Modern slave plantations to firms and labor markets: incentive theory for a growth disaster[1]

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Abstract

The reallocation of property rights at the transition from slavery to free labor in Brazil, the US South, Jamaica, among others, was followed in most cases by a sharp fall in GDP per capita. One theory for the higher productivity of slaves claims it was the coercion available to slave-owners and not to employers. A second argues that plantations were using various incentives – more food, time off etc, to get it. Loss of scale at abolition is the implied theory. In this paper, some recent theories of the firm are used to study the incentive mechanisms when effort at multiple tasks must be supervised. The model shows how wrong incentives after abolition induced former slaves to produce more peasant crops relative to the plantation staples which yielded more GDP. Suitable regulation could have induced more plantations to become firms.

Key words: Firms, labor markets, property rights, incentives, slavery.

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[1] Version 1.2 (08/01) This paper, by a growth theorist, is the result of a sustained but inarticulate interest in the transition, firstly at UWI, Mona, Jamaica, and here at UnB. Apologies are offered to the economic historians for any misreading of their research. Discussions with Maurício Bugarin at UnB and Jean-Luc Rosinger at UFSC were extremely helpful, as were detailed comments by Stanley Engerman on a precursor to this paper which was presented at meetings of the SBE in Dec. 2000, and the SBNEI in March, 2001, both in Campinas, SP and at a seminar in UFSC.

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Section 1.Introduction

The passage from slavery to free labor was followed by a sharp fall in the average income per person of most regions of the Atlantic economy which used this mode, despite exploding demand for their products. In the reallocation of property rights at abolition, both ex-slaves and ex-masters lost, causing negative growth for perhaps 2 decades in the US south, Jamaica, British Guiana among others, and stagnation in Brazil in the same period before 1914 during which the US north made the US the richest country in the world (for GDP, see table attached; for demand, see Eltis [1987] pp185-6). Most have never caught up with the rich regions despite high growth rates over many decades of the 20th century.

There are two theories about the transition. One claims that the coercion or physical force available to slave owners and not to employers, induced output levels beyond what a free worker would choose. We can dub this the consumer inefficiency theory for slavery (Barzel [1977], Fenoaltea [1984] and Versiani [1994]). The other is an implicit producer inefficiency theory for free labor after abolition. It is based on the empirical discovery by Fogel & Engerman [1974, 1977, 1980], that the higher labor productivity on large slave plantations in the US south's cotton belt, 1840-60, was due to economies of scale, reinforced by material incentives to field slaves, to produce more in less weekly work hours. They argued [1977, p289] that coercion could not be the sufficient explanation because plantations of less than 15 slaves were not as productive.

The reasons why an economy should accept an arrangement which leaves agents poorer than they need be are at the heart of the theory of economic growth. Thus the slavery to free labor transition is a case study in that theory. However, it is an important one since it examines some conditions under which the functioning of labor markets may not guarantee higher incomes per person, namely growth.

The paper uses some recent theories of the firm, incentives and power, to model formally this failure of the Coase argument when property rights changed at abolition (see Holmstrom [1998]). It shows how wrong incentives can induce inefficient choices, in levels, of 2 activities. One can be executed by a single agent, working alone. The other activity requires a second complementary, cooperating type 2 agent for its execution. Neither activity needs physical capital. The first is a stylized version of a single-family, peasant farm. It is not necessarily confined to subsistence crops. For example in Jamaica such farms even today grow bananas for export. In late 19th century Brazil many raised cattle and planted food crops for local markets. The second activity, combined with the skills and effort of the type 2 agent, the master, is the core of a stylized plantation.

What is important here is that we assume that effort at the two activities by the type 1 agent must be supervised by the type 2 who, even under slavery, must offer the right incentives to induce an efficient combination with the complementary inputs of the plantation. Activity 1 can be the kitchen

gardens and livestock which slaves were allowed to care for in their spare time. But the more subtle interpretation is that at abolition, before which there was no wage-labor market, this simplified model is equivalent to one with increasing returns to labor (*irl*) in the plantation staple. With *irl*, the notion that individual effort is observable by an outside party becomes tenuous.

The gist of the argument of our model is that abolition induced inefficiently higher incentives for the now free, type 1 agents to allocate rationally, more effort to the first activity and less to the second, independently of product prices. However, to explain the fall in the value of total output we need to assume that the relative prices are such that the increased output in activity 1 does not compensate, in value, for the reduced output of activity 2.

If activity 2 did not exist in this economy, we would have a case of ancient slavery where the master offers no cooperating skills in a joint effort at production. The master's share would be like a tax. The analysis of this case was done by Evsey Domar [1970], in economies with only labor and land, and constant returns. If land is in surplus relative to labor, no one will choose freely to work for someone else. For a rentier class of agents to emerge here, either access to land must be blocked, serfdom, or labor must be coerced, slavery. Labor productivity must of course be above subsistence.

In the Asiatic mode of production the Ottoman pasha offered no cooperating skills (other than public order) in the farming activities of the peasants he taxed. He also had no title to the land they farmed. This resided in the sultan in Istanbul. Marx's insightful objection to the Asiatic mode was exactly its lack of property rights in land, common in feudal Europe. Since the pasha also had none in labor, this mode, unlike Atlantic slavery, could not generate the growth we now know took place here despite the continual harassment by the British after 1807, when they tried, unilaterally, to stop the slave trade. We shall see later that property rights alone are in general not a sufficient incentive for efficient allocations when asymmetric information is present.

For us, the distinguishing feature of modern slavery is the perception by masters, mainly in the Americas and from around the same time as the industrial revolution, that they could obtain more income from their slaves by offering both incentives and some complementary skill in certain activities of the plantation. This was the fundamental contribution of Fogel & Engerman's 1974 book, *Time on the cross*, which caused a furious debate among US economic historians (see especially Paul A. David et al [1976,1979]) some of whom contested, unsuccessfully in our view and Barzel's, their finding that the imputed real income of a slave in the US cotton belt around 1860, was more than that of a free peasant in the same region. Fogel & Engerman attributed the difference to the psychic income derived from being free. Barzel's interpretation of the extra food, time-off etc is that they were the biological complements of the forced labor regime.

Jeffrey Williamson [1999] has published data on wage rates for free workers in late 19th century Brazil, Argentina and Uruguay which showed, for example, that in 1874, a free urban worker in the Brazilian southeast earned 1/5 the wage in Argentina which was in turn ¾ that of a British worker. In the Brazilian northeast, it was even lower, 5%, comparable, according to Williamson, to

those paid in Calcutta at the time. Since both the southeast and Argentina were then operating very similar activities, mainly extensive cattle rearing, one can argue that it was the slavery regime in Brazil which depressed free workers' wages there. Outside the US, I know of no comparison of incomes of slaves and free workers.

Why the presence of slavery devalues the productivity of free labor is, we hope, one of the contributions of this paper. During slavery, free workers seeking a wage contract would be offered less even though their intrinsic skills may be identical to that of a slave, because the wage regime would not be able to offer efficient incentives when effort at multiple tasks must be coordinated in complex ways. Thus we have a better explanation than Fogel & Engerman's psychic income theory for why free workers in the US south did not offer to become slaves, even though their incomes were less than a slave's. We shall see that a free worker would need to be offered more than a slave to induce him to accept the discipline of the plantation and produce its required combination of the 2 products. The plantation would not necessarily be worse off because it would no longer have to pay out the capital cost of the slave contract. In fact, slavery would become redundant if this cost were higher than any reduction in gross income of the plantation caused by abolition. These remarks will become clearer after we present the model.

Our explanation for the inability of these economies to sustain the higher incomes is not economic unfeasibility due to the suppression of coercion as Barzel argues, but rather to the inadequate regulatory framework after abolition. With cotton, it led to share-cropping, which denied the type 1 agent access to the type 2's skills. With sugar, it led to wage labor for the type 1 agent at activity 2 (the plantation staple), which cannot discourage sufficiently activity 1. Both contracts yield lower GDP in our model. Some plantations, mainly in sugar, did learn to develop reputation as good employers of free workers, just like modern firms do.

The British, who were the first European empire to abolish slavery in the Atlantic economy, against the will of their planters, and who also had at the time (1834-38) the most experience at home with free labor in a modern environment, had spotted the potential conflicts over the wage contract. The Westminster parliament, again without the planters' consent, created a system of stipendiary magistrates, a kind of primitive labor court to which both planters and workers could appeal against abuses of the indenture contracts of free immigrants from India to the West Indies, especially to Trinidad and British Guiana (see Adamson [1972] chap. 4). Resort to them probably reached its peak around 1870.

Douglas Hall, the Jamaican economic historian who had studied the post-emancipation period in the British West Indies, and who in previous writings had, by his own admission, swung back and forth between the two hypotheses of pull or push of ex-slaves to and from the plantations, finally concluded (Hall [1978] p 23):

> "The movement of the ex-slaves from the estates in the immediate post-emancipation years (1838-42) was not a flight from the horrors of slavery. It was a protest against the inequities of

early “freedom”. It is possible that, had the ex-slaves been allowed to continue in free use of (kitchen) gardens, houses and grounds and to choose their employers without reference to accommodation, there would have been very little movement of agricultural labour at all from the communities apparently established on the estates during slavery”.

In section 4, the paper constructs a model and proves some sufficient conditions for the existence of an indenture contract which can satisfy the participation constraint of the former slave and yield more income for both him and the former master. Indenture here is not the long-term contract of the history texts. It is simply the static microeconomic conditions under which the type 1 agent will accept voluntarily the authority of the type 2 and reduce his effort at activity 1. In principle, it needs no third party for enforcement. The existence result depends on the relative price and technology of the two products

In practice and in principle, our indenture “contracts” require a functioning market for them. That is, the division of the plantation output between the two types of agents must be disciplined by an efficient, outside option for the type 1, namely working for other plantations, and not solely on his own farm. Since like the firm, its division is not based on marginal product incentives, there is room for much conflict. Reputation as good employers can help plantations to minimize turnover costs and become firms. Labor legislation may also help.

One conjectures that the success or failure of firms versus labor courts would depend on how fast either can build reputation. If reputation is basically a public good, say of the planter class as a group, then courts would be dynamically superior. If it is mainly a private good, then type 2 agents can learn more quickly to acquire it and so become firms. Of course, since the emergence of courts and their jurisprudence (their reputation) may be dependent on the political regime in place, the resolution of this issue may go beyond economic theory. After all, the planter class continued to control the legislatures. However, our model below assumes that effort is not verifiable and so we would claim that firms should be the superior mechanism.

Perhaps the main contribution of the paper is to show why nearly all the historical mechanisms used, share-cropping, rentals(tenancy) or simple wage labor were inefficient. Another, not pursued here, is a new explanation for Arthur Lewis’ dualism. Peasant farms after abolition used too much labor not because of family pressure to employ all its members but because the regulation of the indenture contract market did not function equitably.

Our model differs from the standard neoclassical theory mainly because of the asymmetric information assumed. But the issues are not so far removed, if one introduces increasing returns to labor in the neoclassical production function, whatever may be the other input, physical capital, land or managers. The neoclassical theory completes its model by assuming that as size increases, it is the eventual decreasing returns to the factors which would determine their market price. The market would fix the wage of *all* the employed workers, including the earlier ones taken on at points on the

production function which gave them higher productivity. Competition among firms for workers would then determine a common market wage for them all.

The postulated eventual fall, with size, in the productivity of the supervised (i.e. non-managerial) labor is the issue here. During slavery, there was no wage-based labor market for the supervised workers, the slaves. So the size of the production unit, the plantation, was determined almost entirely by the market discipline in the other inputs, mainly the financing and supervision of the slaves. It is highly likely, therefore, that plantations under slavery, as do many modern oligopolies, were operating on the *irl* part of their production functions. At abolition, therefore, even without assuming asymmetric information, or the introduction of technological innovations (as in Cuba with slaves, and British Guiana with indentured labor), there would have had to be major consolidation of units before the decreasing returns to supervised labor could set in. The wage rate could not be consensual, even if effort were observable, because the units were not in competitive equilibrium in this labor market.

We suggest therefore that our simplified model of the firm with constant returns to supervised labor and unobserved effort may well be equivalent to one where firms, for some reason to do with the economics of supervision, operate on the *irl* interval of their production functions and with putatively observed effort.

In the transition from agriculture to manufacturing known as the industrial revolution, wage labor mechanisms meaning marginal product incentives yielded growth. Some historians point to the poor distribution, but certainly after around 1850, the secular increase in real wage rates in England was so pronounced that it led to the formulation of the neoclassical, marginal productivity theory. The insight gained here is that this success may have been due partly to the introduction of physical capital goods, factories, which made stronger internal monitoring less costly, but also because the external monitoring provided by the labor market, the free worker's outside option, functioned better. Why did it? There is no easy answer, but probably the central feature is that most factories were located in cities where the cost, to workers, of changing jobs was relatively low, which makes credible the threat to quit. Some slaves were used in factories in the US south, but the current view is that plantations outbid them for slaves.The ideas here may also go some way toward an explanation as to why some backward regions like early 20th century Italy and Brazil introduced special labor courts, or like Russia, resorted to collectivization.

The rest of the paper is laid out as follows. The next section treats of some relevant economic history and its interpretation by the historians. Section 3 explains the theory of the firm we use, and section 4 presents the formal model. A concluding section draws some inferences for the construction of a general theory of economic growth. The proofs of the results are in the appendix.

2. Economic history and the historians

We now know that from around 1800, all workers in the Atlantic economy, slave and free, began to increase their productivity. More importantly, we now know that there was no secular decline in the profitability of slave plantations as the nineteenth century progressed. Those regions which continued to use slaves up to around 1860, showed no sign of lags in income per head behind those which used free labor. For example, between 1840 and 1860, the income per head of the US south grew faster than the north. The Cuban and Brazilian economies seemed to have boomed in the first half of the 19th century, but the GDP data before 1850 are sparse. However there are strong indications that most slave regions then were richer than the non-slave.

In the case of Brazil, Celso Furtado's classic [1963, chap 25] is misleading. Furtado claims (p163) that between 1850 and 1950, Brazil's income per head grew faster than that of the US. If this were so, either Brazil should have been a rich country in 1950, or it should have been exceedingly poor in 1850. Neither is true. Our table cites two separate sources, both of which show the fall in income per person in the late 19th century. Stagnation is probably nearer the truth. In 1900, Brazil's per capita income was hardly higher than it was in 1800, despite massive growth in the coffee sector, outside the traditional, dominant northeast sugar region, and large-scale European immigration. Furtado however correctly observed the significant fall in income in the northeast after 1850. This is the case most suited to our model as it had little in-migration or technological change.

Another important point about Brazil is the dating of abolition. Officially, it was 1888 but in fact, only 16% of the population were then still slaves. Abolition in Brazil was protracted, with various legal measures adopted between 1850 and the end, which effectively began to reduce the role of slavery and slave owners in the economy. However, it is our suggestion that the major reason for the different economic performance in the late 19th century relative to the US, with which its economic history bears the nearest comparison, is that Brazil had no region outside the slavery regime when free migrant labor started to become available.

Engerman, the economic historian who has devoted the most attention to the comparative 19th century experience, and especially the use of indentured immigrants in the British regions after 1838, had spotted the failure of the Coase position at abolition (Engerman [1992], footnote 55):

> "The argument that the initial allocation of ownership rights (over labor) will not influence the value of output will not hold in the presence of non-pecuniary tastes and low income and wealth effects."

This explanation of a failure however, does not coincide with Coase's own. He emphasized transaction costs, which at abolition, would involve the costs of bargaining over a new labor contract. The model we present identifies the microeconomic conditions required for the existence of such a contract for free labor, indenture, which can also maintain or increase the previous output levels.

Engerman is hard put to explain the continued profitability of slavery even in those regions (Cuba in the 1860's) where imported contract labor (indenture) was increasingly available. Our interpretation is that the indenture contract can induce the same effort mix as slavery except that it can

cost the plantation more, unless slavery was redundant under the reigning conditions at abolition in the sense that the slave could not earn more for the same total effort if he increased his peasant crop. Our model also explains the more puzzling phenomenon, the almost complete reluctance to use free (non-indentured), wage labor, right to the end.

He correctly rejects Domar's [1970] theory that the incentive to coerce labor would exist only when labor was capable of being forced to produce a surplus over subsistence. According to Domar, coerced labor would end when population growth or more generally, changes in the land/labor rates, drove labor's marginal productivity to subsistence. By the terms of the argument, Engerman [1992, p. 20] pointed out, slavery in the Americas should have expanded, not ended, in the 19th and 20th centuries.

Although this paper does not try to explain the reasons for abolition, we hope it will help to bring that discussion back to the realm of economic theory, from which, surprisingly, both Fogel and Engerman subsequently tried to remove it. Here is Engerman at the end of his 1992 paper:

> "... the range of permissible property rights allocations cannot be explained on the basis of economic factors alone. ... The relationship between ideology and economic change is quite complex. While it might be argued that the ideology itself reflects fundamental long-term economic forces, ... at any moment in time, ideological factors have a direct impact in defining and restricting economic alternatives".

Moses Finley, a scholar of classical antiquity, when called upon in the seventies to comment on the academic debate then hotly pursued over US slavery, made the observation that the economic historians of the modern period did not seem to realize that for most of human history, man did not sell his labor freely to his fellow man. Most forms of coercion were used. His famous remark turned Kenneth Stampp's title on its head – free labor, not slavery, was "the peculiar institution".

It is difficult for the economist to accept that it was the absence of a suitable regulatory framework, an ideology if you wish, which prevented the emergence of labor markets over all these centuries. It would seem that a better explanation, one which he should be equally loathe to accept at face value, is the absence of increasing returns to labor in the technologies then available. In this paper, we claim it was the absence of firms an economic institution which we shall see, does not always use marginal product incentives for labor.

Sharecropping, another non-marginal product incentive, was used widely after abolition. Many papers, both historical and theoretical, have studied the efficiency properties of such contracts. Reid Jr [1973] examined creatively the two issues, the drastic fall of per capita income in the US south after abolition, and the apparent efficiency of the detailed contracts actually used by former masters. He formulated a theoretical model of the risk versus return variety to show that sharecropping achieved an optimal trade-off for the ex-slave between the security but low return of simple wage labor and the high risk, high return of rentals. From this he concluded that "the post-bellum fall in southern agricultural productivity cannot be directly attributed to the rise of tenancy (renting and

sharecropping)" (p107). To explain the fall, he posited a reduced availability of agricultural capital caused by the Civil War, and a drop in the labor supply occasioned by emancipation.

The careful econometric work of James Irwin [1994] rejected the labor supply theory for the US south, 1860 – 1880. Irwin tested with county level data, two competing hypotheses. One was that it was caused by a reduction in labor supply by ex-slaves, as they shifted to work patterns of free people. This labor-leisure decision was the focus of Barzel's theory. The other was Fogel & Engerman's plantation efficiency hypothesis, mentioned earlier, which argued that there were increasing returns to labor in both the plantation crop, with gang labor, as well as the slaves' "domestic production", our activity 1. Irwin found that it was the shift away from gang labor on large plantations (>15–19 slaves) and not a drop in total supply of labor, which caused the decline.

Despite his risk-return model, however, Reid was so impressed with the concern for good farm practice displayed by the details of the sharecrop contracts, he became convinced that "agricultural uncertainty .. (was) not the only (and probably not the main) impetus for sharecropping. *The central feature of a sharecropping contract is the continuing interest of both landlord and tenant in the efficiency of agricultural production"* (his emphasis) (p126). Yet incomes fell. He continues – "this evidence (from the contracts) clearly supports the contention that the sharecropping landlord supplied managerial expertise as well as land to his tenants".

These assertions provide the clue to the central thesis of the paper, that a new institution, firms using supervision and the right to hire and fire was a superior mechanism to such formal contracts. We will study the non-marginal product incentives which the firm uses to combine the two types of skills, and will show that it can reproduce the high productivity of the plantation without the forced labor regime.

2. The theory of the firm

The theory of the firm used here comes from Holmstrom [1998], Hart and Moore [1990], Holmstrom and Milgrom [1994] and Rajan and Zingales[1998]. It says that the firm's behavior can be the opposite to how the market functions in neoclassical theory. It will pay less than the marginal product for some activities of its employees, in order to create incentives for others that are in its core business. The application to the abolition case is simply put. If sugar and cotton is in the core, then the production by its employees of subsistence crops like corn and cassava must be carefully monitored, if not discouraged. And if sugar and cotton yield more GDP, then after slavery GDP will fall, unless some other mechanism than wage labor or share-cropping is forthcoming. Whether the 19th century slave plantation can be regarded in any sense as a firm remains moot and we return to this central issue later. Wage labor here means marginal product incentives for effort and not a fixed payment per period plus supervision.

The reason for the odd behavior of the firm is asymmetric information. The assumption is made that the effort of its employees at minimally 2 activities can only be imperfectly observed and coordinated. For simplicity let's divide them into 2 types, supervised labor and managers. For

relevance to abolition we focus on the incentives of the supervised. These agents are assumed to be able to execute one of the two activities without the need for any cooperating inputs from the rest of the firm. Dramatic modern examples are the proletarianization of the liberal professions as employees, and their liberty or otherwise to operate private clinics simultaneously.

The firm in this view emerges as a mechanism for restoring efficiency to the incentives of the market, when effort cannot be observed or verified. The original theory, first proposed by Hart and Moore [1990], was based on the idea that who owns the physical assets used in the firm will determine the payoffs and hence the efficiency of the allocations of effort to competing activities. For example, complementary assets should be owned by the same party if their joint yield is highest when they are put to working together. The intuition is that if they were owned separately this would be equivalent to joint ownership which is always worse because of the veto power it confers on both owners.

This property rights view has been criticized recently for being able to explain only why *individuals* own assets but not why *firms* do. The critics suggest that firms usually own all the assets used within them in order to create more complex incentive schemes than ownership, for those who agree to do business within them, their employees in our case. High-powered ownership incentives are replaced by lower-powered, non-marginal "wage-type" incentives, in order to encourage cooperation among employees. Markets are still crucial because, to treat the labor case, the right of the firm to fire is an element in its incentive scheme, while the right of the worker to quit is a tool to discipline the abuse of its power. This was basically the center of the efficiency wage theory of Shapiro & Stiglitz [1984].

Once the incentive schemes were generalized away from ownership of physical assets, we got the insight for the application to the slave plantation. It had few such, and operated in economies where land was virtually a free good. The power the firm uses over its employees to pay them less than their marginal product in certain activities seemed similar to that of the plantation.

One of two major differences of course, was the lack of the right to quit on the part of the slaves. The plantation did not have to satisfy the participation constraint of its workers. This is a major issue in our model of the transition. Its satisfaction is a necessary condition for slavery to become redundant. The model allows the possibility of redundancy but we doubt that this was the motive for abolition. Certainly almost everywhere it was imposed on the planters by some exogenous force eg the British, the US north, Haiti's slaves. In 1820, the Spanish government, under pressure from the British, tried unsuccessfully to end Cuba's then booming slave trade. On the other hand, we believe that the resource reallocations required, redistribution in fact, were minor. As we shall see later, the problem was the regulatory framework; in older fashioned language, the political economy of the transition.

The other major difference was the possibility of the use of force by the plantation to induce its slaves to produce more. This is the central alternative hypothesis to our theory. Our model cannot establish explicitly whether the cooperating activity offered by the plantation was more something like

coordination or managerial ability, and not simply physical punishment or the threat of it. The firm's power derives mainly from its right to hire and fire, which was not available to the plantation. However, we assume that individual effort can be only imperfectly observed and so any punishment becomes an extremely crude device, particularly destructive of worker morale. This is the equivalent of the rationale for the modern firm's reluctance to fire workers.

While the empirical data uncovered by Fogel & Engerman on the incentives used by US planters in 1840-60 convince both us and Barzel (see his footnote 7, p.92), his interpretation is that the extra food, time off etc to field workers during the harvest, was just fulfilling a biological necessity induced by the forced labor regime with no incentive component. It is not easy to refute such a claim. Our criticism of his theory however, lies in the fact that it negates a priori the possibility that with free workers and the same technology, there can exist the material incentives to reproduce the high productivity of which we now know the 19th century slave plantation was capable. This is what our model allows. If there is a contract which satisfies the participation constraint of the ex-slave, indenture, then he will voluntarily submit to the authority of the plantation and produce the output mix it requires, possibly even at higher levels than under slavery.

One can get a feel for the economic theoretic issue in this quotation from Adamson [1975]. He had studied the case of British Guiana after abolition in 1838, where sugar expanded with indentured labor, mainly from India. This is the governor to the colonial secretary in 1849:

> "The disadvantages under which most of the British Colonies labour [in relation to places still under slavery].... do not arise.... from the dearness of free labour. [They] are attributable almost entirely to the great difficulty of commanding continuous labour. A planter has a capital of so many thousand pounds invested in his estate, which, provided he could keep his machinery going so many days in the year would yield him a fair return, but he cannot make sugar this week because half the labourers choose to go fishing...".

Sugar after 1840, in those regions where it expanded, is already a more complex environment than the model we present, because of the machinery and equipment being introduced in both field and factory. The higher labor productivity which these innovations permitted for larger enterprises can quickly reduce the conflict over the incentive scheme because, in our model, the plantation activity would become more lucrative for all. Even so, the new theory of the firm helps us to understand better the role of the outside option in its incentive scheme: of the ex-slave, his peasant farm, of the corporation lawyer, his private practice, of the land-less proletarian, the labor market.

In the US mid-west after 1850, on the other hand, peasant farms began to increase their productivity dramatically with technological innovations, most of which were supplied free by the public sector. They soon knocked out the few large-scale agricultural enterprises which competed with them, called there bonanza farms, and eroded the markets of peasant farms in Europe and Anatolia. The regulatory framework, popular democracy restricted to the dominant, immigrant groups seemingly did the right thing for most folk.

4. A model for the transition

4.1 The general framework

Two products y_1, y_2 with perfectly competitive prices p_1, p_2 sold on markets. Later, we shall simplify the model by using $p \equiv p_1 / p_2$, the relative price of the 2 products.

There are two types of agents:

Type 1: can exert effort at two different activities, e_1,e_2. At activity 1, an effort level e_1 produces $y_1 = R(e_1),\ R'(e_1) > 0,\ R''(e_1) < 0$, without need of the second type of agent's input. At activity 2, an effort level e_2 produces $y_2 = e_2$, provided the complementary skills of a type 2 agent are joined.

Under slavery, type 1 agents will be the slaves.

Type 2 : has special skills (marketing, production know-how, coordination) complementary to type 1 agents' effort e_2 at producing y_2. For simplicity, assume fixed proportions and linearity (*crs*) in the effort levels of the two types, and linearity in the disutility of type 2 agents' effort. This ensures that the type 2 agent will always supply the correct, complementary effort level, whatever e_2 the type 1 chooses.

We will focus initially on the type 1 agent's incentives and decisions to allocate effort levels e_1, e_2 between the two tasks, which we assume to be equally disagreeable to him, and non-separable in their disutility.

Type 1 agent's utility: $\underset{\{e_1, e_2\}}{Max}\ U = \alpha_1 R(e_1) + \alpha_2 e_2 - \frac{1}{2}(e_1 + e_2)^2$

$$\text{subject to} \quad e_1, e_2 \geq 0$$

The property rights regime and incentive scheme will determine the values of α_1, α_2, the share of the output of the two goods accruing to this agent.

Given α_1, α_2, his optimal effort levels will be determined by:

$$\begin{cases} \alpha_1 R'(e_1) = \alpha_2,\ R'(e_1) > 0, R''(e_1) < 0 \\ e_2 = \alpha_2 - e_1 \end{cases} \qquad \text{.....(1)}$$

Social welfare

By our simplifying assumptions about the type 2 agent's complementary effort, we can ignore it in our social welfare function:

$$\underset{\{e_1, e_2\}}{Max}\ SW = p_1 R(e_1) + p_2 e_2 - \frac{1}{2}(e_1 + e_2)^2$$

$$\Rightarrow\ p_1 R'(e_1^*) = p_2 \qquad \text{.....(2)}$$

$$e_2^* = p_2 - e_1^*$$

Thus the first-best solution e_1^*, e_2^*, requires that $\alpha_1 = p_1, \alpha_2 = p_2$. That is, the marginal effort expended by the type 1 agent at the two activities must be compensated by the full marginal value product of each activity. Since activity 2 requires effort by both agents, no regime, slavery or free

labor, can achieve this solution. In the language of Makowski & Ostroy [1995], full appropriation of his social contribution by each agent is impossible here, so that markets alone, meaning price-taking behavior, will not lead to efficiency. The model thus creates a role for supervision by one agent of the other, in the plantation under slavery, and in the firm with free labor.

We will now study firstly, how the slavery regime would determine the output mix , and then how this would change if, at abolition, the plantation did not modify its incentive scheme. Specifically, we will show that if it didn't, the freed slave would want to produce more of y_1 and less of y_2 . If the prices of the two products are such that the increased output of the peasant crop, y_1, does not compensate in value for the decrease in the plantation staple, then there will be a fall in GDP at abolition even though the ex-slave's income may rise. Finally, we will show how the plantation can modify its incentives in a way that they both benefit. In this new scheme, it will be operating like a firm in that it will satisfy the participation constraint of its workers, but will use supervision instead of an incentive compatible contract to induce an efficient allocation of effort.

Two regimes are studied :

1. Free workers at abolition with no change of incentives: if the type 1 agent is now a free worker, $\alpha_1 = p_1$, because he can keep all the y_1 revenue, since for this activity he does not need the type 2 agent's skills. Let α_2 be a simple wage-type incentive based on effort at activity 2, e_2. Later we shall study a more complex mechanism which requires supervision by firms.

2. Slavery: if the type 1 agent is the slave of the type 2 , α_1, α_2 are the latter's incentives to him. The type 2 agent must choose α_1, α_2 so as to induce effort levels e_1, e_2 by the type 1 which will maximize his share of the output.

1. Free workers: the type 1 agent will get all the revenue from his effort e_1 at activity 1, and some part β of the revenue from activity 2 which needs the type 2 agent's cooperation. So the type 1 agent's incentives will be:

$$\alpha_1 = p_1 \quad ; \quad \alpha_2 = \beta p_2 \quad ; \quad 0 < \beta < 1$$

Substituting in equation (1), this agent's best response, e_1^F, e_2^F will be given by:

$$\left.\begin{aligned} p_1 R'\left(e_1^F\right) &= \beta p_2 \qquad \ldots(i) \\ e_2^F &= \beta p_2 - e_1^F \ldots(ii) \end{aligned}\right\} \qquad \ldots\ldots\ldots\ldots \quad (3)$$

Since e_1^F is given by $R'(e_1) = \beta \, p_2 / p_1$, $0 < \beta < 1$, $R''(e_1) < 0$ we must have: $e_1^F > e_1^*$.

And from (ii) in (3), $e_2^F < e_2^*$. That is, free workers will want to exert more effort at activity 1 and less at activity 2 than is socially efficient. This result does not depend on the relative price of the 2 goods produced.

Also $\beta \uparrow \Rightarrow e_1^F \downarrow$ because $R''(e_1) < 0 \Rightarrow e_2^F \uparrow$.

As his share of revenue from activity 2 increases, the type 1 agent will want to reduce his effort at activity 1, his outside option, and increase it at activity 2. Only in the extreme case of $\beta = 1$, will his response be the first-best solution e_1^*, e_2^*. However this solution is not attainable because at $\beta = 1$, the type 2 agent gets nothing.

2. Slavery: the type 2 agent as master will want to induce the slave to allocate more effort to the cooperative activity. Slavery, we assume, allows the type 2 the power to expropriate part or all of the output of his slave's activity 1. In practice this can mean, for example, an order say not to work in his kitchen garden until Saturday after midday.

With this power to expropriate, the master can equate incentives across the two activities such that effort at activity 1 under slavery, e_1^S, has the first-best level, e_1^*. The master will set:

$$\alpha_1 = \beta\ p_1;\ \ 0 < \beta < 1;\ \ \alpha_2 = \beta\ p_2 .$$

The slave will then choose $R'\left(e_1^S\right) = \dfrac{\beta\, p_1}{\beta\, p_2} = \dfrac{p_1}{p_2} \quad \Rightarrow \quad e_1^S = e_1^*$.

However, the type 2 agent as master, still cannot induce $e_1^S = e_2^*$. By increasing the value of β, he will always induce higher levels of e_2, without having to sacrifice the e_1 level. But only when $\beta = 1$ will the response of the slave be first best, $e_2^S = e_2^*$, which once again leaves nothing for the type 2 agent. The level of β will be chosen by the master to maximize his profit. Since he does not have to satisfy the participation constraint of his slave, this is a strong assumption since it may lead to various forms of resistance and even flight. Under slavery therefore, some masters may well have respected the constraint. In any case, whatever may be the β under slavery, we shall assume that it is not enough to induce the slave to continue to accept the discipline of the plantation. Put another way, we claim that at abolition, the right to quit had positive value to the slave and we shall even be able to calculate it.

For any given value of $\beta \in (0,1)$, we show now that the slavery response $\left(e_1^S, e_2^S\right)$ is socially superior to the free worker regime, $\left(e_1^F, e_2^F\right)$, by showing that in addition to $e_1^S = e_1^*$, we would have $e_2^S > e_2^F$:

$$\left.\begin{aligned} e_2^F &= \beta p_2 - e_1^F \\ e_2^S &= \beta p_2 - e_1^S \end{aligned}\right\}$$

For any $\beta < 1$, $e_1^F > e_1^*$ and $e_1^S = e_1^* \ \Rightarrow\ e_2^S > e_2^F$.

So we have $e_1^S = e_1^* < e_1^F$ and $e_2^S(\beta) > e_2^F(\beta), \quad 0 < \beta < 1$.

Although the slavery response is socially superior in this specific sense, it does not require that a participation restriction for the type 1 agent (the slave) be satisfied, namely $U^S \geq U^F$. Even if it were satisfied, we would need to make the extra assumption that, given the prices and the technology

of the two products, the socially superior use of the type 1's effort lies in combination with the type 2's. If this assumption is not valid, then neither the firm with free workers, nor the plantation with slaves, will be efficient in the sense used here. In practice, this means that we must assume that GDP is greater at the product mix under slavery. To see this more clearly, think of the free peasant who is denied access to the plantation's complementary input. He may well be earning less than the slave. Yet the plantation would not want to offer him the same β unless he accepts its discipline and in effect become a slave.

We shall see below that as β increases, the slavery regime will increase both the total GDP, $p_1 y_1^S + p_2 y_2^S$, as well as the slave's share. The first is about growth. The second is about distribution in a society where agents are not free to choose their occupation, though they can choose their effort levels, even under slavery, due to our assumption that these are only imperfectly observable. Our argument below is that under free labor, modern firms induce their employees to make exactly such effort choices, but with the participation constraint satisfied. If it can be, without forcing the master to accept a lower share than he would choose freely, then slavery would become redundant.

4.2 Simplification by using the relative price

We show now that by using the relative price, $p \equiv \frac{p_1}{p_2}$, both slave and free worker will always choose the same total effort, independently of prices. That is, for given β :

$$\left(e_1^S + e_2^S\right) = \left(e_1^F + e_2^F\right)$$

This simplifies the analysis considerably because it allows both the participation and incentive compatibility constraints to be defined using only income, without the need to study total effort levels simultaneously. The type 1 agent's utility becomes:

When free : $U^F(e_1, e_2) = pR(e_1) + \beta e_2 - \frac{1}{2}(e_1 + e_2)^2$

When slave: $U^S(e_1, e_2) = \beta\{pR(e_1) + e_2\} - \frac{1}{2}(e_1 + e_2)^2$

$\Rightarrow$ for given β, $\quad e_1 + e_2 = \beta$ whether slave or free.

The diagram below illustrates the simplified problem for type 1 agents.

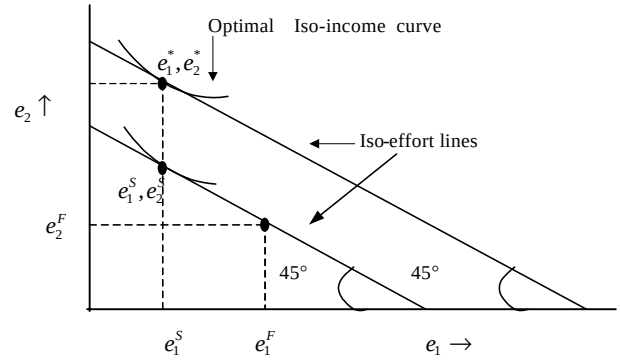

Figure 1

If slavery were redundant at abolition with $\beta = \beta^S$, the slave's income would be higher than the free worker's:

$$I^S \equiv \beta^S \{pR(e_1) + e_2\} > pR(e_1) + \beta^S e_2 \equiv I^F$$

for the same overall effort level, determined by β^S. This is a sufficient condition for redundancy but it is not necessary. We shall argue below that a firm with free workers can operate at a value of β where $I^S < I^F$, by using supervision to overcome the moral hazard problem. However, it must satisfy their participation constraint. So slavery can still be redundant even if $I^S < I^F$.

How then can we refine our definition of redundancy of the slave regime? With free workers, the plantation saves the capital rentals on the slave contract which they paid out to the slave trader – they do not have to buy their employees. So even if they were to lose income at abolition because they had to pay their workers more, they may still be ahead if this extra cost were less than the capital rentals.

For our purposes, we only need to assume that $I^S(\beta^S) < I^F(\beta^S)$ because we do not study how slave prices were determined. Obviously, if the slave regime were to be abolished, these prices would fall to zero, even if slavery were not redundant in our sense.

4.3 Existence of an indenture contract: general case

In this simple model the value of β, the type 1 agent's share of one or both crops, will characterize the incentives for both slave and free worker at abolition. In appendix A we study the comparative statics of the two optimization problems, slave and free, using the envelope theorem to obtain the gradients $\frac{\partial I^S}{\partial \beta}, \frac{\partial I^F}{\partial \beta}$, assuming that $e_1, e_2 > 0$ hold:

$$\frac{\partial I^F}{\partial \beta} = e_2^F(\beta) + \beta \qquad \ldots(i)$$

$$\frac{\partial I^S}{\partial \beta} = pR\left(e_1^S\right) + e_2^S(\beta) + \beta \qquad \ldots(ii)$$

$e_2^F(\beta), e_2^S(\beta)$ are functions of β; $e_1^S = e_1^*$, the social optimum value which does not depend on β. Since we know that $e_2^F(\beta) < e_2^S(\beta)$ for $0 < \beta < 1$, these gradients imply that :

$$\frac{\partial I^F}{\partial \beta} < \frac{\partial I^S}{\partial \beta}$$

and $\frac{\partial I^S}{\partial \beta}, \frac{\partial I^F}{\partial \beta} > 0$ for $0 < \beta < 1$, if $e_1, e_2 > 0$

Since we want to assume that $I^S < I^F$ *at* $\beta = \beta^S$, its value at abolition, and since we know that $I^S = I^F$ *at* $\beta = 1$, these gradients imply that $I^S < I^F$ *for all* $\beta < 1$. This result is very interesting

for the economics of abolition. It means that no matter how much the plantation increases β, the free worker who agrees to accept the discipline of the plantation and allows his peasant crop to be "taxed", will still have an incentive to produce more of it and less of the staple than the plantation would want, a form of shirking. That is, even if β is high enough to satisfy the participation constraint of the free worker who accepts the "tax", the plantation would still have to use supervision to block him from "shirking". In the vision of Holmstrom & Milgrom [1994] and Rajan & Zingales [1998], the plantation would have become a firm.

In our earlier paper (De Castro [2000]), we tried to find a value of $\beta, \tilde{\beta}$, where $I^S(\beta) \geq I^F(\beta), \forall \beta \geq \tilde{\beta}$. If such a $\tilde{\beta}$ existed, *and* the extra cost of an offer of $\tilde{\beta}$ were less than the capital rentals for the slave contract, then both slavery and the firm would be redundant. The firm would be because with such an offer, the worker would internalize the incentive to produce the mix the plantation required and no supervision would be necessary. The offer would satisfy both his incentive compatibility and participation constraints simultaneously, like sharecropping. However, the input of the type 2 agent would still be required but the combining of the two agents' skills would be like a market transaction and not like one within a firm.

4.4. How the plantation chose β^S

Under slavery, the plantation will choose β^S to maximize its gross profit, before the provision for the capital rentals on the slave contract (which goes to the slave trader). To simplify the analysis, we shall ignore the disutility of effort of the type 2 agent in this calculation of β^S. In the general case of $R(e_1)$, we will have under slavery:

$$\underset{\{\beta\}}{Max}\,\Pi_s = (1-\beta)\left\{pR\left(e_1^S\right) + e_2^S\right\}$$

subject to $0 \leq \beta \leq 1$

where e_1^S does not depend on β, and $e_1^S + e_2^S = \beta$

If there are no corner solutions, the first order condition is :

$$\beta^S = \frac{1}{2}\left\{1 - pR\left(e_1^S\right) + e_2^S\right\}$$

Since e_1^S falls with *p*, this gives us an asymptotic upper bound for possible choices of β by the plantation, $\beta^S < \frac{1}{2}$, as its staple becomes more lucrative (*p* falls). For high enough values of *p*, β^S can be zero. We shall assume that *p* is in the range where β^S is clearly defined and is in the open interval $(0, \frac{1}{2})$.

Example: $R(e_1)=\sqrt{e_1} \Rightarrow \beta^S = \frac{1}{2} - \frac{p^2}{8}$

We should note, however, that for some values of β^S, the freed slave would abandon the plantation crop completely at abolition, namely $e_2^F(\beta^S)=0$. This is when $e_1^F(\beta^S)=\beta^S$. Here, one of the non-negativity constraints in the freed slave's maximization problem, $e_2^F \geq 0$, is binding.

Example: $R(e_1)=\sqrt{e_1} \Rightarrow e_1^F = \frac{p^2}{4}\cdot\beta^2$ if $e_1^F, e_2^F > 0$

Let β_L be the value where $e_1^F(\beta_L)=\beta_L \Rightarrow \beta_L = \left(\frac{p^2}{4}\right)^{1/3}$

Case: $p=1 \Rightarrow \beta_L = 0.63$; $\beta^S = 0.375$; $e_1^F(\beta^S) = 1.77\dot{7} > \beta^S$

which violates non-negativity. This means that at this β^S, $e_1^F = \beta^S$ will be chosen, with $e_2^F = 0$.

For any $\beta^S \leq \beta_L$ therefore, we know that the plantation staple will be abandoned at abolition by the freed slave unless it modifies its incentive scheme. This result is not particularly relevant to the plantation's choice of β^S under slavery. It simplifies the calculation of the hypothetical income distribution since the plantation's share will disappear.

Our theory for how β^S is chosen implies that the more lucrative is the plantation staple, the higher would be β^S under slavery and the greater the total effort required of the slave. As we suggested previously, this may be a simplification of how β^S was actually determined. Some masters may well have taken into account the possibility of rebellion, flight and other forms of slave resistance in their calculation of β^S. Its actual value is not crucial for the exisitence of our indenture contracts below. However, it is needed for the determination of whether slavery was redundant. In the case where $\alpha < 1$ in $R(e_1)=e_1^\alpha$, firms are never redundant. Supervision will always be required (for proof see appendix B).

4.5 Possible indenture contracts

Although we use the historical term "indenture" for the incentives which the plantation could have used to induce free workers to accept its restriction on the peasant crop, they are not the long-term contracts found in the history texts. Indentured or bonded labor (servants in British legal terminology) describes the situation of a free worker who signs a contract to work for an employer for an extended period, usually 5 to 10 years, in return for wages and other benefits. In our model, indenture simply means accepting voluntarily the authority of the plantation to restrain production of the peasant crop. In theory, no third party is required for enforcement once the plantation had the right to fire shirkers.

We assume here that the values of the parameters are such that $I^F(\beta) > I^S(\beta), \forall \beta \in (0,1)$ and so supervision by firms will still be required in the incentives to be offered after abolition. Two schemes are studied which the plantation can use to induce a free worker to accept its discipline and allow his peasant crop to be taxed at some rate β. They are :

(i) The plantation can maintain the same value β^S it used during slavery but in addition pay a lump sum per period, a sweetener S, equal to the extra income the worker would earn if he were to reject the tax and produce his peasant crop at the level that is rational for β^S, where :

$$S \equiv I^F(\beta^S) - I^S(\beta^S)$$

His total effort would be the same as under slavery.

(ii) It can increase the value of β^S to $\hat{\beta}$ where $U^F(\beta^S) = U^S(\hat{\beta})$, and pay no sweetener. At $\hat{\beta}$, the free worker would have the same utility he should have had at abolition, if he were to reject the discipline of the plantation then. If he accepts $\hat{\beta}$, he would have to work harder than as a slave, but he will earn more.

It is obvious that both contracts will satisfy the participation constraint of the worker but both will require supervision because of the moral hazard they induce. The one the plantation should offer will depend on which is more profitable for it. This will be determined in the general case by the relative price of the two crops and their technologies which , by our theory, will also fix β^S. If under slavery plantations chose β^S in a less myopic manner to avoid resistance, then this β^S would also enter the calculation.

We define now β^B as the value of β which will yield the same profit to the plantation as keeping β^S constant and paying the sweetener S . Thus, if $\beta^B < \hat{\beta}$, we know that indenture contract (i) will be more profitable to the plantation than (ii) and vice versa. We show now with an example, that the contract chosen will depend, for any $R(e_1)$, on the value of *p*. The more lucrative the plantation staple, the greater is the incentive to increase β^S rather than pay the sweetener.

Example: $R(e_1) = \sqrt{e_1}$

Case : $p = 1 \Rightarrow \beta^S = 0.375 ; \beta^B = 0.75 ; \hat{\beta} = 0.8208$

Remark: Indenture contract (i) is better for the plantation, namely keep β^S and pay the sweetener S, where $S = I^F(\beta^S) - I^S(\beta^S) = 0.6124 - 0.2344 = 0.3780$

Case : $p = 0.6325 \Rightarrow \beta^S = 0.45 ; \beta^B = 0.8705 ; \hat{\beta} = 0.7099$

Remark : Indenture contract (ii) is better for the plantation, namely increase β to 0.7099 and pay no sweetener.

The value to the former slave of the right to quit does not depend on which indenture contract is offered after abolition because his utility will be the same for both. It will therefore be equal to the sweetener, S = 0.3780. Notice however, that even though he would be paid this value in full to induce him to return to the discipline of the plantation, there will still exist the incentive for him to "shirk", that is, produce less of the staple than it would require in the contract. Here is where the role of supervision by the firm comes in and of course, its right to fire.

The following diagram illustrates the two contracts:

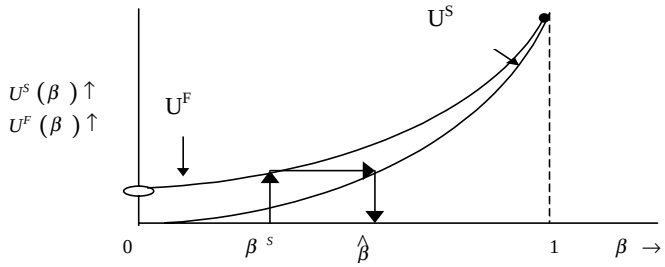

Figure 2

Is it reasonable to expect planters to offer to pay out more after abolition? More precisely, must there be a redistribution of income? The answer is not necessarily, because the planter no longer has to pay out the capital rentals on the slave contract. He might have had an once and for all capital loss at abolition if he were not compensated for the loss of his investment in slaves, but this does not affect future contracts. In fact, when contract (ii) is more lucrative and he increases β, his gross profit may even increase for some parameter values.

In the British case, the Westminster government paid out millions of pounds to their planters in compensation for freeing the slaves. Some of these funds were used to finance the imports of indenture labor, mainly from India, and of new machinery. But this investment occurred only in territories where sugar expanded after abolition. There are some indications of implicit mechanisms for compensation in northeast Brazil, through subsidies for the construction of central factories (*usinas, centrales*) .

4.6 The fall in GDP at abolition

We assume here that at β^S, the income of the slave would be higher for the same total effort, if he rejected an indenture contract at β^S. We then try to find conditions for the fall in GDP at abolition. GDP is the total income of the two agents, equal to the total product, Y^S under slavery, and Y^F after abolition.

$$Y^S \equiv pR\left(e_1^S\right) + e_2^S \quad ; \quad Y^F \equiv pR\left(e_1^F\right) + e_2^F$$

In appendix A, we obtain upper and lower bounds for *p*, the relative price of the products of the two activities, peasant and plantation, such that the two outcomes are compatible, namely, assuming slavery was not redundant at abolition, there will be a fall in GDP:

$B(p) < p < A(p)$ where:

$$A(p) \equiv \frac{\left(e_1^F - e_1^S\right)}{R\left(e_1^F\right) - R\left(e_1^S\right)} \quad ; \quad B(p) \equiv \frac{\beta^S \left(e_1^F - e_1^S\right)}{\left\{R\left(e_1^F\right) - R\left(e_1^S\right)\right\} + \left(1 - \beta^S\right) R\left(e_1^S\right)}$$

Example: $R\left(e_1\right) = \sqrt{e_1}$, with no change of incentives at abolition.

Case : p =1 $\Rightarrow$ $B(p)$ = 0.4486 ; $A(p)$ = 2.0406

β^S = 0.375 ; Y^S = 0.6250 ; Y^F = 0.6124 = I^F because e_2^F = 0.

Case : p = 0.6325 $\Rightarrow$ $B(p)$ = 0.3315 ; $A(p)$ = 1.4460

β^S = 0.45 ; β_L = 0.4642 ; Y^S = 0.5500 ; Y^F = 0.4243 = I^F because e_2^F = 0.

In both cases GDP falls at abolition if the plantation does not modify its incentives. When its staple is more lucrative (p smaller), the fall is much greater. In both cases however, there would be a drastic redistribution of the reduced total income to the ex-slaves since with e_2^F = 0, they would abandon the plantation completely. Their incomes would of course rise in the process but the economy would be worse off. This perhaps is an universal dilemma at every change of regime – growth versus distribution. The main contribution of our paper, we hope, was to show that, at least in the case of the abolition of Atlantic slavery, the economics did not pose such a dilemma. Both growth and redistribution were possible, at least for slaves and their masters. Traders would have had to find alternative employment.

5. Insights for growth theory

Although these economies eventually began to grow again, almost all have never achieved the incomes of the richer regions even today. Most of the world's economies also have not reached such levels, as these regions are clearly among the richest. How then can we generalize the argument to the point where it can become a growth theory valid for all economies?

As a tentative hypothesis we suggest that one legacy of slavery and abolition, which may well be shared by other environments, is the inability to sustain large, private firms which use supervision as a mechanism in their incentive schemes. These are not the only institutions which generate growth since there are many activities which can be done by small, family businesses which operate mainly in spot markets with marginal benefit incentives. Large state-owned enterprises can replicate most of the mechanisms for supervised labor mobilized by the monopolies and oligopolies of modern capitalism, with reinforcing legislation where possible from friendly governments. The supervisors however would not be subject to the discipline of the capital market, which implies that the incentives they offer to their supervised may well be different in spite of the labor markets both institutions face.

This insight comes from a comparison between the US north and south in the late 19th century. By 1890, when the first federal law against cartels was passed (the Sherman act), large enterprises were being put together (called trusts there, confusingly but for local historical reasons) in several sectors of the US economy – petroleum and sugar refining are two famous examples. Such institutions

were absent from British capitalism which had served as the model for the neoclassical theory. We surmise that these enterprises were as crucial as its peasant farms and small businesses, to the US surpassing the British level of income before 1914 (see table attached), and to the gap it opened with the whole of northwestern Europe until around 1950.

So a general growth theory for all economies may be the ability or otherwise to sustain efficiently the large enterprises which use supervision and other complex incentive schemes to allocate labor. In those sectors where in the 20th century such enterprises became one of the two major sources of the innovations which drive growth, failure to do so may have become fatal. The secret may not have been markets alone, but markets and firms.

Appendix A

(i) Proof of the envelope result (ii) in section 4.3. This analysis assumes that $e_1, e_2 > 0$.

1. $MAX \quad I = \beta\{pR(e_1) + e_2\} \equiv f(e_1, e_2; \beta)$

s.t. $(e_1 + e_2) - \beta = 0 \qquad or \qquad g(e_1, e_2; \beta) = 0$

Let the optimal solution be I^S, e_1^S, e_2^S. That is:

$$I^S = \beta\{pR(e_1^S) + e_2^S\}$$

1. By the envelope theorem:

$$\frac{\partial I^S}{\partial \beta} = \frac{\partial f}{\partial \beta} + \lambda \frac{\partial g}{\partial \beta} = pR(e_1^S) + e_2^S - \lambda$$

2. Find λ, the Lagrange multiplier for this problem:

$$L = \beta\{pR(e_1) + e_2\} + \lambda(e_1 + e_2 - \beta)$$

$$\frac{\partial L}{\partial e_1} = \beta pR'(e_1) + \lambda = 0$$

$$\frac{\partial L}{\partial e_2} = \beta + \lambda = 0 \Leftrightarrow \lambda = -\beta$$

$$\frac{\partial L}{\partial \lambda} = e_1 + e_2 - \beta = 0$$

$$\Rightarrow \frac{\partial I^S}{\partial \beta} = pR(e_1^S) + e_2^S + \beta \qquad \text{QED}$$

(ii) Proof of result (i) in section 4.3 is similar.

(iii) Proof of $B(p) < p < A(p)$ in section 3.4

(a) We need to prove: if $Y^S > Y^F$ and $(e_1^S + e_2^S) = (e_1^F + e_2^F)$, then $p < A(p)$

1. $Y^S > Y^F \Leftrightarrow pR(e_1^S) + e_2^S > pR(e_1^F) + e_2^F$

2. Add $(e_2^S - e_2^F) = (e_1^F - e_1^S)$ to both sides and rearrange:

$$p\{R(e_1^S) - R(e_1^F)\} > e_1^S - e_1^F$$

3. Multiply by –1 and rearrange gives the result (a) QED

(b) We need to prove: if $I^F > I^S$ and $\left(e_1^S + e_2^S\right) = \left(e_1^F + e_2^F\right)$, then $p > B(p)$

The proof is similar to result (a).

Appendix B

Proof that firms are never redundant in the Cobb-Douglas case: $R(e_1) = e_1^{\alpha}$ (see section 4.4).

(i) Substitute $R(e_1) = e_1^{\alpha}$ in the envelope result from appendix A:

$$\frac{\partial I^S}{\partial \beta} = (\alpha p)^{1/1-\alpha}\left(\frac{1}{\alpha} - 1\right) + 2\beta$$

$$\frac{\partial I^F}{\partial \beta} = -\left(\frac{\alpha p}{\beta}\right)^{1/1-\alpha} + 2\beta$$

provided $e_1, e_2 > 0$

If $\alpha < 1$ and $p < \frac{1}{\alpha}$ then $\frac{\partial I^S}{\partial \beta}, \frac{\partial I^F}{\partial \beta} > 0$ at $\beta = 1$

To get $\frac{\partial I^S}{\partial \beta} > \frac{\partial I^F}{\partial \beta}$ for $0 < \beta < 1$, we must also have $\alpha < 1$.

(ii) To get $I^F > I^S$, for $0 < \beta < 1$ we must have:

$$p\left(\frac{\beta}{\alpha p}\right)^{\alpha/\alpha-1} - \beta\left(\frac{\beta}{\alpha p}\right)^{1/\alpha-1} > \beta p\left(\frac{1}{\alpha p}\right)^{\alpha/\alpha-1} - \beta\left(\frac{1}{\alpha p}\right)^{1/\alpha-1}$$

After manipulation, this becomes:

$$\beta\left(\frac{\alpha p}{\beta}\right)^{1/1-\alpha} < p\left(\frac{\alpha p}{\beta}\right)^{\alpha/1-\alpha}$$

which reduces to $\alpha < 1, \quad \forall p > 0, \quad 0 < \beta < 1.$ QED

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One table follows this

GDP/head: Selected Countries, Americas, 19th century

Sources:	Moohr	Eisner	Moohr	Eisner	Atack & Passell			Coatsworth			Maddison		
	British Guiana	Jamaica	British Guiana	Jamaica	US South	US Midwest	USA Total	USA	Cuba	Brazil	Brazil	USA	UK
	£ const.		$ current					$ const. 1985			$ const. 1990		
	1912	1910											
1775							60						
1800								807	904	738			
1820							74				670	1287	1756
1830							92						
1832	23.9	15.6	100	65									
1840					74	65	109						
1850	19.4	12.2	77	45				1394	1087	901			
1860					103	89	128						
1870	20.7	11.9	95	55							740	2457	3263
1880					79[1]		205						
1890	22.4	12.4	121	67									
1900											704	4096	4593
1910	24.0	13.7	117	67									
1913							399[2]	4854	1893	700	839	5307	5032
1920													
1930		15.7		93			847[3]						

Sources:

Moohr [1972] gives the GDP data. Population from Mandel. Years after 1832 are for 1852, 1872, 1892, 1912 and not as shown 1850, 1870, etc. Exchange rates to current $ from Lee Craig, Economics Dept, NCSU, Raleigh NC USA.

Eisner [1961]. Exchange rates to current $ from Lee Craig.

Atack & Passell [1994]. Tables 7.1 and 11.5.

Coatsworth is the primary source for Engerman & Sokoloff [1997], table 10.5 in Stephen Haber (ed).

Maddison [1995], table 1-3. Maddison has published elsewhere data showing Brazil's GDP/head increasing monotonically, 1820-1913. However, the increase to 1913 is minimal.

Notes:

1. Engerman [1966]
2. Calculated from Engerman & Sokoloff [1997], Table 10.5.
3. Year 1929.