Creative Destruction and Entrepreneurial Obstruction: Cuban Sugar, 1898-1939

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Abstract

As Joseph Schumpeter developed his argument for "creative destruction," it was motivated, in part, as a warning against contemporary policies intended to obstruct it. Little work has examined the consequences of obstructing it, even though Schumpeter warned of the dangers of nations that were "determined not to allow [it] to function." This paper addresses that issue by contrasting two post-crisis periods in which one would expect the process of creative destruction to be active – that is, in two important episodes in the economic history of Cuba, from 1898 to 1929, and from 1929 to 1939, through the examination of entry, survival and exit patterns of sugar mills and firms. Discrete survival analysis tests for differences in entry, survival and exit patterns in the favorable institutional environment of the former period against the unfavorable institutional environment of the latter. An institutional environment that obstructed the process of creative destruction in the latter period is shown to have had a distortionary effect with negative long-run consequences, as Schumpeter predicted.

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As Joseph Schumpeter developed his argument for "creative destruction," it was motivated, in part, as a warning against some of the policies implemented in the New Deal. Many of the remedies being proposed and implemented, he argued, suppressed a painful but necessary function of economic crises to force liquidation of bad investments and regenerate enterprise in the long run. He insisted that preventing their liquidation would "add to an undigested remnant of maladjustment new maladjustment of its own which has to be liquidated in turn, thus threatening business with another crisis ahead" (1934, p. 20).

The argument was essentially an extension of his earlier work, in *The Theory of Economic Development* (which appeared first in German in 1911), which introduced the entrepreneur as the agent who performs the innovative role of "carrying out new combinations," the driving force of economic development (1934, pp. 66, 74). In that work, one problem he tried to address was the difficulty the entrepreneur faced in acquiring the resources to carry out innovation when existing resources tended to be tied up in the "circular flow" of an economy in equilibrium. Economic crises perform the function of dislodging existing resource commitments, making them more readily available to entrepreneurs seeking to carry out new combinations. Despite the severity of the crisis of the 1930s, Schumpeter thought that this process had to be allowed to work, and he was greatly concerned about the political environment that emerged in the New Deal era to favor its obstruction. "What we face," he complained, "is not merely the working of capitalism, but of a capitalism which *nations are determined not to allow to function*" [italics his] (1934, p. 16).

These arguments are often framed in discussions about the advanced countries of Western Europe and the United States. When one turns to market instability in the less-developed world, it is common to encounter the argument that the financial crises of global capitalism are outside the control of most peripheral countries and are damaging to their economic development, or at least inhibitive to growth (Lewis 1952, Prebisch 1950, Singer 1950, Hadass and Williamson, 2003). Schumpeter, of course, did not argue that the crises were not painful, only that they were regenerative. Little empirical work, however, has been done to explore the operation of creative destruction in the less-developed world.

This paper examines the role of creative destruction, entrepreneurial activity, and the role of institutions in two important episodes in the economic history of Cuba, from 1898 to 1926, and from 1926 to 1939. The main argument of the paper is that there was a policy change after 1926 in which those in power and in control of sugar policy in Cuba were "determined not to allow" the process of creative destruction to function. The historical and empirical sections of the paper show that Schumpeterian creative destruction was operative and performed a regenerative function in the period from 1898 to 1930, but institutional controls were placed upon the sugar industry in 1931 that obstructed the liquidation of excess milling capacity during the 1930s, which inevitably raised the cost of production and reduced Cuba's competitiveness in the global sugar industry.

The empirical approach borrows from recent studies that look at patterns of new firm formation and destruction or appearance and disappearance of establishments as a window for studying the role of the entrepreneur in a dynamic economy. One of the principal contributions of this empirical literature has been the demonstration that small firms tend to exhibit high rates of both entry and exit, or "churning," during times of prosperity (Acs and Armington 2006, Acs and Audretsch 1991, Audretsch 1995, Audretsch, Keilbach and Lehmann 2006, Davis and Haltiwanger 1992).

Theoretical arguments have been advanced, especially of Jovanovic (1982, 1994) and Audretsch (1995), that explain the simultaneous creation and destruction of new firms or establishments as a product of "entrepreneurial learning," or that is, trial-and-error experimentation, learning and adaptation. The theory follows from the basic proposition that firm or establishment survival may be related to firm-specific factors as well as market conditions. On the one hand, newer establishments (sugar mills in this paper) enter without full knowledge of their location's production costs or the capabilities of their, possibly inexperienced, management. Therefore, for given market conditions, recently entered mills might be less likely to survive than more established mills. On the other hand, newer firms or establishments are sometimes better innovators and may be successful at crowding out less innovative existing firms or establishments. To the extent that either learning effect was prominent, one might expect to see higher rates of both entry and exit, possibly with one lagging the other, in times of entrepreneurial stimulus.

The observed "churning" is thus postulated as evidence of the working of the Schumpeterian entrepreneur using new firm formation as one available means to introduce innovations. The ideas posited draw insights from Caballero and Hammour (1994), which explores the relationship between economic crisis, vintage-capital and creative destruction, and also from Bresnahan and Raff (1991) and Bertin, Bresnahan and Raff (1996), which show how creative destruction during the Great Depression caused compositional changes that led to the "survival-of-the-fittest" of more efficient plants in the motor vehicles and blast furnace industries in the United States.

This study, which looks at the entry, survival and exit patterns of both sugar mills (raw sugar processors) in Cuba, adopts methods similar to those used in the above literature. Direct examination of the data described below is accompanied by multivariate discrete survival analysis to test for the effects of institutional obstruction on the effectiveness of creation destruction. Further examination of production cost estimates examines the long-run consequences of a favorable institutional environment, in the former period, against an unfavorable institutional environment in the latter period.

The data used in the paper, collected in collaboration with Richard Sicotte, matches production records of all sugar mills operating in Cuba from 1901 to 1939, reported annually in the Reports of the U.S. military government in Cuba, followed by the annual report on the *Industria azucarera y sus derivados* of the Cuban Secretaría de Hacienda, and the annual *Memoria de la zafra* of the Cuban Secretaría de Agricultura, Comercio y Industria, to records of changes of ownership from a variety of primary and secondary sources. The product is a database that tracks the activity and production levels of all sugar mills, changes of ownership, nationality and other characteristics of the firms and their mills (establishments) annually for the years indicated. The data allow tracking entry and exit of raw sugar-processing firms, and the construction, closures, reopenings, and disappearances of sugar mills, from which I track the rates of entry, exit, and survival at both the mill (establishment) and firm levels. The production data form an unbalanced panel of 258 sugar mills, not all active each year, between 1901 and 1939.[1]

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[1] Collected from Cuba, Secretaría de Agricultura, Comercio y Trabajo, *Memoria de la zafra* (1919-1929), continued by *Memoria azucarera* (1930-1939). Supplemental data on sugar prices come from Willett and

Institutional background

One of the main differences between the two episodes is the institutional contexts in which entry and exit of mills took place. The Cuban War of Independence of 1895-1898 was followed by the institution of the Platt Amendment, a treaty between the United States and Cuba that ceded to the United States the right to intervene to preserve, among other things, private property rights. The United States required the inclusion of the provisions of the Platt Amendment in the Cuban Constitution of 1901 as a condition of military withdrawal. Two of these provisions were most relevant for our purposes. One recognized the right of the United States to intervene militarily in Cuba "for the preservation of Cuban independence and to the maintenance of a government adequate for protection of life, property and individual liberty …." The other prohibited any government of Cuba from contracting public debt in an amount which could not be repaid out of the "ordinary revenues" of the government.[2] These provisions arguably underpinned incentives for foreign investors to finance both local and foreign entrepreneurs to rebuild Cuban sugar production capacity after the devastating war.

Luis V. de Abad (1945) refers to this period after the U.S. withdrawal, in 1902, to the late 1920s as a period of "laissez faire," which he contrasts with the subsequent period as a one of interventionist policy. The subsequent "interventionist" period came about in two phases. The first involved adoption of commodity controls in 1926, attempting to stabilize the sugar industry in crisis. Controls imposed in 1926-1928 and 1931 through 1939 restricted the aggregate size of the Cuban sugar crop and then apportioned rights to produce and export, that is production and export quotas, to all active mills and cane growers in a *pro rata* fashion, with some exceptions for smaller mills, based on their existing milling capacities and cane availability. The introduction of these controls was led, and later implemented, by a corporatist organization of national and foreign-owned sugar manufacturing companies, which owned the sugar mills, with the political endorsement of a pro-sugar and pro-American dictator, Gerardo Machado.

Gray, *Weekly Statistical Sugar Trade Journal*. Data on ownership are from the authors' extensive investigations to identify majority ownership and transfers of ownership. See Table 1 for sources.

[2] The Platt Amendment is reproduced in Root, *Military and Colonial Policy*, pp. 213-14.

Machado was overthrown in 1933 and succeeded first by populist revolutionary government. As Colonel Fulgencio Batista, one of the original revolutionaries, emerged as strongman and *de facto* dictator in 1934, he claim to power required maintenance of the labor-oriented reformist policies of the revolutionary regime. Under his policies, the production and export controls were kept but details were reformed to serve his populist political mandate to favor organized labor. The resulting institutional environment, Henry Wallich notes, was unfriendly to new investment, and it virtually eliminated the net inflow of foreign capital (1960).

The main questions addressed in the paper are: do we observe major differences in the behavior of entry, survival and exit between these two periods, and does it tell us something about the entrepreneurial activity in the two periods? The argument of the paper proceeds as follows. The next section presents evidence of a striking difference in the patterns of entry and exit consistent with Schumpeterian or the theory of entrepreneurial learning. Subsequent historical sections prepare the reader with background about the nature of the technological changes that revolutionized the sugar industry, and the entrepreneurial opportunity in Cuba, during the period of study as well as preceding it. This background is necessary for developing a better understanding of the problem and the design of the quantitative analysis that follows it. Quantitative analysis, then, offers an explanation of the survival of Cuban sugar mills, under the freedom and discipline of the market, that highlights the combined roles of continually improving technological change, entrepreneurial learning, vintage-capital effects, and market conditions. A test of the same forces during the interventionist period after 1931 shows that the same forces were not allowed to function.

Entry and Exit

Table 1 presents figures for the numbers of mills that entered, closed, reopened and exited in the Cuban sugar industry from 1901 to 1959. The data are constructed based on the “appearances” and “disappearances” of mills in the annual sugar industry censuses. The terminology employed in the table (and in the paper) is the following. “Closure” refers to the event of shutting down a mill, whether temporarily or permanently. It was not uncommon for a mill to shut down in one year and reopen in a later year.[3] I use the term "exit" to refer to the event of closing a mill and retiring it for good. In some cases, we know of mills being dismantled, but records of dismantling are not complete. Each exit indicates the first year a mill ceased to be active, if it did not reopen any time from that date to 1959.[4] I use "temporary closure" to indicate the shutting down of a mill that reopened sometime prior to 1959. "Entry" refers to the first year of operation of a newly founded mill. With some effort, I have either identified the founding date of each mill or determined that it was founded prior to 1895. If the first appearance of a mill in my data came after its founding date, it is treated as a "reopening." Hence the large number of reopenings in the early years of Table 1, which immediately followed the war of 1895-1898.

The unit of analysis is the establishment level, the sugar mill. Over the period observed, mills changed hands frequently, and in some cases, new partnerships or corporations were formed as mills were acquired. Although I do have information about the changes of ownership, they are not registered in the entry and exit data; rather, a mill is coded as continuing through the change of ownership if its activity was not suspended. The ownership data are used to produce controls for foreign ownership in the empirical sections below.

Several patterns can be observed in the data. First, consistent with the theory of entrepreneurial learning, entries and exits of mills coincide, indicating a pattern of churning. However, there are clearly periods when either entries or exits dominated. The period immediately following the war exhibited few exits for several years after 1902 but a high rate of entry of new sugar mills. By 1908 we see a renewed series of exits, but the rate of entry was sustained.

Second, from 1912 or 1913 to 1919 we observe higher rates of entry, yet exits all but vanish during the war. Exits reemerged in 1918 after the war ended and exhibited a more balanced churning similar to the period prior to 1915. A resurgence of exits occurred, however; and entries diminished with the onset of the interwar commodity crisis in the sugar industry after 1925. As shown in Figures 1 and 2 the price of sugar fell

[3] Bresnahan and Raff (1991) question whether the apparent "mothballing" in their study was an artifact of the data. I am able to determine in my data that it was a common practice, indeed, not an artifact.
[4] The period on which this study focuses ends in 1939, but Table B presents the data up to 1959 to show the continuity from the 1930s to the Cuban Revolution of 1959.

steadily and unsold stocks of sugar accumulated. After that, only one new mill entered, in 1927. No new sugar mills were built in Cuba from that date until after 1959.

Wherever we observe an imbalance between entries or exits, market conditions, structural, institutional or other factors usually offer a compelling explanation as to why. Consider the period from 1901 to 1908, a small number of exits is to be expected during the recovery from war, which followed a cluster of exits during the war. The weak rate of entry in the immediate aftermath of the war, which is explained by the existence of a large pool of temporarily closed pre-existing mills at that moment, should not raise doubts about the potency of the postwar Schumpeterian regenerative effect.

The variation on the pattern between 1913 and 1919 is explained by the unique conditions of the First World War, which provided a great stimulus to the Cuban sugar industry, as sugar from other principal suppliers in central Europe and the Pacific were interrupted by the war. The price of sugar in the world market rose sharply after 1914, and Cuba became the main country upon which the Allies relied for sugar. The US and UK coordinated price controls on sugar from 1917 to 1919. The lifting of wartime price controls led to a speculative bubble in 1920, which burst in 1921. In the fallout, there was a large number of bankruptcies, distress sales, and closures of mills from 1921 to 1924. The global commodities crisis, characterized by falling prices and rising accumulations of unsold physical stocks, as Kindleberger (1973) has shown, became apparent in the sugar industry and especially in Cuba by 1925 (See Figures 1 and 2). The absence of new entries of mills after 1927 might be explained by the commodity crisis, except that Cuban authorities, trying to deal with falling price and perceived "overproduction," made construction of new sugar mills illegal after 1926.[5]

The rate of exits was sustained, as one might expect, during the late-1920s crisis in the sugar market; however, when the Great Depression hits, nine mills exit in 1930 and 1931, but afterward, only two mills exited – and none at all after 1933, even though Cuban sugar exports hit their low point in 1933 and remained there throughout the 1930s. It is difficult to explain the decline in the number of exits after 1931 as a market

[5] The mill that appears as an entry in Table B in 1927 was permitted because its construction was in progress when the law was passed.

phenomenon because it does not square with data on the milling capacity in the industry. The demand shocks of 1929 and 1930 had caused the demand for Cuban sugar exports to collapse to one-third its 1929 level (See Figure 3). For reasons to be explained, certainly by 1933, if not before, participants in the industry were well aware that the demand for Cuban sugar exports was not expected to recover much more than it had already. By the end of the decade of the thirties, demand for Cuban sugar remained at only half what it had been in the mid-to-late 1920s. One would expect the severity of the crisis to have produced a major shakeout of sugar mills. Instead, we observe an extraordinary pattern of mass reentry of mills that had closed down after 1933, even under these depressed market conditions, shown in Figure 3.

To sum up, casual observation of the pattern of temporary closures and reopenings reveals a pattern that, for most of the period, appears to follow the patterns of entries and exits just described. But two surprises emerge in the period after 1931. First, it is surprising that so many more exits occurred before the deepening of the world crisis than after, as well as under conditions of prosperity from 1898 to the end of the First World War. Second, given the sustained fall in export demand, it is surprising that such a large number of mills shut down only temporarily during the earlier years of the 1930s crisis and then reopened effectively in the continued throes of crisis.

Is there an obvious explanation for the surprising pattern of closures and reopenings after 1931? It is not consistent with standard price theory. It predicts that the sustained price decline should have induced an adjustment in industry-level production that could have come either from an internal adjustment – in the form of a reduction in output per mill, or an external adjustment – a reduction in the number of active mills, or both. Additional evidence on cost structure (discussed below), however, permits us to rule out expectation of internal adjustment. There is evidence that the cost structure of sugar mills in the short run exhibited high fixed costs and constant average variable costs up to milling capacity. This precludes the possibility of an internal adjustment because surviving mills would maximize profits by operating at full capacity. Consequently, the fall in production levels after 1930 leads one to expect to see a shakeout of mills and an increase in the rate of retirement of milling capacity after the onset of the crisis.

An alternative perspective, not necessarily inconsistent with the above, comes from recent theories of entrepreneurial learning, as in Jovanovic (1982, 1994) and Audretsch (1995). The theory of entrepreneurial learning might lead one to expect higher rates of exit and entry to coincide and to occur during periods of acute innovation and entrepreneurial activity. If innovative activity slowed down after the onset of the Great Depression, it might explain the slowdown in both entries and exits during the 1930s.

As a practical matter, testing the validity of the theory of entrepreneurial learning, entry is more difficult to explain than exit. Even the entrants themselves do not know their characteristics at the point of entry; the researcher has, therefore, relatively little to go on to distinguish the heterogeneous characteristics of entrants until they have accumulated a track record. Information is thus revealed over time. The most revealing and readily observable information is in their rates of survival or exit. The revealed information not only helped the former entrant to decide on whether to continue, it also provides the historian with superior information about exits than about entrants. From the standpoint of empirical strategy, therefore, we understand and casually observe entries and exits as related processes, but formal tests in subsequent sections rely strictly on closure, exit or survival rates, which are more operationalizable.

The Entrepreneurial Opportunity

The empirical strategy of the paper also involves finding good proxies for the changing technology. The brief description of the basic technical changes in sugar manufacturing, followed in the next two sections by a fairly close examination of the early developments of the technology in Cuba aims to offer some insights into the choices made.

Observing the rate of growth in the Cuban sugar industry after its occupation by the United States, one may be tempted to think the explosive growth was a result of the introduction of superior sugar production technology from North America during the U.S. military occupation of the island beginning in 1898. Many students of the hegemonic relationship that emerged between the United States and Cuba in this period make such an assumption. Yet economic historians of Cuba, who have conducted thorough analyses of the extant records, have shown conclusively that this view is incorrect. The entrepreneurial vision in Cuba well preceded the U.S. occupation, as for decades Cuban entrepreneurs had led the global sugar industry in experimenting with and implementing new process innovations.[6]

Beginning in the latter quarter of the 19th century, the sugar industry rode the wave of new mechanical and chemical innovations that revolutionized all modern processing and refining industries commonly associated with the second industrial revolution.[7] In the case of sugar manufacturing, several general-purpose innovations of the era were applicable to each of the three core processes of cane sugar manufacture – grinding, evaporation / crystallization, and purging. In the grinding stage, innovations included the use of more powerful and efficient steam engines and three-roller mills made of higher grades of steel and better designs to operate at higher speeds and bear more stress. In evaporation stage, in which the cane juice was reduced to a mass of crystallized sugar mixed with molasses, mechanically sophisticated vacuum pan technology replaced the relatively rudimentary technique of using series of open vats to boil down the juice and crystallize the sugar. And then, in the purging stage, large centrifuges replaced the slow pace of gravity and large, cumbersome drainage houses (*casas de purga* in Cuba) that had been used for centuries to "purge" or separate the mass of crystallized sugar from the molasses (Deerr 1950-1951, Dye 1998).

Yet as with most mechanical innovations, the more spectacular initial advances were followed by a long succession of small, but cumulatively important, improvements. Many of these refined the core mechanical processes, but others introduced auxiliary mechanisms, which either deliberately or as a by-product extended the mechanical control of the factory and introduced the logic of continuous processing.[8] For example,

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[6] For example, it was in Cuba where the first successful use of steam power in a sugar mill took place, in 1797, just 20 years after the first successful commercial applications of the Watt engine. By 1808 they were being adopted regularly, and by 1860 over 90 percent of the Cuban sugar crop was produced with steam power. Cuba was also the seventh country in the world to build a railroad, again primarily to service the sugar industry (Dye 1998, p. 31). See also the brilliant examination of Cuban entrepreneurs by Speck (2006). Other outstanding studies include Moreno Fraginals (1976), Iglesias García (1999), McAvoy (2003), Bergad (1990), Venegas Delgado (1987), among others.

[7] Chander (1977) pp. 240-58, (1990) pp. 22-24.

[8] Compare this description of the sugar industry with related industries, in Landes, *The Unbound Prometheus*, pp. 297-307; and Chandler, *Scale and Scope*, pp. 22-24. Landes describes it in part as a product of the replacement of iron with steel and then cheaper and higher quality steel in the construction of machinery, specialized alloys for different purposes, better lubricants, factory layout and other aspects of

the adoption of vacuum pans was accompanied by the replacement of human transfer of the viscous liquid from one vat to another with a system of mechanical pumps. Hand feeding of cane in the crushing mills was replaced with mechanical feeders. Moving belts replaced human handling of barrels of sugar with mechanical handling of bags of sugar. Electrical power and lighting were introduced in the mills often before it had been introduced in the nearby municipalities. Electrical power ran the auxiliary equipment, and lighting allowed these capital-intensive facilities to run 24 hours per day during the grinding season to increase throughput and lower the per unit fixed costs. As in other continuous-processing industries, total processing time was reduced dramatically – from 30 to 50 days to a day or so, and the volume of throughput increased by orders of magnitude relative to the pre-existing technology.

Continuous processing revolutionized the scale of production. It is a prominent story in all related industries of the era. Scale (and scope) play an important role in Alfred Chandler's work on continuous processing in mass production, which shows how abrupt changes in optimal scales of production induced the organizational innovations of the modern industrial enterprise (1977, 1990).[9] For Cuban sugar, one quantitative manifestation of the technical changes was in the average mill capacity (shown in Table 2), which reflected a steadily increasing optimal scale of production. As in other food-processing industries, soap and papermaking, brewing and distilling, petroleum refining, and so on, the innovations of continuous processing revolutionized the scale of production. Average production per mill per year in Cuba soared a hundredfold from 2,200 bags (of 325 lbs.) in 1860 to 218,000 bags in 1929. The empirical analysis below will exploit the observed association between the new technology and larger scales of production. It is worth emphasizing that a similar association between the technology and scale of production is supported in the related literature and informs our understanding of the profound industrial transformations of this era.

Launching the Trajectory

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organization, diversification of inanimate sources of power, improvements in handling and standardization of routines.

[9] Chandler (1990) highlights these changes in food-processing industries, such as sugar, tobacco, oil refining, paper, rubber, and other industrial chemical processing. See especially pp. 92-145.

Relative to what we can observe afterward, our knowledge of the industry before 1901 is obscure, although mill records for some regions of Cuba have survived. A study by Hernán Venegas Delgado (1987) on the municipal district of Remedios, on the north-central coast of the island, offers an unusually detailed glimpse of the initial phase of the transformation. Remedios was a region that led the way in the adoption of these new technologies. Table 3, which gives average milling capacity for the region, similar to Table 2, suggests a sharp change in the average capacity between 1888 and 1901. Table 4 combines data from Venegas with post-1898 data to show the changing composition of mills.

The surviving mill records indicate that seven pioneering mill owners began to invest new technology in the late 1870s and 1880s replacing existing mills, built using an older technology, with state-of-the-art mills. As they did, their scales of production increased from an estimated 3000 to 5000 bags to about 30,000 bags of 325 lbs., reaching scales unheard of in mills using the older technology. Production records of the other mills are not reported, but the average production for the remaining mills 18 mills is estimated to be about 5000 bags.[10]

The modern mills had large appetites for cane (which had to be supplied locally because of its perishability). Between 1888 and 1890, these mills had taken possession of or contracted out to have the cane from other mills supplied to the new colossal central mills. Seven smaller mills had shut down between 1888 and 1890. By 1894, the seven pioneering mills had increased their mill capacities by 50 percent or more, and several other nearby mills had begun to modernize and expand as well. Between 1890 and 1894, seven more smaller mills shut down. The mills listed as active in the table are presumably the only active mills remaining in the region. The only mill operating at a scale of production consistent with the old technology is the Ingenio San Rafael, which produced 3700 bags in 1894. The table shows that only 14 mills of the 25 mills survived into the post-1898 period. Records tell us further that the cane lands of the Mathilde, Santa

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[10] The reported production of sugar for the region in 1890 of 208,452 bags, given by Venegas (1987, p. 72), undoubtedly understates the capacity for the 25 active mills in the region in 1890. My estimate of 300,000 bags in 1890 is based on the assumption that the production of the top seven mills as a share of the total for the region was the same in 1890 and 1894. This may overstate the overall production by a small amount. The estimate gives an average of 5300 bags production per mill in the remaining 18 mills, which is probably slightly high but plausible for the pre-existing technology.

Catalina, Dolores, and San Rafael were all “absorbed” into the modernizing mills. Of these 14 mills, eleven survived until the Revolution of 1959, and the remaining three closed down between 1922 and 1924. Most continued to upgrade and remain viable, but by the 1920s, none of the 14 was at the technological frontier relative to best-practices on the island.

Chandler has emphasized how such punctuated increases in the scale of production in processing industries induced innovations in the organizations that managed them (1977, 1990). Similar organizational innovations were necessary for the adoption of large-scale technology in Cuban sugar. One of the challenges for the pioneers in the industry was to arrange in advance for the cane to supply these new “colossal” mills. Taking the seven pioneering mill owners of Remedios as an example, one of the problems would-be innovators faced was that the mills to be built would have an appetite for cane about ten times larger than the average *ingenio*, and yet there was no existing market for cane. Cane, once cut, loses water and sucrose rapidly; optimal use of the raw material required that it reach the mill as quickly as possible.

Historians of Cuba characterize the organizational innovation as a movement toward the centralization of the *ingenio* – or the displacement of the traditional *ingenio* with the so-called *ingenio central*, or simply, the *central*.[11] The *centrales* were large-scale mills that procured significant quantities of the raw material, sugarcane, by contracting with outside growers. The first modern mills were built in areas where *ingenios* using older technology had been operating. Adopting the large-scale milling capacities of the new technology required consolidation of existing mills, or in effect, their cane lands, to procure sufficient cane for the large-scale mill. To achieve it, pioneering mill owners often arranged with owners of surrounding outmoded mills to supply cane under contract. Similar arrangements were sometimes made with surrounding properties not formerly in cane, if available and if the soils were suitable. As an example, Venegas shows how the cane lands that fed the Central Narcisa in Remedios combined the lands of several former estates, some formerly in sugarcane, the others probably raised cattle.

[11] The best studies are Moreno Fraginals (1976, 1985) and Guerra y Sánchez (1944, 1946). Other important contributions include Iglesias García (1999), Pino Santos (1976), Santamaría García (2001), Zanetti Lecuona and García Álvarez (1976).

These observations about the reorganization of cane lands seem to highlight the role of liquidation in a manner consistent with Schumpeter's view. The act of consolidation of a number of old, smaller mill estates into a large central mill and its surrounding cane lands is a rather visible form of the role of liquidation of real assets, but it is consistent with how Schumpeter describes the unique problem that entrepreneurs (who seek to create new combinations) have in procuring resources. Assembling his words, from *The Theory of Economic Development*:

> As a rule the new combinations must draw the necessary means of production from some old combinations. …
>
> Procuring the means of production is one distinct problem for the established firms [old combinations] which work within the circular flow. For they *have* them already procured or else can procure them currently with the proceeds of previous production. …
>
> Instead of this problem another exists for [the entrepreneur]: the problem of detaching productive means from the circular flow and allotting them to new combinations (2003, pp. 68-72, original English version, 1934).

Any entrepreneurial mill owner who sought to adopt the new technology faced an initial obstacle of having to scale up significantly because the new minimum efficient scale was several times larger than that of the typical *ingenio*.[12]

Crisis and liquidation play an important part in the story leading up to the 20th century. The diffusion of the new production technology in the last three decades of the nineteenth century faced a number of obstacles. The period from 1868 to 1898 was a prolonged period of political difficulty in Cuba. A failed attempt by separatists to obtain independence from Spain resulted in the Ten Years' War (1868-1878). After its defeat, the separatist movement receded but did not dissipate. The outcome of the Ten Years' War had negative consequences for Cuban sugar producers. Spanish authorities held the colony fiscally responsible for the entire cost of the war and imposed major tax increases

[12] Schumpeter, in these passages from *The Theory of Economic Development*, strictly speaking has something else in mind – that is, the role of credit as an essential intermediary for the entrepreneur who, unlike the manager of an existing enterprise, does not have access to a regular flow of retained earnings. But it is easy to draw the theoretical connection between the essentiality of credit and the role of crisis and liquidation, which becomes central to his concept of creative destruction. Furthermore, the connection is quite cogent for understanding the combined events of adopting continuous-processing technologies, reorganizing the old *ingenios* into central mills, and negotiating with local resource owners to contract out with the central mill.

on colonial production to raise the revenue to repay it. Sugar export taxes were an important source of this revenue. The war had also accelerated the rate of emancipation of slaves. The political process that led to the abolition of slavery in Cuba began with steps taken during the Ten Years' War and was completed in 1886. It resulted in significant capital losses to plantation owners without compensation as well as increased labor costs and uncertainty. The combined effects of these social changes raised the cost of sugar production in Cuba, increased political risk, and made it difficult to determine the outlook for long-term investment in the Cuban sugar industry.

The usual story of the emergence of the *ingenio central* highlights the labor shortages that owners of traditional plantations (*ingenios*) as they anticipated and experienced the abolition of slavery. Adventurous mill owners experimented with abandoning the self-contained slave-based plantation by parceling out land on the peripheries of their plantations to Canary Islanders and other Spanish immigrant, known as *colonos* (literally, "settlers"), to farm sugarcane as a substitute for slave labor and internally cultivated cane. Others leased cane land to emancipated slaves hoping to keep them from moving away. However, the significance of the emerging institution of the outside grower, or *colono*, became more significant as the new technologies were adopted.

In a few regions of the island, such as Remedios, certain mill owners, merchants or others alert to the opportunity, and somehow able to finance it, invested in the new technology. At the same time, organizationally they abandoned the traditional vertically integrated plantation-mill complex and contracted out with neighboring plantations to supply them with the additional cane needed to meet the larger minimum efficient scale. The centralization of the traditional *ingenio* is considered to be one of the great social transformations of Cuban history. Outside procurement of cane was, as far as we know, negligible before 1880, but by 1913 it represented over 85 percent of all cane ground by mills (Dye 1998, p. 189). It also created an important agricultural middle class of *colonos*, who, in times of prosperity in the sugar industry, prospered and multiplied, and in times of crisis, became an important political force (Guerra y Sánchez, Martínez-Alier).

So, in Schumpeterian fashion, the liquidation of encumbered mills, or the reorganization of troubled mills, during the crisis of the 1880s sowed the seeds of regeneration. Most *ingenio* owners could not finance the move to the emerging technologies. Whether the pioneering mill owners who adopted the new technology found credit or relied on retained earnings, the crisis of the 1880s gave assistance in procuring the cane sufficient to supply the larger mills. Neighboring owners of *ingenios* who considered the offer of becoming a *colono* to the incipient central mill now faced higher opportunity costs, with old mills encumbered by debt and increasingly obsolescent. The crisis, therefore, lowered the costs that the pioneering mill owners incurred as they negotiated to procure the necessary resources. The decision to become a *colono*, however, for former sugar planters constituted a social demotion. This may help to explain why the process of transformation prior to the war was so gradual.

The process of liquidation took on a much more punctuated form as the century ended. The second Cuban War of Independence broke out in February of 1895. The extent of destruction during this was massive. As noted, sugar production fell by three-quarters during the years of the war. After the war, only 16 percent of the mills active prior to the war were declared "not destroyed." Another 19 percent were either "reconstructed" or "in reconstruction" by the end of 1899. However, of these two categories of production units, only 22 percent survived the war and became active after 1900. Three-quarters of the mills that closed during the war never reopened.[13]

Of the mills that did not reopen we know several things. First, to the extent that the survey of conditions is accurate, less that half the mills that did not reopen did so because they had been destroyed. The 161 mills declared as "dismantled" reflect a deliberate decision at the time to retire these mills. The failure of 183 mills that were either "not destroyed" or "reconstructed" to reappear after 1900 suggests that the retirement of these mills was also the result of a deliberate decision. Second, by and large, those that did not reopen had not achieved a scale consistent with the best-practice technology. Many of the mills that did reopen also operated at suboptimal production

[13] The evidence for these observations comes from a survey of the condition of sugar mills taken during the first year of occupation by the U.S. military government in Cuba, conducted under the supervision of the Secretary of Agricultural Commerce and Industry, who was a Cuban national, Perfecto Lacoste, who aimed to use the figures to argue for the need to take strong measures to rebuild Cuban agriculture, especially the sugar industry. U.S. War Department (1900).

scales, but those mills sorted into two groups. One group of mills survived by updating their milling equipment and adopting larger scales of production to accommodate it; another group failed to do that, and it was these mills that tended not to survive.

After the turn of the century, this sorting continued but seems to have been accentuated by differential access to the capital market in the United States. The American intervention in the war and the self-asserted obligations it claimed to ensure protection of property and responsible public debt management encourage the inflow of foreign capital, making it possible to raise large sums of foreign equity to finance either the complete renovation of an existing mills or the establishment of a new mill *de novo*. Many parts of the island, particularly in the east, were sparsely populated with good cane lands largely undeveloped, so there were many sites with excellent soils to support a state-of-the-art sugar mill without constraints on its cane capacity (Dye 1998). The continued sorting of mills into those that upgraded fairly regularly and survived, and those that did not upgrade, and eventually failed thus explains the churning observed in Table 1 in the early years of independence through the First World War.

Scale and Vintage

We turn now to look more closely at why mills entered, exited, closed and reopened. Predictions from standard price theory with homogeneous production units do not offer a satisfactory explanation. The simultaneous entry and exit of mills indicates heterogeneity. One standard explanation of heterogeneity is the vintage-capital model of W.E.G. Salter (1966). The model applies to technology that is capital-embodied, as is typical of any specialized machinery, such as sugar milling equipment. The theory predicts that mills with heterogeneous technologies and costs will coexist because, in decisions to replace an outmoded mill with a best-practice mill, the costs of fixed equipment will figure into the cost of the new equipment but not in the cost of the existing equipment, which is already sunk. The decision to continue to use an existing vintage is determined, then, by the condition:

$$p - v_{t-k} \geq 0 \qquad (1)$$

where v_{t-k} is the per unit variable cost in year t for a mill with equipment of age k, and p is the price of sugar; whereas the condition to upgrade by purchasing new equipment is

$$p - v_t - g_t \geq 0 \qquad (2)$$

where g_t is the discounted per unit cost of the new equipment of vintage t.[14] As newer vintages are introduced, they have lower unit variable costs, which may be an optimal choice for some producers. However, outmoded vintages usually coexist with best-practice vintages because there is usually a range of vintages for which the profits rendered in the option implied in condition (1) are higher than in condition (2). If condition (1) is not met, the mill owner has the option either to upgrade, by replacing the mill, now obsolete, with a new, best-practice mill, or close the mill, either to retire it or await better market conditions depending on market expectations. In a given year, decisions could vary from one agent to the next if there were differences in costs of financing, heterogeneities in variable costs, or a range of forecasts about future prices.

Elsewhere I have shown that the vintage-capital model offers a useful characterization of entry patterns and structural changes in the Cuban sugar industry for the period under consideration here (Dye 1998, pp. 121-42). First, the technology used in sugar manufacture satisfies the assumption of capital-embodiment. Second, there were steady improvements in the equipment used in sugar milling throughout the period. As noted, the transformation of sugar manufacturing technology, which began in the late 1870s, was enhanced by many minor improvements in the machinery, power plant, and design of mills through at least the first quarter of the 20th century. Evidence for this is replete in contemporary journals, which contain many announcements of mills with plans to upgrade, feature articles on exceptional innovators, and advertisements trying to market improvement equipment.[15] There are also a few surviving mill inventories that indicate that leading mills were adopting these innovations. One observes, thus, more or less continuous improvements embedded in the fixed capital equipment used in sugar milling in Cuba. Therefore, consistent with Salter's model, each piece of equipment may

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[14] In any year, *t*, the vintages in use will display a range of per unit variable costs of production, v_{t-i} ; and the costs advantages they give are sorted by their vintages, such that $v_t < v_{t-1} < \ldots < v_{t-k}$, where *t* identifies the latest vintage, and *t-k* identifies a vintage that is *k* years old. If costs of fixed equipment are sunk in the short run, a range of technical vintages may be in use at the same time (Salter 1966). A more complete explanation of its application to the Cuban sugar industry is in Dye (1998, pp. 121-42).

[15] They appear, for example, in the Spanish-language journals, *Revista de Agricultura*, *Cuba Económica y Financiera*, and English-language journals, *Cuba Review,* and the *Louisiana Planter*. Venegas Delgado (1987) makes note of them for the 1880s and 1890s, and I have observed them in my previous work on the industry covering 1898 to 1929.

satisfactorily be identified with a "vintage" indicating best practice at the time the equipment was installed, and the trajectory of continual improvement indicates that there was a steady introduction of new vintages.

The empirical analysis below will exploit the observed association between the new technology, larger scale of production and vintage-capital effects. As discussed in the previous sections, a strong association between the scale of production and technology in industries such as sugar is a commonplace in the literature. From the 1880s to the mid-1920s, announcements of ever more "colossal" mills introducing state-of-the-art technology were featured in the trade press.[16] Evidence for it in sugar manufacturing is found as well, for example, in performance measures in the mills, such as the extraction rates of cane juice and yields (sugar-to-cane), which have been shown to be positively correlated with grinding capacities and rates of mill expansion (Dye 1998, pp. 129-37). A simple bilateral comparison of entering or exiting mills and their distinguishing characteristics also supports a strong association. Entering mills tended to adopt relatively larger milling capacities.[17] By contrast, mills that shut down or exited tended to be located near the lower tail of the size distribution of mills.

The vintage-capital model offers a useful prediction about the characteristics of entry and exit that may constitute further evidence for the association between the new technology and the scale of production. Considering condition (2) above, if repeated introductions of new vintages successively reduce the unit costs of production, v_t , using the best-practice vintage, t, then the finite demand for Cuban sugar will be satisfied by progressively lower-cost vintages. Hypothetically, as a new vintage t+1 enters, the added competition would lower the price of sugar, which, from condition (1), induces the least cost-efficient mills in the existing distribution to shut down. If new vintages of machinery also have larger (optimal) capacities, then the vintage-capital model, combined with the dynamics of continual improvement in the technology, predicts a "moving equilibrium" in the size distribution of active mills, or that is, a steady upward shift in the range over which the capacities of active mills fall.

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[16] Ibid.

[17] Dye (1998, pp. 126-42) examines entries carefully and demonstrates how entering mills often entered small because of high adjustment costs in starting up, but they ramped up the scale of production quickly over three to five years to achieve above average milling capacities.

Examination of the size distribution of milling capacity shows that it is consistent with this prediction. Table 6 displays the distribution of mills by size category for each year from 1901 to 1930, where size is measured by the daily grinding capacity of each mill. In the upper tail of the distribution, we observe in 1901 that no mill's daily grinding capacity exceeded 1920 bags of sugar of 325 lbs., and only 4 mills were in the upper size category of 960-1920 bags. The latter category, however, became the modal size group by the First World War, and the largest active mills had more than quadrupled by the late 1920s.

In the lower tail, over the period, the ranks of smaller mills steadily diminished. Mills with less than 30-bag capacities became inactive after 1911; mills with less that 60 bag capacities after 1913, and so on. The exceptions to the pattern prove the rule. The most prominent is the reopening of mills with less than 60-bag capacities from 1917 to 1920. This was a time of high prices, guaranteed under wartime price controls, and public pressure in Cuba to produce as much sugar as possible to assist the Allied war effort. A single mill in the 60-120-bag daily category was active in 1921 and 1924. This mill, the Central Mercedes, was inactive until acquired in 1916 by the Cuba Cane Sugar Corporation, a large sugar conglomerate, which owned 19 mills. The Mercedes, an early 19^{th}-century *central*, had not survived the war of independence but was restored to activity in 1919 and retired after 1924. The reason may have been strategic, to restore the property's cane lands to be incorporated later into another of the company's the vertically integrated operations, or a planned remodeling of the mill may have been aborted. There was an abrupt change in forecasters' outlook for the sugar market before and after 1924 (Dye and Sicotte, forthcoming, Smith 1960).

Therefore, we observe that as new mills were built, or old ones remodeled, they invariably adopted larger scales to meet the steadily increasing optimal grinding capacities of best-practice milling technology.[18] Together with steady improvement of best practices, vintage-capital effects produced the "churning" we observe for the 1920s in Table 1 as a gradual upward shift in the equilibrium size distribution of the grinding

[18] Consistent with the vintage-capital effects of capital-embodied technology, records of the Cuban Secretary of Agriculture, Commerce and Labor show a conventional pattern of diffusion of best-practice technology throughout the beginning of the twentieth century into 1920s; and cost surveys conducted by the U.S. Tariff Commission (1926) show a predictable pattern of cost heterogeneity among mills.

capacities of mills, as new mills entered with larger grinding capacities and the older, smaller mills exited (Salter 1966). It offers an alternative explanation to the entrepreneurial learning proposition of Jovanovic and Audretsch – one which is more consistent with the data in this case, as we see below.

Now consider some implications of the vintage-capital model. If the price should fall, active mills that were near the closure margin prior to the decline may be induced either to renovate or close. Observing Figure 1, the price fluctuated in the early 1920s, fell steadily from 1925 to 1933, and began to reach historically minimal levels by 1930. Casual observation of the period prior to 1930 in Table 1 reveals a pattern of closures consistent with the model. Mills closed, either permanently or temporarily, steadily as long as the price fell. Ordinarily, the absence of exits from 1936 to 1938 might be thought to be consistent with the vintage-capital model, since the price leveled off and then recovered slightly during those years, halting the contraction of the closure margin. But in this case, it cannot be explained by the leveling off of prices, since such a large gap between optimal capacity and utilized capacity remained.

Table 6 offers some evidence suggesting an altered pattern after 1930. After a pattern of steady decline from 1901 to 1929 in the number of mills with daily grinding capacities rated at less than 960 bags, we observe, first a leveling off, followed by an increase in the number of mills with less than 960-bag grinding capacities. After 1933, not only did smaller mills, with older vintages, continue to survive, a few even reopened, after having closed temporarily. It is difficult to reconcile this reversal with the vintage-capital model. There was a slight recovery of the price of sugar, but it was not enough to restore mills to profitability. From 1931 on, there was a wave of bankruptcies, and a debt moratorium remained in effect throughout the period. More indicative, however, of a change of regime is that the vintage-capital natural selection process, which according to the model worked through the price mechanism, no longer functioned to maintain a capacity consistent with long-run demand. On average, mills were operating at just above 50 percent capacity from 1932 to 1939, with a reversal, rather than an acceleration, in the rate of retirement of mill capacity, as observed in Figure 3. The 1930s called for a Schumpeterian liquidation of relatively inefficient assets, a shakeout of milling capacity; yet it did not happen. Why not?

Measuring Vintage-Capital Effects

The next two sections develop a discrete-time survival analysis to test for the influence of vintage capital and other factors on decisions to close or exit. I first test for the presence of vintage-capital effects for the pre-1930 period, which the data strongly support. Then I test the hypothesis that the parameters that capture the vintage-capital effects in the model changed during the years of crop restriction.

The first task is to operationalize the effect of vintage capital on rates of survival. Observed patterns of mill entry, survival and exit over the three decades following Cuban independence suggest an association between continual process innovation and survival. Unfortunately, data on the type of equipment in the mills are not available. I argue that the age of the mill and its grinding capacity, and various constructions that can be obtained from these two variables offer good proxies. *Age* is measured as the number of years from the date a mill was founded, except that, to eliminate meaningless outliers (some of the mills in the sample were founded in the 18^{th} century), any mill founded before 1875 is treated as if it was founded in 1875. A possible shortcoming of this measure is that 163 out of 257 mills in the dataset were founded in 1875 or before.

An possibly superior alternative is a reconstruction of the age of the equipment. *Age* measures how long the estate has existed. In some cases, such as the Central Narcisa described above, the mill on the estate may have been completely dismantled and rebuilt. In most cases, we have no way of knowing. Even in cases where the mill was not dismantled, since the various processes were modular, new technology could be adopted in a piecemeal fashion. In addition, most large mills scaled up by having multiple runs in at least two of the three key processes. I have argued elsewhere that the largest technical economies of scale appear to have been in coordinating the delivery of cane to the mills, which involved hauling cane by railroad. Processes in the factory could be met with larger capacity (later vintage) equipment or by duplicating existing processes. From extant records of mills' equipment inventories, we know that both were practiced.

Although it is not possible to observe the age of the milling equipment directly, it is possible to reconstruct it to a first approximation from milling capacities using some simple assumptions. *Equipment age* is constructed, therefore, on the basis of the following assumptions. First, for lack of better information, in 1902 and thereafter, I assume that no equipment is older than 1895. Any subsequent increase in capacity is assumed to involve purchase of equipment that was new in the year we observe the capacity increase.[19] *Equipment age* is calculated as a weighted average of the age of all equipment in the mill using two basic assumptions. For example, if a mill had a daily capacity of 100 bags in 1902, and it increased its capacity to 150 bags in 1903, then the *equipment age* is estimated as 1902 – 1895 + 1 = 8 in 1902, and 0.667·(1903-1895+1) + 0.333·1 = 6.336 in 1903. If, then, the mills did not increase its capacity the next year, the age is 6.336 + 1 in 1904.

Capacity is directly observable (not derived from production figures) from 1917 to 1939, but the series were reported differently in 1917-1929 and 1930-1939. The Secretaría de Agricultura, Comercio y Trabajo reported engineer-rated daily grinding capacity of mills in the 1930s, but it reported annual rated capacity estimates from 1917 to 1929, which depended on both the equipment and the expected number of days of the grinding season.[20] Before 1926, the length of the grinding season was determined by weather conditions. Grinding took place during the dry season because, during times of heavier rainfall, sucrose content in the standing cane fell, fields were muddy and difficult to work, and the wheels of the ox-carts used to gather harvested cane sunk down into the mud and could damage the root systems of the cane. But one does observe considerable variation between mills apparently because of different rainfall patterns, extent of irrigation, the amount of cane available, and possibly road conditions (which could be impassible during the rainy season). I convert the annual series to a daily series by making the plausible assumption of no change in capacity from 1929 to 1930.[21]

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[19] Capacity is observed or estimated as described in the following paragraph.

[20] Daily grinding capacities were reported annually to the Cuban Sec. de Agricultura, Comercio y Trabajo and published in the annual sugar industry *Memoria*.

[21] There is no ideal assumption, but this one seems the more plausible of the obvious options. It is unlikely that mills would have invested in increased capacity in 1930, given ongoing debate in Washington over the sugar tariff in the Hawley-Smoot bill, which was passed in May-June of 1930, and the October 1929 crisis. As for reductions of capacity, the data exhibit downward rigidity, reflecting the durability of existing equipment. One might expect mill owners to postpone any major capital decisions, upward or downward, until the heated battle over the sugar tariff in the United States had been decided. As for the tariff, I have examined the correspondence of some of the key players in the industry, which reveals that they did not expect the crisis that began in 1929 to be of unusual depth or length and were prepared to weather it at that time. That inaccurate forecast was being revised by the end of 1931 (Dye and Sicotte).

Comparable data on capacity are unavailable before 1917, so I estimate capacity using local production maxima. The data employed in the regressions assume the milling capacity to be equal to the maximum production achieved in the most recent 5 years including the current year.[22] The results using this method appear satisfactory for the current purpose. The competitive pressure on mills to expand during the period produced a ratcheting effect on production levels which suggests that local production maxima plausibly capture capacity. Comparison of directly observed capacities and estimates using the method described for the period 1917 to 1929 by inspection supports the validity of the approach.

It is possible that relative milling capacity offers a better proxy for vintage than absolute capacity. For one thing, based on the observations in Table 6, a daily capacity of 960 bags seems to represent a new vintage in 1902, but not so in 1929. A mill that entered at 960-bag capacity in 1902 and remained at that capacity throughout should be at low risk of exit in 1902, but at higher risk in 1929. I calculate *relative capacity*, for each year *t*, as the cumulative rank of mill *i* (based on lowest-to-highest grinding capacity) divided by the number of active mills in year *t*. This produces a variable that ranks all active mills each year from 0 to 1 by grinding capacity. The smallest mill has the lowest value, and the largest mill has value of 1.

The final variable is referred to as the *expansion history*. It is the ratio of the maximum to the minimum rated capacity achieved by each mill between 1907 and 1929. This variable serves to complement to the other measures of vintage. It is a time-invariant variable that aims to capture mill owners' revealed ability to modernize. Consistent with the entrepreneurial learning model, it assumes heterogeneous management capabilities, in which some mill owners were better learners, had advantaged access to credit in local or foreign capital markets, or better connections in the international market for human

[22] Alternatives of 10-year local maxima and global historical maxima were also calculated and compared with the 5-year local maxima. The series vary little for most mills, which either expanded fairly steadily over the period or production was relatively constant. In the cases where there was a reduction, the downward adjustments to estimated capacity using the 5-year local maxima most closely resemble the downward adjustments observed in the 1917-1939 rated capacity data. Since only annual production data are available, a level adjustment is made to convert annual to daily estimates. Conversion factors are calculated using a four-year overlap period from 1917 to 1920. The average conversion factor across mills for which this overlap existed is used in cases where mills closed prior to 1917.

capital. Others, because of differential managerial ability or inability to signal, may have had more limited access. Inspection of the data suggests such an effect.

Baseline Regressions

As a baseline, I test for the presence of vintage-capital effects for the period 1902-1929. The full data set used in the regressions form an unbalanced panel consisting of the population of 258 mills active at some time during the period, not all active each year, between 1902 and 1939.[23] A random-effects logit model is estimated in the form $y_i = f(\alpha + \beta x_i + \varepsilon_i)$ for three dependent variables: *Closures* assigns a "1" to the first year a mill was inactive (in a period of inactivity); "0" otherwise, it combines, and does not distinguish between, temporary and permanent closures. *Exits* identifies the first year of inactivity of a permanently closed mill, where "permanent" is defined as above.[24]

Other controls include *North American*, which identifies mills owned by persons or companies from the United States or Canada.[25] *Refiner-owned* identifies mills that were owned as an upstream subsidiary of a North American refinery. *Bank-owned* identifies mills owned by a North American bank, which acquired 20 mills in the 1920s

[23] Collected from Cuba, Secretaría de Agricultura, Comercio y Trabajo, *Memoria de la zafra* (1919-1929), continued by *Memoria azucarera* (1930-1939). Supplemental data on sugar prices come from Willett and Gray, *Weekly Statistical Sugar Trade Journal*. Data on ownership are from the authors' extensive investigations to identify majority ownership and transfers of ownership. See Table 1 for sources.

[24] This treatment of dependent variables in a limited-dependent variable model follows a conventional discrete-time method of survival analysis. See Box-Steffensmeier and Jones (2004), and Yamaguchi (1991).

[25] Most non-North American owners were Cuban citizens or immigrants from Spain. A few were residents, in most cases long-time residents, who self-declared as French, Dutch or English. In the historical literature, a prominent view underscores the imperialist argument – that North American companies exercised market power that was unavailable to nationally owned companies (Ayala 1999, Guerra y Sánchez 1944, Ibarra 1998, Pino-Santos 1973). Controlling for ownership constitutes a test of the argument. If it is valid, North American companies should be seen to survive more frequently than non-North American companies. This includes firms that were owned by families that might be considered of "transnational," combined North American and Cuban or Spanish heritage. "Transnationals" include such persons as the Bostonian, Edwin Atkins, married and maintained his family in Cuba, while he directed a Boston sugar refinery and managed sugar mills in Cuba. There were English-Canadian investors who lived permanently in Cuba, but maintained close connections in North America. They also include the Rionda family, which was one of the most important "sugar baron" families in Cuba, owning multiple sugar mills as well as the prominent New York sugar brokerage, the Czarnikow-Rionda Co. Two of three brothers of this family migrated from Spain to Cuba and invested in sugar mills. The third, who migrated to New York, became the President of the New York branch of Czarnikow-McDougall, which later split off and became Czarnikow-Rionda. He became the patriarch of all the family's properties who worked with his New York-born nephews to run the brokerage and set up his Cuban-born nephews to manage the family's sugar mills in Cuba, under his direction (McAvoy 2003).

(Dye and Sicotte 2006).[26] A few Cuban or Spanish banks also owned mills. Market-related controls include the *price* of sugar, *aggregate lagged entries* and *aggregate lagged exits*. The price of sugar is measured as the average annual spot price. Expectations of future prices are the relevant concept for *p* in the vintage-capital shut-down condition in equation (1). The aggregate lagged entries and exits, which are the sum of all entries or exits in a given year (from Table 1, lagged one year), are intended to capture forward-looking expectations, since market-determined decisions to exit or enter are likely to cluster. Dichotomous variables for the six Cuban provinces are included as geographical controls (not shown in the results).

Descriptive statistics for the variables are given in Table 7. The baseline regression estimates for the dependent variable *exits* are given in Table 8 and for *closures* in Table 9. The results confirm prior expectations and differ little between the two dependent variables. The equation specifications alternate between a*ge* and *equipment age* and *capacity* and *relative capacity* because both pairs are highly correlated.

All proxies for vintage capital are significant with the expected signs. The only minor exception is *age*, which is statistically significant only in the *exit* equations (Table 8), not in the *closure* equations (Table 9). Thus, as expected, mills with older equipment were, as expected, less likely to survive, all else equal. The *age* variable captures presumably the same relationship, but imperfectly, since founding dates and equipment age for some mills differed substantially. Mills that were founded on the best cane lands in the 18th or early 19th century, and kept up to date would confound estimates using *age*. These old estates with up-to-date equipment, nevertheless, clearly did not dominate. Larger mills and mills that were of higher rank in the size distribution (*relative capacity*) were more likely to survive. In trial specifications that include both *capacity* and *relative capacity*, the latter tends to dominate. (See, for example, column 5 in Table 8 and 9.) In other respects, the results shown are robust to changes in specification. *Expansion history*, which proxies for the managerial ability to innovate, is also robust and seems to capture the effect of sorting based on managerial capacity or related mill-specific characteristics. Mills tended to sort into the group of survivors by regularly upgrading

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[26] Vertical integration or subsidiary status is a common variable found in the survival literature (e.g. Harhoff 1998).

their milling equipment, or not. This result shows that mills with strong track records in innovation were less likely to fail.

As for the market controls, the three variables together are always jointly significant. The price of sugar bears the wrong sign, possibly indicating the prominence of forward-looking price expectations in these decisions. Lagged exits and entries, which reflect average expectations of prices and profitability, have the expected signs. The controls on foreign ownership confirm a common theme in the historical literature, which is that North American firms were advantaged; however, the results do not support the view, sometimes put forth, that monopoly power of vertically integrated refineries, the "sugar trust," was the principal source of these advantages.

Production Restrictions

Restrictions on sugar production and exports in Cuba were initially adopted as part of a broader effort led by sugar mill owners in Cuba to organize an international sugar cartel to coordinate an orderly reduction of accumulated physical stocks of unsold sugar and to stabilize the falling price of sugar. Crop controls were placed on the size of the Cuban sugar crop in May 1926. A 10 percent reduction from the previous year's crop was imposed in 1927, and another 10 percent reduction was imposed in 1928. The restriction was suspended in 1929 and 1930 but reimposed in 1931. The restrictions before 1929 were understood by producers more as stopgap measure to address perceived overproduction of sugar. From 1931 on, the expected duration was more indefinite, and the effect of crop restriction on utilization of capacity was also more severe.

To implement crop restriction, legislation was promulgated that apportioned the rights to produce among all sugar mills and growers using a system of internal production and export quotas. It was initially intended as stability measure during the crisis, but it came to be used politically to prevent the closure or exit of sugar mills. The key rules and provisions included the following:

1. The President was authorized by law to decree the aggregate size of the sugar crop and the date that grinding would begin each year.
2. The administering agency then assigned production quotas to mills, following rules established in the existing legislation. From 1931 to 1935, this agency was

CENDA (the National Sugar Export Corporation). In 1935, the authority passed to ICEA (Cuban Sugar Stabilization Institute).[27] Contingencies not provided for in the legislation were detailed in the administrative rules established by the agencies.[28]

3. Mill production quotas were assigned *pro rata* based on (i) existing grinding capacity and (ii) available standing cane, including internal and contracted cane, with restrictions on how much internally grown cane could be used.[29] As an exception, small mills (with annual production not exceeding 60,000 bags) were given preferential minimum quotas. The stated reason was to protect national mills. Mills at risk of closure tended to be small and owned by Cuban or Spanish nationals. Most foreign-owned mills enjoyed greater economies of scale and newer technology.
4. About 85 percent of the sugarcane grown in Cuba was under contract with independent suppliers. CENDA assigned quotas at the level of the raw sugar processor (or mill) and the level of the sugarcane grower and supplier.

Other critical questions involved which mills had the right to be assigned a quota and under what conditions quotas were transferable.

5. Under CENDA rules, mills that were active in either of the previous two crops had a right to a quota. A mill that had not ground in the last two crops could

[27] CENDA was founded originally in 1929 as a "single seller" or central marketing organization through which all sugar producers had to sell their sugar. After 1935, CENDA was abolished, and its responsibilities were transferred to the Cuban Sugar Stabilization Institute, known as ICEA (the Instituto Cubano de Estabilización del Azúcar). The agency reform resulted in a transfer of authority from an organization, CENDA, that was made up of representatives of the North American banking and foreign-owned sugar companies as well as Cuban or Spanish sugar interests, but most of whom might be considered "transnationals" in a dependency framework, to an organization, ICEA, that was made up of representatives of interest groups recognized as strictly national – Cuban mill owners and colonos. Zanetti (2004).

[28] These more detailed regulations were updated occasionally, when new contingencies or controversies emerged, and were published regularly as "Reglas de la Corporación Exportadora Nacional del Azúcar sobre entrega de cuotas de aportación a la misma y producción y exportación de azúcar." Copies are found in the paper of Manuel Rionda, Braga Brothers Collection, University of Florida—Gainesville, Series 10C, Box 108, f. "CENDA"; and Box 109 "curtailment sugar laws".

[29] Cane growers initially were "attached" to the mills with which they had contracted historically. Later, regulations were relaxed that allowed them to renegotiate contracts with other mills, always subject, of course, to the natural restriction that cane could not be effectively shipped long distances.

receive a quota if (i) it verified that its mill was operable and (ii) it had sufficient cane (either internal or under contract).

6. CENDA rules in 1931 established that quotas were transferable, but only on the condition that the transferee must fulfill the contractual obligations of the transferor toward the growers. This rule was more restrictive than it may appear. Sugarcane, which is highly perishable after being cut, could only be transported locally. Non-local transfers of production quotas, therefore, could not be coupled with physical transfers of cane and would require compensation of the grower whose quota would be left unground. Yet even these limited transfers met political opposition, especially from labor (discussed below). In subsequent years, authorities imposed the additional restriction that, in quota transfers, the grower's cane must be transferred physically with the quota, effectively restricting all production quota transfers to local transactions.

From 1932 to 1934, growing nationalism in sugar politics and labor mobilization increased the political risk faced by foreign-owned mills in particular. A climax was reached with a political revolution in 1934, which virtually incapacitated the government and subjected mill owners to widespread strikes, seizures of mills by militant labor, and the temporary control of some milling operations by labor-run soviets (Whitney 2000). The unstable political climate introduced significantly greater uncertainty over how the rights to receive a quota might be determined in the near future, or whether existing rules would continue to be enforced with equanimity.

The explosive nationalist politics meant future rights to receive a quota were not clearly defined. If they had been, and if transfers of grinding quotas between mills had been more liberally permitted, cost heterogeneities and potential economies of scale would have given efficient mills the incentive to acquire quota rights from less efficient mills. The shakeout of inefficient milling capacity would have occurred despite controls, although with compensation to the owners or creditors of the acquired mills.

Institutional features had the effect, instead, of blocking the acquisition or closure of mills. Table 1 provides preliminary evidence of this effect. Of the 65 mills that closed permanently between 1919 and 1939, only nine closed after 1931; and none closed permanently from 1934 on, after the revolutionary government of 1933 and its successors came into power. Forty-four mills closed temporarily during the 1930s period of controls, but most had reopened by 1938.

Test for Obstruction

To test the obstructive effect, I reintroduce data overlapping with the period when crop restrictions were in effect, instead of the using reduced set as in the baseline regressions. The proposition of obstruction is effectively that the crop controls interfered with the market mechanisms that underlay the vintage-capital natural-selection process by which, in the years prior to controls, most inefficient mills were either upgraded or closed. As noted above, the politics of crisis after 1926, and even more after 1931, was complicated, and it changed rapidly.

The measures available to us are unlikely to capture much of this complexity. I choose to conduct a simple test by postulating a change of vintage-capital parameters during the years of crop restriction. I estimate the regression $y_i = f[\alpha + \delta\eta + (\beta + \delta\gamma)x_i + \varepsilon_i]$, where δ is an indicator variable such that $\delta = 1$ for the years 1926-1928 and 1931-1939, the years during which production controls were imposed, and $\delta = 0$ otherwise.[30] The proposition is rejected if the interaction variables are insignificant from zero or if they strengthen the effects identified in the baseline regressions. If there was an obstructive effect, however, we would expect the parameters $\delta\gamma$ to partially or wholly offset the effects captured in β.

In various stages of estimation I used two different cuts of the data. One set covered 1902 to 1939, the other from 1902 to 1933. The reason for the latter cut is that, as we have observed, there was a distinct regime change after 1934, after which there were no exits. The estimated model as specified is thus a poor predictor of exit behavior after 1933. One would like to try to capture the regime change in the empirical model; however, an indicator defined as “1” from 1934 to 1939 perfectly predicts the absence of exits. As an alternative, I drop the years 1934 to 1939 and reestimate. The parameter

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[30] This variable does not treat the earlier crop restriction years of 1927 and 1928 as within the “years under controls” for two reasons. In these were pre-depression years, the controls were considerably less stringent; most mill owners saw them as temporary measures intended to correct an overhang of excess accumulation of unsold physical stocks of sugar from the bumper crop of 1925. By contrast, the control measures from 1931 and after were perceived as an indefinite or possibly permanent state intervention in the sugar industry.

estimates are similar using either cut, but the marginal effects for the pre-1934 period are better identified in the reduced set. In what follows, I present the results for 1902-1933.

The regression estimates for *exits* are given in Table 10. The coefficients not interacted with δ are consistent with the baseline model and show robustness to the extended dataset and incorporation of parameter changes during the years of crop restrictions. Hypothesis tests of no parameter change ($\delta\gamma = 0$) on the variables that proxy vintage-capital effects are rejected for age, equipment age, and relative capacity in all regressions.

Moreover, the relative magnitudes on the estimates of the non-interacted β and the interacted $\delta\gamma$ (from the regression equation in the above paragraph) show, for the cases of *age* and *equipment age* that the parameter change under crop restriction more than offsets the market influences of unrestricted years, such that the effect of *age* or *equipment age* on the probability of exit is actually reversed during the period of crop restrictions. Such a reversal is also apparent in the case of the *expansion history*, which controls for the mill's managerial capacity or innovation track record. In the case of *relative capacity*, the association, which existed prior to 1926, of *exits* with the smallest (oldest vintage) mills was partially offset after crop controls were introduced.

The marginal effects are presented in Table 11. The most prominent observation is that most of the obstructive effect we have identified worked through *relative capacity*, which accounts for the majority of the combined effect of the three vintage-capital variables – *equipment age* (or *age*), *relative capacity*, and *expansion history*. The combined effects given in the table represent, in the first column, a unit increase in age and a unit decrease in relative capacity and expansion history. In the second column, the combined effect shows, in the case of age, the marginal effect of moving from the mean age to one standard deviation above the mean, combined with movements of the other two variables from the mean to one standard deviation below the mean.

In Table 11, we see that the reversals of the effects of age and track record on mill survival during crop restrictions, although statistically significant, were relatively small. The effective of the relative capacity, or the location of the mill in the size distribution, was not small. Prior to the adoption of crop restrictions, our estimate suggests that a one-standard-deviation fall in the mill's rank increased the probability of exit by 2 percent.

This was a large effect when compared with the average number of mills that exited per year from 1902 to 1939, which was 2 percent. We find, therefore, that after crop restrictions were adopted, but prior to 1934, according to the estimates, the effect of the mill's vintage on survival was reduced by roughly one-third, but not eliminated. When one combines this with the reversal of effects from *age* and *expansion history*, the combined effect of crop restrictions was to reduce the vintage-capital effect on mill exits by one-half. Then from 1934 on, a change of regime causes exits to vanish altogether.

Table 12 repeats the exercise for *closures*. *A priori*, one might expect the results on all *closures* to be weaker than for exits. On the one hand, the vintage-capital explanation for what causes an outmoded mill to shut down appears to apply equally regardless whether the decision to shut down is perceived as temporary or permanent. Consistently, the results in Tables 8 and 9 suggest little difference in how these factors affected *exits* and *closures* in the baseline regressions. However, the rules that governed the crop restrictions permitted temporary closures of mills without loss of future rights to quotas. One might expect sustained vintage-capital effects on temporary closures – that is technically marginal mills may still have made decisions to close as in equation (1) above, but only temporarily so as not to lose the right to the quota. In the meantime, the option of upgrading to a new vintage has been precluded because the restrictions discouraged investment in additional milling capacity. The results in Table 12, which mixes *exits* and *temporary closures*, confirm this prior expectation. The estimated coefficients on the interaction terms $\delta\gamma$ are insignificant for *relative capacity* and *expansion history*. They are significant for *age* and *equipment age*, but the reversal effect is weaker. The results reported in Table 12 are for 1902-1933; however, temporary closures do not vanish after 1934, as exits do, and the regressions for closures in the full sample, 1902-1939, give similar results.

An Alternative Explanation

The method of using a temporal indicator variable to identify these changes is admittedly crude. Using time to capture the effects of an institutional change can be confounded by other secular changes that coincide with the institutional change. One possible alternative explanation for the results above might be that there was a slowdown in the rate of technical change and in the rate of creation of new vintages. This is probably correct, yet there are reasons to think that the technological frontier did not matter much at the time for exit patterns. Even if entry of new vintages was no longer putting pressure on obsolescent mills at the lower margin of the distribution to shut down, the demand shock of the 1930s had reduced expected demand by about half. The pressure remained to reduce the excess capacity in the industry by a substantial amount.

This argument holds, however, only if mills did not choose independently to reduce their production levels voluntarily. If mills had textbook cost structures, then the fall in the price would have induced a fall in the optimal level of production. However, a closer look at the cost structure of the sugar mill suggests that, regardless of the price, mill managers would either choose to operate at capacity or shut down. The framework I use employs Alchian's (1959) cost model as a framework, which was used in a similar fashion by Bresnahan and Raff (1991) to examine the effect of the Great Depression on the motor vehicles industry in the United States.

Consider a model of production that distinguishes three dimensions over which internal output decisions could be made: $y = r \cdot z$, where y is the annual production of sugar, r is the average daily rate of sugar processing, and z is the length of the grinding season, which was determined by weather conditions. To maximize the sucrose recovered during processing, sugar manufacturers timed the harvest and grinding to coincide with the dry season, typically lasting about six months, from December to June.

Daily production decisions may be closely approximated by assuming constant average variable costs with respect to varying the daily rate of production, r, significant fixed costs in the short run; and a fixed upper limit to the daily grinding capacity, k. Variable costs, v, went largely to sugarcane, labor and fuel. Sugarcane was procured by long-term contract for a pre-determined per unit rate (Dye 1994). Labor was paid competitive wages, and there was no evidence of diseconomies in the short run in the consumption of any of the variable production factors. Fixed costs, F, constituted a major share of total costs because the technology used in sugar milling was recently developed, capital-intensive, and comparable with other cutting-edge continuous-processing technologies of the second industrial revolution. Besides capital-intensive milling equipment, other fixed investments included fire lanes, bridges and other infrastructure to haul cane to the mills (Dye 1998).

The implication of this cost structure is that, absent other constraints, mill managers would have minimized costs by spreading the fixed costs over more units of production. Therefore, prior to the imposition of controls, when competitive conditions reigned, the model predicts that price-taking managers would have set the rate of production, r, at its maximum, k. Similarly, they would have maximized the length of the grinding season, z , subject to the weather constraints on the grinding season.

Table 13, which shows average levels of r and z, confirms these predictions for the period before crop restrictions were imposed, but not afterward. Daily rates of production, r, per day and per effective day are shown in columns i and ii. Average production per day grew steadily during the 1920s. This was caused by steady adoption of new, larger-scale technology in the 1920s. At the onset of the crisis, investment in equipment virtually ceased with the crisis, yet the daily rate of production, r , did not fall. It remained steady throughout the period.[31] As for the length of the grinding season, z, the table shows that, in times of no controls, 1919-1925, 1929-1930, the average grinding season ranged between 112 and 145 days.[32] After 1931, when controls were in place, the length of the grinding season was 40-45 percent shorter than the average for the uncontrolled years – a difference that cannot be explained by changes in weather

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[31] The difference between the effective and official days of grinding are explained primarily by weekly shutdowns, delays in expected deliveries of cane, and occasional cane fires. See Dye (1998a,b) for analyses of the delays and their consequences.

[32] Controls were also imposed in 1926, 1927 and 1928. The legislation for it was passed in May of 1926, after most of the mills had completed their 1926 grinding campaigns, so for practical purposes, we do not consider 1926 to have been an effective control year. Controls were more significant in 1927 and 1928, but less stringent than in the post-Depression years. Also, mill owners considered them as a temporary stopgap measure for dealing with the immediate accumulation of physical stocks, such as those highlighted in Kindleberger (1973). For the purposes of the paper, we do not treat these two years as part of the "control period," but we also do not include them when making comparative inferences about the uncontrolled years.

The shorter grinding seasons in 1929 and 1930 are probably explained by cane shortages in some mills caused by disease and reduced cane acreage following the crop restrictions of 1927 and 1928. A disease known as mosaic was ravaging the varieties of cane commonly grown in Cuba at that time. Some mills were importing mosaic-resistant varieties from Java, but the commodity crisis in the sugar industry, fully under way by that time, slowed the rate of investment in importing and renovating the cane stock. Braga Brothers Collection, Series 10c. Some mills apparently faced shortages of cane. In any case, in 1927, 1928 and from 1931 to 1939, we distinctly observe the effect of government-controlled crop restrictions on the number of days grinding.

conditions. The smaller dips in 1926, 1927 and 1928 are explained by a less severe crop restriction relative to the post-1931 restrictions.

Together the mill-level production data show that adjustment to lower post-crisis demand for sugar was accomplished by shortening the grinding season at each mill. The adjustment came about only because of the imposition of controls. If they had not been constrained by regulation, mill managers would have extended their grinding for the duration of the natural grinding season. Adjustment to lower demand would, then, necessarily have come about through a survival-of-the-fittest process. Without reference to the restrictions on production and protection of active mills, it is difficult to explain why the post-1931 downward adjustment of sugar production was accomplished by an across-the-board shortening of the length of the grinding season at each mill. Nothing other than an institutionally induced restriction can adequately explain it.

Conclusion

In recent years, there has been a resurgence of work inspired by the Schumpeterian concept of the entrepreneur as an underlying explanation for high rates of simultaneous entry and exit of firms or establishments, particularly in small firm sectors. Although the findings of the literature shed some light on the role of creative destruction, little work has examined the consequences of obstructing it, even though it was, in part, this concern that nations were “determined not to allow [it] to function” that may have prompted his interest in the concept.

This paper looks into the question by contrasting two post-crisis periods in the Cuban sugar industry in which one would expect the process of creative destruction to have been active. The main question was: Do we observe major differences in role of creative destruction in the two periods? We do. The period from the 1880s at least to the mid-1920s was a period of continual technological change in the sugar industry, with continual opportunity to upgrade one’s production technology at the mill. Vintage capital caused those decisions to operate at two margins – that of introduction new techniques either in existing or *de novo* mills and that of retiring old techniques by scrapping machinery or shutting down operations. The coincident occurrence of entry and exit, or churning, as well as the sorting one observes between mills that upgraded and mills that, in effect, stagnated indicates that the process of liquidation and regeneration of productive capacity was an ongoing process. Crises may affect the rates of entry and exit differently, as like Caballero and Hammour (1994) conclude, there seems to be no reason to associate the notion of creative destruction with the paradoxical notion that recessions are “desirable.” The evidence from the pre and post-1898 episode is insufficient to offer proof; however, it at least suggests that destruction of milling capacity caused by the war was unnecessary for the continuation of creative destruction. It did accelerate the rate of liquidation of milling capacity, which left a vacuum that was filled by a high rate of renovation and steady entry of mills in the early years after independence.

Quantitative analysis of the subsequent period shows steady rates of both liquidation and regeneration in the form of simultaneous entry and exit of mills. An institutional story may be offered for these observations. Spanish imperial policies slowed the rate of investment in new milling technology prior to the war of independence. Independence lifted the yoke of imperialism, but the military intervention by the United States and the imposition of the Platt Amendment encouraged foreign investors, who perceived perhaps lower political risk because of the promise of intervention of the United States to defend private property and ensure the fiscal responsibility of the Cuban government. Whether caused by the lifting of institutions that gave disincentives or the introduction of institutions that gave protections to investors, the evidence in the survival and exit data show patterns that demonstrate active investment and freedom of the market to stimulate the replacement of old and inefficient technology with newer, more efficient vintages by a process of vintage-capital natural selection.

Moving forward to the mid-1920s and 1930s, the role of institutions becomes prominent and identifiable. The introduction of crop restrictions as a stabilization policy in Cuba had the effect, intended or unintended, of suppressing the natural-selection process. This emphasis on the role of institutions may shed a different light on the usual association of creation destruction and crisis. Rather than raise the question whether economic crisis is a “desirable” event, it may point to some potential dangers of crisis. In economic crisis the political pressures and the temptations to intervene to forestall liquidation are greater. It is not that crises provide a necessary liquidation function in capitalist society – we have plenty of evidence that that function can be performed also during prosperity; it is, instead, that crisis can create a political environment in which "nations are determined not to allow [the process of liquidation] to function."

It remains for future work to consider the consequences of entrepreneurial obstruction in Cuba. In other work-in-progress I have estimated the potential consequences of the institution of controls in Cuban sugar on increased costs to be considerable. More circumspectly, in the first three decades of the 20th century Cuba was the world's preeminent sugar producer– the least-cost producer globally; however, contemporaries in the 1940s and 1950s lament the national industry's loss of global competitiveness. In the case of Cuban sugar, the question of the introduction of crops controls, which certainly obstructed entrepreneurial behavior, must be followed by the question of why they persisted. The entry and exit data correspondingly show a dynamic industry, in terms of entry, exit and vintage regeneration in the first quarter of the century contrasted with a completely lethargic industrial capacity (by this measure) after 1933.

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Table 1. Entries and Exits of Sugar Mills in Cuba, 1901-1959

year	entries	exits	reopen	temp-orary closure	temp-orarily closed	active
1901	0	0	21	12	37	151
1902	3	9	8	9	36	146
1903	0	0	17	0	15	167
1904	1	1	12	2	10	172
1905	1	1	3	1	8	175
1906	0	0	2	2	8	175
1907	3	0	6	0	0	185
1908	1	8	3	9	9	169
1909	1	0	4	4	8	171
1910	1	2	4	1	5	173
1911	1	4	3	5	8	167
1912	3	3	3	0	5	170
1913	2	3	3	0	2	172
1914	5	4	0	4	6	169
1915	5	0	2	1	5	175
1916	10	0	3	0	2	188
1917	12	1	2	1	1	199
1918	4	6	1	0	0	198
1919	9	8	0	1	1	198
1920	1	5	0	1	2	193
1921	5	1	1	0	1	198
1922	7	11	0	6	7	188
1923	1	8	4	3	6	182
1924	1	2	3	4	7	180
1925	3	2	5	3	5	183
1926	0	4	1	4	8	176
1927	1	3	4	1	5	177
1928	0	7	2	0	3	172
1929	0	3	1	7	9	163
1930	0	2	0	5	14	156
1931	0	7	3	12	23	140
1932	0	1	3	9	29	133
1933	0	1	6	13	36	125
1934	0	0	14	4	26	135
1935	0	0	3	5	28	133
1936	0	0	13	0	15	146
1937	0	0	11	1	5	156
1938	0	0	2	0	3	158
1939	0	0	0	1	4	157
1940	0	0	0	1	5	156
1941	0	0	1	1	5	156
1942	0	0	2	0	3	158
1943	0	0	0	1	4	157
1944	0	0	1	0	3	158
1945	0	0	2	0	1	160
1946	0	0	1	1	1	160
1947	0	0	1	0	0	161
1948	0	0	0	0	0	161
1949	0	0	0	0	0	161
1950	0	0	0	0	0	161
1951	0	0	0	0	0	161

1952	0	0	0	0	0	161
1953	0	0	0	0	0	161
1954	0	0	0	0	0	161
1955	0	0	0	0	0	161
1956	0	0	0	0	0	161
1957	0	0	0	0	0	161
1958	0	0	0	2	2	159
1959	0	0	2	0	0	161
Total	81	107	173	131	402	6571

Source: Author's elaboration of records from Cuba, Sec. de Hacienda (1904/05-1915/16); Cuba, Sec. de Agricultura, Comercio y Trabajo, *Memoria de la zafra*, (1916/17-1929), continuing as, *Memoria azucarera* (1930-1939); Cuba Económica y Financiera, *Anuario azucarero* (1940-1959).

Exits and temporary closures count the first year a mill closed. Exits are mill closures without reopening by 1959. A temporary closure is the closure of any mill that reopened again prior to 1959.

Table 2. Sugar Production per Mill, Cuba 1860-1929

Year	No. active mills	Total sugar produced (000s bags of 325 lbs., raw sugar equivalent)	Sugar produced per mill (000s bags of 325 lbs., raw sugar equivalent)
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

Source: Dye (1998), p. 12.

Table 3. Active Mills and Sugar Production in Remedios, 1860-1910.

Year	**No. active mills**	**Production (000s bags)**	**Production per mill**
1860	44	104.3	2.4
1878	40	223.3	5.6
1888	32	243.8	7.6
1890	25	214.5	8.6
1901	8	305.3	38.2
1906	14	648.9	46.4
1910	14	910.2	65.0

Condition of Mills on Dec. 31, 1899	**No. of mills**
Active	7*
not destroyed	7
reconstructed	6
destroyed	12
dismantled	0
total surveyed	25

* The survey of the U.S. occupational government included all but two mills known to be active in 1895. According to the survey, out of the 7 mills that were "active" in 1900, four had not been destroyed and three had been reconstructed.

Sources: Venegas Delgado (1987); United States, War Dept. (1900); Cuba, Secretaría de Hacienda (1905/06, 1909/10).

Table 4. Remedios: Active mills and sugar production (000s of bags of 325 lbs)

Mill	1890	1984		1901	1906	1910	condition of mill on Dec. 31, 1899
Adela	32.1	58.7	w	50.8	65.3	94.7	reconstructed
Narcisa	30.4	63.6	a	61.5	70.0	104.9	not destroyed
San Augustin	43.4	68.1	r		55.0	96.0	destroyed
Zaza	43.0			79.9	100.5	93.0	not destroyed
Fe	10.2	41.9	o	24.2	39.5	60.5	reconstructed
San Jose	30.8	36.9	f		31.0	48.4	unknown
Victoria	14.8	34.2		50.2	81.4	104.2	not destroyed
Matilde *		28.8	i				reconstructed
Altimira *		26.2	n	22.4	36.2	48.6	not destroyed
Santa Rosalia		18.2	d	14.3	23.0	23.0	not destroyed
Reforma		17.4	e	13.6	48.3	98.9	reconstructed
Convenio		14.4	p		40.4	64.2	destroyed
Julia *	96.3	18.1	e		11.8	10.5	destroyed
Santa Catalina *		17.1	n				reconstructed
San Pablo		17.1	d	11.0	25.2	29.6	not destroyed
Dolores *		14.2	e				not destroyed
San Rafael *		3.7	n				probably dismantled
Carmita			c		7.5	11.2	unknown
Seven unnamed mills			e				
total	300.9	555.3		327.7	635.1	887.7	

* Estate lands were incorporated into a nearby central mill, according to Venegas (1987).

Sources: Venegas Delgado (1987); United States, War Dept. (1900); Cuba, Secretaría de Hacienda (1905/06, 1909/10).

Table 5.
Condition of Mills after the War of Independence, Dec. 31, 1899

Classification	no of mills [a]	percent	active by 1901-1907 [b]
not destroyed	91	15.9	66
reconstructed	110	19.2	62
destroyed	210	36.7	19
Dismantled [c]	161	28.1	4
other surviving			12
Total	572	100.0	163
Active in 1900	105		

[a] Does not include Santiago de Cuba where there were 15 active mills reported in 1901.
[b] Mills in each condition which later reappear as active at some time between 1901 and 1907.
[c] Includes mills that were dismantled or retired and the estate is dedicated to another crop.

Source: U.S. War Department (1900)

Table 6. Size Distribution of Mills by Milling Capacity
No. of mills in each category (milling capacity in daily capacity of bags of 325 lbs.)

	0 > x ≥ 30 bags	30 > x ≥ 60 bags	60 > x ≥ 120 bags	120 > x ≥ 240 bags	240 > x ≥ 480 bags	480 > x ≥ 960 bags	960 > x ≥ 1920 bags	1920 > x ≥ 3840 bags	3840 > x ≥ 7680 bags	x > 7680 bags
1901	11	16	22	37	44	17	4	0	0	0
1902	2	9	14	36	49	30	6	0	0	0
1903	4	9	14	31	51	44	14	0	0	0
1904	2	8	12	28	56	49	16	1	0	0
1905	1	6	11	20	60	57	19	1	0	0
1906	2	6	8	19	54	62	23	1	0	0
1907	3	5	8	14	59	68	24	3	1	0
1908	2	3	4	12	53	66	25	3	1	0
1909	2	4	3	11	48	70	27	5	1	0
1910	3	2	3	10	45	66	34	8	2	0
1911	2	0	4	8	44	64	36	8	1	0
1912	0	1	1	8	41	66	41	10	2	0
1913	0	1	1	6	30	59	58	16	1	0
1914	0	0	0	5	25	63	56	17	3	0
1915	0	0	1	5	24	63	59	19	4	0
1916	0	0	0	5	20	69	66	24	4	0
1917	1	0	1	5	17	63	81	26	5	0
1918	1	0	2	2	13	58	84	31	7	0
1919	1	1	0	4	9	55	86	33	8	0
1920	1	1	0	3	7	52	87	32	10	0
1921	0	0	1	2	11	46	92	37	8	0
1922	0	0	0	2	6	44	85	41	10	0
1923	0	0	0	1	3	44	80	44	10	0
1924	0	0	1	2	3	35	85	41	13	0
1925	0	0	0	1	2	30	88	46	16	0
1926	0	0	0	0	1	22	75	57	21	0
1927	0	0	0	1	2	25	67	58	24	0
1928	0	0	0	1	1	15	69	60	21	5
1929	0	0	0	1	1	11	64	59	21	6

	0 > x ≥ 30 bags	30 > x ≥ 60 bags	60 > x ≥ 120 bags	120 > x ≥ 240 bags	240 > x ≥ 480 bags	480 > x ≥ 960 bags	960 > x ≥ 1920 bags	1920 > x ≥ 3840 bags	3840 > x ≥ 7680 bags	x > 7680 bags
1930	0	0	0	1	1	10	60	57	21	6
1931	0	0	0	0	0	10	50	53	23	4
1932	0	0	0	0	1	8	48	52	19	5
1933	0	0	0	0	0	12	41	48	19	5
1934	0	0	0	0	0	11	52	49	17	6
1935	0	0	0	0	0	7	52	50	18	6
1936	0	0	0	0	1	11	60	50	18	6
1937	0	0	0	0	0	14	65	53	18	6
1938	0	0	0	0	1	12	66	56	17	6
1939	0	0	0	0	0	10	68	55	18	6

Source: see text.

Table 7. Summary Statistics of the Regression Variables

	N	Mean	St. dev.	Min	Max
Dependent variables					
exits	7059	0.01	0.12	0	1
closures	6875	0.03	0.18	0	1
Explanatory variables					
age	7081	35.04	16.55	1	66
equipment age	9826	21.38	150.28	0	3077
expansion history	10062	5.31	20.19	0	236.4
capacity	9794	1169.00	1324.64	0	10000
relative capacity	8431	0.35	0.24	0.004	1
North American	10686	0.20	0.40	0	1
Bank-owned	10686	0.04	0.19	0	1
Refinery-owned	10686	0.02	0.13	0	1
sugar price	10412	3.03	1.78	0.925	11.34
lagged exits	10412	2.82	3.07	0	11
lagged entries	10412	5.23	4.93	0	18

Sources: See text.

Table 8. Baseline Regressions on Exits (1902-1930)

Dependent Variable: Exits	(1)		(2)		(3)		(4)		(5)	
Age (log)	0.41	*	0.21	***						
	(0.22)									
Equipment age (log)					1.41	***	1.04	***	1.08	***
					0.21		0.20		0.21	
capacity (log)	-0.56	***			-0.52	***			-2.02	**
	(0.11)				0.10				0.81	
Capacity squared (log)									0.26	***
									0.08	
Rel. capacity			-14.23	***			-13.32	***	-19.12	***
							1.45		1.98	
Expansion history (log)	-1.00	***	-0.75	***	-1.28	***	-1.08	***	-1.27	***
	(0.22)				0.20		0.20		0.22	
North American = 1	-1.97	***	-1.33	**	-2.02	***	-1.42	**	-2.14	***
	(0.58)				0.58		0.59		0.61	
Bank-owned = 1	1.05	*	0.86		0.78		0.67		0.19	
	(0.54)				0.54		0.58		0.60	
Refinery-owned = 1	2.10	**	2.71	**	1.90	**	2.80	**	2.74	**
	(0.89)				0.93		1.37		1.35	
Sugar price	0.25	***	0.07		0.20	***	0.05		-0.07	
	(0.05)				0.06		0.07		0.08	
Agg. Exits (t – 1)	-0.00		0.01		-0.01		0.01		0.02	
	(0.04)				0.04		0.04		0.05	
Agg. Entries (t – 1)	-0.13	***	-0.09	**	-0.10	***	-0.08	**	-0.02	
	(0.04)				0.03		0.03		0.03	
No. obs. (groups)	5225	(257)	5175	(257)	5225	(257)	5175	(257)	5175	(257)
Log likelihood	-367.97		-277.83		-346.15		-266.97		-249.37	
Wald chi-sq.	106.59	***	132.72	***	134.04	***	144.52	***	132.37	***

Standard errors in parentheses. Regressions are random-effects logit regressions. Constant and provincial controls included, not shown.
*** indicates significance at 0.01, ** at 0.05, and * at 0.1.

Table 9. Baseline Regressions on Closures (1902-1930)

Dependent Variable: Closures	(1)		(2)		(3)		(4)		(5)	
Age (log)	0.15		0.15							
	(0.14)									
Equipment age (log)					0.98	***	0.74	***	0.69	***
					0.15		0.14		0.14	
Capacity (log)	-0.67	***			-0.64	***			-0.87	
	(0.08)				0.08				0.59	
Capacity squared (log)									0.09	**
									0.06	
Rel. capacity			-6.82	***			-6.41	***	-7.05	***
							0.64		0.80	
Expansion history (log)	-0.44	***	-0.30	**	-0.64	***	-0.47	***	-0.45	***
	(0.14)				0.14		0.13		0.13	
North American = 1	0.77	***	-0.56		-0.85	***	-0.65	**	-0.77	**
	(0.30)				0.30		0.29		0.30	
Bank-owned = 1	0.86	**	0.76	*	0.65		0.56		0.56	
	(0.44)				0.44		0.46		0.46	
Refinery-owned = 1	0.61		1.00		0.55		0.98		0.92	
	(0.79)				0.81		0.90		0.89	
Sugar price	0.14	***	0.02		0.09	*	-0.04		-0.07	
	(0.05)				0.05		0.06		0.06	
Agg. Exits (t – 1)	-0.00		0.01		-0.00		0.01		0.01	
	(0.03)				0.03		0.03		0.03	
Agg. Entries (t – 1)	-0.12	***	-0.07	***	-0.10	***	-0.06	**	-0.04	*
	(0.03)				0.03		0.02		0.02	
No. obs. (groups)	5126	(257)	5126	(258)	5126	(258)	5126	(258)	5126	(258)
Log likelihood	-620.53		-564.15		-597.40		-550.45		-548.86	
Wald chi-sq.	125.74	***	168.90	***	163.04	***	194.70	***	197.62	***

Standard errors in parentheses. Regressions are random-effects logit regressions. Constant and provincial controls included, not shown.
*** indicates significance at 0.01, ** at 0.05, and * at 0.1.

Table 10. Regressions on Exits with Interactions on Crop Restriction (1902-1933)

Dep. Var.= exit	(1) Coef.	Std. err.		(2) Coef.	Std. err.		(3) Coef.	Std. err.		(4) Coef.	Std. err.	
Age (log)	0.604	0.244	**	0.614	0.219	***						
Age (log) * δ	-0.855	0.334	***	-0.772	0.338	**						
Equipment age (log)							1.534	0.217	***	1.157	0.208	***
Equipment age (log) * δ							-1.551	0.471	***	-1.146	0.461	***
Capacity (log)	-0.603	0.108	***				-0.553	0.101	***			
Capacity (log) * δ	-0.127	0.366					-0.230	0.364				
Rel. capacity				-13.370	1.535	***				-12.357	1.465	***
Rel. capacity * δ				5.888	2.213	***				4.551	2.171	**
Expansion history (log)	-1.011	0.239	***	-0.786	0.223	***	-1.429	0.223	***	-1.198	0.218	***
Expansion history * δ (log)	1.242	0.385	***	1.023	0.381	***	1.617	0.388	***	1.385	0.385	***
North American = 1	-2.349	0.543	***	-1.768	0.544	***	-2.361	0.539	***	-1.780	0.542	***
Bank-owned = 1	1.550	0.430	***	1.259	0.454	***	1.398	0.431	***	1.171	0.450	***
Refinery-owned = 1	1.923	0.857	**	2.117	0.972	**	1.941	0.861	**	2.210	0.968	**
Sugar price	0.248	0.053	***	0.092	0.062		0.199	0.057	***	0.073	0.064	
Agg. Exits (t – 1)	-0.001	0.041		0.006	0.043		-0.012	0.043		0.005	0.044	
Agg. Entries (t – 1)	-0.088	0.039	**	-0.062	0.035	*	-0.060	0.036	*	-0.059	0.035	*
No. obs. (groups)		5892	(257)		5842	(257)	5892	(257)		5842	(257)	
Log likelihood		-413.97			-332.41			-391.88			-320.51	
Wald chi-sq.		122.87	***		155.68	***		146.83	***		169.85	***

Standard errors in parentheses. Regressions are random-effects logit regressions. Constant and provincial controls included, not shown.
*** indicates significance at 0.01, ** at 0.05, and * at 0.1.

Table 11. Marginal Effects for Regressions on Exits

Coefficient	Variable	(1) marginal effect	marginal effect * σ_x	Variable	(2) marginal effect	marginal effect * σ_x
β (baseline)	age	0.010	0.008	age	0.004	0.003
β (interactive)		0.002	0.002		0.005	0.004
$\beta + \delta\gamma$		-0.001	-0.001		-0.001	-0.001
β (baseline)	capacity	-0.014	-0.018	rel. capacity	-0.110	-0.026
β (interactive)		-0.002	-0.003		-0.112	-0.026
$\beta + \delta\gamma$		-0.003	-0.003		-0.062	-0.015
β (baseline)	exp. history	-0.025	-0.019	exp. history	-0.006	-0.004
β (interactive)		-0.004	-0.003		-0.007	-0.005
$\beta + \delta\gamma$		0.001	0.001		0.002	0.002
β (baseline)	combined*	0.050	0.045	combined*	0.120	0.034
β (interactive)		0.008	0.007		0.123	0.035
$\beta + \delta\gamma$		0.001	0.002		0.059	0.012
		(3)			(4)	
β (baseline)	equipment age	0.034	0.025	equipment age	0.008	0.006
β (interactive)		0.002	0.002		0.008	0.006
$\beta + \delta\gamma$		0.000	0.000		0.000	0.000
β (baseline)	capacity	-0.013	-0.016	rel cap	-0.099	-0.023
β (interactive)		-0.001	-0.001		-0.089	-0.021
$\beta + \delta\gamma$		-0.001	-0.001		-0.056	-0.013
β (baseline)	exp history	-0.031	-0.024	exp hist	-0.008	-0.006
β (interactive)		-0.002	-0.001		-0.009	-0.007
$\beta + \delta\gamma$		0.000	0.000		0.001	0.001
β (baseline)	combined*	0.078	0.065	combined*	0.114	0.035
β (interactive)		0.005	0.004		0.106	0.034
$\beta + \delta\gamma$		0.001	0.001		0.055	0.012

* The combined effect is the sum of the marginal effects of a one-unit or one-standard-deviation increase in age or equipment age and a one-unit or one-standard-deviation decrease in the remaining two vintage-capital variables in the equation.

Table 12. Regressions on Closures with Interactions on Crop Restriction (1902-1933)

	(1)			(2)			(3)			(4)		
Dep. Var.= exit	**Coef.**	**Std. err.**		**Coef.**	**Std. err.**		**Coef.**	**Std. err.**		**Coef.**	**Std. err.**	
Age (log)	0.291	0.161	*	0.245	0.150	*						
Age (log) * δ	-0.420	0.225	**	-0.298	0.223	*						
Equipment age (log)							1.028	0.157	***	0.802	0.146	***
Equipment age (log) * δ							-0.799	0.333	**	-0.591	0.321	*
Capacity (log)	-0.677	0.084	***				-0.633	0.084	***			
Capacity (log) * δ	-0.052	0.258					-0.099	0.259				
Rel. capacity				-6.192	0.644	***				-5.623	0.618	***
Rel. capacity * δ				1.363	1.033					0.936	1.030	
Expansion history (log)	-0.249	0.137	**	-0.132	0.134	*	-0.496	0.141	***	-0.345	0.136	**
Expansion history * δ (log)	0.061	0.264		-0.048	0.255		0.266	0.266		0.130	0.255	
North American = 1	-0.804	0.245	***	-0.655	0.248	***	-0.852	0.247	***	-0.674	0.246	***
Bank-owned = 1	1.170	0.303	***	1.114	0.318	***	1.081	0.304	***	1.023	0.310	***
Refinery-owned = 1	0.342	0.652		0.580	0.680		0.399	0.656		0.623	0.673	
Sugar price	0.084	0.048	*	-0.062	0.054	*	0.035	0.051		-0.090	0.056	
Agg. Exits (t – 1)	-0.001	0.028		-0.001	0.029		-0.009	0.029		-0.007	0.029	
Agg. Entries (t – 1)	-0.119	0.027	***	-0.076	0.024	***	-0.091	0.026	***	-0.059	0.024	**
No. obs. (groups)	5730	258		5730	258		5730	258		5730	258	
Log likelihood		-796.108			-745.25			-772.499			-730.296	
Wald chi-sq.		140.8	***		158.6	***		166.35	***		184.52	***

Standard errors in parentheses. Regressions are random-effects logit regressions. Constant and provincial controls included, not shown.
*** indicates significance at 0.01, ** at 0.05, and * at 0.1.

Figure 1. The Price of Sugar in New York and London, New York
(Includes net-of-duty price on Cuban sugar in New York.)

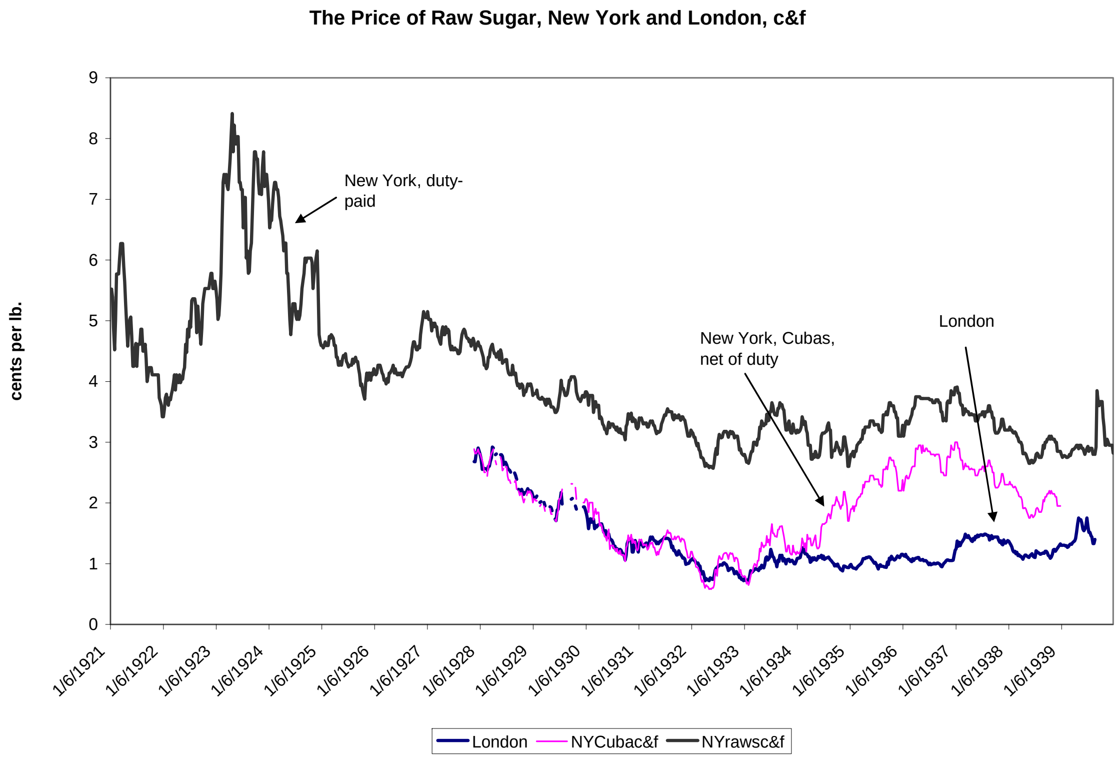
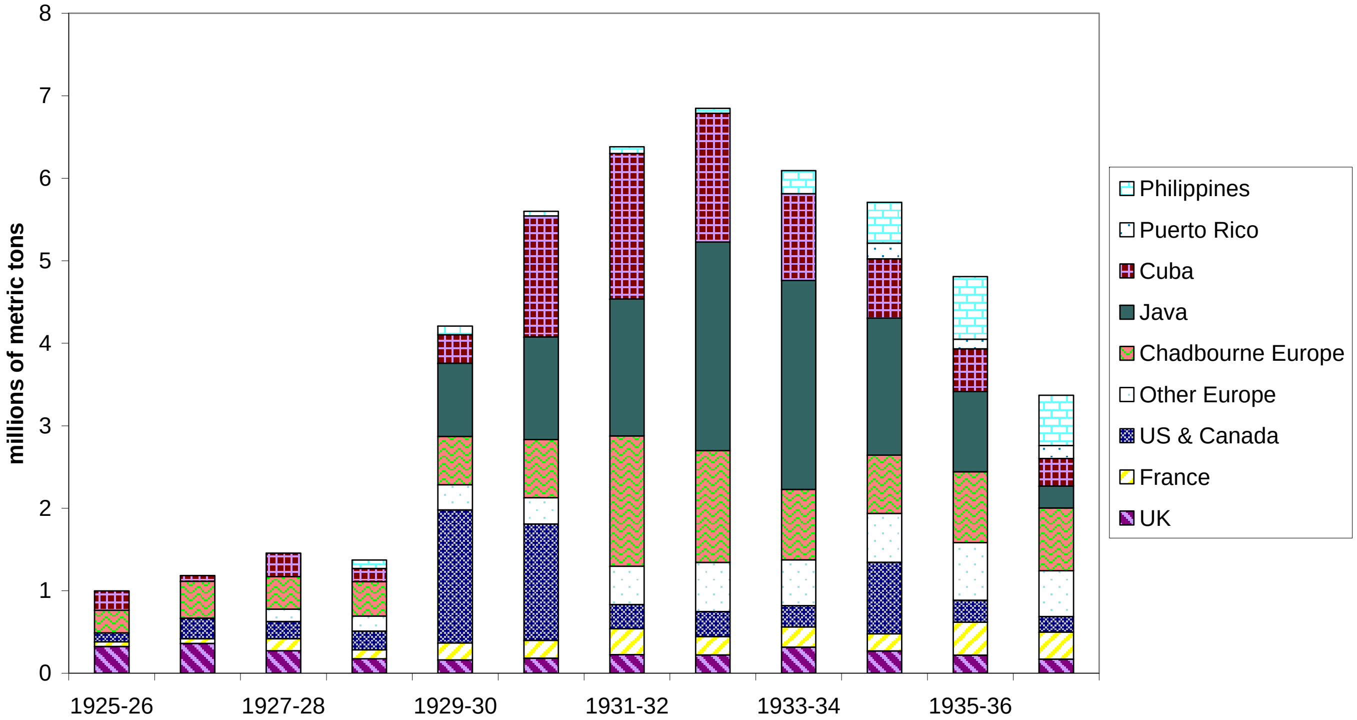
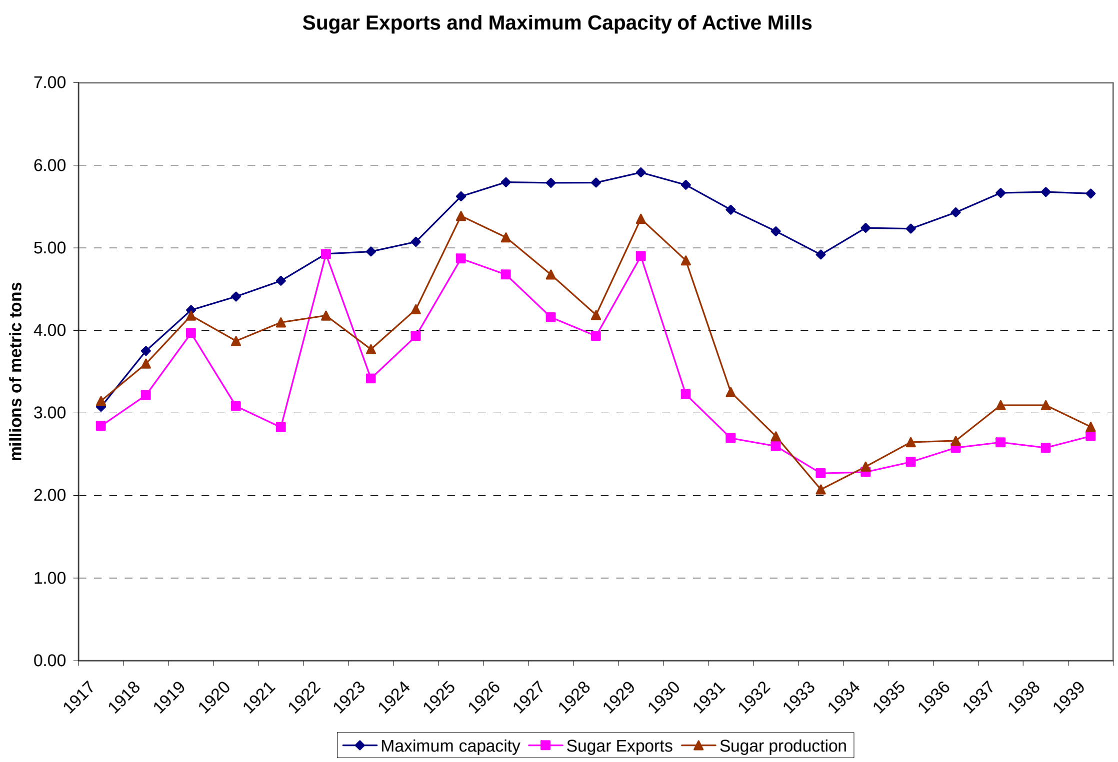


Figure 2. Stock of Sugar, End-of-Crop-Year Surpluses



Source: Willett & Gray, *Weekly Statistical Sugar Trade Journal, passim*.

Figure 3. Sugar Production, Exports and Maximum Capacity of Active Mills



Sources: production figures are from Moreno Fraginals (1978), vol. 3; exports are from Cuba Económica y Financiera, *Anuario azucarero* (1959); mill capacities are authors' elaboration using data from the Sec. de Agricultura, Comercio y Trabajo, *Memoria de la zafra* (1919-1929); continued by *Memoria azucarera* (1930-1939).

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