# ON IDENTIFYING CHANDLER INDUSTRIES THROUGH AN ANALYSIS OF CAPITAL/LABOUR RATIOS

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*In this essay, Won Chai notes a possible relationship between those manufacturing sectors which are largely affected by transportation and technology improvements and their corresponding capital-labour ratios. This is investigated using through an analysis of the pig iron and woollen goods industries, in an effort to determine whether or not these ratios may be used to identify Chandler industries.*

## Introduction

In *Industrial Structure and the Emergence of the Modern Industrial Corporation*, Jeremy Atack argues that the manufacturing sectors most affected by improvements in transportation and technology had the lowest establishment-to-minimum establishment ratios in 1900. He notes that these "High-High" industries were Chandler industries, industries hypothesized to have undergone significant structural change due to continuous process production technologies and improvements in transportation (Atack, 1985).

Making selections based on data availability, I attempt to determine whether Atack's HH (High-Transportation/High-Technology) industries exhibited capital/labour (K/L) ratios that were significantly different from that of other industries. I begin my analysis with an examination of the pig iron (HH) and woollen manufacture (LL) industries from 1860 to 1900. Relying upon findings made in this introductory analysis, I then turn to analysis of K/L ratio trends for multiple industries, and attempt to see if the behaviour of a given industry's K/L ratio can indicate whether it was a Chandler industry or not.

Part I contains a description of data methodology. Part II analyses technological developments, transportation effects, and their relationship to consolidation in the pig iron and woollen goods industries. Part III examines K/L ratio trends from 1860 to 1900. Part IV concludes and summarizes preliminary findings.

## Methodology and Data Sources

All data, unless otherwise noted, were obtained from U.S. Decennial Censuses from 1860 to 1920. Data for a given industry were often compromised by changes in industry classification. To maximize consistency, special manufacturing reports in the decennial censuses were used whenever possible to back-check older data. Data summations were also sometimes done to maintain consistency. Breakdowns for these summations are as follows:

Tobacco Manufacture: Tobacco used for chewing, smoking, snuff, cigars, and cigarettes.

Pig Iron: Pig Iron (Blast Furnaces). The term “blast furnaces” is often used as a synonym for “pig iron”.

Wool Manufacture: Woollen goods, worsted goods, carpets, wool hats, hosiery and knit.

Brick and Tile: Brick, tile.

Except for the four industries listed above, all data for K/L ratio comparisons were obtained from decennial census tables for general manufacturing statistics of the United States.

All capital, wage, and value of product data, unless otherwise noted, are given in current dollars. Establishment and employment statistics are given in their natural numbers. Ratios of capital value-to-wage are used in order to avoid problems with deflation and to allow for labour skill changes. As an alternative, real capital value-to-employee ratios are also calculated. GDP was deflated[1] to obtain real dollar figures for 2004. I used the GDP deflator instead of the CPI because the quantities being deflated are producer-related, and the GDP deflator includes the prices of non-consumer capital goods (Bernanke and Abel, 2005).

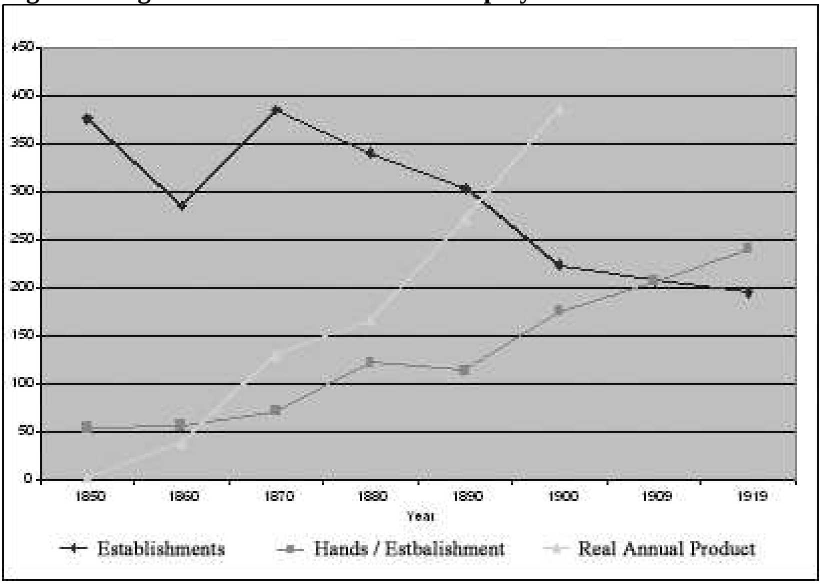
The census included “hand and neighborhood industries” before 1904, but did not do so afterwards (O’Brien, 1988:644). Establishment number analysis after 1904 is avoided. Census capital stock data were always attended by warnings of inaccuracy and should be treated with caution.

[1] Using the GDP deflator calculator at www.eh.net.

## The Pig Iron Industry: High Impact of Transportation – High Impact of Technology

The pig iron industry underwent significant reorganisation in the latter half of the 19th century. According to Atack, the industry had an establishment-to-minimum establishment ratio of about 0.40 in 1900 (Atack, 1985). This decline in establishment number occurred when the market for pig iron was still growing. Although establishment numbers declined, both employees per establishment and real annual product increased. The industry therefore did not shrink, but became concentrated as it grew.

**Figure 1: Pig Iron Establishments and Employees Per Establishment**




Much of the consolidation was probably fuelled by technical innovation. The technological discoveries in the pig iron industry were expensive, but critical. Firms that did not apply them could not remain competitive. The Bessemer process "vastly increased" a firm's ability "to provide steel at a given price," and the open-hearth furnace allowed for huge energy savings through the reuse of exhaust fumes for heating purposes (Termin, 1963:454). However, only those firms with sufficient resources could afford to invest in the necessary capital. The Bessemer process, which was discovered in 1855, and the open-hearth furnace, which was invented in 1865, required large investments in huge converters and furnaces. These investment requirements caused consolidation because small firms could not purchase the required capital by themselves, but needed to do so in order to remain competitive.

Blast furnaces use ore to make pig iron, and pig iron is used to make steel. Vertical integration in the pig iron industry was common in the 1880s and 1890s (Dennison, 1939). The exact causes of integration are under debate, but vertical consolidation was most likely spurred by a desire to ensure continuity and dependability in raw material supply (ibid). For vertical integration to be feasible, however, transportation had to be dependable. Pig iron production, especially integrated pig iron production, relied critically upon it. Mines and power stations were often located far apart from each other, and the fixed capital associated with pig iron production was for all intents and purposes impossible to move (Mancke, 1972). Bessemer converters were very large. The chance of key production units being located next to each other was small. In fact, pig iron producers who wanted to vertically integrate often hunted for specific locations where multiple inputs were located (ibid). Improved transportation, by making the hunt for special locations unnecessary, spurred integration. Improved technology, by lowering costs, made it appealing to have everything occur under a single managerial 'roof' (ibid).

Transportation and technology were mutually dependent in the reshaping of the pig iron industry. Technology spurred investment, but waves of consolidation required reliable connections between geographically separate areas in order to be profitable. Transportation allowed for the expansion of markets, but was not able to spur waves of consolidation by itself. Required investments played a key role by placing pressure upon small firms to integrate and remain competitive in the face of more powerful, more far-reaching, and lower-cost firms.

## The Wool Industry: Low Impact of Transportation – Low Impact of Technology

Atack calculates that wool manufacture had a 2.48 establishment-to-minimum establishment ratio. This industry, unlike pig iron, had characteristics inimical to consolidation. A very significant portion of wool manufacture was carried out in small, dispersed firms, and these firms were often self-contained production entities (Weld, 1912). The exclusion of "hand and neighborhood industries" from the 1904 Census onwards reveals how numerically important these small firms were.

**Table 1. Decennial Change in Number of Firms**

| | Establishments | Percent Change in Establishments |
|---|---|---|
| **1870** | 3,456 | N/A |
| **1880** | 2,689 | -22.19328704 |
| **1890** | 2,489 | -7.437709186 |
| **1900** | 2,335 | -6.187223785 |
| **1909** | 1,115 | -52.248394 |
| **1919** | 1,016 | -8.878923767 |

Besides the ubiquity of small, local-market firms, lack of a standardized product hampered consolidation in the woollen goods industry (Cole, 1923). A woollen product's quality, besides determining what market it will be sold in, directly determines the amount of labour that must be put into its creation. Mass production, and profitable homogeneity, was therefore limited by the varying styles and tastes of wool consumers (ibid). Moreover, wool manufacture cannot rely upon a limited natural resource to facilitate consolidation at a particular location. The wool industry also did not experience major technological change. Steam power revolutionized the industry, but was implemented very early in the 19$^{th}$ century.

Besides creating disincentives to consolidate, the above characteristics dampened the effects of transportation. Wool manufacturers were widespread. Transportation therefore provided little opportunity for market expansion. It also failed to facilitate integration, as it did in the pig iron industry, because vertical integration was already realized to some extent in the self-contained wool manufacturer, and there was no technological development that *had* to be invested in.

## Examination of Capital/Labour Ratios

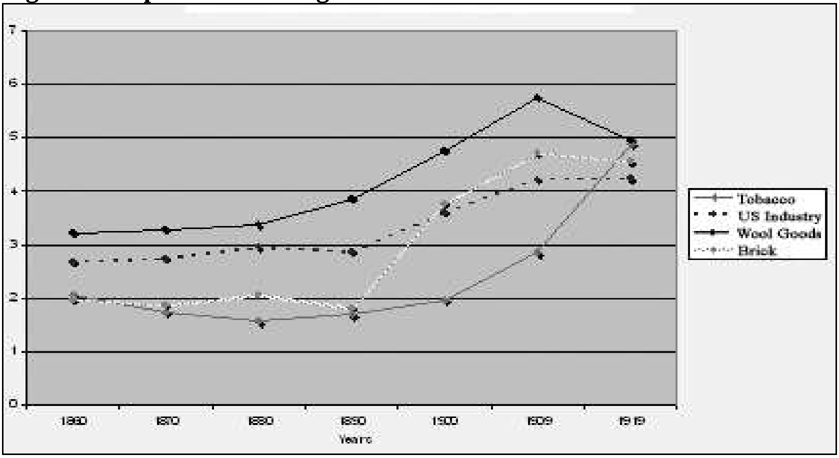
Any examination of capital labour ratio trends should keep in mind that such trends can change for a variety of reasons unrelated to investment in new technology. The real interest rate, aggregate savings, changes in the relative prices of capital and labour, and demography are a few of the factors that can have significant effects upon the K/L ratio (Field, 1987). Inflation is also a problem if employee numbers are used in the calculation. This last problem can be addressed in part by using wages, but such a solution introduces labour market factors which are bound to further complicate analysis.

The elasticity of substitution between capital and labour addresses some of the issues mentioned above. Most importantly, by explicitly factoring in the prices of capital and labour, it accounts for the idea of biased technical change,[2] which can lead to misleading movements in the K/L ratio unrelated to technological innovation (Cain and Paterson, 1986). Theorists generally agree that, if the capital share rises over a given period and if the elasticity of substitution between capital and labour was less than one during that period, some evidence has been found for the presence of a labour-saving bias to technological change (Field, 1987). Many scholars have argued that the elasticity of substitution was below one during the period I am examining, and I will rely upon their arguments in my analysis of capital share trends (ibid).

Figure 2 displays capital/wage lines for three industries from 1860 to 1919.[3] Surprisingly, the wool industry, an industry in which the rate of technological change was low and the effect of transportation was minimal, had a higher K/L ratio than tobacco manufacture, which was revolutionized by the invention of the Bonsack machine, and brick and tile production, which was electrified by the invention of the Vervalen bricking-making machine in 1852 and the steam shovel in 1874. Despite our data, it would be a mistake to conclude that the wool industry was more labour-saving than tobacco and brick manufacture. Besides K/L ratio interpretation problems, a variety of fixed characteristics in wool manufacture may have made that industry's K/L ratio significantly higher than that of industries which actually experienced more significant changes in technology and transportation.

[2] Biased technical change occurs when relative price changes cause producers to change their mix of inputs.
[3] The pig iron industry's ratio was often more than double the value of any other industry's ratio, and its K/L trend was excluded to facilitate comparison.

**Figure 2. Capital Value/Wages Ratio**




Although analysis of a particular industry's characteristics would involve detailed calculations and many assumptions, analysis of Figure 2 suggests an alternative to individual industry analysis. Figure 2 reveals that significant changes, presumably caused by technological innovation and transportation improvements, resulted in significant shifts in the K/L ratio in the 1890s. It also shows that K/L ratios remained fairly stable throughout previous decades. Given the above, an examination of the change in the K/L ratio from the middle to the late 19$^{th}$ century may reveal significant information. By calculating percentage changes, this method can also avoid the pitfall of misinterpreting K/L ratios for industries with significant fixed characteristic effects. However, the approach is not without fault. The proposed analysis must make the assumption that fixed effects for a particular industry do not influence its rate of K/L ratio growth. Ideally, only transportation and technology effects will have had this power. It must also be assumed that overall trends in capital deepening and demography did not overly affect specific industries' K/L ratios to the extent that simple size comparisons between industries become invalid.

Table 2 displays K/L ratio averages for different transportation/technology industries in 1900. Averages were calculated in order to mitigate the effect of outliers.[4]

[4] The meat packing, sawmill, iron foundry, sheet metal, and farm machinery industries were left out of the calculation due to consistent data unavailability.

**Table 2. Examination of K/L Ratios for 1900**

| 1900 | Real 2004 Cap. Value/Employee Number | Current Cap. Value/Wages | Real 2004 Cap. Value/Employee Number | Current Cap. Value/Wages |
|---|---|---|---|---|
| | High Technology | | Low Technology | |
| High Trans | $116,797.57 | 11.03687 | $27,317.90 | 3.389069 |
| Low Trans | $55,434.19 | 6.1623774 | $30,528.11 | 3.862841 |

Given my assumptions and arguments, the data above seem to indicate that high technology industries generally had K/L ratios significantly larger than that of low technology industries. Low technology industries averaged a K/L ratio only 43% of that of high technology industries.[5] Since we would expect an industry in which the effect of technology was significant to have a higher K/L ratio than one in which it wasn't, this finding both checks our method and suggests that the K/L ratio may be able to identify HH industries through ratio size. The HH category's K/L ratio average was 95% higher than that of the category whose K/L ratio average was second highest.

In order to determine whether our preliminary conclusions still hold when the effects of technology and transportation were not significant, the same calculations were performed with 1860 data. Table 3 reveals that HH industries already exhibited K/L ratios in 1860 that were much larger than that of non-Chandler industries. This result is surprising. The Bonsack machine was patented in 1880. The open hearth furnace was invented in 1865. Chilled porcelain and iron rollers for flour mills were developed in the 1860s and 70s. All the industries under examination should not have been consolidated in 1860 to levels outside of the 1870 ranges predicted by Atack (Atack, 1985).

[5] The calculation is done as follows: [(HL/HH) + (LL/LH)] / 2, where LH stands for Low Transportation, High Technology. This calculation is done for both the dollar value K/L and the unit-less K/L, and the two numbers are averaged. All future calculations regarding percent comparisons of the K/L ratio are done in this way.

**Table 3. Examination of K/L Ratios for 1860**

| 1860 | Real 2004 Cap. Value/Employee Number | Current Cap. Value/Wages | Real 2004 Cap. Value/Employee Number | Current Cap. Value/Wages |
|---|---|---|---|---|
| | High Technology | | Low Technology | |
| High Trans | $39,362.80 | 6.77826 | $11,545.17 | 2.330012 |
| Low Trans | $13,801.91 | 2.691653 | $11,562.34 | 2.33379 |

Although neither technological innovation nor consolidation had yet occurred, K/L ratios in 1860 still clearly differentiate HH industries. All of our previous conclusions still apply. To see if the growth rate, rather than the straight value, of the K/L ratio can also identify Chandler industries, I compute average growth rates from 1860 to 1900 for each of the four transportation/technology categories.

Although the absolute average value of the K/L ratio was greater for HH industries than for other industries, Table 4 suggests that the growth rate of the HH industry's K/L ratio was not exceptional. The growth rate of the LH industry, which was more than double that of other industries, dominates.

**Table 4. Examination of the Growth Rate of K/L Ratios between 1860 and 1900**

| 1900 – 1860 | %ΔReal 2004 Cap. Value/Employee Number | %ΔCurrent Cap. Value/Wages | %ΔReal 2004 Cap. Value/Employee Number | %Δcurrent Cap. Value/Wages |
|---|---|---|---|---|
| | High Technology | | Low Technology | |
| High Trans | 196.70% | 63% | 136.60% | 45.50% |
| Low Trans | 301.60% | 128.90% | 164% | 65.50% |

One would expect high technology industries to have similar growth rates that are jointly larger than those of low technology industries. The interaction of transportation and technology may explain the seemingly counter-intuitive results in Table 4. It seems plausible that HH industries, although forced to make investments in new, industry-changing technology, experienced less pressure to directly increase capital holdings because they could ship inputs amongst each other and effectively consolidate and specialize across regions. In other words, transportation improvements may have mitigated HH firms' need to personally invest in capital and technology. They could avoid investment, to some extent, by consolidating and integrating.[6] The LH industry, due to its inability to benefit greatly from improvements in transportation, may have been forced to invest in capital more heavily than its more transportation-adept counterpart. The HH industries, due to fixed characteristics, may have had inherently higher K/L ratios than LH industries, but the effect of transportation may have slowed down HH industry K/L ratio growth, resulting in comparatively greater LH K/L ratio growth in the late 19$^{th}$ century.

## Conclusion

The above analysis suggests that certain general trends in the K/L ratio may be correlated with identification as a Chandler industry. However, many assumptions regarding the elasticity of substitution, movement in the K/L ratio, and general economic conditions had to be made. At this point, to declare that K/L ratios have the power to identify Chandler industries would be a mistake. The discussion notably neglects treatment of economy wide shocks, which could have had different effects upon the industries examined. Generalisation from two observations also runs the risk of selection problems. Finally, non-physical production innovations and their effects upon physical capital and labour were not given any treatment. Technology in this paper was mechanical. A more thorough research effort should expand the scope of analysis and pay more attention to non-physical input factors.

Reservations aside, however, a preliminary look at K/L ratio statistics seems to indicate that there may be a relationship between these ratios and Chandler industries. As expected, high technology industries had K/L ratios much higher than that of low technology industries. As posited in the analyses of the pig iron and woollen manufacture industries, interaction

[6] The pig iron industry, discussed above, was a model for this sort of consolidation. Aggregate capital stock growth rates hit a trough for the industry during the 1890s.

between transportation and technology was important. Large transportation effects did little to change the K/L ratio in low technology industries, but may have been responsible for LH industries' surprising K/L ratio growth. Chandler industries had inherently high K/L ratios, but significant transportation effects may have slowed K/L ratio growth in these industries by allowing them to adapt to technological change without going all out on investments in physical capital. LH industries may have had no other choice but to buy the new machines themselves.

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