Working Paper 92-37
September 1992

División de Economía
Universidad Carlos III de Madrid
Calle Madrid, 126
28903 Getafe (Spain)
Fax (341) 624-9875

COLONOS, CENTRAL FACTORIES, AND RENEGOTIATION:

A Fixed Effects Analysis of the Adoption of New Technologies in the Cuban Sugar Industry, 1899-1929*

Alan Dye*

Abstract

This paper focuses on the relationship between technical and institutional changes in Cuba a leader in the use of continuous-process technologies being applied to cane sugar manufacture in the first three decades of the twentieth century. Using a fixed effects model of the sugar manufacturer's decision to invest in new technologies, we show that a change in institutional factors had an impact on the adoption of the new technologies. The results show that differences in cane contracting arrangements affected the ease with which mills adopted new technologies. These differences were based on historical factors in the evolution of the cane farming institution in Cuba that affected whether the cane lands were the property of the farmer or the mill. This distinction created differences in the cane farmers' bargaining positions in the renegotiation of contracts with the mill, and it resulted in variation in the long-run costs of procuring cane at different mills.

Key words:
Economic History, institutional Economics, vertical integration, economics of technology.

*Departamento de Economía, Universidad Carlos III de Madrid. I wish to thank Larry Neal, Jeremy, Stanley Engerman, and James Simpson for comments on earlier versions of this paper, and Shane Greenstein for conversations at its preliminary stages. I am also grateful to participants at the seminar in economic history at the Universidad Carlos III de Madrid; Carl Van Ness, archivist, at the University of Florida at Gainesville for his indispensable help; and the Fanjul family for making the Braga Brothers Collection available.

In the late nineteenth and early twentieth centuries, production techniques in sugar manufacturing changed so dramatically that a major restructuring of cane sugar enterprises was necessary if cane sugar producers were to remain competitive. In the 1880s, this was due to the threat of the European beet sugar industry, which was growing rapidly. But afterwards, innovations, based on greater exploitation of continuous processing methods, were introduced and adopted by cane sugar producers. By the turn of the twentieth century, cane sugar technology had been fundamentally altered. These innovations were related to techniques being adopted in many processing industries in the industrialized world at the same time -- in petroleum refining, distilling and food processing, etc. So the alteration in sugar manufacturing was essentially an extension of a technical revolution being experienced generally in processing and refining industries (Chandler, 1977).

At the same time, the organization of labor on cane plantations was also changing. Many formerly prosperous slave-based sugar-producing areas were in decline because of labor shortages after emancipation. The variety of institutional responses to this situation in the history of the sugar industry has attracted the attention of economic historians who examine its implications for the relationship between technical and institutional changes (Engerman, 1983, 1984, 1986; Shlomowitz, 1979a, 1979b, 1984; LaCroix and Roumasset, 1990). In this regard, the literature has tended to ask questions about the effects of the technical factors on the institutions, with special attention given to labor institutions. In this paper, we focus on the obverse and show quantitatively that a change in institutional factors had an impact on the adoption of the new technologies in one of the leading sugar producing islands (in terms both of market share and of the adoption of continuous-process techniques) -- Cuba.[1] Regional differences in cane

[1] This figure includes both cane and beet sugar. Cuba produced over 20 percent of all sugar (both cane and beet) and over 30 percent of the cane sugar on the world market. The other clearly dominant producer was Java. Cuba and Java produced over 50 percent of the cane sugar on the world market and

contracting arrangements, based on historical factors in the evolution of the cane farming institution in Cuba, affected the ease with which mills adopted new technologies.

With the new technologies, the organization of the sugar industry in Cuba changed dramatically as the nineteenth-century slave-based plantation system was replaced by a central factory system. Several major changes should be pointed out. First, sugarmills became highly capital-intensive relative to the mills of the plantation system. And along with the capital intensification, the optimal scale of mills using the new technologies increased enormously. A high rate of growth in the capacities of mills in Cuba proceeded from before the turn of the century to 1929. As a consequence of the increase in the optimal scale of production, the manufacturing (milling) operations of the existing plantations on the island came to be consolidated into many fewer centralized mills, called centrales; yet the agricultural operations -- the activity of cane cultivation and the cane plantations -- remained decentralized in the hands of farmers, known in Cuba as colonos. This system of centralized milling and decentralized cane cultivation in Cuba was called the colono system.[2] A second observation, although larger mill capacities (associated with newer technical vintages) were adopted in all parts of the island, the mill capacities in the east, an area of new expansion of the sugar industry, were in general much larger than mill capacities in the western provinces, where the plantation-based industry of the

---

over 30 percent of all sugar on the market. These figures on based on estimates of world supplies made by Deerr. They tend to underestimate the share of cane sugar production on the world market. See Deerr (1950), pp. 490-91. Refined cane and beet sugars, by the twentieth century, were virtually indistinguishable, and so from the point of view of consumption they were perfect substitutes.

[2] Cane farming developed in many parts of the world at around the same time, though institutional details of cane farming varied from place to place. An analysis of the economic conditions surrounding the establishment of the cane farming system in Queensland around the turn of the twentieth century, see Shlomowitz (1979a, 1982, 1984). The establishment of the colono system began relatively early in Cuba, prior to the abolition of slavery in 1886, see Scott (1984, 1985). The colono system was later adopted in other former colonies of Spain, see Moreno Fraginals (1986), Ramos Mattei (1984), del Castillo (1985), and Nagano (1988). Other cane farming systems developed in these decades in the English-speaking Caribbean, see Johnson (1972), and Haraksingh (1984).

nineteenth century had existed.

The empirical results of this paper show that regional differences in the contractual arrangements between the centrales and the colonos had a significant influence on why mills adopted larger capacities in the east. (1) In the first section, we analyze the bargaining relations between the colonos and the central to show that there is reason to expect that the bargaining relationship affected the ease with which sugarmills could expand the capacities of their mills in order to adopt new, large-scale technologies. (2) In the second section, we present a quantitative method for detecting the effects of these institutional influences on the expansion behavior of mills based on the estimation of a fixed effects model of the investment decisions of sugarmill managers. The results show that in the western part of the island the adoption of larger scales of production was hindered by institutional factors that raised the costs of securing the sugarmills' cane supplies. As a late-comer, the east benefited because investors there had greater flexibility in forming institutional arrangements that suited them (Cf. Gerschenkron, 1979).

The data used in the study come from two rich, previously unexamined sources. The papers of the sugar producer and broker, Manuel Rionda, recently made available, provide extensive records of factor price data and the operation of sugarmills.[3] Records of mill production statistics, published by the República de Cuba, Secretaría de Agricultura, Comercio, y Trabajo, provide a panel of 13 years and 130 sugarmills which includes data on the capacities and performance of the mills. It is used to model the investment behavior of the mills, to estimate the fixed effects and infer the influence of institutional factors on the adoption of new technologies.

---

[3] The Braga Brothers Collection, University Archives, Gainesville, Florida, is a business archives whose principal holdings are related to the Czarnikow-Rionda Company of New York, one of the leading sugar brokerage houses of the twentieth century, and its affiliate, the Cuban Trading Company, which handled a large proportion of the exports from Cuba. Also it contains the personal and business papers of Manuel Rionda y Polledo, founder and president of the company. Many of these papers are related to the management of sugar estates that he and his family owned; included are reports of other sugar estates in Cuba. Data used in this paper are from Record Groups II and IV.

The use of panel data offers econometric advantages. Most important, differencing allows us to avoid the specification bias which would otherwise be present since important individual features of mills are unobservable. The results show that, after accounting for individual investment incentives, the expansion behavior of individual mills is strongly correlated with the prevalence of colonos independientes at the mills -- colonos who owned the land they cultivated. But also important was the mill's orientation towards North America. The evidence supports our hypothesis that the regional variations in mill capacities were influenced by differences in the bargaining positions of the colonos who owned their land relative to those who did not.

I. THE INSTITUTIONAL SETTING.

The period 1899-1929 was a period of rapid growth in sugar production in Cuba's history whose beginning and end mark two major crises. The year 1899 was the end of the Cuban War of Independence (1895-98), in which the sugar industry had suffered enormous damage, production declined by two-thirds during the war and took more than half a decade to recover its prewar level of production once the war had ended. (See Figure 1.) The endpoint, 1929, marks the beginning of the depression in the United States and the increase in protection of Cuba's major market for sugar finalized by the passage of the Smoot-Hawley tariff. Between these years was a period of U.S. intervention in Cuba that precipitated a huge influx of North American capital and established close business links between North American and Cuban sugar interests. Cuba during this period received a 20 percent discount on the standard sugar tariff, which allowed Cuban producers to compete, albeit on an unequal basis, with American beet sugar producers and producers in Hawaii, Puerto Rico and the Philippines, all of which had duty free status. The Cuban provision of the U.S. demand for sugar between 1910 and 1929 fluctuated between 40 and

65 percent and tended to be higher in the twenties (U.S. Congressional Committee on Agriculture, 1962).

The huge increase in the capacities of sugarmills in Cuba is seen in Table 1 where the average level of sugar production per mill in Cuba increased from 1877 to 1929 by 7200 -- an annual rate of 8.3 percent on average. The growth in the capacities of individual mills was steady throughout the period. The technology was capital-embodied, but the larger mill capacities, which offered economies of scale, could be adopted gradually because the capacity could be increased by adding additional machinery units to existing capacity. Larger scales of production were, indeed, adopted gradually because there were sizeable adjustments costs associated with the expansion of mill capacity which prevented the immediate adoption of the largest scales of production.[4] The mill capacities achieved were considerably higher in the eastern provinces. Contemporaries and historians commonly noticed the difference and emphasized the correspondence between the large mill capacities in the east and the greater presence of North American capital (Guerra y Sánchez, 1944; Pérez, 1986, 1988). But behind these capital flows were incentives that made the east more attractive to investors than the west. Table 2 presents data to demonstrate these differences. The "east" consisted of the province of Oriente and Camagüey, and the "west" consisted of Habana, Matanzas and the western part of Santa Clara. The contrast between the east and west is seen most clearly in comparison of the provinces of Camagüey, which was the most recent area of expansion, and Matanzas, which was the heart of the nineteenth-century industry. (See the map in Figure 2 for the location of the provinces.) The figures in Table 2 on the percentage of cane

---

[4] Adjustment costs are defined as costs associated with rate of capital accumulation, which increase with the rate of investment. Empirical evidence of both the economies of scale and the magnitude of adjustment costs is presented in Dye (1991). An implication of this finding is that the adjustment costs caused the optimal vintage to be adopted only gradually, and the presence of significant adjustment costs which helps explain why we observe a pattern of steady growth in the size of individual mills over the period rather than a sudden adoption of larger scales. Modifications in technology and organizational methods over time probably also contributed to the pattern.

ground by mills with greater than 400 thousand bag capacities show some resemblance between the provincial aggregates of western province of Habana and the eastern province of Oriente. This reflects urbanization and the construction of three large, modern mills in Habana. A few mills with more than 400 thousand bag capacities were built in each of the western provinces, but most of the mills that reached capacities of 400 thousand bags were in the east. The arguments we pose in the first section of the paper are framed in terms of this west-east distinction to follow contemporary views as well as to aid the exposition; however, the empirical analysis in the second section of the paper is performed at the mill level so that the conclusions we draw are not dependent on provincial aggregates.

Technical constraints and the reorganization.

Around the turn of the twentieth century the last of the nineteenth-century, self-contained plantations, known in Cuba as ingenios, finally disappeared. The ingenios, organized along lines suited for slave-based production and the old milling technologies, replaced by large-scale centrales. The restructuring of the system of production resulted in consolidation of the milling processes; but the activity of cane cultivation remained decentralized, and cane cultivated by colonos took on greater importance. Regarding the figures in Table 1, the 1860 production per mill represents the average mill capacities of the ingenio system, and the figures for 1913 and 1929 demonstrate the growth in the mill capacities in the centrales.

Implicit in these figures, the new continuous-processing techniques in sugar manufacturing tended to have much higher optimal scales of operation than the techniques they replaced. Chandler describes the fundamental change which took place with the adoption of capital-embodied continuous-processing as a radical increase in the minimum volume of materials that could be handled economically. The greater capital intensification of production implied a much

higher ratio of fixed costs in the total outlays (Chandler, 1990). But also in order to realize the cost advantages of larger scales of production, improvements in the coordination and synchronization of the flow of materials within the plant was necessary. Coordination failures, bottlenecks in the flow of materials, reduced the volume and could result in substantially higher unit fixed costs. Therefore, careful coordination of inputs and intermediate materials, in particular the cane, between the various activities in the sugarmills was essential for the efficient operation of the modern, continuous-process plants.

Two features of cane cultivation imposed important additional technical constraints on the restructuring of production. One made the problem of coordination between the harvest and the mills particularly crucial for manufacturing processes. During the harvest, cane after being cut deteriorates quickly; generally it has to be ground within 24 hours to avoid significant loss of sucrose.[5] The larger mill capacities required much larger supplies of cane, and since no significant improvements in cultivation techniques had been developed for centuries, cane had to be brought to the mills from much larger distances. The use of railroad networks to haul cane over the large distances to the mills became essential to insure the rapid delivery of cane, in order to avoid significant loss of sucrose. These requirements caused centrales to adopt a hub-and-spoke system of cane supply in which the canefields were located as near as possible to the central and connected to it by rail lines.[6] The second characteristic is that cane is a perennial crop.

---

[5] The object was to obtain high volumes of sucrose in the cane, which was extracted and crystallized in the milling process. Sucrose, glucose and fructose are all present in cane, but only the sucrose was useful to the producer. The other sugars, commonly referred to by sugar manufacturers as invert sugars, did not crystallize or provide the desired taste, so the economic value of the cane was directly related to the sucrose content of the cane. When the cane was cut, the sucrose in the cane began the process of inversion of the sucrose into the other sugar forms--glucose and fructose. In general, it had to be ground 24 hours after being cut to avoid a significant loss of sucrose (Deerr, 1911; Robertson, 1934).

[6] Furthermore, the harvest (zafra) had to be accomplished during the dry season, which in Cuba was between December and June. This meant that the milling plant was only employed for roughly six months out of the year; therefore, efficient use of this capital during the limited period of the zafra was even more crucial. When the zafra commenced in the winter, it proceeded feverishly as a race to grind as much cane

After the initial crop, ratoons (or canes grown from the roots of previously planted crops) could be harvested about once a year for 6 to 10 years. (Cane matured in Cuba in between 12 to 15 months.) Therefore, for the central, the establishment of canefields was a capital investment. Because of the problem of deterioration, the investments in canefields and railroads resulted in significant site-specificity of the central's assets in the fields and created strong incentives for the central to maintain control over these investments (Williamson, 1985). The profitability to the central of the machinery at the mill, the railroad, and the canefields themselves was in question unless the central was assured of sufficient cane supplies for the life of the equipment. Because the railroad network was, for all practical purposes, fixed once it was laid down, the central was committed to the cane lands surrounding the railroad.

At the same time, another aspect of the restructuring of the system of production had to do with a reorganization of the structure of property rights to the canefields. The formation of central factories did away with the vertical integration of the cane cultivation and sugar manufacturing activities under the plantation system. Until the last few decades of the nineteenth century, cane cultivation and sugar manufacture were typically performed in the self-contained, slave-based plantation. But around the middle of the nineteenth century the cane farming system, or colono system, began to appear. Initially it was an institutional innovation, stimulated by the decline in the slave trade, adopted by owners of ingenios to attract white labor for cane cultivation as the slave trade was ending in Cuba. As slaves became scarcer, the owners of ingenios apportioned their land and leased it to colonos who contracted to supply cane to the owner's mill. But the formation of the colono system became inseparable from the development of the central.

---

as possible before the rainy season arrived again. Therefore, the coordination between the canefields and the mills during the zafra was crucial to the successful operation of the mill. We have shown elsewhere that coordination of the delivery of cane to the mills, based on diversification of canefields, resulted in much larger optimal scales of production (Dye, 1991).

(On the nineteenth-century colono system, see Scott, 1984, 1985; Bergad, 1990; and Moreno Fraginals 1986.) As the number of mills needed to absorb the cane being produced on the island was reduced greatly, some owners of ingenios ceased to mill their own cane to become colonos contracting with other mills. The timing of these changes can be explained in part by the financial crisis after the Ten Years War (1968-78) (Bergad, 1990). While many planters could not raise the operating capital to grind their cane at their own ingenios, they could obtain contracts and advances to harvest their cane and grind it at other mills. But advantages to these cane contracting arrangements became evident, and the colono system eventually became the principal institution to support the enormous cane requirements of the centrales.[7] By 1905, 70 percent of all the cane supplied to mills in Cuba was supplied by colonos. (See Table 3.)

Regional differences in contractual relations.

The tenure arrangements for cane production in Cuba were classified according to three categories based on whether production was managed by the central directly or through the colono system, and whether the colono occupied land owned by the central or not. Direct management of the canefields by the salaried personnel of the central was referred to as the "administration system," and the cane that was so derived was referred to as "administration cane." Under the colono system, the contract between the colono and the central was a share contract in which the colono agreed to supply the cane produced from a specified plot of land (the colonia) to the central in return for a specified share of the sugar produced from that cane. The contract also

---

[7] Given the site-specificity of the assets in the canefields, why this occurred is an interesting question. Williamson (1985) suggests that this kind of asset specificity presents the strongest incentives for vertical integration. A careful examination of monitoring costs and risk dispersion is needed to answer the question, but this must be left to another paper. The argument here depends on another feature of the contractual relation -- the question of the retention of capital assets at the termination of a contract. To address this issue, we assume that the revealed preference for the decentralized colono system was the result of a rational calculation of benefits and costs.

usually included lease and credit agreements through which the colono obtained access to land and credit advances for the work contracted; however, the extent to which the colono depended on the central for land and credit varied with his means. The colonos were not homogeneous. They varied from being locally influential, large landowners (sometimes absentee, possibly foreign) to landless tenants with little means. The landless colono, who depended on the lease of a plot of land from the central was referred to as a colono del central; and the colono of greater means, who contracted out the services of his own often sizeable tracts of land, was referred to as a colono independiente.[8]

The three classifications of tenure arrangements were, then, the administration plantations, the colonias del central, and the colonias independientes. The distribution of the cane supplies of centrales deriving from these three different classifications of tenure arrangements for the period from 1905 to 1929 can be observed in Table 3. The lower panel shows that the proportion of colonos independientes was considerably higher in the west than in the east. Although by 1930 the pattern was becoming much less distinct, in the years of expansion prior to 1930 it was quite distinct. Over time an increasing share of cane was derived from colonos de los centrales.

The geographical distribution of the colonos independientes was related to the different timing of development of the sugar industries of the west and the east. In the western provinces of Habana and Matanzas, most of the good cane lands were in cultivation by the 1850s; therefore, the ingenios there were forced to consolidate if they were to adopt the new large-scale technologies. In contrast, the sparsely populated, eastern provinces of Oriente and Camagüey had abundant cane land. Prior to the War of Independence, less than 10 percent of the Cuban sugar

---

[8] There has been a tendency in the economic history literature to consider the colono as a smallholder. Initially, in the nineteenth century the institution was set up to attract smallholders, but with the process of centralization of milling many larger landholders were attracted to contracting cane as colonos. (See Engerman (1983, Bergad (1990), and Scott (1984). By the twentieth century, the colono's lands could be as large or larger than the plantations of the ingenio system.

crop came from the east, though by the twenties the east came to produce the major part of the Cuban crop. Consolidation of old estates was thus necessary in the west but not in the east. In the east, the large-scale central factories were constructed in frontier areas new to the sugar industry without the institutional vestiges of the older system.[9] In those areas, contractual relations were developed at the same time that the mills were established such that the cane requirements of the new technology were taken into consideration at their formation. The Commission on Cuban Affairs invited by Cuban President Carlos Mendieta in 1934 to review economic conditions in Cuba came to the same conclusion: that many of the colonos in the west were independientes originating from planter families of the nineteenth century, and many of the estates of colonos in the west were once estates of the ingenio system. The east, being an area of new expansion, did not have this same historical connection with the sugar industry of the nineteenth century (Commission on Cuba Affairs, 1935).[10]

The centrales and control over investments.

As we have argued, given the long-term interests of the mill, the management of the

---

[9] In the east, the lands were more often acquired first by the central and then leased to colonos del central; although, sometimes they were acquired by a third party who would either lease them to the central or contract as a colono independiente -- though the number of colonos independientes is the east was inferior to that in the west. Many of the canelands in the east were formerly occupied by open-range cattle grazing. See Guerra y Sánchez (1944), and Braga Brother Collection, Record Group II, series 10a. Many of these lands in the east were purchased in large tracts in speculation immediately after the War of Independence and during the first U.S. occupation. See Pérez (1988, 1986).

[10] "The degree to which these different field systems prevail on any given estate seems to depend chiefly on the original conditions of land tenure and the availability of cane. In the older provinces of the island there were a great many holdings, and with the reorganization of the sugar industry after the Ten Years War [1868-78] the owners of many of these planted cane to secure a cash crop. Many centrales are the result of a concentration about a single producing unit of a number of old plantations. Many plantation owners thus became colonos to large centrales. ... With the rise of sugar production in the eastern end of the island in new areas another situation presented itself. Companies bought land in large tracts and found it convenient to grant much of it on lease to farmers and others with capital who undertook the work of clearing the land and assisted in recruiting the necessary field labor" (Commission on Cuba Affairs, 1935).

central had an incentive to control the cane production of these lands--to insure its supplies. Much of the control over investments in the canefields, assigned in the contract between the central and the colono, was allocated to the central. The contractual mechanism by which the central maintained control of its investments was similar to what Cheung (1969) finds in Chinese sharecropping arrangements and Reid (1973) finds in the arrangements of the U.S. post-Civil War South. The central administration maintained control of all major investment and production decisions by the specific terms of the agreement, the duration of which was usually 6 to 10 years -- corresponding roughly to the lives of the canefields. The contract both established specific requirements of the colono for the regular delivery of cane assignments to the mill during the grinding season, and it also set up specific obligations for the development of canefields and other capital improvements to be made on the colonia.

The standard procedure of the centrales was to write up a contract in which the terms offered to the colono were rather stringent, and then the degree to which this contract could be altered in individual negotiations depended on the strength of the bargaining position of the colono. In general, the capital investments to be made were specified in the contract. The proportion of acres to be planted in cane -- a capital investment -- and other "minor" crops was strictly specified.[11] Additionally, the central reserved the discretion to determine how, where and when the cane plantings were to be laid out in the colonia. The colono was given the obligation to construct or maintain other capital goods on the colonia such as wells, cane-loading machines to load cane from the ox-carts to the rail cars, scales, housing for laborers, etc. If the

---

[11] For example, the Central Manati required the colono to plant 90 percent of the lands in cane, and the rest were to be devoted to crops and grassland to support inputs in cane production. The basic contract does not seem to have varied greatly from central to central, although, as we shall see, variations according to the capital inputs and bargaining power of the colono were common. Braga Brothers Collection, series 10c, box 17, f. 9; and series 10c, box 27, f. 20. A similar standard contract, of the Central Oriente, was published in an appendix of Guerra y Sánchez (1944).

central deemed the colono negligent in these responsibilities, it reserved the right to intervene to fulfill them at the colono's expense. There were also numerous restrictions placed on the colono's productive activities during the grinding season which controlled the flow of the services of these capital investments during harvest; for example, the central determined the timing of cutting of all canefields on the colonia. These restrictions on the investment activities of colonos all illustrate the interest of the central in maintaining very strict control over the activities in the canefields to maintain coordination and synchronization with the needs of the mill. Under such contractual terms, the colono del central had little control over the major decisions regarding the level of production and investment on the colonia. However, the degree of control which the central could maintain differed depending on whether the colono was dependent or independent of the central for the provision of land and other capital.

The colono del central was typically dependent on the central not only for the land but also for advances of credit to carry out the terms of the contract, and the colonia was likely his only source of income; hence his very weak bargaining position. It was another matter in the case of the colonos independientes. They often owned large tracts of land and had a number of sources of income. In many cases they held contracts to supply cane to more than one central simultaneously. They often contracted with subcolonos rather than managing them directly, and in many cases they managed their colonias absentee. The large colonos were often in much better positions to negotiate more favorable terms for themselves. Most important, as the owners of the land, they retained the property rights to their land at the termination of the contract, and they often were able to obtain the property rights to the capital improvements on the colonia, as well, at the termination of the contract. This question of the turnover of property rights of the cane supply infrastructure at contract termination created a fundamental difference from the point of view of the central in the attractiveness of the two types of colonos.

The retention of the property by the colono independiente greatly affected the terms of contract renegotiations. To connect the canefields to the mill, the central constructed railroad feeder lines to the colonias. If the property of the colonia was large enough, a railroad would have had to be run into it to make the cane accessible to the mill. The fixed investment in the railroad committed the central in the long term to the lands of that colonia. If that property was owned by the colono, a bilateral relationship was established between the colono and the central, and consequently, the central had to renegotiate on much more equal terms when the contract was up for renewal. This explains the rising share of the colonias de los centrales which we observe in the data of Table 3. The relative attractiveness of the colonias de los centrales to the centrales was their relatively weak bargaining position during renegotiation.

Another important feature of the bargaining relationship between the colono independiente and the central was the access of the colono independiente to the public railway system.[12] Virtually all of the centrales depended in part on private rail lines to transport their cane to their mills; however, the degree of that dependence varied. Some depended exclusively on private lines, and others combined the use of public and private rail systems. In many cases the large colonia was a tract of land located adjacent to a public railroad. When a colonia was established, the central would construct a siding or a private feeder line connecting to the public line to obtain access to the canelands in the colonia. During the harvest, the central would combine the use of its private lines in the colonia and the public railway to ship the cane of the colonia to be ground. This connection with the public railway could have been of great strategic advantage to the colono. If the colono owned the land, and if the ownership of the private railroad on his property

---

[12] The "public" railroads in Cuba were those which offered freight and passenger services to the general public, as opposed to "private" railroads owned by private (mostly sugar) companies which employed them exclusively for their own enterprises. All railroads were privately owned, although heavily regulated.

reverted to him at the termination of the contract, then the bargaining position shifted abruptly in his favor. The access of his cane lands to the public rail system opened his land up for competition with nearby mills during contract renegotiation. This, of course, strongly affected the terms of the renegotiation because it broadened the options open to the colono independiente. Anecdotal evidence of this dynamic in contract renegotiations is readily found. In correspondence of mill managers, one finds cases in which managers expressed concern about upcoming renegotiations with large colonos independientes because the ownership of the rail feeder lines, sidings, along with telephone lines, scales and other equipment reverted to the colono, who would threaten to contract with a neighboring mills unless a higher liquidation rate (the rate of exchange of sugar for cane) were offered (Braga Brothers Collection, series 10c; box 23, f. 62; box 69, f. 25).

The presence of this dynamic in the bargaining process created regional differences in the relative bargaining positions of centrales and the colonos independientes across Cuba. First, colonos independientes were concentrated in the western part of the island. Second, the public railroad system was much denser in the western part of the island.[13] The relatively dense public railroad system in the west offered the larger colono independiente a means of obtaining better a bargaining position and better contractual terms because access to the railroad could

---

[13] The public rail network had been developed much more thoroughly and its configuration was much denser in the western part of the island. The first railroad built on the island, begun in 1834, extended from the western port of Havana inward. From that point railroad expansion proceeded at a rapid pace to open up the western interior to sugar production. The major part of the rail network in the west was built in the nineteenth century with the aim of connecting the numerous small ingenios to the ports. That construction resulted in a relatively dense layout of public railroads by the beginning of the twentieth century. In contrast, in the east most of the public railroad lines were few and widely separated. Construction of public railroads continued in the east as well as the west in the twentieth century. But centrales in the east depended much more on private plantation rail systems to obtain their cane supplies. Preference for private railroads increased after 1902, when private railroad operation was deregulated by the U.S. occupational government. In 1913, the density of public railroads (km. railroad per square km. land) in the west was about three times that of the east, and in 1930 it was still twice that of the east (Zanetti and García, 1987; Guerra y Sánchez, 1944).

provide alternative cane buyers with whom he could contract. In the east where public railroads were sparse and crossed few canelands, the central administration could reduce the bargaining positions of the colonos by building relatively isolated private rail networks that connected only minimally if at all with the public railroads. Once the colono had established relations with one mill, his access to the cane demands of other mills was reduced. Thereby an effective monopsonistic relationship was established between the central and the colono (Guerra y Sánchez, 1944). In the west, this strategy was not so easily adopted, given the land requirements of the new techniques, because the land was too closely interwoven with public railroads.[14]

From these arguments, we hypothesize that the prevalence of colonos independientes, and the local densities of competing sugarmills and public railroad branches affected the ease with which a mill could adopt the newest techniques, which implied a large scale of production. Historical factors that affected the locations, the infrastructure, and the institutional settings of mills created differences in the relative attractiveness to potential investors of different mill locations. Cane costs were the largest component of the unit costs in the accounts of the centrales; therefore, the relatively weaker bargaining positions in which the centrales found themselves in the west inhibited their abilities to attract investors because preferable alternatives,

---

[14] The problem in the west--from the central's point of view--of the presence of a dense public rail network might have been overcome by building bridges that crossed but did not connect with the public rail lines. However, the building of bridges was not permitted by the regulatory authority. The regulations established by the occupational government of 1902 gave the Railroad Commission considerable authority over the crossing of any two railroads, whether public or private, and policy of the Commission was to require that whenever a private line crossed a public line it become a public railroad, i.e. that it was required to provide general services to the public and was subject to the regulation of the Railroad Commission as a public railroad. Private railroads were allowed to connect to, but not to cross, the public lines. Braga Brothers Collection, series 10c, boxes 67-73, contains numerous references to this regulation.

The regulations for both public and private railroads are recorded in the Civil Report of Major General Leonard Wood (1902). The regulations imposed by General Wood during the military occupancy were not easy to alter. The Platt Amendment to the new constitution of the new republic, known for giving the United States the right to intervene militarily in Cuban affairs for "the maintenance of a stable Government adequately protecting the life, property and individual liberty," also provided that all "Acts of the United States in Cuba [ratified] during its military occupancy" would be "maintained and protected." See Pérez (1990).

given the new technological system and the historical factors, could be found in abundance in the east. We now turn to provide evidence for this hypothesis -- that these regional or structural factors were capable of hindering the growth of mills to the optimal larger scales of production.

II. THE EMPIRICAL ANALYSIS.

The approach we follow is a fixed effect analysis of the structural factors in which we isolate and examine econometrically the composite influences of structural factors on the expansion of mill capacities. The data used to perform the estimations are a panel of 130 Cuban sugarmills observed over a period of 13 years, 1917-29. These data are sufficiently detailed to allow us to model the investment decision of the sugarmills with some care. A two step procedure will be used to perform the analysis. First, we estimate the fixed effects by specifying and estimating a model of the decision to invest in greater mill capacity. The estimated fixed effects offer summary statistics for the investment behavior of each mill which are controlled for time-variant effects, such as changes in market conditions or technical incentives. Hence, the statistical information included in these fixed effects is the influence of the remaining, time-invariant factors. These can be thought of as an indicator of the composite structural features of each mill -- both observable and unobservable.

Estimating the fixed effects and then examining them is superior to including a number of dummy variables to account for the observable structural effects for two reasons. By differencing the data properly, estimation biases caused in OLS regressions by omitting unobserved explanatory variables can be eliminated using the fixed effects model and the CVE estimator. Also, the estimated fixed effects offer a summary of the discrete annual investments of a single mill stretching over a period of several years. Obtaining this summary of behavior over several years reduces the variation in the sample due simply to differences in the points of time at which

different mills choose to invest.[15]

Specification of the investment decision.

With the diffusion of new techniques and larger scales of production, a huge range of variation in the capacities of mills existed in Cuba. Much of this variation in the scale of production can be explained by rational investment behavior without any appeal to differences in structural features. The variation in the scales of production reflected both time-variant and time-invariant influences. The time-variant factors were derived from vintage effects in the investment in new machinery that caused delays in the adoption of new techniques, and from sensitivity of the investment decision to markets for investment equipment and other inputs. These were short-term or medium-term influences which caused capacities of mills to change gradually over time and also caused the rate of change to depend on market-based fluctuations in investment costs. The time-invariant influences were derived from the prevalence of relatively permanent structural features of the mills that affected the long-term costs of maintaining the capital investments in the canefields. These influences were site-specific differences that caused producers to have different long-run expected cane costs.

We have shown elsewhere that much of the variation in the capacities of mills as well as their patterns of growth can be explained by vintage capital effects with high adjustment costs to investment (Dye, 1991). The evolution of mill capacities in the industry exhibited a pattern of change similar to the Salterian "moving equilibrium" of vintage-capital models (Salter, 1960).

---

[15] Mills had a long-term investment outlook which was not necessarily revealed by their investment behavior in any one year. Adjustment costs imposed restrictions on investment behavior that caused mills to take time at reaching the optimal scale of production. Fluctuations in prices and uncertainties about market conditions also caused constant revision of investment goals. Therefore, although each investment decision had a long-term outlook, the decision itself to invest in a single year and its statistical manifestation was a short-term, discrete event. The discreteness of year-by-year decisions to expand the mill capacity introduced an element of discontinuity into the annual series of data that record the expansion of the capacities of individual mills. Because of discontinuities in the behavior of mill capacity expansion, to compare the long-term behavior of different mills, we need a way to summarize the decisions of each mill management over a period of several years. The fixed effects provide this summary.

Much of the technology that was being adopted was capital-embodied -- improvements in machinery, and mechanization of transportation and conveyance of materials within the factories; so the incentives for a given central to adopt improvements depended on a comparison of the productivity that the new technology could offer relative to the productivity offered by the technological vintage of the existing plant, given that fixed costs in the existing plant were sunk. Because the vintages of machinery varied between mills, the points in time at which they were willing to respond to invest in any recent improvements varied as well. But more importantly, the fluctuation in the markets for sugar and for investment inputs dictated that the timing of investment was affected by changes in market prices from year to year. By taking explicit account of these influences in the model of the investment decision, we control empirically for these market influences, separate them from the site-specific, structural differences between mills, and focus on the structural differences.

To specify the investment decision we must direct a few words toward the definition of a "vintage" in the model. It is customary in theoretical literature to treat the vintage of a plant as fixed once the physical investment is made. This simplification, however, is not directly applicable empirically to Cuban sugarmills. The capital-embodied improvements of pieces of equipment within the mill were permissible and common. There were many performance-improving modifications in the designs of individual pieces of equipment which could have been introduced in existing plants without encountering problems of compatibility of old and new equipment (Frankel, 1955). Therefore, in general, improvements in the factories implied replacement of pieces of machinery but not of the entire plant. For example, grinding mills received a number of design modifications that increased their resistance to stress, and these new designs could be easily introduced into the grinding plant component by component as desired (Deerr, 1911, 1950; Braga Brothers Collection, series 10a, 10c).

The adoption of the new technologies required larger scales of production, but because of high adjustment costs, managers were not able to adopt the larger optimal scales of production

immediately. However, managers could gradually expand their scales of production over time, adding new equipment piece by piece, with the aim of eventually reaching the optimal scale of production. To use one important series of technical improvements as an example, the lengths of tandems (number of rollers in the grinding mill)[16] increased over the period. Extensions were made to the tandem by adding trapiches (3-roller mill units). Lengthening the tandem in this manner was not simply an intensification of the capital input of the grinding process. It also increased the capacity of the grinding process and, consequently, required an increase in the capacity of the entire mill. Extensions to the tandem could be made by adding a trapiche of the latest design, and, either at the same time or at a later date, the outmoded trapiches could be updated or replaced. This behavioral choice applied as well to the equipment of other processes in the mill -- evaporating equipment, railroad and other transport equipment.

The implication for modeling investment is that managers must be allowed to choose between expanding the capacity of the mill, to approach the long-run optimal scale, and replacing the outmoded equipment in the mill. To do this, we assign a vintage to each machine in the plant, rather than to the entire plant, and assume that the vintage of the plant (mill) can be described as a weighted average of the vintages of all the machines in the mill. Both replacing outmoded equipment and expanding mill capacity required the purchase of new mill equipment; but expansion of capacity entailed additional costs to obtain other strictly complementary inputs--complementary mill machinery, railroads and canefields. Investment costs are specified accordingly as

$$G_t = g_{1t} u_t + g_{2t} \beta_t u_t + h(\beta_t, u_t) \qquad (1)$$

where u_t is the purchases of new equipment measured in terms of the addition to the mill capacity

---

[16] The grinding mill consisted of a line of up to 18 rollers, but the mill machinery itself came in units of 3-roller mills, called trapiches, which followed a standardized design. The trapiches were interconnected by conveyor belts and other auxiliary equipment and called a "tandem."

that the new purchase was capable of providing, and g_{1t} is the purchase price per capacity unit of new mill equipment. The factor, β_t, is the proportion of that investment which went toward expanding the capacity of the mill, as opposed to replacing old equipment, and g_{2t} is the additional costs of complementary factors associated with a unit expansion of the capacity of the mill. The function, $h(\beta_t, u_t)$, represents the adjustment costs to investment where the first and second derivatives with respect to both terms are positive (Eisner and Strotz, 1963; Lucas, 1967; Treadway, 1971). All are functions of the year, t.

The problem faced by the central administration was to maximize the return to their investments. Given the available technologies, managers perceived an optimal amount of investment, an optimal amount of replacement of outmoded equipment, and therefore, an optimal mill capacity. But because of adjustment costs they could not arrive at the desired long-run mill capacity in a single year, so the decision variables available to the managers were (1) the purchases of new equipment each year, u_t, and (2) the proportion of that investment in new equipment which went toward expanding the scale of operation, β_t. The rate of expansion of the mill capacity is $\dot{x}_t = \beta_t u_t$, where x_t is defined as the capacity of the mill, and $\dot{x}_t$ is the time-rate of change in the production capacity of the mill. The investment problem is the following.

$$\max_{\beta_t,\, u_t} \quad V = \int_{t_0}^{t_1} [\pi_t - g_{1t}u_t - g_{2t}\beta_t u_t - h(\beta_t, u_t)]e^{-rt}\,dt \qquad (2)$$

$$s.t. \quad \dot{x} = \beta_t u_t$$

The term, π_t, is the operating profits of year t, or

$$\pi_t = [p_t - v(\rho_{t-1}, x_{t-1}, w_t)]\, y_t \qquad (3)$$

where p_t is the price of sugar, $v(\rho_{t-1}, x_{t-1}, w_t)$ is the unit operating (variable) costs, and y_t is the level of sugar output. The vintage of the plant affected the investment decision through its effect on the unit operating costs, and new vintages of equipment improved the performance of mills by

reducing the cane requirement. If the vintage of the mill was a weighted average of the vintages of its equipment, the vintage make-up of the mill is reflected in the unit cane requirement of the mill.[17] Therefore, the unit cane requirement of the mill can be used as an indicator of the vintage make-up of the mill. The scale of production is also included as an argument of unit operating costs to capture scale effects on unit operating costs. Therefore, we assume the unit operating costs, v, are a function of the unit cane requirement of the equipment already existing in the plant, ρ_{t-1}; the existing capacity of the mill, x_{t-1}; and the prices of variable inputs, w_t. If the mill is producing at full capacity, $y_t = x_t$.

With these assumptions, a solution to the investment problem represented by equations (2) and (3) is of the form $u_t^* = u^*(\rho_{t-1}, x_{t-1}, w_t, g_{1t}, g_{2t})$ and $\beta_t^* = \beta^*(\rho_{t-1}, x_{t-1}, w_t, g_{1t}, g_{2t})$, and the optimal mill expansion is

$$\dot{x}_t^* = \beta_t^* u_t^* = \dot{x}^*(\rho_{t-1}, x_{t-1}, w_t, g_{1t}, g_{2t}). \tag{4}$$

---

[17] The history of choices between replacing outmoded equipment and expanding mill capacity is reflected in the weighted average. If the mill manager could choose to apply new investment either to replace old equipment or to expand the capacity of the mill, the new vintage which was introduced will have had a different contribution to the average cane requirement of the mill depending on whether the investment was applied to expanding the capacity of the mill or replacing existing equipment. New vintages of equipment improved the performance of the mill by reducing the cane requirement. However, each mill was composed of many machines of various vintages. If the average cane requirement of the mill was a weighted average of the vintages of equipment in the mill, the introduction of a machine of the latest vintage increased the average cane requirement according to the following expression.

$$\rho_t = \frac{\rho_{t-1}x_{t-1} + \rho_t^N u_t - (1 - \beta_t)\rho_t^o u_t}{x_t}$$

where ρ_t is the average unit cane requirement of the mill in year t, ρ_t^N is the marginal cane requirement contributed by a unit of the latest vintage of equipment, and ρ_t^o is the marginal unit cane requirement of a unit of old equipment that is being retired and replaced by new equipment. The term $\rho_t^N u_t / x_t$ represents the contribution of the investment in new equipment to the average cane requirement at the mill ($\rho_t^N \leq \rho_t$), and the term $[(1 - \beta_t)\rho_t^o u_t] / x_t$ represents the reduction (improvement) in the average cane requirement due to the withdrawal of old, outmoded equipment. If all investment in year t went toward expansion of the capacity of the mill, rather than replacement of outmoded equipment, then $1 - \beta_t = 0$, and the reduction of the average unit cane requirement, ρ_t, is less than it would have been if some of the old equipment had been replaced, since no old equipment was retired.

The econometric model with fixed structural effects.

We estimate equation (4) in the form

$$x_{it} - x_{i,t-1} = \gamma_o + \gamma_1 p_{i,t-1} + \gamma_2 x_{i,t-1} + \gamma_3 q_t + \gamma_4 m_{it} + \gamma_5 z_i + e \qquad (5)$$

where all symbols represent the log forms of the variables defined above (the subscripts i and t represent mill i and year t), q_t is a vector the logs of annual market prices--time- variant, but individual-invariant. The m_{it} is a vector of cane qualities--the logs of the percent sucrose and water contents of the cane juice.[18] The variations in weather and soil quality were transmitted to the mill through their effects on the quality of the cane; therefore, these variables capture the variations of soil qualities and weather conditions at each mill which may have affected their investment decisions. The z_i are the individual fixed effects, to be treated as unobserved. Not all are unobservable; however, there were many influential individual characteristics that cannot be observed. These would include such effects as the managerial experience, information flows, and the access of each mill to credit markets in North America. Because some important time-invariant factors are unobservable, we treat the composite structural effects as unobservable, estimate their influences, and then we attempt to sort out some of the components of the estimates using the individual structural characteristics that we can observe.

The specification bias that might otherwise enter as an effect of unobserved variables is

---

[18] The dependence of the Cuban sugar industry on its unusually favorable soils was well known. The different soils on the island were also known to have different qualities that affected the cane crop. Also, the amount and timing of rainfall and sunshine affected the cane crop, which varied from year to year. The primary way that weather and soil conditions entered the production outcome was through their effects on the quality of the cane delivered to the mill. Therefore, accounting for the quality of the cane entering each mill each year accounts for time-variant effects on investment decisions at each mill that were related to weather and soil variability. Fortunately, we have excellent measures of the qualities of cane entering each of the mills each year, published by the Secretaría de Agricultura, Comercio, y Trabajo, taken from the lab reports of the mills. Of the variables employed in the regression, the sucrose content of the cane juice, is taken directly from the reports, and the water content of the cane juice is calculated using a chemical model of cane composition that employs the routine measurements taken in the mill laboratories of that time, included in the reports of the Secretaría de Agricultura, Comercio, y Trabajo (1916/17-1929). These measures are discussed in greater detail in Dye (1991). S.a. Prinsen Geerligs (1917) and Robertson (1934).

eliminated by taking differences of the observed variables from their individual-means (the means of each individual mill taken by averaging yearly observations across time). We obtain a sample mean of all variables in equation (5) for each of the mills to obtain

$$\bar{\Delta} x_i = \gamma_o + \gamma_1 \bar{p}_i + \gamma_2 \bar{x}_i + \gamma_3 \bar{q} + \gamma_4 \bar{m}_i + \gamma_5 z_i + \epsilon . \qquad (6)$$

where i indexes each mill in the sample. Then we subtract equation (6) from equation (5). The individual fixed effects, $\gamma_5 z_i$, are canceled and drop from the equation. We then estimate all the coefficients except γ_5 using the covariance estimator (CVE) (Hsiao, 1986). After these coefficients are estimated we obtain estimates of the fixed individual effects, $\gamma_5 z_i$, which are interpreted, similarly to dummy variables, as shift factors in the constant term.

The data.

The data needed for estimating equation (5) include mill capacities, yields, cane qualities, and market prices. The data for the mill capacities, yields and cane qualities are taken from a panel which includes most of the mills operating in Cuba for a period of thirteen years, 1917-1929; that number ranged between 163 and 198 mills. In the regression, we limit attention to those mills that were in operation throughout the entire period in order to eliminate the mills that failed some time during the period. Their failure may reflect unsound investment practices, and there is no way of accounting for such behavior in the model. In symmetry, we eliminate the mills which entered the industry sometime during the period of observation as well. Since the data are at the plant level, whether the entering mill belonged to an old or a new firm might have affected investment behavior and the returns to investment through the experience of the owners

and managers.[19]

These exclusions render a sample of 130 mills for 12 years, when lags in the model are accounted for. However, some of the mills failed to file complete reports of their factory data, so the panel is made incomplete by missing observations. In the results below, two estimates of equation (5) are presented, one based on the larger sample of 130 mills which form an incomplete panel of 1473 observations and a second based on the smaller sample of 71 mills which forms a complete panel of 852 observations. We will refer below to the larger sample as the "full sample" and the smaller sample as the "limited sample." The statistical properties are the same for the covariance estimation of the incomplete panel and the complete panel since the missing observations are randomly missing, as long as the error terms are distributed independently between mills (Hsiao, 1986). The advantage of the complete panel is that equal amounts of information are provided from each mill and each year, but in the complete panel the number of degrees of freedom is reduced.

As regards capturing the influences of market prices in the investment decision, price expectations play an important role. In the decision model formulated in equations (2) and (3), the prices that enter the decision through operating profits, π_t, are dominated by the managers'

---

[19] The unit of observation is the mill rather than the firm. Some firms owned a number of mill in different locations. However, many firms only owned one mill. The decentralization of mill ownership on the island remained relatively high compared with other sugar islands in the Caribbean, due probably only to the relative size of Cuba's land area.

The presence of marginal mills operating in the short run in the sugar industry is an interesting occurrence and important not to overlook. Due to the low capital costs of restarting with the cane (ratoons) standing in the fields, many small, obsolete mills which had shut down could maintain the option of re-entering production in years of high sugar prices or low labor costs. Consequently, in favorable years there were a number of mills grinding cane using techniques (machinery) that could not have covered operating costs in more ordinary market conditions. A discussion of the behavior of these "primitive" mills, as they were called by contemporaries, is found in the trade sugar journal, Sugar 23 Jan. 1921, pp. 1-2. Sugar producers made the observation that these marginal mills had a stabilizing effect on sugar prices by providing additional production capacity in the industry when prices were high, thus they had an offsetting effect on the price in years when it was rising. From the beginning of World War I to 1925 sugar prices were abnormally high, and so there were many marginal mills in operation during the period of investigation.

expectations of future prices. As always, price expectations are tricky, but in this case they are especially so because we are dealing with a period of wartime/post-wartime price adjustment. Sugar prices were subjected to the abnormalities of commodities supplies during World War I, two years of price controls and, at their removal, speculation over the sugar price. Producers understood that the high sugar prices of World War I were abnormal, and for the purposes of their long-term investment plans, they would not have formed expectations of future sugar prices adaptively on wartime prices, which were at a level clearly unsustainable in peacetime. What their expectations were is hard to know, but it is not difficult to arrive at a plausible pattern of expectations. From 1903 to 1914, the sugar price had remained relatively stable. The price of Cuban sugars in New York, c. & f. net of duties, fluctuated between 2 and 3 cents per pound. In 1916, the sugar price reached abnormally high levels of above 5 cents. In 1918 and 1919, international price control agreements maintained these abnormal prices. Then in 1920, when the price controls were lifted a speculative bubble occurred, known as "the Dance of the Millions," in which the price rose as high as 22.5 cents per pound then fell to 3.75 cents all in the same season.[20] The average price of sugar for the year 1920 was 400 percent higher than the prewar level. (See Figure 3.) The abnormal prices of 1916 to 1920 would not have entered into the managers' calculations of long-term price expectations. Given the stability of prices for the decade and a half before the war and given the lack of any other information about sugar price expectations, it is plausible to assume that during, the period of high wartime prices, managers believed that in the long run the sugar price would return to its prewar level. There is also

---

[20] Many sugar producers were ruined at the end of the speculation because the producers were storing their stocks of sugar, holding out for higher prices, when the price plummeted. This also resulted in a crisis in the banking industry in Cuba in which many Cuban and Spanish banks on the island failed. Of the three leading banks in Cuba, the Banco Nacional and the Banco Internacional went bankrupt, and the Banco Español was severely hurt. North American banks, the National City Bank and the Royal Bank of Canada suddenly replaced these Cuban and Spanish houses as the leading banks in the country (Pérez 1986; Jenks, 1928). These North American banks (also included were Chase National and Guaranty Trust) opened many branches during World War I, and were indeed heavily exposed to Cuban sugar when the bubble burst. They continued to meet depositors' demands to withdraw funds by tapping the funds of their Head Offices (Cleveland and Huertas, 1985).

anecdotal evidence to support this assumption.[21]

As a further consideration, keeping the specification of price expectations simple is essential for the econometric model because there is a strict upper limit to the number of time-variant, individual-invariant explanatory variables that can be included. Given only twelve years of observation, inclusion of twelve or more time-variant, individual-invariant variables introduces strict multicollinearity in the matrix of explanatory variables and singularity of its cross-products matrix. The most attractive simple approximation is to assume a constant level for the expected long-term price of sugar over the period. This specification can account for an aspect of price expectations that is commonly overlooked in econometric models. Different managers may have been more or less optimistic in their assessments of the future sugar price. The fixed effects will pick up any differences of this sort between individual mills. Though we cannot observe the differences, there is no danger of bias entering the estimated coefficients through not having controlled for them explicitly.

We must also consider the short-term effects of the high wartime prices on the sugar market. It is possible that investors would have wished to take advantage of short-term high prices to accumulate capital because the capital expenditures could have been written off quickly. However, it is also possible that the uncertainty introduced in the long-run price due to wartime price controls, speculation, and the general disruptive effects of the war may have had a stronger influence that offset the former. The higher level of uncertainty would have had the effect of reducing the level of investment as producers postponed improvements of their mills until conditions in the market settled down (Hey, 1979, 1984). To capture these influences, we include a dummy variable, the "war dummy," which is defined to be equal 1 during the years 1917-20.

---

[21] After the war, there is evidence of belief among Cuban sugar producers that the price would fluctuate throughout the rest of the decade around a level not too much different from the prewar levels. Manuel Rionda, who was the president of the sugar brokerage firm, Czarnikow-Rionda, which at one time handled over 60 percent of Cuban sugar sales in New York, wrote in personal correspondence as late as 1929 that he expected a recovery in the price of sugar. Such comments are found in the private letterbooks of Manual Rionda. See the Braga Brothers Collection, series 2.

Regarding the input prices that figure into operating costs, expectations of future prices are treated in a similar manner to expectations of the price of sugar. However, current variable input prices are included among the explanatory variables because they also affected the costs of investment. The investments in the fields required largely unskilled labor for establishing canefields, and building railroads and bridges. We employ the wages of cane cutters to represent the cost of unskilled labor in the fields.[22] The price of steel rails and an index of the price of sugarmill machinery is included among the explanatory variables to represent the material and equipment costs of railroad and mill construction. The price of bituminous coal for fueling the boilers is included to represent the cost of fuel at the mill. The mills generally were fueled by bagasse (cane trash) supplemented with coal, wood or fuel oil. The bagasse was a by-product of sugar production. The cost of wood was primarily the labor cost of gathering it. Because the use of fuel oil was being newly introduced in Cuban sugarmills, the sales price of oil in Cuba was out of line with international oil prices and were not representative of the long-run cost of adopting oil

---

[22] The liquidation rates of colonos for deliveries of cane--the payment to the colonos in sugar for each 100 arrobas of cane delivered to the mill--have been examined but are not included among the explanatory variables in the regression for two reasons. Unfortunately, we have average liquidation rates for only a few mills. Liquidation rates relevant to the investment decision would have differed considerably from mill to mill depending on the age and expiration dates of their contracts with their colonos. The liquidation rates were fixed in the contracts, which were of six to ten years duration; therefore, the fluctuation of the rates was restricted by the expiration and renewal of contracts. The average liquidation rates paid by mills could not generally respond to fluctuations in the market for sugar or for cane. There were other means employed by mill managers to provide incentives for short run responses in cane supply, but these expenses were determined by the cost of labor. The primary means was the use of credit advances both for planting and for maintenance of canefields. When managers wished to stimulate cane production in the short run, they intensified the maintenance of the canefields to increase the yields per acre of cane. Advances of this sort were typically tied to a specific cultivation or planting task; so to intensify maintenance, they simply increased the number of tasks they financed. The amount of each advance was determined by the cost of performing the particular task required. Since these tasks were labor-intensive, changes in costs of this sort are reflected in the wages of field labor.

I have been able to construct a time series of liquidation rates that would apply reasonably well to mills in eastern Camagüey province and western Oriente. These demonstrate that here was a rising trend in the liquidation rates in the area around eastern Camagüey and western Oriente. This trend would need to be accounted for in the investment decision. The trend likely was a general trend on the island, so the available data for liquidation rates though limited might be useful for representing the general trend. However, the series of liquidation rates is severely collinear with the war dummy and the wage for cutting cane. Given this, we have excluded the liquidation rates from the regression, understanding that any influence of the rising trend in liquidation rates is picked up by the cutting wages and the war dummy.

as a fuel (República de Cuba, Secretaría de Hacienda, 1917-29b).[23] Changes in the price of coal, its closest substitute, were more representative of the changes in relative costs of using each of the supplementary fuels. All the factor prices are scaled for changes in the general level of prices using the U.S. Bureau of Labor Statistics wholesale price index (1890-1930). The ties of Cuban sugar producers to the U.S. markets for producers goods was very close. Mills depended on imports of machinery, fuel and capital. The Cuban peso was tied one-to-one to the dollar, and U.S. currency circulated in Cuba. Given the ties of Cuban sugar producers to the U.S. markets for imports of most factors of production, this is the best available measure of general fluctuations in prices.

The regression estimates.

The regression estimates are presented in Table 4. The overall fit of the regression model is very good for both full and limited sample estimates. The F-ratio for both is significant at all reasonable levels of significance. The signs and significance of the estimated coefficients follow a priori expectations, except for the lagged yield.

Among the input prices multicollinearity is present, so it is inaccurate to draw conclusions about their significance using the individual tests. Joint tests of significance based on comparison of restricted and unrestricted models, presented in Panel B of Table 4, show that the input prices are jointly significant with the cutting wages and the war dummy. The presence of multicollinearity, of course, presents no problem since we are not attempting to distinguish or

---

[23] The use of fuel oil in sugarmills in Cuba was first introduced in the midst of our sample period. One observes that the prices of fuel oil imported from the United States reported in Comercio Exterior are much lower than the price of fuel oil in the United States in the first few years after it began to be reported in Cuban trade statistics. The apparent reason for the lower price is that a portion of the payment for fuel oil by those innovators who first adopted it was made in other forms. Those who first used fuel oil in the mill also founded oil distributing companies at Cuban ports as subsidiaries of major U.S. oil companies. The agreements they made with mother companies to establish distribution facilities in the country very likely included remuneration in terms of discounts on oil purchases in exchange for capital investments designed to open the Cuban fuel oil market. Braga Brothers, series 10c.

separate the influences of these prices. Furthermore, the statistical insignificance of the prices of non-labor investment inputs -- and even the positive signs on the coefficients -- is not unexpected theoretically given the pattern of complementarity between the inputs in investment. Investment in canefields required primarily labor input, but investment in railroads and mill equipment required the combination of material inputs with labor (steel rails or equipment). Steel rails could be purchased but were of little use without employing labor to install them. Given the presence of this complementary relationship in railroad and mill construction between material and labor inputs, the estimated coefficients absorb the influence of cross-price effects. If the price of steel rails and wages move in opposite directions, the own-price effect of steel rails on investment will be offset by the cross-price effect of wages on railroad construction. Meanwhile, at the same time, the own-price effect of wages on canefield development is not offset by the movement in the cost of steel rails. This result is derived from the cost structure developed above in equation (1).[24]

The sign on the coefficient of the war dummy is negative. This result suggests that the uncertainties of World War I and its aftermath tended to discourage mill expansion and/or the new banking environment of Cuba in the twenties, with greater North American presence, was stimulative to the growth in mill capacities. It turned out that after the bubble of 1920, sugar

---

[24] This result follows directly from the investment cost structure we developed above. Cf. equation (1). Consider the function of net returns to investment, $F = \pi[x_1, z(x_2)] - w_1(x_1 + x_2) - w_2 z(x_2)$, where π is a function of returns to investment which is convex in order to exhibit diminishing returns to investment, and x_i and z are the labor and materials inputs (steel rails, etc.) obtained at prices w_i $(i = 1, 2)$. Because of complementarity, the labor input, x_i $(i = 1, 2)$, enters both directly in the function, π, and indirectly through the material inputs, $z = z(x_2)$, since the materials must be combined with labor in order to be useful. Necessary conditions for maximizing net returns to investment are

$$\pi_2 z' = w_1 + w_2, \quad \text{and} \quad \pi_1 = w_1$$

where $\pi_2 z' \equiv \frac{\partial \pi}{\partial z}\frac{dz}{dx_2}$, and $\pi_1 \equiv \frac{\partial \pi}{\partial x_1}$. Because of diminishing returns, the derivatives of $\pi_2 z'$ and π_1 with respect to x_2 are negative. If w_1 and w_2 move in opposite directions, the own-price effect of w_2 on z is offset by the complementary effect of w_1 on z. However, w_1 has an own-price effect, through x_1, which is not offset. Consequently, we detect statistically the inverse relationship between w_1 and x_1, but not that of w_2 and z.

properties fell into the hands of the North American banks because of foreclosures on bad debt. In many cases, they decided to maintain possession and continue to make investments in these properties at least for the short run hoping that the demand for sugar properties, affected adversely by the uncertainty in the sugar price, would improve in the near future (Cleveland, 1985).

The lagged mill capacity is highly significant. The expected sign is negative because the smaller the existing capacity of the mill, the greater are the potential economies of scale. This result may provide some corroboration that mills pursued larger scales as the constraint of costs of adjustment were relaxed in order to reap economies of scale. However, this result should be obtained regardless since $x_{it} - x_{i,t-1}$ and $x_{i,t-1}$ are not independently constructed. The lagged yield is mildly significant at the 0.1 level in the full sample, and insignificant in the limited sample, and as well, the signs of the coefficients alternate between the two sample estimates. One would expect the yield offered by the existing equipment to be smaller the older the vintage of the mill because there would be a greater incentive for updating the equipment. However, the use of the lagged yield as a proxy for the vintage of the equipment is not reliable because of other factors which influence the yield, particularly weather conditions, which are highly stochastic and had a very strong influence on the yield. So the insignificance of the lagged yield probably arises because it is a poor proxy of the vintage of equipment at the mill. Finally, the sucrose and water contents of the cane are significant and exhibit the expected signs, since for a given weight of cane higher contents of sucrose and water in the cane juice indicate a lower impurity content.

The fixed effects.

The principal objective is to examine the correlation of the manager's propensity to expand the mill capacity with the structural features that might have affected the bargaining positions of colonos. To this aim, we focus on the correlation of the share of cane supplied by colonos independientes at each mill with the estimated fixed effects. A negative correlation supports the hypothesis that the independent colono was able at times to obtain a better bargaining

position vis-à-vis the central relative to the colono del central. To examine the correlations, we calculate estimates of the fixed effects based on the estimated covariance regression results presented in the previous section. Then we estimate a second regression using the estimated fixed effects as the dependent variable and the percentage of cane supplied by colonos independientes as a dependent variable. We also include a number of additional explanatory variables to control for other structural factors that might also have affected the magnitudes of the estimated fixed effects.

Among the additional explanatory variables, we include a proxy for the orientation of each mill toward North American credit markets. A correlation of this variable with the fixed effects might indicate some imperfection in credit access; however, since the results we obtain offer no evidence regarding causation, we cannot conclude that credit imperfections existed. In fact, the orientation of the mills toward North America may be a indicator of other very important unobservables--the quality of management and technical skills, which were likely to have differed between mills; and the differences in tacit (internally learned) knowledge about the new techniques being used at each mill. Greater North American orientation can suggest greater access to markets for technical specialists or greater access to information about specialized labor markets in the United States.

Estimates of the fixed effects are obtained from the estimated coefficients of the covariance regression and the individual-mill sample means of the explanatory variables in the regression. Define μ_i to be the fixed, individual mill effects, $\mu_i = \gamma_5 \ln z_i$ (notation of equation (5)). We estimate μ_i with

$$\hat{\mu}_i = \Delta\bar{x}_i - \hat{\gamma}_o - \hat{\gamma}_1\bar{x}_i - \hat{\gamma}_2\bar{p}_i - \hat{\gamma}_3\bar{q} - \hat{\gamma}_4\bar{m}_i \qquad (7)$$

where i indexes each mill.

We estimate and analyze fixed effects obtained from the estimated coefficients of both the limited and full sample regressions. Comparison of the two sets of estimates lends confidence to

the inferences because they are similar using either set. Because of the lack of data of structural effects for some of the 71 mills in the limited sample, we have used the sample means of the full sample and the estimated coefficients of the limited sample to obtain the second set of fixed effects estimates in Table 5. Therefore, the estimated fixed effects from the full and limited sample regressions, used to obtain the results of Table 5, have the same number of observations (mills); the only difference between them is that they employ different estimates of the coefficients, γ_i, $i = 0, 1, 2, 3, 4$. This is a reasonable procedure since the purpose for using the second set of fixed effects estimates is to observe the sensitivity of the results to plausible variations in the estimated coefficients of Table 4 due to the effects of multicollinearity between the factor price variables.

The correlations of the fixed effects estimated by

$$\hat{\mu}_i = \delta_o + \delta_1 CI_i + \delta_2 CA_i + \delta_3 MA_i + \delta_4 RB_i + \delta_5 \bar{s}_i + \delta_6 YC_i + \delta_7 OR_i + \nu_i \quad (8)$$

where CI_i is the percentage of cane supplied by to mill i by colonos independientes, CA_i is the percentage of cane supplied by the mill i administration, MA_i is the number of other mills within a ten kilometer radius of mill i, RB_i is the number of branches of public railroads within fifteen kilometers of mill i, $\bar{s}_i$ is the mean sucrose content in the cane juice of mill i for the seasons from 1917 to 1929, YC_i is the yield of cane per acre of mill i in 1930, and OR_i is a dummy representing the orientation of the mill toward North America.

The fits of the estimated regressions, presented in Table 5, are good in both cases; the F-ratio for each is significant at 0.01; and the signs of all the coefficients correspond with a priori expectations. Multicollinearity between explanatory variables is not a problem; all pairwise correlation coefficients between explanatory variables are less than 0.3. Examination using the characteristic roots test reveals no significant other linear combinations between explanatory variables.

To interpret the results, we focus initially on two variables both of which are statistically significant. (1) First is the percent share of cane supplied by colonos independientes, which is highly significant. This suggests that the greater the percentage of cane supplied by colonos independientes, the smaller was the long-run expected yearly rate of expansion of the capacity of the mill. This result corroborates our hypothesis that colonos independientes indeed occupied bargaining positions which hampered the expansion of mills. Thus it supports the conclusions of the first section of the paper. The percent share of cane supplied by the central administration is also included but is found to be insignificant. The figures for both these variables are for the 1930 crop.[25]

(2) A dummy variable included to represent each mill's orientation towards North America is also highly significant. It attempts to capture any differences between mills due to their access to North American credit markets, access to managerial and technical information and support, or as well, any differences in the quality of management stemming from association with the North American business environment. Orientation towards North America is proxied by a list compiled in 1928 by the Sugar Club of Cuba (a mill owners' business and technical organization), which categorized mills by the national orientation of their business connections.[26] The significance of this variable indicates that the connections with the United

---

[25] The data for these shares are of the 1930 crop obtained from the Secretaría de Agricultura, Comercio, y Trabajo, Industria Azucarera, 1930. Data for other years within the period are not available. Nonetheless, the end-period observation is the preferred one. The reason is that some mills that depended heavily on colonos independientes before World War I tended to reduce their dependence on colonos independientes as time progressed. If these mills could foresee their opportunities for reducing their dependence on colonos independientes, the end-period observation better represents their expectations. Of course, they could not have achieved significant reductions in the dependence of colonos independientes instantaneously because of contract duration, but they could, and in fact did, negotiate cane contracts in advance or concurrently with plans to expand mill capacity.

[26] Braga Brothers Collection, series 10c, box 61, f. 11. The list does not correspond to the nationalities of the owners of the mills. Most mills were incorporated, and their shareholders as well as their boards of directors consisted of people of different nationalities. Instead, the list classifies the nationalities of mills according to their connections to the business communities of either Cuba or the United States, as assessed by the members of the Sugar Club. A handful of the mills in the sample are not

States were important for obtaining the resources needed for expanding to large-scale techniques. Whether the difference was in terms of credit access or management or technical skills or something else cannot be determined from these results. To compare the relative magnitudes of the effects of mill orientation and the prevalence of colonos independientes, see note b in Table 5.

(3) Two variables are included to account for the other mills in close proximity which provide feasible alternatives to the local colonos for establishing cane supply contracts. The number of mills within a ten kilometer radius of the mill in question is included to represent the presence of alternative mills in close proximity. Nearness was important because shipping the cane over larger distances was costly and perilous to the quality of the cane if it could not reach the alternative mill quickly enough or without interruption. The number of branches of public railroad lines which passed within fifteen kilometers of the mill is included to represent the access of the colonos to public railroads. The availability of public rail transportation to the colonos was necessary to allow them a means of transporting their cane quickly enough to an alternative mill site. These variables were based on figures for 1920.[27] The insignificance of these variables indicates that there was considerable variation in the correlation of these variables with the expected yearly rate of expansion of the capacities of mills. The signs indicate that the proposed influence may still have existed, though it is not easy to capture statistically.

(4) The mean sucrose content of each mill over the period 1917-29 is included to control for the quality of the soil of each mill's cane lands. Its significance indicates that variation in the expansion tendencies of different mills was related either to the composition of soils or to the

---

included in this list. The orientation of these mills is determined by the country in which the sugar company was incorporated, which is obtained from the Secretaría de Hacienda, Industria Azucarera y sus Derivados (1928).

[27] The number of branches was entered as 0, 1, 2, or 3. If more than three branches were near the mill, that observation of the variable was assigned a value of 3, in order not to place extremely high weights on portside mill sites. The data were obtained using maps of the Cuban sugar industry in 1920 published in the Secretaría de Agricultura, Comercio, y Trabajo, Industria Azucarera, 1919/20.

depletion of the fertility of soils at various mills, which would have had an effect on the long-run outlook of the mill's productive potential.

(5) Cane yields per acre are included to control for differences between mills in the costs of cultivating cane. Cane yields could have affected the unit requirements of labor and other inputs in cane cultivation and delivery. If some mills had lower cane productivities and a low elasticity of substitution between land and labor, unit labor costs on the colonia would have been higher and the prices demanded by colonos at these mills for supplying cane to the centrales might as well have been higher. This would imply higher costs to these mills in obtaining the additional cane supplies needed upon expansion. If the differences in land productivities affected the costs of production to the mill, investors may have chosen to invest in mills that had higher cane yields. If so, this might suggest an advantage to the eastern lands because there was much virgin land suited to cane available in the east but little remaining in the west.[28] Land prices may have accounted for and offset some of these differences in fertility, but they would have accounted for the differences only imperfectly, particularly in cases where the land was purchased by the mill owners before it was put into cane, such that the actual productivity was not known. Cane yields, however, turn out to have an insignificant effect on mill expansion behavior. To be complete, the cane yields account for cost differences in cane cultivation related to the volume of cane obtained from a given amount of land. They do not account for the quality of cane, but the mean sucrose content of the cane juice controls for such variation in quality.

As an additional comment, we have observed that the coefficient of the share of the cane supplied by the central administration is insignificant. This corresponds with our observation elsewhere that the larger centrales in Cuba seem to reveal a preference against integrating the cane

---

[28] The data used are the yields of cane per acre reported by the Secretaría de Agricultura, Comercio y Trabajo, Industria Azucarera, Memoria de la Zafra, in 1930. It is unfortunate that it is necessary to use cane yields from 1930 rather than from the middle of our period. Cane yields were not collected on an annual basis, and the year 1930 is the first year in which cane yield data are available after 1913.

cultivation vertically with the sugar manufacturing activities (Dye, 1991). While we have not explained why this was the case, these results confirm that there was no significant statistical relationship between the vertical integration of cultivation and milling, and the tendencies of mills to expand their capacities.

The results of these regressions suggest that the correlations of the estimated fixed effects with the observable structural features of mills conform to the pattern we have proposed. They show that there was an association between the mill's expansion and the prevalence of colonos independientes, thus they provide evidence to support the proposition that the colonos independientes could affect the contractual relationship sufficiently to discourage managers from expanding their mill capacities. The results also suggest that the influence of the orientation of mills toward North America was very strong and merits further attention.

From this analysis, it is difficult to say exactly what the causal factors are that contribute to the influence of mill orientation. It is likely that this variable represents the variation of many factors related to information flows and personal contacts between Cuba and the United States. Its high degree of significance indicates the dependence of the Cuban sugar industry on the capital resources emanating from the United States. It is no surprise that the orientation of mills should have been so significant. Relying on these correlations, we cannot actually distinguish the mills' orientation towards North America from other factors that are highly correlated with it. An aspect of the ownership structure of mills--whether the mill was held by a company that controlled several mills--is highly positively correlated with the orientation of mills towards North America. The correlation between these two variables is 0.75.[29] The significance, then, of the orientation

---

[29] Like the mill's orientation, we have defined the ownership structure variable as a dummy variable. The variable is assigned a value of 1 if the company that owned the mill in 1928 also owned other mills. This is also determined from the list compiled by the Sugar Club, see footnote 26. Though they are not reported, I calculated regressions that included an ownership structure dummy variable in place of the orientation variable. As one would expect, the results are virtually the same.

of mills toward North America may indicate organizational factors related to the upper management's investment decisions and international marketing abilities. While it is disheartening that the various influences involved here cannot be separated statistically, the result does strongly reflect the influences Chandler emphasizes in the development of U.S. and British industry during this period. And it suggests that the forces behind the growth, the technical change and the structural change in the Cuban sugar industry were related to the general developments in modern technology and business in the industrial countries in the early twentieth century.

On the other hand, the influences that we observe of the colonos independientes on the ease of adoption of larger scales of production suggest that their ability to bargain for more favorable terms in the cane supply contracts made expansion of mill capacity relatively costly. This influence was independent of the orientation of the mill. These regional differences between the east and the west that affected the institutional settings and the infrastructure of the mills created relative differences in the attractiveness of sugarmills from the points of view of prospective investors. The foreign capital which flowed into Cuba was scarce and tended to flow to those areas of the island where the centrales found themselves in better position to maintain the capital invested in the cane supply networks with as little threat from local colonos independientes as possible.

Table 1

Sugar production per mill in Cuba, 1860-29.

year	mills grinding	sugar produced by all mills	sugar produced per mill
	(no.)	(000s of bags of 325 lbs.)	(000s of bags of 325 lbs.)
1860	1365	2968	2.2
1877	1190	3574	3.0
1904	174	7253	41.7
1916	189	21,063	111.4
1929	163	35,540	218.0

Sources. República de Cuba, Secretaría de Hacienda (1903, 1916); República de Cuba, Secretaría de Agricultura, Comercio, y Trabajo (1929); Ferrara (1915); Pezuela (1863).

Table 2

Summary statistics of mill capacities in each provincial for the 1929 grinding season.

province	no. mills[a]	no. mills at with least 400 thousand bag mill capacity	average capacity[a]	st. dev. capacity[a]	maximum capacity	minimum capacity	percentage cane ground by mills with more than 400 thousand bag capacities[a]
Pinar del Rio	10	0	178.0	52.1	300	100	0.0
Habana	11	3	299.5	167.5	600	85	51.8
Matanzas	22	2	231.1	132.7	600	50	24.3
Santa Clara	47	2	197.7	76.5	400	75	9.1
Camagüey	29	18	481.2	241.3	1100	150	80.8
Oriente	34	11	404.0	311.4	1300	30	60.8

Source. República de Cuba, Secretaría de Agricultura, Comercio, y Trabajo (1929).

[a] This column includes only mills with capacities of at least 100 thousand bag capacities. Using the survival technique developed in Stigler (1958) and Weiss (1963), we conclude that mills under 100 thousand bag capacities were inviable in the long run. Additional evidence based on the size of new mills upon entry confirms this conclusion (Dye, 1991).

Table 3.

Shares of cane supply (percent) supplied by each tenure arrangement.

province	year	administration cane	colonos del central	colonos independientes
All Cuba	1905	30.3	33.1	36.5
	1913	13.4	56.9	29.7
	1929	18.3	65.9	15.7
Pinar del Rio	1905	27.8	30.5	41.7
	1913	18.7	44.3	37.0
	1929	24.6	46.8	28.6
Habana	1905	22.6	38.0	39.4
	1913	8.8	50.3	40.9
	1929	12.6	74.5	12.9
Matanzas	1905	27.4	35.2	37.3
	1913	8.1	46.8	45.1
	1929	4.5	58.9	36.5
Santa Clara	1905	24.6	26.4	49.0
	1913	16.1	50.6	33.3
	1929	11.5	70.5	18.0
Camagüey	1905	55.5	43.5	1.1
	1913	10.6	79.2	10.2
	1929	14.5	77.1	8.4
Oriente	1905	41.9	40.4	17.6
	1913	17.6	72.1	10.3
	1929	32.7	55.0	12.3

(Table continues next page.)

Table 3 (cont.).

		no. observations
sample sizes:	1905	179
	1913	98
	1929	136

Sources. República de Cuba, Secretaría de Hacienda (1904/05); República de Cuba, Secretaría de Agricultura, Comercio, y Trabajo (1912-14, 1930)

Table 4

Estimated Regression of Mill Expansion.

A. Dependent variable: the increase in mill capacity as a proportion of existing capacity

	Full Sample				Limited sample			
N	1473				852			
F	89.245	** [a]			49.524	**		
R squared	0.328				0.320			
MSE	0.154				0.176			
DW	2.007				1.987			
Explanatory variable	estimated coefficient	t-ratio	prob > |t|		estimated coefficient	t-ratio	prob > |t|	
capacity lagged one year	-0.509	-25.679	0.000	**	-0.474	-17.930	0.000	**
yield lagged one year	0.105	1.763	0.078		-0.100	-1.116	0.682	
war dummy	-0.026	-2.174	0.030	*	-0.024	-1.645	0.082	
wages for cutting cane	-0.260	-9.080	0.000	**	-0.247	-6.914	0.014	*
price of coal	-0.009	-0.352	0.725		-0.008	-0.234	0.815	
price of steel rails	0.087	1.415	0.157		0.055	0.725	0.468	
price of equipment	-0.018	-0.899	0.369		0.010	0.395	0.693	
sucrose content of cane juice	0.483	3.672	0.000	**	1.035	5.539	0.000	**
water content of cane juice	3.601	4.795	0.000	**	6.495	6.191	0.000	**

(Table continues next page.)

Table 4 (cont.)

B. Tests of joint significance[b]

Zero restrictions imposed on:	F		F	
wages for cane cutting, war dummy	95.229	**	57.888	**
price of steel rails, war dummy	10.928	**	5.263	**
price of coal, war dummy	5.352	**	3.289	*
price of equipment, war dummy	5.352	**	4.078	*
price of steel rails, wages for cane cutting	92.393	**	54.268	**
price of coal, wages for cane cutting	90.830	**	55.058	**
price of equipment, wages for cane cutting	91.500	**	52.029	**
prices of coal, steel rails, and equipment	2.379		0.965	
prices of steel rails and coal	2.899		1.184	
prices of steel rails and equipment	2.676		1.447	
prices of coal and equipment	1.784		0.526	
sucrose content, cane content	24.309	**	41.311	**

Sources. República de Cuba, Secretaría de Hacienda (1917-1929a, 1917-1929b), República de Cuba, Secretaría de Agricultura, Comercio, y Trabajo (1917-1929), U.S. Bureau of Labor Statistics (1890-1930), Braga Brothers Collection, series 10a, box 7, f. 1, series 10c, box 27, ff. 27, 38, series 96.

[a] ** indicates signficance at 0.01 and * at 0.05.

[b] Maximum likelihood test of the compatibilities of the unrestricted model of Panel A and the following zero-restricted models.

Table 5

Regression to examine correlations between the fixed effects and the structural features of mills.

Dependent variable: Fixed effects based on the estimated coefficients based on the:

			B. full sample				A. limited sample	
N			82				82	
F			5.865	** [a]			5.422	**
R squared			0.357				0.339	
MSE			0.236				0.239	
Explanatory variables:	estimated coefficients	t-ratio	prob > |t|		estimated coefficients	t-ratio	prob > |t|	
constant	-7.812	-3.517	0.001	**	-21.609	-9.587	0.000	**
orientation towards North America [b]	0.176	3.258	0.002	**	0.190	3.453	0.001	**
percent cane supplied by colonos independientes [b]	-0.005	-3.791	0.000	**	-0.005	-3.768	0.000	**
percent cane supplied by administration	-0.000	-0.012	0.990		-0.000	-0.043	0.996	
mean sucrose content in cane juice	-2.554	-3.193	0.002	**	-1.901	-2.342	0.022	*
cane yields per acre	-0.001	-0.338	0.736		0.001	0.250	0.803	
no. of competing mills within 10 km. radius	-0.014	-0.490	0.626		-0.012	-0.416	0.679	
no. of branches of public railroad within 15 km. radius	-0.024	-0.790	0.434		-0.032	-0.622	0.536	

(Sources and notes on next page.)

Sources and notes to Table 5.

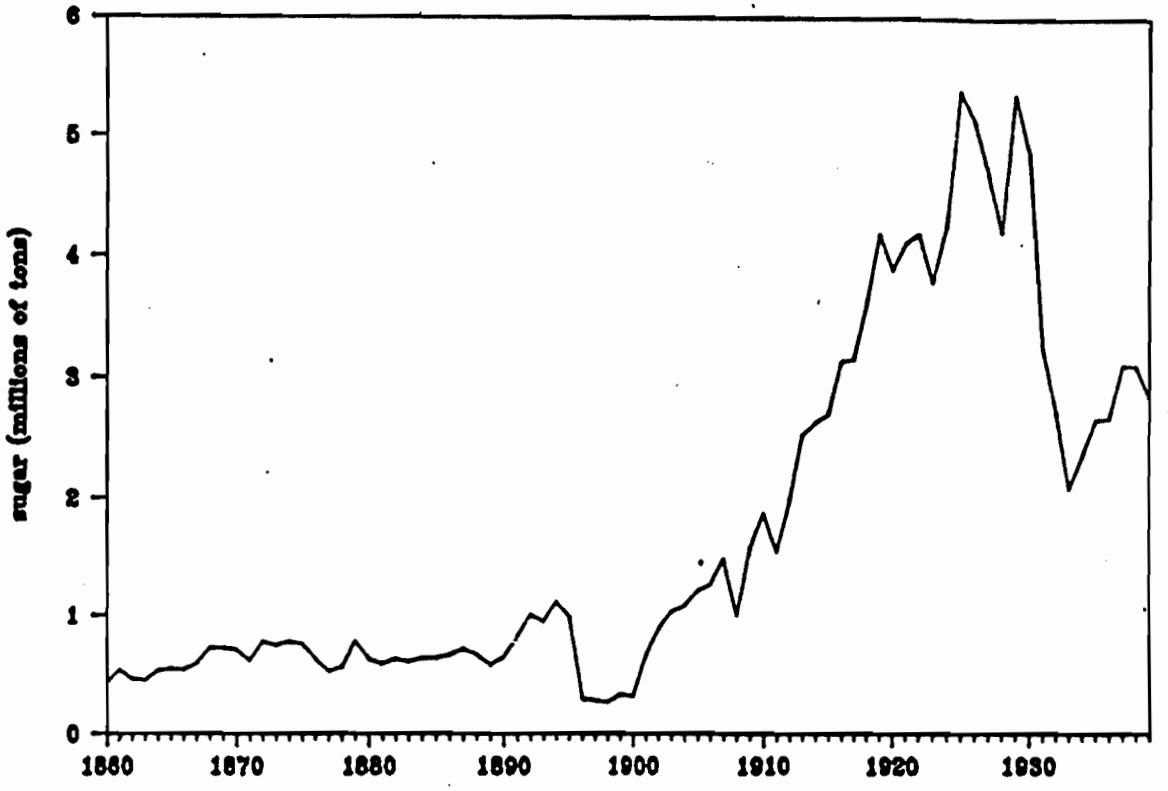
Sources. Table 4; Braga Brothers Collection, series 10c, box 61, f. 11; República de Cuba, Secretaría de Agricultura, Comercio y Trabajo (1930); and República de Cuba, Secretaría de Hacienda, (1905a).

[a] ** indicates significance at the 0.01 level and * at 0.05.

[b] In order to consider the relative strengths of the effects of the coefficients of mill orientation towards North America and the share of cane supplied by colonos independientes, we need to consider the dimensions of these two coefficients. The coefficient (0.18-0.19) of the mill orientation is the difference in the average annual rate of increase in mill capacity between a mill that has an orientation toward North America and one that does not. The coefficient (-0.005) of the share of cane supplied by colonos independientes is the difference in the average annual rate of increase in the mill capacity given a one percent difference in the share of cane supplied by colonos independientes. The mean value in the sample of the percent share of cane supplied to the mill by colonos independientes is 19.4; the standard deviation is 22.1. If we compare two mills, one whose share of cane supplied to a mill by colonos independientes is the mean and one whose share is one standard deviation above the mean, our results suggest that we expect the average annual rate of increase to fall by $0.005 \cdot 22.1 = 0.111$. And if the second mill is two standard deviations away from the mean, the influence is twice as much. The maximum share supplied by colonos independientes in the sample is 81.9; therefore, we can see that the effects of the mill's orientation and the prevalence of colonos independientes on mill expansion behavior, according to our results, are of the same order of magnitude.

Figure 1.

Cuban sugar production, 1860-1932.



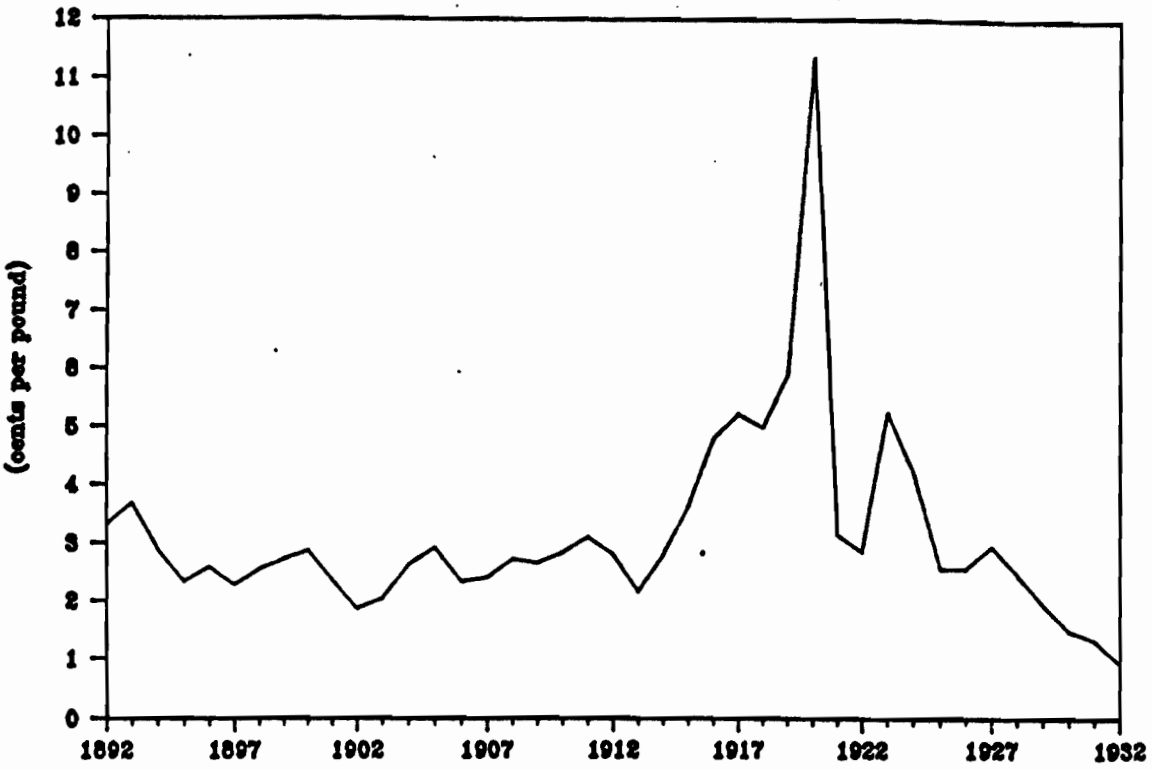
Source. Moreno Fraginals (1978).

Figure 2.

Map of Cuba showing provinces and major cities.

Figure 3.

Price of Cuban sugars in New York, cost and freight.[a]



Sources. Willett and Gray (1911, 1930, 1940); Czarnikow-Rionda (1939).

[a] Average annual prices for Cuban 96° pol. centrifugal sugars (the grade most commonly traded throughout the world) presented net of of duties.

References

Bergad, L.W. (1990), Cuban Rural Society in the Nineteenth Century: the Social and Economic History of Monoculture in Matanzas. Princeton Univ. Press.

Castillo, del, J. (1985), The Formation of the Dominican Sugar Industry: From Competition to Monopoly, from National Semiproletariat to Foreign Proletariat." In Manuel Moreno Fraginals, Frank Moya Pons, and Stanley Engerman (Eds.), Between Slavery and Free Labor: The Spanish-Speaking Caribbean in the Nineteenth Century. Baltimore: Johns Hopkins Univ. Press.

Chandler, A. (1977), The Visible Hand. Cambridge, Mass.: Belknap Press of the Harvard Univ. Press.

Chandler, A. (1990), Scale and Scope. Cambridge, Mass.: Belknap Press of the Harvard Univ. Press.

Cheung, S. (1969), "Transaction Cost, Risk Aversion, and the Choice of Contractual Arrangements." Journal of Law and Economics **12**, 23-42.

Cleveland, H., and Huertas, T.F. (1985), Citibank: 1812-1970. Cambridge, Mass.: Harvard Univ. Press. Pp. 105-07.

Cuba, República de, Secretaría de Agricultura, Comercio, y Trabajo (1916/17-1930a). Industria Azucarera, Memoria de la Zafra. Habana: Imprenta y Paplería de Rambla, Bouza y Ca.

Cuba, República de, Secretaría de Agricultura, Comercio, y Trabajo (1914b), Portfolio Azucarero, Industria Azucarera de Cuba, 1912-14. Habana: Lib. e Imprenta "La Poesía Moderna."

Cuba, República de, Secretaría de Hacienda (1903/04-1929a), Industria Azucarera y sus Derivados. Habana: Imprenta Mercantil; P. Fernandez y Ca.; Imp. y Lit. "Habanera;" Imprenta y Papelería "La Propagandista;" Montalvo y Cárdenas; Imp. Carasa y Ca.; Fernandez Solana y Cia.; Tipos Molina y Cia.

Cuba, República de, Secretaría de Hacienda (1917-29b), Comercio Exterior. Habana: Imprenta "La Propagandista."

Czarnikow-Rionda (1930), Czarnikow-Rionda Annual Sugar Review.

Deerr, N. (1911), Cane Sugar: A Textbook on the Agriculture of the Sugar Cane, the Manufacture of Cane Sugar, and the Analysis of Sugar House Products. Manchester: Norman Rodger. Pp. 11-12.

Deerr, N. (1950), History of Sugar. 2 vols. London: Chapman and Hall, Ltd.

Dye, A. (1991), Tropical Technology and Mass Production: the Expansion of Cuban Sugarmills, 1899-1930. Ph.D. dissertation, University of Illinois at Urbana-Champaign.

Eisner, R., and Strotz, R.H. (1963), "Determinants of Business Investment." In D.B. Suits (Ed.), Impacts of Monetary Policy. Englewood Cliffs, New Jersey: Prentice-Hall.

Engerman, S. (1983), "Contract Labor, Sugar and Technology in the Nineteenth Century." Journal of Economic History **43**, 635-60.

Engerman, S. (1984), "Economic Change and Contract Labor in the British Caribbean: the End to Slavery and the Adjustment to Emancipation." Explorations in Economic History **21**, 133-54.

Engerman, S. (1986), "Servants to Slaves to Servant." In P.C. Emmer (Ed.), Colonialism and Migration: Indentured Labour Before and After Slavery. Dordrecht: Martinus Nijhoff Publishers.

Ferrara, O. (1915), Anuario Estadístico de la República de Cuba. Habana: Imprenta "El Siglo XX."

Frankel, M. (1955), "Obsolescence and Technological Change in a Maturing Economy," American Economic Review **45**, 296-319.

Gerschenkron, A. (1979), Economic Backwardness in Historical Perspective. Cambridge, Mass.: The Belknap Press of Harvard Univ. Press.

Guerra y Sánchez, R. (1944), Azúcar y Población en las Antillas, 3d ed. Habana: Cultural.

Haraksingh, K. (1984), "Labour, Technology and the Sugar Estates in Trinidad, 1882-1906." In Bill Albert and Adrian Graves (Eds.), Crisis and Change in the International Sugar Economy 1860-1914. Norwich and Edinburgh: ISC Press, 133-47.

Hey, J.D. (1979), Uncertainty in Microeconomics. New York: New York Univ. Press.

Hey, J.D. (1984), "Decision Under Uncertainty." In Frederick van der Ploeg (Ed.), Mathematical Methods in Economics. John Wiley and Sons.

Hsiao, C. (1986), Analysis of Panel Data. Cambridge Univ. Press.

Jenks, L.H. Our Cuban Colony, New York: Vanguard Press. Pp. 242-45.

Johnson, H. (1972), "The Origins and Early Development of Cane Farming in Trinidad." Journal of Caribbean History **5**, 46-73.

LaCroix, S.J., and Roumasset, J., (1990), "The Evolution of Private Property in Nineteenth-Century Hawaii." Journal of Economic History **50**, 829-51.

Lucas, R. (1967), "Adjustment Costs and the Theory of Supply." Journal of Political Economy **75**, 321-34.

Maxwell, Francis (1927), Economic Aspects of Cane Cultivation. London: Norman Rodger.

Moreno Fraginals, M. (1978), El Ingenio: El Complejo Económico Social Cubano del Azúcar. Habana: Editorial de Ciencias Sociales.

Moreno Fraginals, M. (1986), "Plantation Economies and Societies in the Spanish Caribbean, 1860-1930." In Leslie Bethell (Ed.), The Cambridge History of Latin America. Vol. 4. Cambridge Univ. Press.

Nagano, Y. (1988), "The Oligopolistic Structure of the Philippine Sugar Industry during the Great Depression." In Bill Albert and Adrian Graves (Eds.), The World Sugar Economy in War and Depression. London: Routledge.

Pérez, L.A., Jr. (1986), Cuba Under the Platt Amendment, 1902-1934. Univ. of Pittsburgh Press. Pp. 69-72, 182-89.

Pérez, L.A., Jr. (1988), Cuba: Between Reform and Revolution. Oxford Univ. Press, 1988). Pp. 195-96.

Pérez, L.A. (1990), Cuba and the United States, Singular Ties of Intimacy. Athens, Georgia: University of Georgia Press. Pp. 109-10.

Pezuela, de la, J. (1863), Diccionario Geográfico, Estadístico, y Histórico de la Isla de Cuba. Madrid: Imprenta del Establecimiento de Mellado.

Prinsen Geerligs, H.C. (1917), Chemical Control in Cane Sugar Factories. 2d. ed. London: Norman Rodger.

Ramos Mattei, A.A. (1984), "The Growth of the Puerto Rican Sugar Industry Under North American Domination: 1899-1910." In Bill Albert and Adrian Graves (Eds.), Crisis and Change in the International Sugar Economy 1860-1914. Norwich and Edinburgh: ISC Press, 121-32.

Reid, J.D. (1973), "Sharecropping as an Understandable Market Response: the Post-Bellum South." Journal of Economic History **33**, 106-30.

Robertson, C.J. (1934), World Sugar Production and Consumption. London: John Bale, Sons & Danielsson, Ltd. Chs. 2, 4.

Salter, W.E.G. (1960), Productivity and Technical Change. Cambridge Univ. Press.

Scott, R. (1984), "The Transformation of Sugar Production in Cuba After Emancipation." In Bill Albert and Adrian Graves (Eds.), Crisis and Change in the International Sugar Economy 1860-1914. Norwich and Edinburgh: ISC Press.

Scott, R. (1985), Slave Emancipation in Cuba. Princeton Univ. Press.

Shlomowitz, R. (1979a), "The Search for Institutional Equilibrium in Queensland's Sugar Industry, 1884-1913." Australian Economic History Review **19**, 91-122.

Shlomowitz, R. (1979b), "Team Work and Incentives: The Origins and Development of the Butty Gang System in Queensland's Sugar Industry, 1891-1913." Journal of Comparative Economics **3**.

Shlomowitz, R. (1982), "Melanesian Labor and the Development of the Queensland Sugar Industry, 1863-1906." In P. Uselding (Ed.), Research in Economic History. Vol 7. Greenwich, Conn.: JAI Press.

Shlomowitz, R. (1984), "Plantations and Smallholdings: Comparative Perspectives from the World Cotton and Sugar Cane Economies, 1865-1939." Agricultural History **58**, 1-16.

Stigler, G. (1958), "The Economies of Scale," Journal of Law and Economics 1, 61-67.

Treadway, A.B. (1971), "The Rational Multivariate Flexible Accelerator." Econometrica 39, 845-55.

U.S. Commission on Cuba Affairs (1935), Problems of the New Cuba. New York: Foreign Policy Association, J. J. Little and Ives Co, pp. 269-70.

U.S. Congressional Committee on Agriculture (1962), History and Operations of the U.S. Sugar Program. 87th Congress. Washington D.C.: U.S. Government Printing Office.

U.S. Dept. of War (1902), Civil Report of Major General Leonard Wood. Vol. 2, Civil Orders and Circulars, No. 34, February 7, 1902. Baltimore, Maryland: Guggenheimer, Weil and Co., Printers.

U.S. Bureau of Labor Statistics (1890-1930), Wholesale Prices and Price Indexes. Washington D.C.: Bureau of Labor Statistics.

Weiss, L. (1963), "The Survival Technique and the Extent of Suboptimal Capacity." Journal of Political Economy, 246-61.

Willett and Gray (1911, 1930, 1940), Willett and Gray's Weekly Statistical Sugar Trade Journal.

Williamson, O.E. (1985), The Economic Institutions of Capitalism. New York: Free Press, Macmillan.

Zanetti Lecuona, O., and García Alvarez, A. (1987), Caminos para el Azúcar. Habana: Editorial de Ciencias Sociales.