavery also requires a sufficiently large population to be profitable: the smaller is the population, the higher is the cost of holding people out of the labor force. Therefore, in labor-scarce societies a hunter-gatherer type of equal-sharing rule may dominate slavery.

A too large population also rules out slavery, by making the marginal product of labor fall so low that it becomes cheaper to let the slaves free, knowing that they can be hired back at a competitive wage, without any need for guards watching over them.

In essence, our model thus predicts that slavery dominates both free labor and hunting and gathering when agricultural technology is sufficiently productive, and population density is at intermediate levels – not too high, not too low. In other words, the model suggests that growing population has played different roles in history: it was initially a factor which spurred the transformation of hunter-gatherer societies into a slave societies, and later a factor driving the transition from slavery to free labor.

This brings us to the final two components of our model: the endogenous and 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 (see Boserup 1965).[4]

The result is a feedback loop in which the economy moves from an initial state with low population density and simple agricultural technology toward increasingly dense populations and more advanced usage of land, mutually reinforcing each other. In this process the society evolves endogenously through a hunter-gatherer state, a slavery state, and finally a free-labor state.

Our model also predicts that if an initially densely populated and free society colonizes a sparsely populated land mass, it may switch back from freedom to slavery. This explains why slavery was re-introduced by the Europeans in the Americas.

[3]We shall let the term hunter-gatherer society refer to a society where output is shared equally, as well as a society not using farming. In our model this makes sense, because the equal-sharing option is chosen in less agriculturally advanced societies.

[4]One example could be the very birth of farming, which may have followed the extinction of big mammals, like the mammoth (Smith 1975, 1992). Another is the empirically documented scale effect from population density to technological progress (cf. Kremer 1993, Nestmann and Klasen 2000, and Lagerlöf 2002).

We also present evidence supporting the underlying mechanisms driving our results. First we look at what has made egalitarian societies transit into slavery. We argue that this has required (1) dense enough population, and (2) advanced enough agricultural technology. One indication of this is the seemingly parallel emergence of larger-scale warfare and slavery and the common use of war captives as slaves in early civilizations. Keeping with a military requires a certain surplus of food and labor – i.e., an average level of output sufficiently above the subsistence needs of each worker – to make it possible to use people for other tasks than food production.

We also present evidence from societies transiting from serfdom/slavery into free labor: medieval Europe, 16th century Portugal, and 19th century US. Consistent with our model, states/provinces had a larger fraction of slaves in the population if they had (1) sparser populations; and (2) higher agricultural productivity, the latter being measured as a warmer climate. We also compare slave imports across Atlantic regions and draw the same conclusion.

Previous work on slavery includes a large literature on the plantation system in the American South, focusing on measuring how profitable it was and what could account for its profitability.[5] Our main aim here is rather to set up a unified framework to explain the rise and fall of slavery as a general economic phenomenon.

There is also some mirco-oriented literature on slavery. Fenoaltea (1984) uses an informal model to discuss the choice between "sticks and carrots" to induce slaves to work. More formal models include Findlay (1975), who analyzes slaves' incentives to work when they can buy their freedom. Again, these papers take the slave system as given, and do not attempt to give a more macroeconomic explanation for its rise or fall. Others analyze bonded labor as an ex-ante voluntary choice (see Genicot 2002 and references therein). This, however, seems a bit aside the topic here: for example, an enslaved war captive hardly made any such voluntary choice.

Closest to our model is Domar (1970), who makes the case that labor-abundance was an important factor driving the transition from slavery and serfdom to free labor. However, Domar does not discuss the shift from hunting and gathering to slavery, or long-run agricultural technological progress, and he does not set up a formal model.

Our paper also relates to a recent growth literature on economic and (often) demographic development prior to the industrial revolution. This includes Galor and Weil (1999, 2000), Galor and Moav (2002), Galor and Mountford (2002),

[5]Some classic contributions are Conrad and Myers (1958) and Fogel and Engerman (1974, 1977). For recent overviews see Hughes and Cain (1998, Ch. 10) and Hummel (1996, pp. 61-75). We discuss American slavery more in the conclusions in Section 5.

Goodfriend and McDermott (1995), Hansen and Prescott (2002), Jones (2001), Kremer (1993), Kögel and Prskawetz (2001), Lagerlöf (2002), Lucas (2002, Ch. 5), and Tamura (2001, 2002).[6] In one sense, our work is less ambitious than most of these papers, since we do not try to explain the most significant historical events from the perspective of a growth theorist: the industrial revolution and the demographic transition. In the terminology of e.g. Galor and Weil (1999, 2000), our framework is restricted to a Malthusian phase in which living standards are stagnant; it cannot account for the transition into sustained growth in per-capita income. On the other hand, our work is more ambitious in another dimension: we set up one single framework which endogenously explains a complete institutional transformation of human societies, from egalitarianism into slavery, and further on into a system of free labor.

Finally, our paper adds to a literature on the development of agriculture and property rights to land in early human societies. For example, Smith (1975) proposes that farming was induced by the extinction of large mammals. Baker (2002) models land ownership under varying ecological conditions. Brander and Taylor (1998) discusses environmental disasters in farming societies and the downfall of early human civilizations.[7] Although the themes of these papers are similar to ours – e.g. the interest in the origin of land ownership – none of these papers talks about property rights in *humans*, i.e., slavery.

This paper proceeds as follows. Next, Section 2 presents some stylized facts about the transitions in and out of slavery. Section 3 sets up the model. The first important result arrives in Section 3.6, where we see how the choice between the three types of society is made. It is characterized by two state variables: population and agricultural technology. Then, in Section 4 the dynamics of population and agricultural technology is derived. We then see how these state variables evolve over time and generate transitions from one type of society to another. Section 4.4 helps the reader to get an overview of the different components of the model by considering a very simple numerical simulation. Section 5 concludes.

2. The Facts

We shall next discuss what makes a society practice slavery, or not. We organize this section as follows: First, in Section 2.1, we take a "bird perspective" and look at some anthropological evidence on how human societies have transited into

[6] There is also more empirically focused work on long-run growth by Acemoglu, Johnson, and Robinson (2001, 2002, 2003).

[7] See also Skaperdas (1992) and Hirshleifer (1995) for examples of canonical models of property rights and conflicts. For more applications to land ownership, see Faria and de Oliveira (2002) and Marceau and Myers (2000).

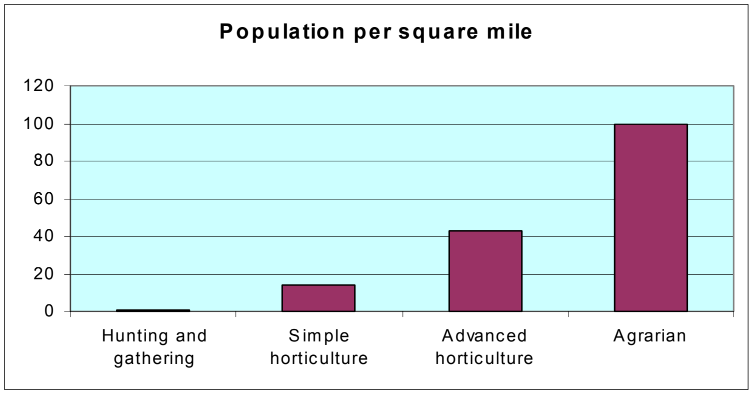

Figure 2.1: Population density by type of society. *Source:* Noland and Lenski (1999, p. 125).

and out of slavery. We then take a closer look at some evidence on what forces may have been driving each of these transitions: from egalitarianism to slavery (Section 2.2); and from slavery to free labor (Section 2.3). Section 2.4 then sums up our conclusions.

2.1. The full transition

The best overview of what we are trying to understand comes from looking at some descriptive numbers from the so-called *Ethnographic Atlas*, a data set compiled by the famous anthropologist G.P Murdock. This consists of some thousand human societies known by anthropologists, both historic and present.[8] Even though it is a cross section, it tells us something about time trends, since changes in food production (and many other variables) tend to go in one and the same direction, e.g. from hunting and gathering to farming (see e.g. Wright 2000). The illustrations below are based on numbers cited from Nolan and Lenski (1999).

Figure 2.1 shows how average population density varies across societies at different stages of agricultural development.[9] 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 2.2 shows the fraction of all societies at a particular stage of develop-

[8]What constitutes a society is defined according to certain criteria: for instance, any two societies must have been separated for at least 1000 years to count as independent observations. See Murdock (1967, pp. 3-6) for details.

[9]As mentioned, horticulture is farming without plows; agriculture with plows. Simple horticultural societies are distinguished from advanced by the use metallurgy in the latter.

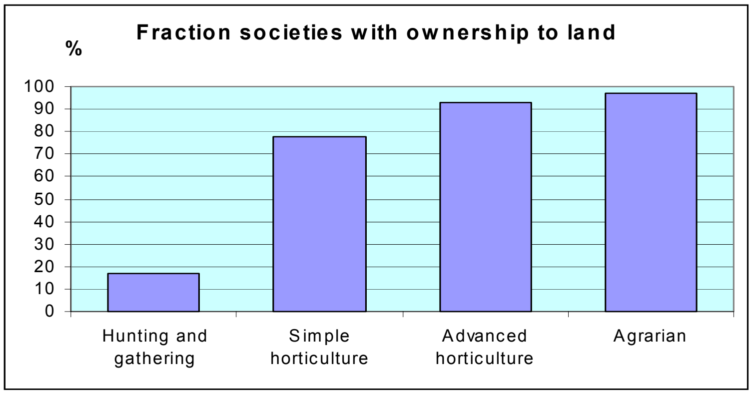

Figure 2.2: Presence of ownership to land by type of society. *Source:* Nolan and Lenski (1999, p. 107).

ment in which ownership to land is present. As seen, in the process of agricultural development ownership to land becomes more common.

Figure 2.3 shows the fraction of societies practicing slavery. Slavery essentially amounts to ownership of people. Different from the case with land ownership, however, slavery is most common among advanced horticultural societies, and far less common among both hunter-gatherers and agrarian societies. As seen, this hump-shaped pattern holds both when considering slavery in general, and when looking at the more narrow definition of hereditary slavery.

With some simplification, one may thus describe this long-run process as passing through three stages. The first stage is an egalitarian hunter-gatherer stage, with *no property rights at all*. The second stage is a horticultural slave society where *both humans and land are held as property*. Finally comes the agrarian stage, where *land is owned, but ownership to humans, i.e. slavery, is not practiced*. Below we shall try and decide what may have been the likely causes of these transitions.

2.2. From egalitarianism to slavery

One theory of the birth of slavery is given by Jared Diamond (1999, p. 291-292) in his best-seller *Guns, Germs, and Steel.* He suggest that the increasing scale of warfare as societies become more advanced provides a supply of war captives who can be used as slaves. (See also Kopytoff 1996.) This fits with indications that the incidence of warfare, just like slavery, depends on agricultural development in a non-linear fashion: it is increasing with agricultural development at those stages where slavery also becomes more common, i.e., when going from hunting

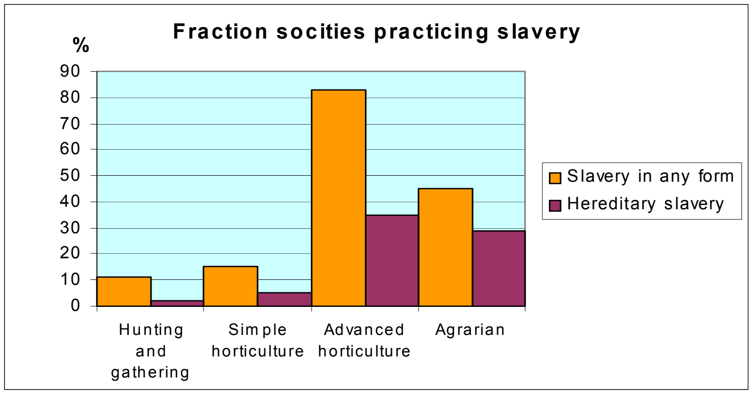

Figure 2.3: Practice of slavery by type of society. *Source:* Nolan and Lenski (1999, p. 144).

and gathering to advanced horticulture (Nolan and Lenski 1999, p. 133). As for later stages of agricultural development, Leavitt (1977) finds some evidence that the incidence of warfare is falling. This is also consistent with the observation in Figure 2.3, that slavery at later stages of development is more commonly hereditary. Slaves in mature slave societies, like the American south, were not captured in wars but rather supplied through breeding (slave imports to the US stopped in 1808).

Reading Diamond, the rise of warfare and slavery seems to be associated with (1) increasing population density; and (2) expanding output per worker (i.e., more advanced agricultural technology). The fact that there are wars to fight in the first place, and captives to take, requires a large enough population in the area which is conquered. Otherwise, there would not be a large enough payoff in terms of enslaved labor to make it worthwhile keeping a class of warriors out of productive activities.[10] By the same token, higher output per worker is needed to generate a surplus that makes it possible to use people for other tasks than immediate food production, like conquering and enslaving other societies.

Note also that slavery need not be interpreted too literally here. To tax a conquered tribe heavily could amount to the same thing and would also require an army.

[10]Diamond (1999, p. 291) makes essentially the same point by pointing out that where "population densities are very low, as is usual in regions occupied by hunter-gatherer bands, survivors of a defeated group need only move farther away from their enemies. That tends to be the result of wars between nomadic tribes in New Guinea and the Amazon."

2.3. From slavery to free labor

Next we examine the transition from slavery into free labor. We do this by looking at different groups of societies which can be thought of as being on the border of transiting from slavery into free labor. As we shall argue, the overall picture suggests that free labor is more common, and slavery less common, in regions with (A) colder climate; and (B) denser populations. The first factor we interpret as a proxy for low agricultural productivity.

2.3.1. Europe

In Europe higher population density seems associated with freer labor. Serfs in the more densely populated Western Europe had arrangements with their feudal lords similar to voluntary labor contracts. For instance, they were tied to the land, and could not be traded as property. Serfs in the more sparsely populated Eastern Europe (in particular Russia) had a situation more similar to that of slaves, in the sense that they could be sold and moved from one piece of land to another (Domar 1970; North and Thomas 1971).

Colder climate also seems associated with freer labor, since plantation slavery was practiced mainly in Southern Europe. The tradition goes back to the Roman latafundia, but was revived with the introduction of sugar to Europe following the crusades. Sugar production requires a warm and wet climate, and it is also very labor intensive. In medieval Europe, sugar had a high value-to-bulk ratio, implying a high marginal product of labor whereever it could be grown (Curtin 1998, p. 4). This is exactly what our theory says should make slave labor more attractive compared to free labor.

2.3.2. Portugal

Data from Saunders (1982, pp. 49, 60) over slavery and population in six Portuguese provinces 1527-1535 show that sparsely populated regions had a larger fraction of slaves in the population (see Figure 2.4). The slope of a linear regression line is negative, although not significant at conventional risk levels.

2.3.3. The Americas

The discovery of the Americas in 1492 can be thought of as a controlled experiment. At that time, serfdom and slavery had died out in most of the densely populated Europe (Eltis 2000, pp. 1-2). The windfall drop of a largely unpopulated land mass led to the reintroduction of slavery on a scale never seen before in human history. The low population density of the Americas seems the obvious reason why slavery was reintroduced in the first place (Domar 1970).

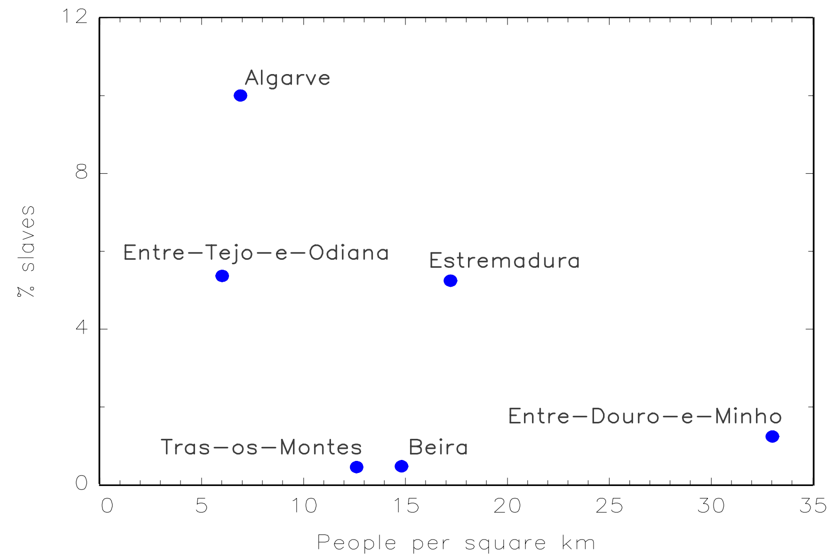

Figure 2.4: Slaves (in % of population) and population density in Portugal.

Climate seems important for where slaves were shipped. Most were imported to regions like Brazil and the Caribbean Islands (see Table 2.1 and Appendix A.1.1 for details).[11] There is another factor which can be thought of as agricultural productivity in a wider sense, namely how close the location where the output was produced was to the European market, i.e., to the Atlantic. Clearly, the Caribbean Islands where better off in this respect than the inland of South America. (A flip side of this is the fact that the European economic expansion at the time occurred in the Atlantic regions; cf. Acemoglu et al. 2003.)

Population density seems to have been important too. We may look at Table 2.1 to compare Europe, the US, and the region which corresponds to today's Argentina, Uruguay, Paraguay, and Bolivia. These all have roughly the same climate, and Europe and the US have about the same landmass; the third region is roughly half the size of Europe and the US. Out of these three regions, most slaves were imported by the US (4.5%), with Argentina-Uruguay-Paraguay-Bolivia being second (1%), and Europe third (0.5%). The ranking of these regions with respect to slave imports matches that for population density, but not e.g. landmass.

[11] São Thomé received 1% of the imports, but is left out because we could not find data over its area. Therefore the percentage column sums up to 99%.

Region	km^2 (mill.)	pop. (mill.)	density	imports (%)
Mainland Europe	9.60	81.00	8.44	0.5
Madeira, Canaries, Cap Verde Is.	0.08	0.05	0.63	0.3
US (excl. Alaska)	7.88	0.80	0.10	4.5
Mexico	2.00	5.00	2.50	2.1
Central America, Belize	0.44	0.80	1.80	0.3
Carribean Islands	0.24	0.30	1.25	42.2
The Guyanas	0.47	0.10	0.21	5.6
Brazil	8.51	1.00	0.12	38.1
Argentina, Uruguay, Paraguay, Bolivia	4.47	1.40	0.31	1.0
Chile	0.76	0.60	0.79	0.1
Peru	1.29	2.00	1.55	1.0
Colombia, Panama Ecuador	1.50	1.60	1.07	2.1
Venezuela	1.91	0.40	0.44	1.3

Table 2.1: Regional shares of total slave imports in the Atlantic slave trade. Population refers to A.D. 1500.

Figure 2.5 shows a plot of slave imports against population density in 1500. (We use logarithmic scales, since Europe, Brazil, and the Caribbean would otherwise dwarf the other regions.) The slope of a linear regression line is negative, although not significant.

2.3.4. The United States

The strongest support for the hypothesis that density and climate are important determinants of slavery comes from the 19th century US. As seen in Figures 2.6 and 2.7 the percentage of the population being held as slaves were lower in states with denser population, and colder climate. A state's climate is measured as its freeze period, i.e., the mean number of days per year when the temperature falls below 32° Fahrenheit in the state capital (see Appendix A.1.2 for details).

Regressing the length of the freeze period and population density on the percentage of the population held as slaves gives:

$$\%\text{ slaves} = \underset{(3.94)}{44.71} - \underset{(0.038)}{0.28}\text{ freeze period} - \underset{(0.046)}{0.09}\text{ density.} \tag{2.1}$$

(The standard deviations are given in parentheses.) The length of the freeze

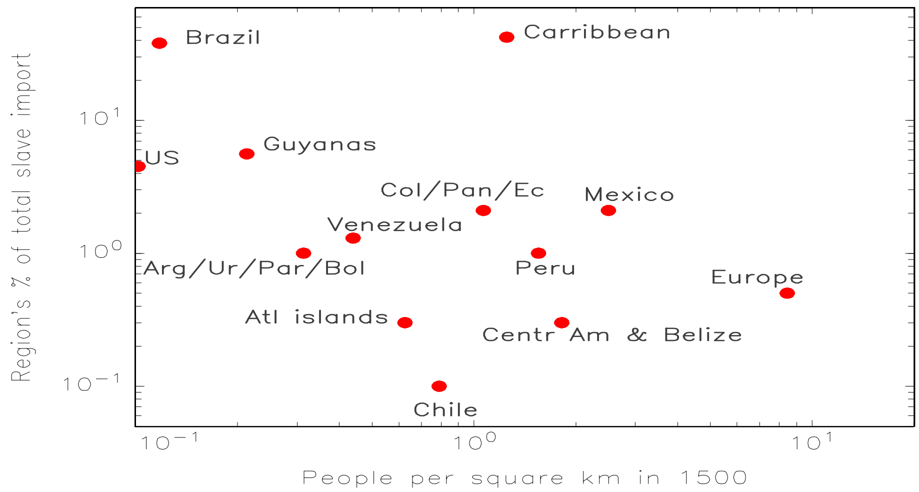

Figure 2.5: Slavery imports and population density across American regions and Europe. The data is from Table 2.1.

period has a significant and negative effect on the fraction of slaves; population density has a negative and (almost) significant effect.

We should also be aware of the practice of "white servitude" in regions where plantation slavery was made impossible by the climate. This amounted to European immigrants paying for their fares by selling contracts on their future labor (see e.g. Grubb 1994).

2.4. Concluding summary

The evidence we have cited seems to suggests that:

I. Among societies bordering between hunting and gathering and slavery, slave societies tend to be those with *denser* populations and more advanced agricultural technology.

II. Among societies bordering between free labor and slavery, slave societies tend to be those with *sparser* populations and more productive land (warmer climate).

In other words, the role of growing population density has changed from being a factor transforming hunter-gatherer societies into slave societies, to being a

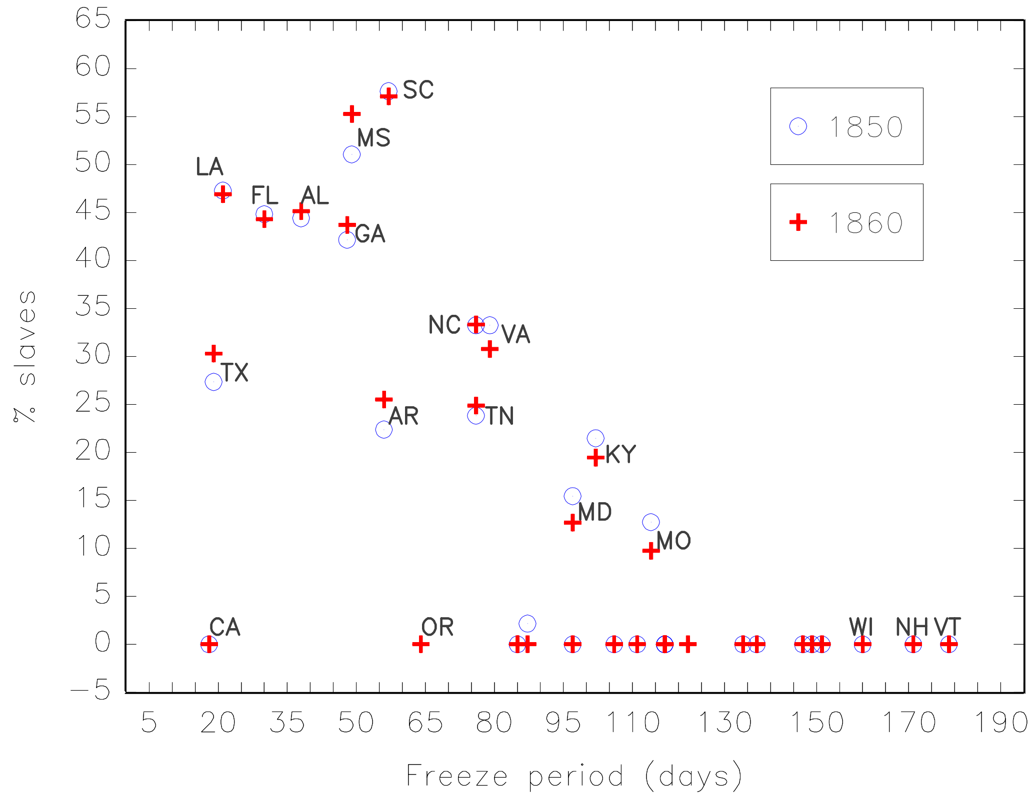

Figure 2.6: Slavery (in % of total state population) and the freeze period (see text) across US states.

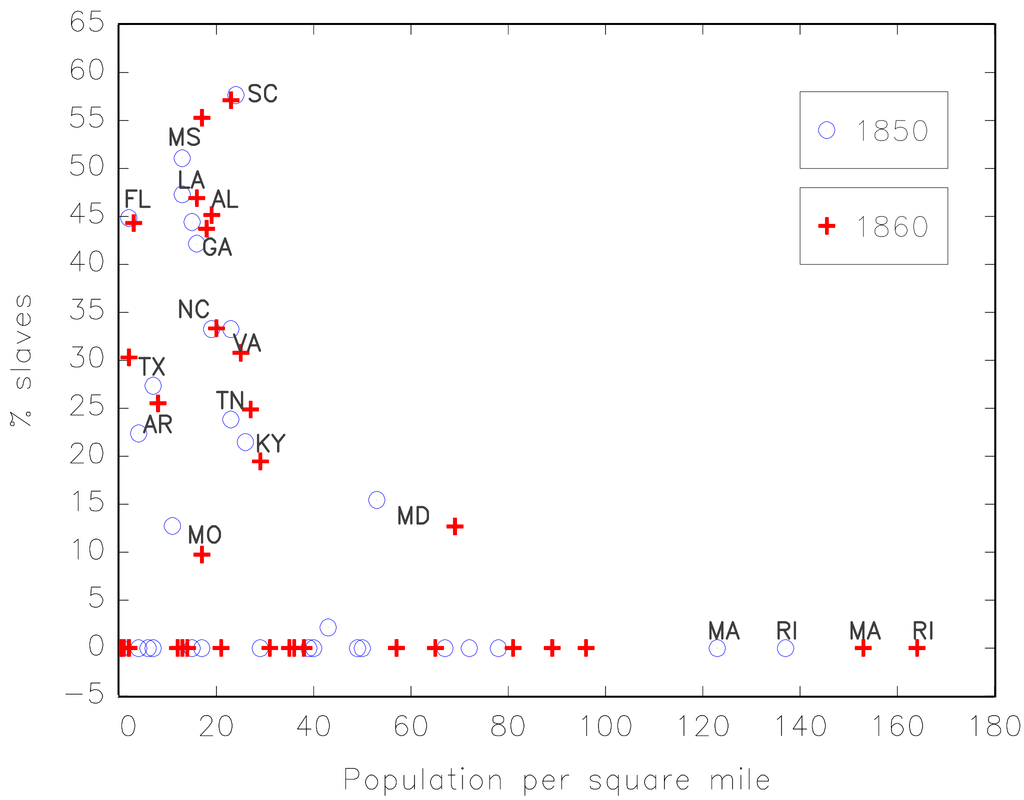

Figure 2.7: Slavery (in % of total state population) and population density across US states.

factor driving the transition from slavery to free labor.

3. The Model

Consider the following overlapping-generations framework. People live in two periods: as dependent children and working adults. Children make no decisions, but carry a cost, q, to rear. A representative agent who is adult in period t is referred to as agent t; we refer to him by a male pronoun.

3.1. The budget constraint

Adults earn an income (of sorts; see below) which is spent on own consumption and child rearing. For the moment, denote this income by w_t. We can then write agents t's budget constraint as

$$c_t = w_t - qn_t, \tag{3.1}$$

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

3.2. Preferences, labor, and subsistence

Labor supply is indivisible, so that each agent supplies either one unit of labor, or none. Work requires energy: an agent must eat a certain amount of food, $\bar{c}$, to be productive. In other words, regardless how much pain incentives a slave is given he cannot work unless he is fed at least $\bar{c}$. To capture this, we let preferences of a working agent t take this form:

$$V_t^{\text{work}} = \begin{cases} (1-\beta)\ln c_t + \beta \ln n_t & \text{if } c_t \geq \bar{c} \\ -\infty & \text{if } c_t < \bar{c} \end{cases}. \tag{3.2}$$

Solving the utility maximization problem amounts to maximizing the first line in (3.2), subject to the constraint that $c_t \geq \bar{c}$ (and whatever other constraints are relevant).

For an agent who is not working – which would here be a slave owner or a landowner – the first line in (3.2) extends to the case when $c_t < \bar{c}$:

$$V_t^{\text{no work}} = (1-\beta)\ln c_t + \beta \ln n_t. \tag{3.3}$$

The distinction between working and non-working agents' utilities is not crucial for any of our results, but facilitates the algebra somewhat when comparing payoffs later on. In particular, as long as the non-working agent earns an income far above $\bar{c}$ this distinction will not matter.

3.3. Hunting and gathering, slavery, and free labor

Agents are dispersed across several land areas, each populated by equally many agents. Agents living in a particular land area are referred to collectively as a tribe, or a society. In each tribe there is "leader" who is randomly chosen by nature in each period (i.e., this leadership is not inherited, or elected). Ruling over all tribal leaders is one "king." In each given period t, the king sets a law on how the societies should be organized, with the objective to maximize the payoff of each tribal leader in a symmetric equilibrium.[12] When writing the law, the king can choose between three sorts of society:

1. An **(egalitarian) hunter-gatherer society**, meaning there are no property rights, so that total output is shared equally among all tribesmen.

2. A **free (labor) society**, where the tribal leader has property rights to his tribe's total land estate, and his fellow tribesmen own their labor and can work as free laborers.

3. A **slave society**, where the tribal leader has property rights to *both* the land *and* his fellow tribesmen's labor, i.e., he is a slave owner. He must pay the slaves their subsistence consumption (else they would not be able to work, by assumption) and he must also cover the subsistence of some other tribesmen to guard over the slaves to stop them from running away.

We let the choice between 1, 2, and 3 be made by a king, rather than by each tribal leader on his own, because of an element of strategic interaction between different tribal leaders. For instance, one leader's choice to let slaves free affects the equilibrium wage rate in other tribal areas, since freed slaves can migrate. In our setting, the king decides to abolish slavery (i.e., force all leaders to let their subjects free) if the payoff for each leader – in the resulting symmetric equilibrium – is greater than that of maintaining slavery.

3.4. Production

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

$$Y_t = \left(M\widetilde{A}_t\right)^{\alpha} L_t^{1-\alpha} \equiv A_t^{\alpha} L_t^{1-\alpha}, \tag{3.4}$$

where α is the land-share of output, and A_t denotes the productivity-augmented size of the tribe's land. In other words, A_t can increase either due to a rise in the

[12]This could be motivated by assuming that the king collects a fraction of each leader's income in tax.

productivity of land (i.e., improved agricultural techniques), or due to an increase in the amount of available land (e.g., the discovery of new continents).

3.5. The tribal leader's payoffs

Each one of the above options (1 to 3) yields a certain income, or payoff, for the tribal leader (as well as for other tribesmen). We denote the period t payoff by π_t^i, where $i = H, F, S$ indicate the payoffs of being a leader in a hunter-gatherer, free, or slave society, respectively. Figure 3.1 shows how they are calculated.

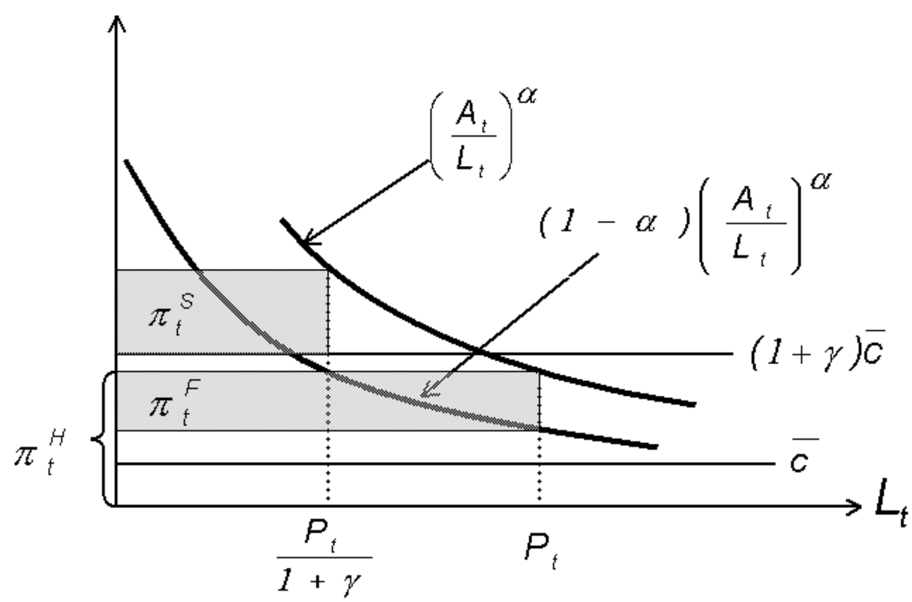

Figure 3.1: Illustration of how the payoffs are calculated.

3.5.1. Payoff in a hunter-gather society

Consider first the hunter-gatherer option. Let the adult population size be given by P_t. In this society, each agent consumes the average product, so that the leader's payoff is the same as that of every other tribesman, and given by

$$\pi_t^H = A_t^\alpha P_t^{-\alpha}. \tag{3.5}$$

This implicitly assumes that every agent is able to work earning the average product ($A_t^{\alpha} P_t^{-\alpha} \geq \bar{c}$). From now on, we shall restrict attention to combinations of A_t and P_t where this holds. The example illustrated in Figure 3.1 shows a case where this is true.

3.5.2. Payoff in a free labor society

Consider next the free labor option. In this society, the leader owns all land, but (for simplicity) we assume he supplies no labor. (This can be thought of as capturing the idea that he must devote all his time to administration.) Instead he hires his fellow tribesmen as free workers. Since there are many identical societies, the fact that workers are free means that they can migrate to other societies, and thus the landowner hires labor on a perfectly competitive market where he takes the wage rate, w_t, as given.

The tribal leader's payoff is thus given by

$$\pi_t^F = \max_{L_t} \left\{ A_t^{\alpha} L_t^{1-\alpha} - w_t L_t \right\}. \tag{3.6}$$

Solving the maximization problem leads to a labor demand function:

$$w_t = (1-\alpha) A_t^{\alpha} L_t^{-\alpha}. \tag{3.7}$$

Since an agent must eat $\bar{c}$ to be able to work, labor supply is given by

$$L_t = \begin{cases} P_t & \text{if } w_t \geq \bar{c} \\ 0 & \text{if } w_t < \bar{c} \end{cases}. \tag{3.8}$$

Depending on A_t and P_t there are now two possible types of equilibrium: one where all agents work, and one where only some of them work. These are illustrated in Figure 3.2. Consider first **Case A**. This is a society with a small population (like P_t^0 in Figure 3.2), so that all agents can work and the marginal product of labor still exceeds subsistence consumption, i.e., $(1-\alpha) A_t^{\alpha} P_t^{-\alpha} > \bar{c}$, or $A_t > \left[\frac{\bar{c}}{1-\alpha}\right]^{\frac{1}{\alpha}} P_t$. The land-owning tribal leader simply keeps the land-share of output, given by $A_t^{\alpha} P_t^{1-\alpha} - w_t P_t$, where $w_t = (1-\alpha) A_t^{\alpha} P_t^{-\alpha}$, i.e.,

$$\pi_t^F = \alpha A_t^{\alpha} P_t^{1-\alpha}. \tag{3.9}$$

Next, consider **Case B**. This refers to a society with a large population (like P_t^1 in Figure 3.2), implying that only some of the agents work and eat whereas the rest starve and/or die, and the equilibrium wage is kept down to subsistence consumption. Put differently, the number of agents working, L_t, is determined

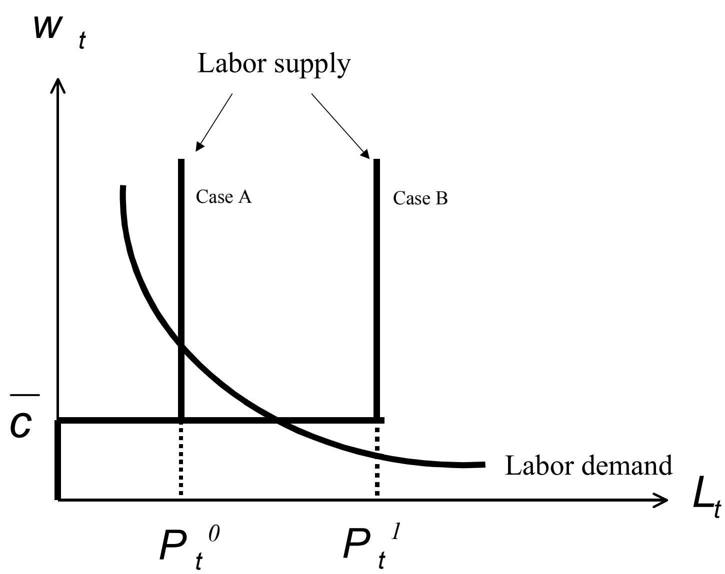

Figure 3.2: How the wage rate is determined. In Case A, where population size equals P_t^0, the marginal product of labor is large enough that free workers can live on the competitive wage; in Case B, where population size equals P_t^1, the wage is kept down to subsistence.

by setting the marginal product of labor equal to subsistence consumption: $(1-\alpha)A_t^{\alpha}L_t^{-\alpha}=\overline{c}$, or $L_t=\left[\frac{1-\alpha}{\overline{c}}\right]^{\frac{1}{\alpha}}A_t$. Inserted into the profit expression inside the max argument in (3.6) this gives the payoff to the land-owning tribal leader as:

$$\pi_t^F=\alpha\left[\frac{1-\alpha}{\overline{c}}\right]^{\frac{1-\alpha}{\alpha}}A_t. \tag{3.10}$$

We can thus write:

$$\pi_t^F=\begin{cases}\alpha A_t^{\alpha}P_t^{1-\alpha} & \text{if } A_t>\left[\frac{\overline{c}}{1-\alpha}\right]^{\frac{1}{\alpha}}P_t\\ \alpha\left[\frac{1-\alpha}{\overline{c}}\right]^{\frac{1-\alpha}{\alpha}}A_t & \text{if } A_t\leq\left[\frac{\overline{c}}{1-\alpha}\right]^{\frac{1}{\alpha}}P_t\end{cases}. \tag{3.11}$$

3.5.3. Payoff in a slave society

Consider finally the slavery option. In this society, the leader owns all land, and forces his fellow tribesmen to work for him as slaves. He pays each slave the minimal amount required to keep him productive, $\overline{c}$. We also assume that he must pay someone to guard the slaves, to keep them from eloping. Let γ

denote the number of guards needed to watch over one slave, and let each guard's consumption be kept to the same level as that of the slaves, $\overline{c}$. Then the cost of keeping S_t slaves equals $(1+\gamma)\overline{c}S_t$.[13] The returns to the slave owner are simply given by total output, with the number of slaves, S_t, replacing L_t in the production function in (3.4).[14]

Note that the slave owner does not need to hold all his tribesmen as slaves; he may let some of them free (or kill them).[15] The maximum number of slaves is restricted by the number of agents in the tribe, 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 to being a slave owner is given by

$$\pi_t^S = \max_{S_t \leq P_t/(1+\gamma)} \left\{ A_t^{\alpha} S_t^{1-\alpha} - (1+\gamma)\overline{c}S_t \right\}. \tag{3.12}$$

Let S_t^* denote the "desired" number of slaves. This is simply the unconstrained choice of S_t in (3.12) above, given by $(1-\alpha)A_t^{\alpha}S_t^{-\alpha} - (1+\gamma)\overline{c} = 0$, i.e.,

$$S_t^* = \left[\frac{1-\alpha}{(1+\gamma)\overline{c}}\right]^{\frac{1}{\alpha}} A_t. \tag{3.13}$$

The slave owner will be unconstrained in the number of slaves if the desired number of slaves, plus the γS_t^* guards needed to watch over them, is less than the tribe's total population, i.e. if $S_t^*(1+\gamma) \leq P_t$, or

$$A_t \leq \left(\frac{1}{1+\gamma}\right)\left[\frac{\overline{c}(1+\gamma)}{1-\alpha}\right]^{\frac{1}{\alpha}} P_t \equiv \Gamma(P_t;\gamma). \tag{3.14}$$

We shall call this **Case 1.** This amounts to keeping S_t^* agents as slaves, and $S_t^*\gamma$ guarding the slaves; the remainder are set free (or killed). The slave owner's

[13] Here we assume that guards do not need to be guarded. We could just as well assume that each guard must be watched by γ guards, who in turn must be watched by γ guards, and so on. Assuming $\gamma < 1$ the cost of keeping S_t slaves would become

$$\overline{c}S_t + \overline{c}\gamma S_t + \overline{c}\gamma^2 S_t + ... = \overline{c}S_t/(1-\gamma),$$

which is equivalent to our formulation, if we define a new parameter $\eta > 0$, such that $1+\eta = 1/(1-\gamma)$.

[14] With an alternative interpretation we could call guards "warriors," and say their task is to conquer and enslave another people ("people" here meaning another segment of the tribe; we can think of those enslaved as e.g. belonging to another ethnic group). Each warrior enslaves $1/\gamma$ other tribesmen. For example, the warriors could be Romans and the slaves captives from defeated Germanic tribes. In that sense, our model fits with the stylized facts about war, conquest, and slavery, discussed in Section 2.2.

[15] As we shall see, in the case slavery will always be dominated by a free labor society.

payoff is then given by $A_t^\alpha S_t^{*1-\alpha} - (1+\gamma)\overline{c}S_t^*$, which together with (3.13) and some algebra gives

$$\pi_t^S = \alpha \left[\frac{1-\alpha}{(1+\gamma)\overline{c}}\right]^{\frac{1-\alpha}{\alpha}} A_t. \tag{3.15}$$

Next, consider **Case 2**, where the slave owner is constrained: $P_t/(1+\gamma)$ agents are kept as slaves, and the remainder used for guarding the slaves. The slave owner's payoff is thus given by

$$\pi_t^S = A_t^\alpha \left(\frac{P_t}{1+\gamma}\right)^{1-\alpha} - \overline{c}P_t. \tag{3.16}$$

We can thus write:

$$\pi_t^S = \begin{cases} A_t^\alpha \left(\frac{P_t}{1+\gamma}\right)^{1-\alpha} - \overline{c}P_t & \text{if } A_t > \Gamma(P_t;\gamma) \\ \alpha \left[\frac{1-\alpha}{(1+\gamma)\overline{c}}\right]^{\frac{1-\alpha}{\alpha}} A_t & \text{if } A_t \leq \Gamma(P_t;\gamma) \end{cases}. \tag{3.17}$$

3.6. Comparing payoffs

The king will choose hunting and gathering, slavery, or freedom, respectively, depending on which gives the tribal leaders the greatest profit: π_t^H, π_t^S, or π_t^F. These payoffs are given by (3.9), (3.11), and (3.17). The choice thus depends on the levels of agricultural technology, A_t, and population size, P_t, and exogenous parameters.

Define

$$\Psi(P_t) = \left[\frac{\overline{c}(1+\gamma)^{1-\alpha}}{1-\alpha(1+\gamma)^{1-\alpha}}\right]^{\frac{1}{\alpha}} P_t, \tag{3.18}$$

where we assume that $1-\alpha(1+\gamma)^{1-\alpha} > 0$,

$$\Omega(P_t) = \left[\frac{\overline{c}(1+\gamma)^{1-\alpha}P_t^{1+\alpha}}{P_t-(1+\gamma)^{1-\alpha}}\right]^{\frac{1}{\alpha}}, \tag{3.19}$$

and

$$\Phi(P_t) = \left(\frac{1}{\alpha}\right)^{\frac{1}{1-\alpha}} \left[\frac{\overline{c}}{1-\alpha}\right]^{\frac{1}{\alpha}} P_t^{-\left(\frac{\alpha}{1-\alpha}\right)}. \tag{3.20}$$

We can now state the following (proven in Appendix A.2):

Proposition 1. *The payoffs associated with slavery, hunting and gathering, and free labor are ordered as follows:*

1. *Slavery dominates when:*

$$\pi_t^S \geq \max\{\pi_t^F, \pi_t^H\} \Longleftrightarrow \left\{ \begin{array}{c} A_t \geq \max\{\Psi(P_t), \Omega(P_t)\} \\ \textit{and} \\ P_t > (1+\gamma)^{1-\alpha} \end{array} \right\}; \tag{3.21}$$

2. *Freedom dominates when:*

$$\pi_t^F \geq \max\{\pi_t^S, \pi_t^H\} \Longleftrightarrow \ \{P_t \geq 1/\alpha \textit{ and } \Phi(P_t) \leq A_t \leq \Psi(P_t)\}\,; \tag{3.22}$$

3. *Hunting and gathering dominates otherwise.*

What this proposition states is most easily understood from Figure 3.3. As seen, hunting and gathering dominates at low levels of A_t and P_t, and an increase in either could move the economy into the slave region. The intuition is that a rise in A_t implies more profits to reap by introducing slavery compared to sharing equally. A rise in P_t means a lower payoff under the equal sharing rule, but only gains for a slave owner since he has his tribesmen's labor at his own disposal (i.e., he can kill some if he finds their marginal product too low relative to the costs of feeding and guarding them).

The region in which hunting and gathering dominates becomes larger at the expense of the slavery region if, for example, subsistence consumption, $\overline{c}$, increases. [Note that the border separating the hunting and gathering and slavery regions – $\Omega(P_t)$ – is increasing $\overline{c}$.] Since $\overline{c}$ measures what the slave owner must pay to feed each slave, a higher $\overline{c}$ makes slavery less attractive. With the same logic, the hunter-gatherer region expands and the slavery region shrinks if the guard-per-slave ratio, γ, rises, as this makes it costlier to hold slaves.

Next compare slavery to free labor. An increase in P_t lowers the marginal product of labor. This makes free labor cheaper and more profitable compared to slavery, moving the economy from the slavery region into the free labor region. Vice versa, a rise in A_t – e.g., an increase in the land available, following to the discovery of the Americas – could push an economy from the free labor region into the slavery region, as it raises the marginal product of labor and makes it less attractive to pay workers a competitive wage.

We also see that the border separating the free labor and slavery regions – $\Psi(P_t)$ – pivot-shifts up when $\overline{c}$ and γ increase, as this makes slavery less attractive.

Finally, we see that the hunting and gathering region grows at the expense of the free labor region if the land-share of output, α, falls, since this makes it less attractive to be a landowner in a competitive market.

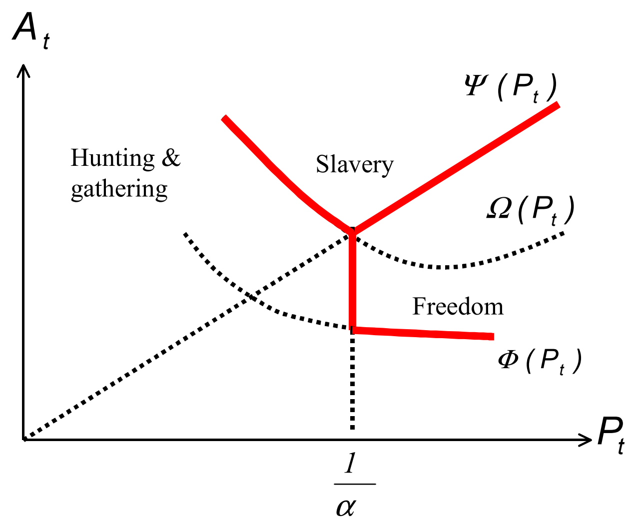

Figure 3.3: Regions where slavery, hunting and gathering, or free labor is chosen.

4. Dynamics

Having determined how the selection of the type of society depends on population and agricultural technology, we next look at how population and agricultural technology evolve over time in each type of society.

4.1. Agricultural technology

We let A_t evolve according to

$$A_{t+1} = \overline{A} + DA_t^{1-\theta} P_t^{\theta} \tag{4.1}$$

where $\overline{A}$ is some minimum level of agricultural technology, $D > 0$, and $\theta \in (0, 1)$.

The Boserupian feature of this relationship is that A_t grows faster if population pressure, P_t/A_t, is large. One example could be the very birth of farming, which may have followed the extinction of big mammals, like the mammoth (Smith 1975, 1992). It could also capture a scale effect from population density to technological progress (cf. Kremer 1993, Nestmann and Klasen 2000, and Lagerlöf 2002).

4.2. Population

4.2.1. Population dynamics in a free labor society

The most complicated population dynamics appear in a free labor society, since both the landowner and the workers rear children. Consider first the landowner.

He does not perform any physical work so his fertility is given by maximizing (3.3), subject to (3.1) with π_t^F replacing w_t. Together with (3.11) this gives:

$$n_t^{\text{landowner}} = \frac{\beta \pi_t^F}{q} = \begin{cases} \frac{\beta \alpha A_t^\alpha P_t^{1-\alpha}}{q} & \text{if } A_t > \left[\frac{\overline{c}}{1-\alpha}\right]^{\frac{1}{\alpha}} P_t \\ \frac{\beta\alpha}{q}\left[\frac{1-\alpha}{\overline{c}}\right]^{\frac{1-\alpha}{\alpha}} A_t & \text{if } A_t \leq \left[\frac{\overline{c}}{1-\alpha}\right]^{\frac{1}{\alpha}} P_t \end{cases}. \tag{4.2}$$

Next consider workers. Recall that the work force will always adjust so that the equilibrium wage rate never falls below subsistence consumption: $w_t \geq \overline{c}$. Maximizing each worker's utility function in (3.2), subject to (3.1), gives the fertility rate of the working class:

$$n_t^{\text{worker}} = \begin{cases} \frac{w_t - \overline{c}}{q} & \text{if } \overline{c} \leq w_t < \frac{\overline{c}}{1-\beta} \equiv \overline{w} \\ \frac{\beta w_t}{q} & \text{if } w_t \geq \frac{\overline{c}}{1-\beta} \equiv \overline{w} \end{cases}. \tag{4.3}$$

The landowner has zero measure, so P_t constitutes the total mass of agents. All agents die after the adult phase of life, so P_{t+1} is simply given by the total number of children born in period t, i.e., the sum of: (1) the landowner's number of children; and (2) the number of children per worker, times the number of workers, i.e.,

$$P_{t+1} = n_t^{\text{worker}} P_t + n_t^{\text{landowner}}. \tag{4.4}$$

To simplify the analysis, and reduce the number of cases needed to be considered, we now make the following assumption:

Assumption 1. $\overline{n} = \frac{\beta \overline{c}}{(1-\beta)q} < 1 - \alpha$.

This implies that a free society with a very large population – such that the wage rate falls below $\frac{\overline{c}}{1-\beta} \equiv \overline{w}$ – will see its population falling over time. (See Appendix A.3 for details.) To understand this, note that we can interpret $\overline{w}$ as the wage rate at which the subsistence constraint ($c_t \geq \overline{c}$) is just binding, and $\overline{n}$ is the associated fertility rate. This means that a worker earning $w_t < \overline{w}$ has fewer than $\overline{n}$ children, and if $\overline{n} < 1$ the working class cannot reproduce itself. Population may still be growing if $\overline{n} > 1 - \alpha$. In this case, the land-share of output is large enough to make the fertility of the single landowner compensate for the below-reproduction birth rate of the working class. This case is ruled out by imposing Assumption 1.

Consider thus a society where $w_t \geq \frac{\overline{c}}{1-\beta} \equiv \overline{w}$. Since this implies that $w_t > \overline{c}$, we know that all P_t agents work and the wage rate is given by $w_t = (1-\alpha)A_t^\alpha P_t^{-\alpha}$ (cf. Figure 3.2). Using (4.2) to (4.4) we can then write the population dynamics of a free society as:

$$P_{t+1} = \underbrace{\frac{\beta(1-\alpha)A_t^{\alpha}P_t^{-\alpha}}{q}}_{n_t^{\text{worker}}} P_t + \underbrace{\frac{\beta\alpha A_t^{\alpha}P_t^{1-\alpha}}{q}}_{n_t^{\text{landowner}}} = \frac{\beta A_t^{\alpha}P_t^{1-\alpha}}{q}. \tag{4.5}$$

We thus conclude that population in a free society evolves according to:

$$\Delta P_t = P_{t+1} - P_t \left\{ \begin{array}{c} > \\ = \\ < \end{array} \right\} 0 \iff A_t \left\{ \begin{array}{c} > \\ = \\ < \end{array} \right\} \left(\frac{q}{\beta}\right)^{\frac{1}{\alpha}} P_t. \tag{4.6}$$

4.2.2. Population dynamics in a hunter-gatherer society

In a hunter-gatherer society all agents have the same income, given by π_t^H in (3.5). Since all are working, their fertility rates are derived in a similar fashion as with workers in the free-labor case above. Analogous to (4.3) we can thus write the hunter-gatherer's fertility rate as

$$n_t^{\text{hunt-gath}} = \begin{cases} \frac{\pi_t^H - \bar{c}}{q} & \text{if } \bar{c} \leq \pi_t^H < \frac{\bar{c}}{1-\beta} \equiv \overline{w} \\ \frac{\beta \pi_t^H}{q} & \text{if } \pi_t^H \geq \frac{\bar{c}}{1-\beta} \equiv \overline{w} \end{cases}. \tag{4.7}$$

It is straightforward to check that under Assumption 1, $\pi_t^H < \overline{w}$ implies that $P_{t+1} < P_t$: a hunter-gatherer society where average output falls below $\overline{w}$ cannot reproduce itself (cf. the case for workers in a free society above). When $\pi_t^H \geq \overline{w}$ we can use the definition of π_t^H in (3.5) together with the second line in (4.7). It is then seen that the population dynamics coincide with that of a free society [see (4.5)], and the sign of ΔP_t is illustrated by (4.6).

4.2.3. Population dynamics in a slave society

Finally, consider a slave society. Recall that slaves' consumption is constrained to subsistence, implying that their fertility rate is zero, so population dynamics are driven solely by the leader's fertility. This can be thought of as a caricature of the demographic features of the first civilizations on earth. These were all strongly polygynous, and the rulers had more wives, or sex partners, and thus more offspring, than their subjects (Betzig 1986, 1993).

Thus, population in period $t+1$ is given by the slave owner's number of offspring in period t:

$$P_{t+1} = n_t^{\text{slaveowner}} = \frac{\beta \pi_t^S}{q} = \begin{cases} \frac{\beta}{q}\left[A_t^{\alpha}\left(\frac{P_t}{1+\gamma}\right)^{1-\alpha} - \bar{c}P_t\right] & \text{if } A_t > \Gamma(P_t;\gamma) \\ \frac{\beta\alpha}{q}\left[\frac{1-\alpha}{(1+\gamma)\bar{c}}\right]^{\frac{1-\alpha}{\alpha}} A_t & \text{if } A_t \leq \Gamma(P_t;\gamma) \end{cases}. \tag{4.8}$$

where $\Gamma(P_t;\gamma)$ is defined in (3.14). Recalling Assumption 1 again, the second line in (4.8) can be seen to imply that $P_{t+1} \leq (1-\beta)\alpha\left(\frac{\overline{n}}{1-\alpha}\right)P_t < P_t$. This implies that in a slave society population is always shrinking whenever $A_t \leq \Gamma(P_t;\gamma)$. This leaves us with the first line in (4.8), which tells us that population shrinks (or grows) if $P_{t+1} = \frac{\beta}{q}\left[A_t^{\alpha}\left(\frac{P_t}{1+\gamma}\right)^{1-\alpha} - \overline{c}P_t\right] < (>) P_t$. Rearranging, we thus conclude that population in a slave society evolves according to:

$$\Delta P_t = P_{t+1} - P_t \left\{\begin{array}{c} > \\ = \\ < \end{array}\right\} 0 \iff A_t \left\{\begin{array}{c} > \\ = \\ < \end{array}\right\} (1+\gamma)^{\frac{1-\alpha}{\alpha}} \left[\frac{q}{\beta} + \overline{c}\right]^{\frac{1}{\alpha}} P_t. \qquad (4.9)$$

4.3. Phase diagram for all three societies

At a given level of A_t, either (4.6) or (4.9) characterizes how population evolves over time – which depends on what type of society is chosen. Free societies and hunter-gatherer societies have the same population dynamics, as given by (4.6). We let $(\Delta P_t = 0)^{\mathrm{H/F}}$ denote the locus along which free societies and hunter-gatherer societies have constant population ($P_{t+1} = P_t$). This is simply the equality case in (4.6). Similarly, for a slave society we denote the corresponding locus by $(\Delta P_t = 0)^{\mathrm{S}}$, as given by the equality case in (4.9).

The corresponding $(\Delta A_t = 0)$-locus – which is the same in the hunter-gatherer, slave, and free regions – is given by setting $A_{t+1} = A_t$ in (4.1). We can write this as $A_t = \zeta^{-1}(P_t)$, where $\zeta(\cdot)$ is given by

$$\zeta(A_t) = \left[\frac{A_t - \overline{A}}{DA_t^{1-\theta}}\right]^{\frac{1}{\theta}}. \qquad (4.10)$$

Examples of these loci are shown in Figures 4.1 and 4.2.

4.3.1. Hunting and gathering, slavery, and freedom – the full transition

The specific shapes of the different loci depend on exogenous parameters (see Appendix A.4). Consider first the case illustrated in Figure 4.1. Here the $(\Delta P_t = 0)^{\mathrm{S}}$-locus does not appear because it is too flat to enter the slavery region; we can say that the $(\Delta P_t = 0)^{\mathrm{S}}$-locus is "invisible." In other words, population is never constant at levels of A_t and P_t where slavery dominates.

Let the economy start off somewhere in the hunting and gathering region, between the $(\Delta A_t = 0)$- and $(\Delta P_t = 0)^{\mathrm{H/F}}$-loci. From there A_t and P_t will grow through mutual reinforcement: advancements in agricultural technology spur

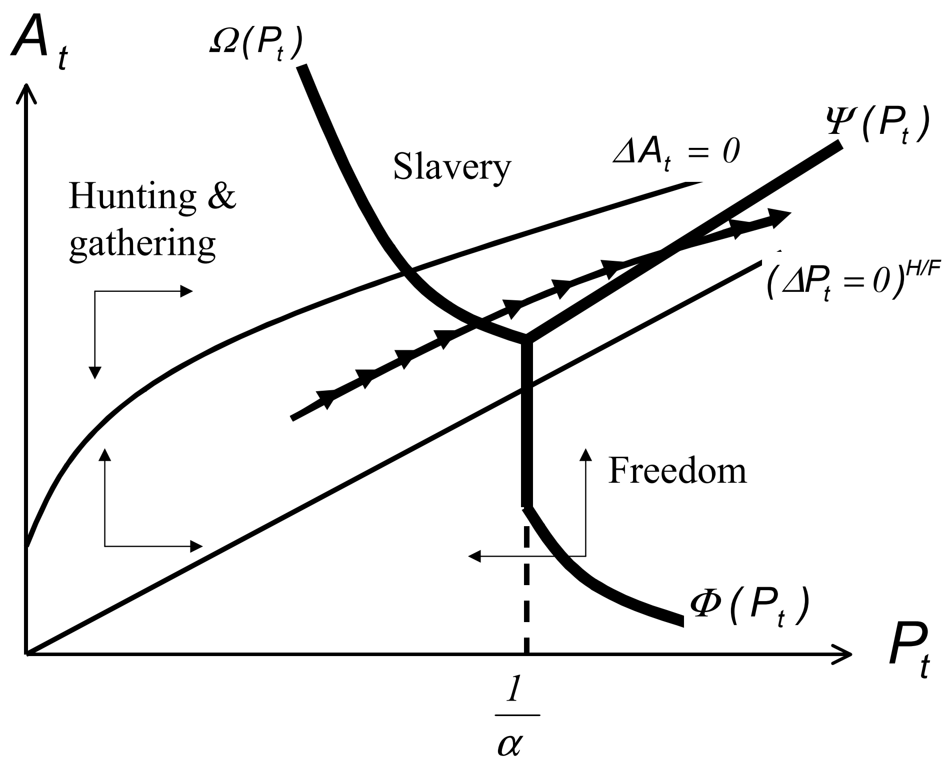

Figure 4.1: The full transition.

population growth in a Malthusian fashion. This feeds back into more agricultural progress through the Boserupian effect, and so on.

As the economy enters the slavery region (if it does – this depends on starting values) population dynamics is governed by the difference equation which refers to a slave society, i.e. (4.9). As a result, population growth slows. [I.e., population still *grows* in the slavery region, because the economy is above the $(\Delta P_t = 0)^{\mathrm{S}}$-locus. However, population grows *slower* because the economy is closer to the $(\Delta P_t = 0)^{\mathrm{S}}$-locus than it was to the $(\Delta P_t = 0)^{\mathrm{H/F}}$-locus in the hunter-gatherer region.] With population continually growing – and agricultural technology being bounded from above, or not growing too fast – the economy eventually reaches the free labor region, and completes the transition.

4.3.2. Differential paths

As shown in Appendix A.4, there may exist a locally stable steady state within the slavery region. This case is illustrated in Figure 4.2. In this scenario, the economy

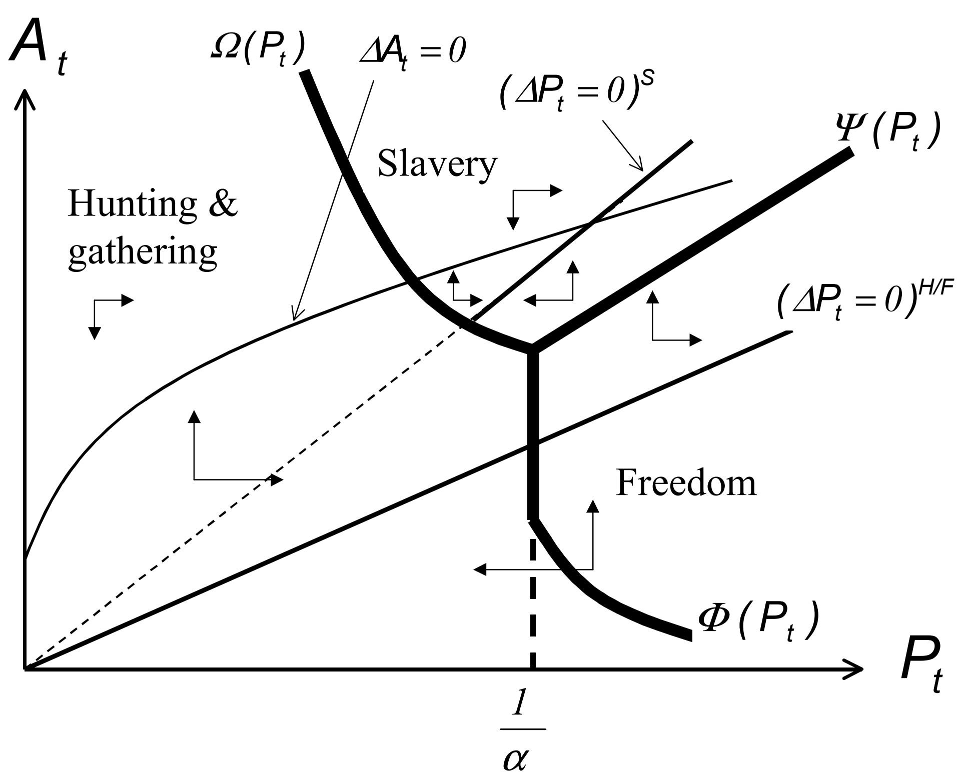

Figure 4.2: The case with a stagnant slavery trap.

q	β	α	θ	$\overline{A}$	D	γ	$\overline{c}$
2.75	0.18	0.88	0.6	20	5.74	0.75	1

Table 4.1: Parameter values.

could follow either a trajectory leading from hunting and gathering directly into free labor; or it could get sucked into the slavery region and stagnate in a trap with low levels of both A_t and P_t.

4.4. A numerical example

It becomes somewhat easier to follow the workings of the model by looking at a simple numerical simulation. Table 4.1 shows a set of parameter values which generates a type of dynamics shown in Figure 4.1. Note that there is no reason for choosing this particular set of numbers; they serve only as an illustration.

Figure 4.3 shows the different regions corresponding to those in Figure 3.3. Figure 4.4 shows the loci corresponding to those in Figures 4.1 and 4.2. Figure 4.5 shows the path of the economy through the three regions, corresponding to the trajectory in Figure 4.1. The start values are set to $P_0 = 0.1$ and $A_0 = 10$.

Figure 4.6 compiles all this information into one diagram. We now see how population growth – as measured by the increments on the P_t-axis – slows down in the slavery region, where the dynamics are governed by the $(\Delta P_t = 0)^{\mathrm{S}}$-locus. [Note that the $(\Delta P_t = 0)^{\mathrm{S}}$-locus does not enter the slavery region.] When the trajectory enters the free labor region population growth spurts again as the economy starts gravitating toward the $(\Delta P_t = 0)^{\mathrm{H/F}}$-locus. Note that the path is completely deterministic, although it looks somewhat stochastic as it enters the free labor region.

5. Conclusions

This paper presents a unified model explaining the rise and fall of slavery. A number of identical tribes, each with one leader, can be organized in either one of three ways: each tribal leader may own his tribe's land and his tribesmen's labor (a slave society); the leader may own the land only but have no slaves (a society with free labor); or there may be no property rights at all (an egalitarian hunter-gatherer society). A king who rules over all tribes then decides how the societies should be organized, according to what maximizes the income of each tribal leader.

The tribal leaders' payoffs are maximized under a slave society if the agricultural technology is productive enough, and population is at intermediate levels. If

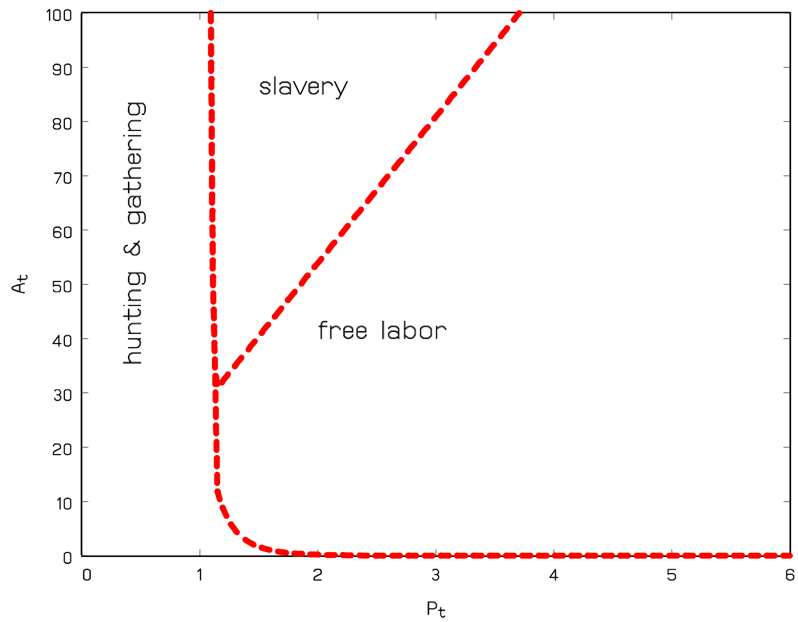

Figure 4.3: The slave, free, and hunter-gatherer regions.

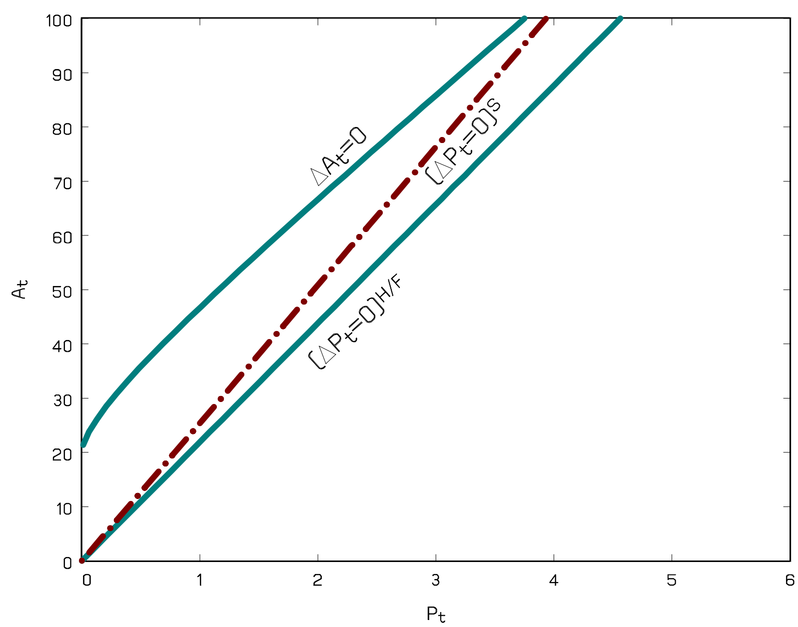

Figure 4.4: The loci.

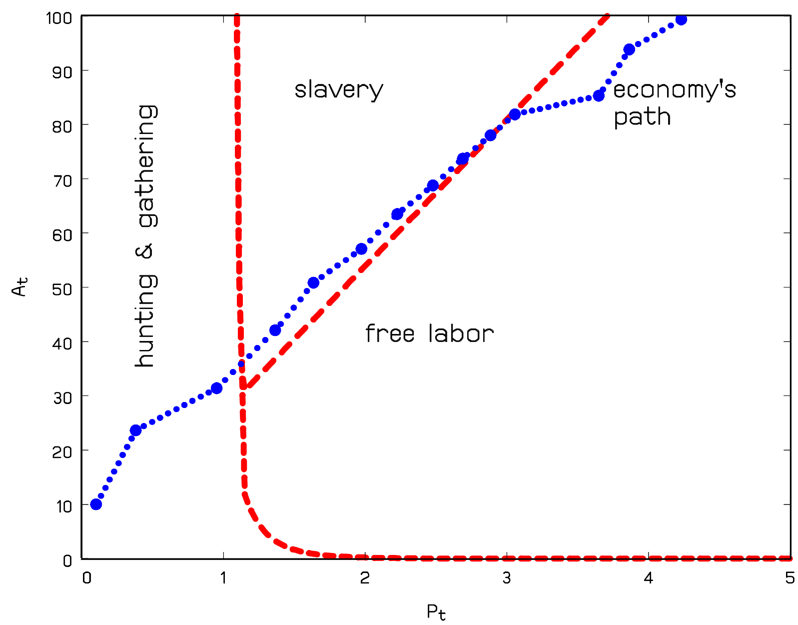

Figure 4.5: The trajectory with start values set to $P_0 = 0.1$ and $A_0 = 10$.

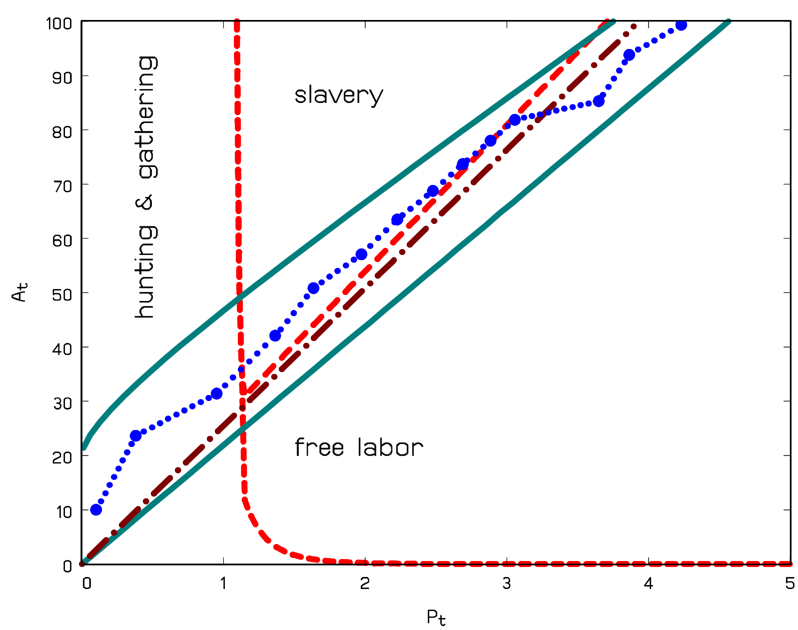

Figure 4.6: All information in one graph. Note how population dynamics in the slave region differ from that of the other regions.

population is too large, a free labor society dominates slavery, since the marginal product of labor is so low that it is cheaper to hire free workers than holding them as slaves and paying guards to watch over them. If population is too small, a hunter-gatherer society dominates slavery, because the shortage of labor makes it too expensive to keep people as unproductive guards.

There are variations to this story, which may in some cases overlap with ours. Consider first the question why slavery was *introduced*. Some would reformulate this question and ask why highly stratified class societies came to replace more egalitarian ones. This seems to require some type of "surplus," to support a non-working population, like a military or bureaucracy. There is also some consensus that this surplus followed with the development of more productive ways of using the land (see e.g. Diamond 1999). Another theory is suggested by Lucas (2002, p. 134) who suggests that the surplus may have resulted from improved incentives to accumulate resources, driven by the introduction of property rights. In our model the causality is reverse: agricultural advancement, and/or a growing population *causes* the introduction of property rights by generating enough resources for a despotic leader to claim and defend these rights.

As for why slavery was *abandoned* there are many competing theories, some of which partly overlap with ours. A lot of interest has been paid to slavery in the US, although it was not quantitatively the largest slave society at the time (see Table 2.1). This debate has focused on questions about whether slavery would have survived, had it not been for the civil war, and, if so, for how long. (See Hughes and Cain 1998, Ch. 10, for an overview.)

It seems well established that plantation slavery before the civil war earned a high return compared to other investments and was not a sector of the economy in decay, suggesting that slavery would not have vanished without the civil war (cf. Conrad and Myers 1958). However, later research has pointed to the unusually high cotton prices around this time; they fell sharply in the 1870's (see e.g. Hughes and Cain 1998, p. 271, and further references therein). The fall in cotton prices may have been due to increased production in India. Consistent with our model, the fact that India could grow a labor intensive crop like cotton without using slavery in turn seems related to its high population density. (This theory is consistent with Galor and Mountford 2002 who argue that Chinese and Indian industrialization was hampered due to an abundance of labor.)

Aside from the high cotton prices prior to the civil war Hummel (1996) suggests that slavery would have been far less profitable had it not been for the Fugitive Slave Law of the North, which provided legal support for Southern slave-owners to retrieve their run-away property. This essentially constituted a subsidy on the cost of keeping slaves in check (captured by the parameter γ in our model).

Note finally that the abolishment of slavery imposes great capital losses on slave-owners (see e.g. Goldin 1973). Thus, slavery being so profitably may simply reflect the fact that the return to investing in slaves and other plantation capital earned a risk premium over the return to other investments.

Another issue is the impact of the Black Death on European serfdom. If we believe the theory presented here, a significant fall in population should push the economy from free labor to slavery/serfdom. This failed to happen after the Black Death. Domar (1970) suggests that one reason could be the expansion of less labor intensive forms of agriculture, in particular sheep herding. In terms of our model this would amount to a rise in the land-share of output, α, which expands the free-labor region at the expense of the slavery region in Figure 3.3.

Another explanation could be that the 25% reduction in population during the years of the Black Death in the 1360's – however huge it may seem – was not large enough. European population fell to the levels of 1200, and had recovered by 1500 (McEvedy and Jones 1978, p. 18). These are not a huge leaps in time, considering that maybe 1000 (or more) years had elapsed from the time at which the Roman slave society was at its peak, until slavery and serfdom had vanished in Europe.

A. Appendix

A.1. Data

A.1.1. Data over the Atlantic slave trade

The numbers for area and population size in Table 2.1 come from McEvedy and Jones (1978). The density numbers are simply the second column over the first. One may note that the density figures are very close to those reported in Acemoglu et al. (2002), which may be of better quality. Here we use McEvedy and Jones since we need to aggregate regions (like the whole of mainland Europe) to compile with data over to slave imports. The numbers for slave imports are from Curtin (1969, Table 24). São Thomé received 1% of the imports, but is left out because we could not find data over its area.

A.1.2. US data

The table in Figure A.1 shows the numbers used for the plots in Figures 2.6 and 2.7. The freeze period is defined as the mean number of days per year in which the temperature falls below 32° Fahrenheit (0° Celsius). These numbers were retrieved from the Weatherbase website at http://www.weatherbase.com, and refer to the state capital (except for Maryland, where the freeze period refers to Baltimore; the Weatherbase web site had no data for Annapolis).

Data over population size, the number of slaves, and population density come from Potter (1965; Tables 11 and 12). We removed the outlier DC, since its population density was so exceptionally high. The density numbers are taken directly from the table, since they were calculated using the area of each state at the time. Potter also reports the total area of the same states today in his tables, which in some cases makes population size and area inconsistent with the reported density numbers. This also explains why e.g. Texas' population density fell between 1850 and 1860, even though its population grew: Texas was larger in 1860.

A.2. Comparing payoffs

A.2.1. Comparing π_t^S and π_t^H

Comparing slavery to hunting and gathering, we need to distinguish between the two cases for calculating π_t^S. Consider first Case 1, which upon recalling (3.14) can be written as $A_t \leq \Gamma(P_t;\gamma)$. Using (3.5) and the first line of (3.17), we see that $\pi_t^S \geq \pi_t^H$ when $\alpha \left[\frac{1-\alpha}{(1+\gamma)\bar{c}}\right]^{\frac{1-\alpha}{\alpha}} A_t \geq A_t^\alpha P_t^{-\alpha}$, or

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

Consider next Case 2: $A_t > \Gamma(P_t;\gamma)$. Using (3.5) and the first line of (3.17), we see that $\pi_t^S \geq \pi_t^H$ when $A_t^\alpha \left(\frac{P_t}{1+\gamma}\right)^{1-\alpha} - \bar{c}P_t \geq A_t^\alpha P_t^{-\alpha}$. This requires both that $P_t > (1+\gamma)^{1-\alpha}$ and $A_t \geq \Omega(P_t)$, where $\Omega(P_t)$ is defined in (3.19).

Considering both cases together we thus conclude:

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

A.2.2. Comparing π_t^F and π_t^H

Comparing hunting and gathering to freedom, we distinguish between the two cases for calculating π_t^F. Consider first Case A: $A_t > \left[\frac{\bar{c}}{1-\alpha}\right]^{\frac{1}{\alpha}} P_t$. Using (3.5) and the first line in (3.11) we see that $\pi_t^F \geq \pi_t^H$ when $\alpha A_t^\alpha P_t^{1-\alpha} \geq A_t^\alpha P_t^{-\alpha}$, or

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

	1850			1860			Freeze period
State	**Population**	**Slaves**	**Density**	**Population**	**Slaves**	**Density**	**Days<32F**
Maine	583	0	17	628	0	21	151.1
New Hampshire	318	0	40	326	0	36	171
Vermont	314	0	39	315	0	35	178.7
Massachusetts	995	0	137	1231	0	153	97
Rhode Island	148	0	123	175	0	164	117
Connecticut	371	0	78	460	0	96	134
New York	3097	0	67	3881	0	81	147
New Jersey	489	0	72	672	0	89	85
Pennsylvania	2312	0	49	2906	0	65	106
Delaware	92	2	43	112	0	57	87.2
Maryland	583	90	53	687	87	69	97
Virginia	1422	473	23	1596	491	25	79
North Carolina	869	289	19	993	331	20	76
South Carolina	668	385	24	704	402	23	57
Georgia	906	382	16	1057	462	18	48
Florida	87	39	2	140	62	3	30
Ohio	1980	0	50	2340	0	57	117
Indiana	988	0	29	1350	0	38	117
Illinois	851	0	15	1712	0	31	111
Michigan	398	0	7	749	0	13	149
Wisconsin	305	0	6	776	0	14	160
Kentucky	982	211	26	1156	225	29	102
Tennessee	1003	239	23	1110	276	27	76
Alabama	772	343	15	964	435	19	38
Mississippi	607	310	13	791	437	17	49
Iowa	192	0	4	675	0	12	137
Missouri	682	87	11	1182	115	17	114
Arkansas	210	47	4	435	111	8	56
Louisiana	518	245	13	708	332	16	21
Texas	212	58	7	604	183	2	19
California	93	0	0.5	380	0	2	18
Oregon	*new states in 1860*			52	0	0.5	64
Washington				12	0	0.1	85
Minnesota				172	0	2	117
Kansas				107	0	1	122

Figure A.1: Data for Figures 2.6 and 2.7. Numbers for population and slaves are in thousands.

Consider next Case B: $A_t \leq \left[\frac{\bar{c}}{1-\alpha}\right]^{\frac{1}{\alpha}} P_t$. Using (3.5) and the second line in (3.11) we see that $\pi_t^F \geq \pi_t^H$ when $\alpha \left[\frac{1-\alpha}{\bar{c}}\right]^{\frac{1-\alpha}{\alpha}} A_t \geq A_t^{\alpha} P_t^{-\alpha}$, or $A_t \geq \Phi(P_t)$, where $\Phi(P_t)$ is defined in (3.20).

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

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

A.2.3. Comparing π_t^F and π_t^S

The most complicated comparison is between slavery and free labor, since the payoffs to choosing either involve two cases each. Consider first the combination of Case A under free labor and Case 2 under slavery, which we shall name **Case I**. Since $\Gamma(P_t;\gamma) > \left[\frac{\bar{c}}{1-\alpha}\right]^{\frac{1}{\alpha}} P_t$ [see (3.14) and recall that $\gamma > 0$] this can be written as

$$A_t \geq \Gamma(P_t;\gamma). \tag{A.5}$$

Using the first lines in (3.11) and (3.17) we see that $\pi_t^F \geq \pi_t^S$ when $\alpha A_t^{\alpha} P_t^{1-\alpha} \geq A_t^{\alpha}\left(\frac{P_t}{1+\gamma}\right)^{1-\alpha} - \bar{c}P_t$. This becomes $A_t \geq \Psi(P_t)$, where $\Psi(P_t)$ is defined in (3.18).

Consider next the combination of Case A under free labor and Case 1 under slavery, which we name **Case II**. This amounts to

$$\left[\frac{\bar{c}}{1-\alpha}\right]^{\frac{1}{\alpha}} P_t < A_t < \Gamma(P_t;\gamma). \tag{A.6}$$

Using the first line in (3.11) and the second line in (3.17) we see that $\pi_t^F \geq \pi_t^S$ when $\alpha A_t^{\alpha} P_t^{1-\alpha} \geq \alpha \left[\frac{1-\alpha}{(1+\gamma)\bar{c}}\right]^{\frac{1-\alpha}{\alpha}} A_t$, or

$$A_t < \left[\frac{\bar{c}(1+\gamma)}{1-\alpha}\right]^{\frac{1}{\alpha}} P_t = (1+\gamma)\Gamma(P_t;\gamma), \tag{A.7}$$

which always holds in Case II, where $A_t < \Gamma(P_t;\gamma)$ [see (A.6) above].

Consider finally the combination of Case B under free labor and Case 1 under slavery, which we name **Case III**. This amounts to

$$A_t \leq \left[\frac{\bar{c}}{1-\alpha}\right]^{\frac{1}{\alpha}} P_t. \tag{A.8}$$

Using the second lines in (3.11) and (3.17) we see that $\pi_t^F \geq \pi_t^S$ when $\alpha \left[\frac{1-\alpha}{\bar{c}}\right]^{\frac{1-\alpha}{\alpha}} A_t \geq \alpha \left[\frac{1-\alpha}{(1+\gamma)\bar{c}}\right]^{\frac{1-\alpha}{\alpha}} A_t$, or $(1+\gamma)^{\frac{1-\alpha}{\alpha}} > 1$, 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 $\Psi(P_t) > \Gamma(P_t;\gamma)$ [see (A.5) and (3.18)]. Considering all cases together we thus conclude:

$$\pi_t^F \geq \pi_t^S \iff A_t \leq \Psi(P_t). \tag{A.9}$$

A.2.4. Conditions for $\pi_t^S \geq \max\left\{\pi_t^F, \pi_t^H\right\}$

Slavery (weakly) dominates both freedom and hunting and gathering when $\pi_t^S \geq \max\left\{\pi_t^F, \pi_t^H\right\}$, i.e., when $\pi_t^S \geq \pi_t^F$ and $\pi_t^S \geq \pi_t^H$. As seen from (A.9), $\pi_t^S \geq \pi_t^F$ requires that $A_t \geq \Psi(P_t)$.

The second condition on the right-hand side of the implication arrow in (A.2) shows the condition for $\pi_t^S \geq \pi_t^H$. As long as $\pi_t^S \geq \pi_t^F$ and thus $A_t \geq \Psi(P_t)$, it must always hold that $A_t > \Gamma(P_t;\gamma)$ since $\Psi(P_t) > \Gamma(P_t;\gamma)$ [see (A.5) and (3.18)]. It is then straightforward to use (A.2) to see that $\pi_t^S \geq \max\left\{\pi_t^H, \pi_t^F\right\}$ when A_t is greater than both $\Psi(P_t)$ and $\Omega(P_t)$, and P_t is strictly greater than $(1+\gamma)^{1-\alpha}$, i.e.,

$$P_t > (1+\gamma)^{1-\alpha} \text{ and } A_t \geq \max\left\{\Psi(P_t), \Omega(P_t)\right\}, \tag{A.10}$$

as stated in Proposition 1.

A.2.5. Conditions for $\pi_t^F \geq \max\left\{\pi_t^H, \pi_t^S\right\}$

Freedom (weakly) dominates both slavery and hunting and gathering when $\pi_t^F \geq \max\left\{\pi_t^H, \pi_t^S\right\}$, i.e., when $\pi_t^F \geq \pi_t^H$ and $\pi_t^F \geq \pi_t^S$. As seen from (A.9), $\pi_t^F \geq \pi_t^S$ requires that $A_t \leq \Psi(P_t)$. The condition for $\pi_t^F \geq \pi_t^H$ is given in (A.4): both $P_t \geq \frac{1}{\alpha}$ and $A_t \geq \Phi(P_t)$ must hold. Thus, $\pi_t^F \geq \max\left\{\pi_t^F, \pi_t^S\right\}$ holds when

$$\Phi(P_t) \leq A_t \leq \Psi(P_t) \text{ and } P_t \geq \frac{1}{\alpha}, \tag{A.11}$$

as stated in Proposition 1.

A.3. Population dynamics in free societies

We here show that if $w_t < \overline{w}$ in a free society it implies that its population is falling. Consider first the case when $A_t \leq \left[\frac{\bar{c}}{1-\alpha}\right]^{\frac{1}{\alpha}} P_t$. Then the labor force, L_t, adjusts so that the wage rate equals subsistence consumption: $w_t = \bar{c}$. Thus $n_t^{\text{worker}} = 0$, and $P_{t+1} = n_t^{\text{landowner}} = \frac{\beta\alpha}{q}\left[\frac{1-\alpha}{\bar{c}}\right]^{\frac{1-\alpha}{\alpha}} A_t < \frac{\beta\alpha}{q}\left[\frac{1-\alpha}{\bar{c}}\right]^{\frac{1-\alpha}{\alpha}}\left[\frac{\bar{c}}{1-\alpha}\right]^{\frac{1}{\alpha}} P_t < P_t$, from using Assumption 1, $\alpha < 1$, and $1-\beta < 1$. Next, consider the case when

$A_t > \left[\frac{\bar{c}}{1-\alpha}\right]^{\frac{1}{\alpha}} P_t$, implying that the wage rate exceeds subsistence consumption: $w_t > \bar{c}$. Thus, $n_t^{\text{worker}} = \frac{w_t - \bar{c}}{q} > 0$, and $P_{t+1} = \frac{\beta}{q}\alpha A_t^{\alpha} P_t^{1-\alpha} + \frac{w_t - \bar{c}}{q} P_t$. Since all P_t agents are working it must hold that $w_t = (1-\alpha)A_t^{\alpha} P_t^{-\alpha}$. Some algebra then tells us that $P_{t+1} = \frac{\bar{c}\beta}{q(1-\alpha)(1-\beta)} P_t$. Then $w_t < \overline{w}$, together with Assumption 1 demonstrates that $P_{t+1} < P_t$.

A.4. Steady-state equilibria with hunting and gathering and freedom

From (4.6) and (4.9) we see that the $(\Delta P_t = 0)^{\text{S}}$-locus slopes steeper than the $(\Delta P_t = 0)^{\text{H/F}}$-locus. For the $(\Delta P_t = 0)^{\text{S}}$-locus to pass through the slavery region, it must slope steeper than the line separating slavery from freedom, i.e. $\Psi(P_t)$ defined in (3.18). Using (3.18) and (4.9) gives the following inequality:

$$\alpha(1+\gamma)^{1-\alpha} < \frac{q/\beta}{\bar{c} + q/\beta}. \tag{A.12}$$

If this holds, and assuming the right shape of the $(\Delta A_t = 0)$-locus, there exists a steady state with slavery, as given by the intersection of the $(\Delta P_t = 0)^{\text{S}}$-locus and the $(\Delta A_t = 0)$-locus, and illustrated in Figure 4.2.

In Figure 4.2 it also holds that the $(\Delta P_t = 0)^{\text{H/F}}$-locus passes through the region with free labor. In other words, the line separating slavery from freedom – $\Psi(P_t)$ in (3.18) – is steeper than the $(\Delta P_t = 0)^{\text{H/F}}$-locus. Using (3.18) and (4.6), and some algebra, this holds whenever

$$\alpha(1+\gamma)^{1-\alpha} > \frac{q/\beta}{\bar{c}/\alpha + q/\beta}. \tag{A.13}$$

Thus, with the right shape of the $(\Delta A_t = 0)$-locus, we can also have a steady state with free labor at the point where the $(\Delta P_t = 0)^{\text{S}}$-locus and the $(\Delta A_t = 0)$-locus intersect.

Figure 4.2 shows the case where both (A.12) and (A.13) hold. Note that, if the inequality in (A.12) is reversed, (A.13) must hold, since $\alpha(1+\gamma)^{1-\alpha} > \frac{q/\beta}{\bar{c}+q/\beta} > \frac{q/\beta}{\bar{c}/\alpha+q/\beta}$. In this case the $(\Delta P_t = 0)^{\text{S}}$-locus never intersects the slavery region (and is thus invisible), but the $(\Delta P_t = 0)^{\text{H/F}}$-locus intersects the free labor region. This is illustrated in Figure 4.1.

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