Title

Industrialization and Urbanization: Did the Steam Engine Contribute to the Growth of Cities in the United States?

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Did the Steam Engine Contribute to the Growth of Cities in the United States?

by

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Abstract

Industrialization and urbanization are seen as twin processes of economic development. However, the exact nature of their causal relationship is still open to considerable debate. This paper uses firm-level data from the manuscripts of the decennial censuses between 1850 and 1880 to examine whether the adoption of the steam engine as the primary power source by manufacturers during industrialization contributed to urbanization. While the data indicate that steam-powered firms were more likely to locate in urban areas than water-powered firms, the adoption of the steam engine did not contribute substantially to urbanization.

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I. Introduction

Economic historians have long been concerned with whether the nature of technological innovations responsible for industrial revolution or modern economic growth is defined by small incremental continuous changes or by sharp episodic discontinuous jumps. For Mokyr (1990), the British industrial revolution was a discontinuous process caused by a sudden concentration of radically new macro-inventions. However, Sokoloff (1988) and Sokoloff and Khan (1990) find that the inventive activity during early industrialization in the United States increased in response to demand and that the supply elasticity of inventive activity was relatively flat suggesting that the expansion of markets led to a continuous, incremental flow of inventions into the marketplace. For Rostow (1960), modern economic growth was characterized by a discontinuous take-off stage powered by the introduction of major single inventions such as a railroad; however, Fogel's (1964) social savings estimate of the railroad was too modest to suggest that single inventions were likely to lift an economy upwards.

The debate on the nature of technological changes responsible for economic development or growth has re-emerged recently with the idea of a general purpose technology. A concept introduced by Bresnahan and Trajtenberg (1995), a general purpose technology is defined as having three key characteristics: technological pervasiveness, dynamism and complementarities. The existence of such a technology implies that economic growth is a discontinuous process characterized by sudden a acceleration of productivity as the technology is invented, adopted, diffused, and exhausted. The most frequently cited examples of general purpose technologies are the steam engine, the electric motor, and the computer, but other technologies such as the waterwheel, and the internal combustion engine have also been identified as potential candidates.[1]

Most empirical studies of general purpose technologies have used the growth accounting framework to estimate their impact on the economy. Oliner and Sichel (1994) estimate the impact of computers on labor productivity in the early 1990s for the United States and find that their impact was relatively small. However, when the industry was expanded to include all information technologies, Oliner and Sichel (2000) find that the impact was much more significant. Crafts (2004) and Crafts and Mills (2004) estimate the impact of the steam engine on UK economic growth in the nineteenth century and find that the contribution was relatively modest. Ark and Smits (2004) examine the diffusion of the steam engine, electricity and information technologies for many European nations and the United States and study their impact on productivity. They find that the diffusion and productivity effects of general purpose technologies varied greatly by industries, countries and time.

While there is no consensus on the economic impact of general purpose technologies, one major lesson which emerges from the growth accounting based empirical literature is that the direct impact of any single invention, even a general purpose technology, is likely to be small. The results of Oliner and Sichel (1994) and Crafts (1994) indicate that, from a growth accounting perspective, even general purpose technologies such as computers and steam engines are simply too small relative to the overall economy to have a major impact on aggregate productivity. While redefining a general purpose technology from computers to include all information technologies increases the economic impact of this sector on the economy, the change in definition implicitly acknowledges the limited impact of any single inventions.

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1 Lipsey, Bekar and Carlaw (1998) provide a useful review of the theoretical concept, definition and identification of

However, the results of the growth accounting literature on general purpose technologies are unlikely to settle the debate on the economic impact of these technologies. Most models of general purpose technologies assume that the most important economic impact of these technologies are caused by their increasing returns properties. Bresnahan and Trajtenberg (1995) emphasize two types of externalities: one between general purpose technology and those that uses the technology and across the general purpose using sectors. Since the neoclassical growth accounting framework assumes constant returns to scale, it cannot hope to estimate the indirect effects of general purpose technologies from external economies. Similar arguments were proposed by Rostow (1960) who argued that the most important economic impact of the railroad was not the decline in transportation costs but the external effects on other industries.

Unfortunately, it is extremely difficult to estimate the external benefits of general purpose technologies. Recently, Rosenberg and Trajtenberg (2004) propose that the indirect external benefits of steam engines can be measured by estimating their impact on urbanization. For these scholars, the Corliss steam engine, which became the dominant design for stationary, high-powered engines in the late nineteenth century, was a general purpose technology that triggered economic growth in the late nineteenth century U.S. By releasing firms from the locational limitations of topography and climate and offering them the freedom to locate in cities, Rosenberg and Trajtenberg (2004, p. 94) believe that "the deployment of Corliss engines served as a catalyst for the relocation of industry away from rural areas and into large urban centers, thus fueling agglomeration economies, attracting further population, and fostering economic growth."

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general purpose technologies.

This paper uses firm-level data constructed from the manuscript censuses of manufactures by Jeremy Atack, Fred Bateman and Thomas Weiss to explore whether the steam engine was responsible for the growth of cities in the late nineteenth century.[2] Empirical estimates indicate that steam-powered firms were on average about seven times more likely to locate in urban areas than water-powered firms between 1850 and 1880. However, hand-powered firms were more likely to locate in urban areas than steam-powered and water-powered firms. Thus, if firms shifted their power source from hand to steam, then these firms were less likely to locate in urban locations. Firms who used animal power were more likely to locate in urban locations than water-powered firms but less likely than steam-powered firms.

While the steam-powered firms were more likely to reside in urban locations than water-powered firms, the data analysis suggests that the adoption of the steam engine for primary power source was likely to have had only a modest impact on urbanization.[3] If about 11% of water-powered firms chose to locate in urban areas, the odds-ratio implies that about 46% of the steam-powered firms chose urban locations. A simple counter-factual calculation suggests that the adoption of the steam engine may have contributed to about 16% of the increase in urban firms between 1860 and 1880; however, for urban employment, the contribution is likely to be lowered by about half. When other factors such as power intensities are taken into account, the contribution of steam to urban growth is likely to be even smaller. Thus, contrary to the claims made by Rosenberg and Trajtenberg (2004), the steam engine was unlikely to have been a major enabling technology for urbanization.

2 See Atack and Bateman (1999) for a description of the data.

3 Unlike Rosenberg and Trajtenberg (2004), who focus only on Corliss steam engines, this paper uses data on all steam engines. While Corliss steam engines may have been more efficient than their rivals, there is no reason to believe that location advantages of steam engines applied only to the Corliss type.

II. Industrialization and Urbanization in the Late Nineteenth Century

This paper uses the Atack-Bateman-Weiss (ABW) sample of manufacturing firms drawn from the manuscripts of the decennial censuses for 1850, 1860, 1870 and 1880 to examine whether the adoption of the steam engine contributed to urbanization in the late nineteenth century.[4] The random samples of national firms contain between 4,582 and 5,920 firms per census year.[5] The data include firm level information on output, raw materials, capital, labor, wages, and primary power source. For 1850-1870, the data contain information on five types of power sources: water, steam, hand, animal, and combination. For 1880, the data contain information on only two power sources, water and steam.[6] The ABW data contain information on the location of firms at the county level and whether its location is urban or rural. The firms are categorized by standard industrial code (sic) at the 3-digit industry level.

Unlike the trend in the share of urban population seen in Figure 1, the growth in the share of urban manufacturing was uneven between 1850 and 1880. Tables 1 and 2 show that, although the shares of urban establishments and employment rose from 26 to 33% and 44 to 54% between 1850 and 1860 respectively, these gains were essentially erased by 1870.[7] However, these figures rose

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4 Atack, Bateman and Margo (2002, 2003, 2004) use the same census manuscript data in their studies of industrialization in the late nineteenth century.

5 From the original Atack-Bateman-Weiss sample, this paper eliminated firms that were not categorized as manufacturing firms and those that reported zero or no values for labor, output, and other pertinent variables.

6 It is important to note that the so-called special agent industries are under-represented in the 1880 sample (see the discussion in Atack, Bateman and Margo (2004)). Because Atack and Margo suspect that large urban firms in the special agent industries were especially likely to be under-enumerated, it is important to re-weight these industries to match the aggregate published data or to examine if the results are not sensitive to the under-enumeration of special-agent industries. I am grateful to Bob Margo for pointing out the problems associated with the special-agent industries as well as for suggesting potential remedies.

7 The declines in the shares of urban firms and establishments between 1860 and 1870 are more likely due to sampling

dramatically between 1870 and 1880, rising to 47% and 70% respectively. The regional variations in the share of urban firms and employment of the ABW data also differed markedly from that of the overall population shown in Figure 2. By 1880, however, the ABW data matched the overall urban population data, and exhibited the emergence of north-south divergence in urbanization.

Tables 3 and 4 show that the tendency to locate in urban areas varied by industries for the firms in the ABW sample. Firms in tobacco, apparel, printing and miscellaneous industries were much more likely to reside in urban areas than those in other industries throughout the sample period. On the other hand, firms in food and lumber and wood were much more likely to reside in rural areas. For firms in some industries such as textiles and primary metals, the locational patterns shifted somewhat over time as they became more concentrated in urban areas.

The primary sources of inanimate power for manufacturing shifted from water to steam between the early and the late nineteenth century (see Fenichel (1979), Atack (1979) and Rosenberg and Trajtenberg (2004)). The data in Table 5 show that steam overtook water power capacity in manufacturing by 1870 and that there was considerable regional variation in steam and water power capacities. In particular, the New England and South Atlantic regions possessed higher capacity for waterpower than other regions. The data on power usage by the random sample of firms in the ABW sample reported in Table 6 correlate surprisingly well with the overall power capacity in manufacturing. Like the aggregate data, more firms in the ABW sample used steam as compared to water power by 1870. Moreover, the firms in the New England and South Atlantic regions (and Middle Atlantic in 1880) of the ABW sample were also less likely to use steam compared to those in other regions.

complications associated with the 1870 data, perhaps an under-enumeration of firms in the South.

Table 7 presents information on manufacturing power intensities for both the aggregate and the ABW sample of firms in 1880. Data from Fenichel (1979) for all manufactures indicate that the ratio of horsepower to labor was significantly higher for food, lumber and wood, paper and primary metals. In general, there was a positive correlation between the ratios of water and steam power to labor by industries. But there were exceptions: the firms that used waterpower in the paper industry were much more likely to use higher levels of horse power per worker than those that used steam, but the pattern was reversed for the firms in the primary metals industry. Once again, despite some notable differences from the aggregate published data, power intensities of the ABW sample of firms correlate well with that of all manufacturing. One notable difference is that the firms in the ABW sample that used water power, unlike those of all manufactures, used higher horsepower per worker than firms that used steam.

Finally, Table 8 provides descriptive statistics for rural and urban firms in the ABW sample for 1850-1880. The data show that urban firms were larger than rural firms by a variety of measures. In all years, urban firms exhibited higher levels of output, input, capital, and labor employed than rural firms. Employees in urban firms also received higher wages. While the urban firms were generally larger than rural firms, their factor intensities, measured by ratios of capital and inputs to labor, respectively, were relatively similar to those of rural firms. In general, the composition of employees favored men in rural firms whereas it favored women in urban firms. Urban firms were much more likely to operate full time all year around than rural firms.

While rural firms were much more likely to use water than steam power, the share of firms that used steam power did not differ greatly between rural and urban firms. Table 8 shows that 22% to 38%

of the rural firms in the ABW sample indicated waterpower as their primary energy whereas only 4% to 8% of the urban firms used waterpower between 1850 and 1880.

As for steam power, urban firms were more likely to use steam than rural firms in 1850, but the pattern was reversed in 1880. Throughout 1850-1870, the period for which the data are available, hand power was reported as the most widely used power source, especially for urban firms.

III. Did the Steam Engine Contribute to the Growth of Cities?

To assess whether the adoption of the steam engine led firms to locate in urban areas, we select a discrete choice model where the dependent variable takes on a value of 1 if a firm is located in an urban area and 0 if it is located in a rural area. More specifically, the regression estimates are based on the logit model of the following form:

(1) $ln[P_i/(1 - P_i)] = a + ß_1\ Location_i + ß_2\ Industry_i + ß_j\ S_j\ X_{ji} + ß_k\ S_k DPower_{ki} + u_i$

where P_i is the probability that a firm i is located in an urban area and $(1-P_i)$ is the probability that it is located in a rural area. To estimate the impact of primary power sources on location, we construct dummy variables for various power sources. For 1850-1870, dummy variables are created for water, steam, hand, and combination; the omitted category is animal power. For 1880, we create dummy variables for firms that utilized water, steam and combination of water and steam where the omitted category is all other firms that used neither water nor steam power.[8] In addition, for 1880, we run a second set of regressions using the levels of horsepower of water and steam power.

8 In the years between 1850-1870, the census data reported whether a firm used a particular type of power (water, steam, hand, animal, combination) and the overall amount of horsepower used. In 1880, data on power sources only reported the overall amounts of water and steam power used by a firm and did not report information on other types of power. To make the 1880 data somewhat comparable to those of earlier years, dummy variables are created

To control for other factors that may cause a firm to locate in an urban or a rural area, we include as independent variables, X_{ji}'s, that capture a firm's other technological characteristics such as capital and raw materials intensities, the share of male employees, and whether a firm operated over the full year. For additional controls, we use locational fixed-effects at the county level and industry fixed-effects at the 3-digit industry level to sweep out any locational and technological factors that also determine firm location. Finally, to examine the impact of location and industry fixed-effects on urban location, we estimate the logit regressions using dummy variables for US Census regions as well as for 2-digit industry categories.

Estimating the Determinants of Urban Location

The logit regression is estimated for two different specifications. One specification uses the establishment as the unit of observation whereas the second specification is weighted by employment. These two different specifications are likely to capture different types of agglomeration economies. The un-weighted logit regression may capture some type of agglomeration economies such as information spillovers or the presence of non-traded industry specific inputs whereas the employment-weighted regression is more likely to capture agglomeration economies from labor market pooling.

<u>Logit Regression Estimates For Establishments</u>

Table 9 reports the un-weighted logit regression estimates in terms of odds-ratios for locating in urban areas for 1850, 1860, 1870 and 1880. Controlling for locational and industry fixed-effects and firm technological characteristics, the data show that steam-powered firms were more likely to locate in urban locations than water-powered firms. In 1850, steam-powered firms were 14 times more likely to

depending upon whether the firm reported positive values only for water or steam or for both (combination).

locate in urban areas than water-powered firms. The odds-ratio fell to 6.5 and 4.5 in 1860 and 1870 respectively but then rose again to 8 in 1880. However, the data also show that steam-powered firms were less likely to locate in urban locations than hand-powered firms. For the period between 1850 to 1870, hand-powered firms were 1.2 to 1.4 times more likely to locate in urban areas than steam-powered firms. By contrast, the residual category of firms that used animal or a combination of different power sources was generally more likely to reside in urban areas than water-powered firms but less likely when compared to steam-powered and hand-powered firms.

Although the steam-powered firms were more likely to locate in urban locations than water-powered firms, firms that used higher levels of horsepower were more likely to locate in rural areas. The logit regressions for 1850 to 1870 show that an additional increase in horsepower per worker lowered the odds of a firm locating in an urban area by 0.85 to 0.91. For 1880, the logit regression estimates indicate that a unit increase in steam power lowered the odds of locating in urban locations by 0.82 whereas a similar unit increase in water power lowered the odds of locating in urban locations by 0.77.[9] Moreover, these odds-ratios indicate that a unit increase in the use of steam compared to water power increased a firm's likelihood of locating in urban locations by only 1.1 (0.82/0.75). Thus, steam-powered firms that used horsepower intensely were only slightly more likely to locate in urban areas than water-powered firms.

Table 11 reports the pooled logit regression estimates for years 1850-1870 and for all years 1850-1880. For the un-weighted regression, steam-powered firms were 6.3 times more likely to locate in urban areas for the full sample; for the pooled sample for 1850-1870, steam powered firms were 6.7

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9 If a one-unit increase in horsepower for steam and water lowered the odds for locating in urban areas by 0.87 and

times more likely to locate in urban areas than water-powered firms. Hand-powered firms were 1.4 times more likely to locate in urban areas than steam-powered firms. The pooled regressions also indicate that firms that were intensive in male labor and horsepower were less likely to locate in urban locations.

For the full sample, dummy variables on years indicate that firms in 1860 and 1880 were 1.5 to 3.6 times more likely to reside in urban areas and firms in 1870 were 0.7 times less likely to locate in urban areas than those in 1850. However, the pattern is reversed for 1870 when one controls for the level of horse-power intensity. For the sub-sample, 1850-1870, when the regression controls for horse-power ratio, the odd-ratio for 1870 goes from 0.7 to 1.3. Thus, despite the fact that the ratio of urban to rural firms fell sharply in 1870 in the ABW sample as reported in Table 1, when one controls for economic factors as well as horse-power intensity, it appears that firms generally became more urban over time.

Other technological characteristics also influenced urban locations to some extent. In all specifications, logit regressions find that input and capital intensities were statistically significant but not economically significant in that the odd-ratios for locating in an urban area were close to 1. However, firms that used male labor and horsepower more intensely were both less likely to locate in urban locations. For the entire pooled-sample, a unit increase in male intensity led to lower odds of locating in urban locations by 0.22. For the sub-sample period, 1850-1870, an increase in a unit of horsepower intensity lowered the odds of locating in urban locations by 0.92.

<u>Logit Regression Estimates Weighted by Employment</u>

0.77 respectively in 1880, a ten unit increase in horsepower lowered these respective odds to 0.14 and 0.07.

In general, the logit regression estimates weighted by employment reported in Tables 10 and 11 differ from the un-weighted estimates in their size rather than sign of coefficients. Except for 1860, the relative odds of steam-powered employees compared to that of water-powered employees locating in urban areas declined. The relative odds fell from 14 to 5 in 1850, from 4.5 to 2.9 in 1870, and from 7.8 to 6.6 in 1880; however, in 1860, the relative odds rose from 6.5 to 10. [10] For the entire pooled sample, 1850-1880, the relative odds fell by half from 6.3 to 3.2; for the sub-sample, 1850-1870, the ratio fell from 6.7 to 5.1. [11] In addition, employees who used horsepower more intensely were even more less likely to locate in urban areas as compared to the un-weighted logit estimates whereas the coefficient increased appreciably for firms that used male labor more intensely.

A Counter-factual Exercise

While the logit regressions based on dummy variables on power sources indicate that steam-powered firms were much more likely to be located in urban areas than water-powered firms, it is important to estimate the steam engine's overall impact on urbanization. Over the late nineteenth century, between 1850 and 1900, the share of the overall urban population increased from 15.3% to

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10 As noted earlier, the 1880 data are subject to under-enumeration of special-agent industries. The special agent industries in the ABW sample comprise of 0.0258 and 0.0259 of establishments and employment respectively; however, these industries make up 0.046 and 0.226 in the published aggregates. As suggested by Bob Margo, the 1880 regressions were also run when the special-agent industries of the ABW data were adjusted to match the published aggregates. The special-agent adjusted regressions were essentially identical to those reported in table 10 for 1880. For equation (4) in Table 9, the coefficient on steam fell slightly from 1.18 to 1.03 and the coefficient on water increased slightly from 0.18 to 0.23. Thus, the relative odds of steam-powered employees locating in urban areas compared to water-powered firms declined from 6.6 to 4.5 when the data were adjusted for special-agent industries. A closer examination of the data reveals that although the 1880 special agent industries in the ABW sample were smaller than their counterparts in 1870, they were over-represented in urban areas in 1880 compared to 1870.

11 To make sure that the regression estimates were not sensitive to the special-agent industries in 1880, the pooled regressions were also run for the entire sample consisting only of non-special agent industries. Once again, the regression estimates were very similar to those reported in table 11.

39.7%. But how much of the increase in urbanization over the late nineteenth century can be accounted for by the adoption of the steam engine? The following counter-factual exercise suggests that the role of steam as a catalyst for urbanization may have been over-emphasized.

We can use the odds-ratios estimated from the logit regressions to estimate the impact of steam on urbanization. If we let P and Q be the probabilities that steam-powered and water-powered firms are likely to locate in urban areas respectively, then the ratio (P/1-P)/(Q/1-Q) captures the odds that steam-powered firms are more likely to locate in urban locations than water-powered firms. The logit regression estimates based on power source dummy variables suggest that this odds-ratio ranges from 3 to 10; for this exercise, we use an odds-ratio of 7. If we assume that Q=0.11, then P=0.46. Thus, the odds-ratio indicates that 46% of the firms that adopted the steam engine were likely to locate in urban areas.

The data in Table 6 show that 816 firms or 15% used steam power in 1860 and that this figure rose to 1,468 or 20% in 1880. Thus, over these two decades, there was an increase of 652 firms who adopted the steam engine. Of these, 300 firms are likely to locate in urban locations because it adopted the steam engine. Since there was an increase of 1833 additional firms in urban locations over this period, the adoption of steam power potentially accounts for a little over 16% of the overall increase in urban firms over this period.

There are many reasons to believe that the impact of the steam engine on urbanization was considerably lower. First, the counterfactual calculation presented above is based on firms rather than employment. The logit regressions weighted by employment suggest that the relative odds-ratio of locating in urban areas by steam-powered employees relative to water-powered employees was only about half that of establishments or firms.[12] Second, firms that used steam-power more intensely were more likely to reside in rural rather than in urban areas. If one accounts for the level of power used by firms, the role of steam declines even more. Third, the calculation was based on the assumption that all firms who adopted the steam-engine shifted away from water rather than from other types such as hand or animal power. Finally, the logit regressions reported in Tables 9-11 assume that the decision to adopt the steam engine or water power is exogenous. If the choice of power source is also endogenous, then there may be an endogeneity bias in the regression estimates because urban firms were more likely to adopt steam engines rather than water wheels.[13] Consequently, the coefficients on steam-power in tables 9-11 are likely to be biased upwards whereas those on water-power are likely to biased downwards.

Decomposing Locational and Industry Fixed-Effects

Table 12 decomposes the locational fixed-effects by estimating the logit regressions based on dummy variables for U.S. census regions rather than county fixed-effects. Since the missing category is the East South Central region, the odds-ratios reported are relative to that region. Although firms in other regions were more likely to locate in urban areas than firms in the East South Central region for all years, the regressions show changing geographic patterns over time. In 1850, firms in the Pacific, West North Central, South Atlantic and Middle Atlantic regions were most likely to locate in urban areas;

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12 When the logit regressions were estimated for samples of firms restricted to those with more than 5 employees, the relative odds ratios of locating in urban areas for steam-powered versus water-powered firms for all years was smaller than that for the full sample.

13 Rosenberg and Trajtenberg (2004) find that the adoption of the Corliss steam engine is positively correlated with population at the county level, a good proxy for urbanization.

they were followed by firms in the East North Central and New England regions. In 1860 and 1870, there are considerable fluctuations in the relative rankings of regions. However, by 1880, firms in the northern regions, East North Central, Middle Atlantic and New England were more likely to locate in urban areas than those in the southern regions, especially the East and West South Central regions.

The manuscript census data on manufactures indicate that some industries were much more likely to locate in urban areas than others. Table 13 examines the role of industry fixed-effects by estimating logit regressions based on dummy variables for 2-digit industries. The omitted industry was stone, clay and glass (sic 32), as well as a few other manufacturing industries (sic 29, sic 30, sic 36, sic 38) whose sample sizes were very small. While there were considerable variations in the data, the logit regressions show that firms in some industries such as lumber and wood, chemicals, leather, and transportation were relatively more likely to locate in rural areas; on the other hand, firms in printing, miscellaneous and apparel manufactures were generally more likely to locate in urban areas.[14]

While it is difficult to infer causal factors from the industry dummy variables, it is interesting to note that most of the industries that were more likely to locate in rural areas were intensive in raw materials derived from agriculture and forests. On the other hand, the industries that were more likely to locate in urban areas were mostly labor intensive such as printing, miscellaneous and apparel, and to a lesser extent tobacco and textiles industries. Data in Table 7 indicate that those industries that were more likely to locate in rural areas were much more intensive in horsepower per worker (for both steam and water) whereas those industries that were more likely to locate in urban areas were much less

14 These industry patterns are consistent with those found in Kim (2000). For 1880, Kim finds that apparel and printing industries were over-represented in the largest cities whereas the lumber and wood industry was severely under-represented.

intensive in both types of power.

IV. Conclusion

In recent years, the debate on whether economic growth is characterized by discontinuous technological shocks or by continuous incremental accumulations in knowledge has resurfaced in the idea of general purpose technologies. Yet, despite the current interest in the theory of general purpose technologies, there is little empirical evidence on their economic importance. In fact, studies based on the standard growth accounting framework suggest that the direct impact of general purpose technologies such as computers or steam engines on aggregate productivity is likely to be small (Oliner and Sichel (1994), Crafts (2004) and Crafts and Mills (2004)).

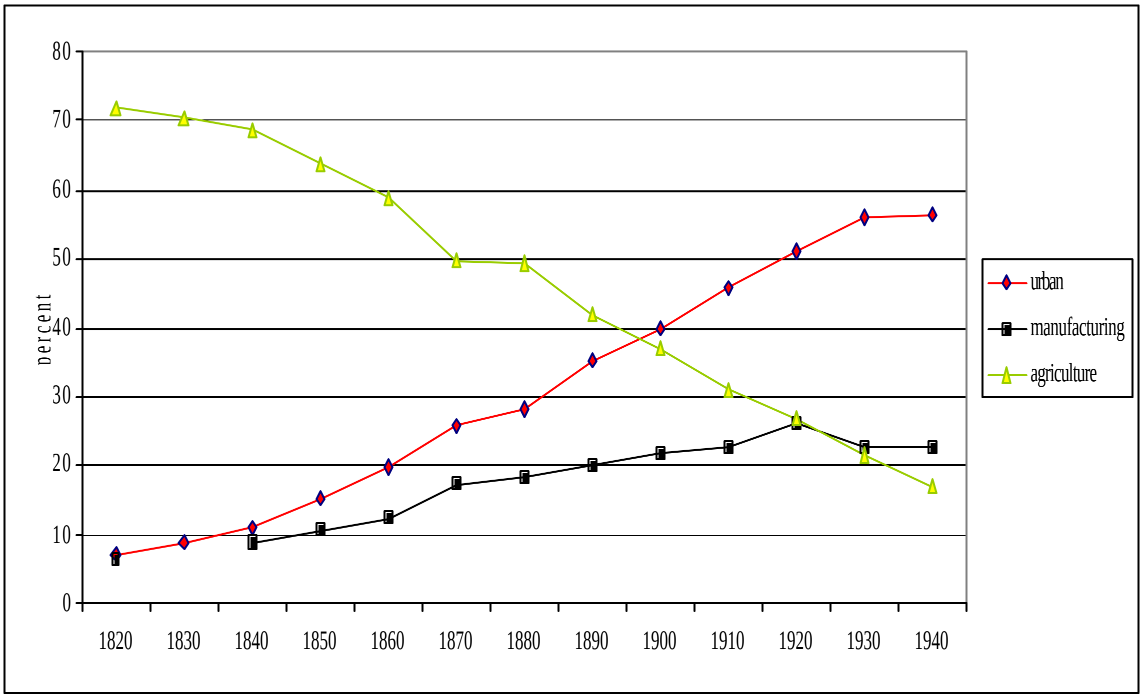
However, the proponents of the theory of general purpose technologies believe that the economic impact of these types of technologies are unlikely to be captured through a neoclassical growth accounting exercise since the benefits of general purpose technologies are likely to be caused by external economies. Thus, Rosenberg and Trajtenberg (2004) argue that the economic impact of steam engines is more likely to be captured by estimating their impact on urbanization. They believe that the Corliss steam engine, by allowing firms to capture agglomeration economies in cities, contributed significantly to raising aggregate productivity.

This paper uses firm level data constructed from the manuscript censuses by Atack, Bateman and Weiss to examine whether the steam engine was responsible for the rise of urbanization during the second half of the nineteenth century in the United States. While the data indicate that steam-powered firms were more likely to locate in urban areas than water-powered firms, the steam engine is unlikely to be the cause of urban growth during this period. A simple counter-factual calculation, based on the estimate that steam-powered firms were on average about seven times more likely to locate in urban areas than water-powered firms, indicate that the steam engine may account for about 16% percent of the increase in urbanization between 1860 and 1880. However, the actual figure is likely to be considerably less for a variety of reasons. Steam-powered employees were only three rather than seven times more likely to locate in urban areas than water-powered employees and firms that used steam-power more intensely were more likely to reside in rural locations.

In sum, there seems to be little evidence that the steam engine was a source of discontinuous economic growth in the late nineteenth century United States. The invention of the steam engine was unlikely to have had a singular impact on urbanization. Moreover, even if the shift in the source of inanimate power from water wheels to steam engines contributed to urbanization in the late nineteenth century U.S., there is little evidence that this shift in power sources unleashed the benefits of agglomeration economies as claimed by Rosenberg and Trajtenberg (2004). Just as likely, steam-powered firms chose urban locations because coal prices were cheaper in these locations. Steam-powered firms may have been more mobile than water-powered firms, but they were also dependent upon supplies of coal. Thus, steam-powered firms may have chosen urban locations due to the simple benefits of hub and port economies of railroad and water transportation rather than due to the benefits of Marshallian type agglomeration economies.

Figure 1

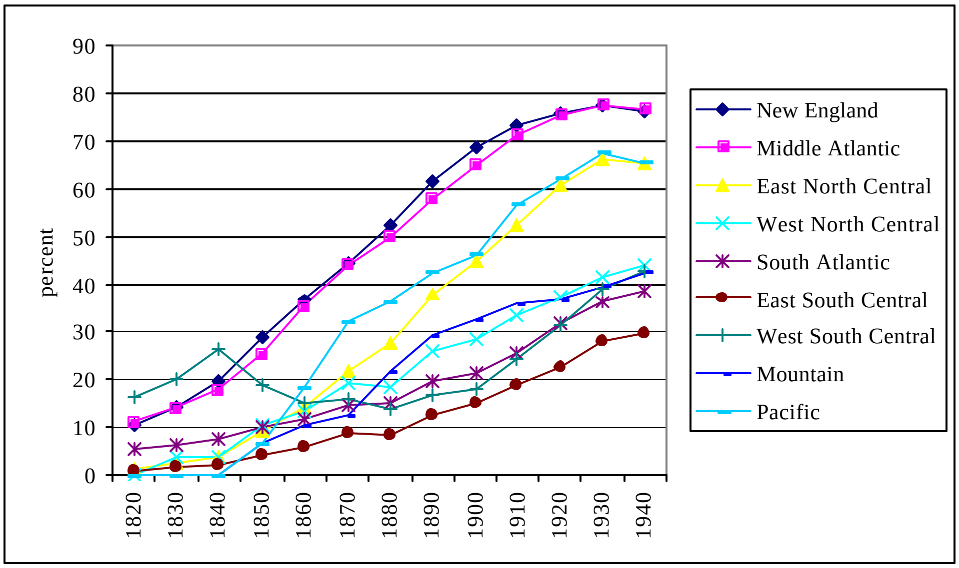
Share of Urban Population and Shares of Agriculture and Manufacturing Labor Force, 1820-1940



Sources: Historical Statistics of the United States, 1977 and Census of Population, 1960.

Figure 2

Share of Urban Population by Region, 1820-1940



Source: Leven (1993)

Table 1

Share of Urban Manufacturing Establishments by Region:
Data from the Census Manuscripts (percentage)

	1850	1860	1870	1880
United States	26.1%	33.1%	23.5%	47.2%
New England	22.6	28.1	23.1	55.6
Middle Atlantic	28.9	44.0	27.6	54.2
East North Central	18.1	27.0	18.6	46.4
West North Central	38.1	34.1	22.6	41.2
South Atlantic	35.7	26.4	14.5	34.9
East South Central	13.1	15.5	27.6	23.6
West South Central	13.3	6.1	17.4	29.8
Mountain	-	-	-	-
Pacific	80.4	29.5	47.9	57.5

Sources: See Atack and Bateman (1999).

Table 2

Share of Urban Manufacturing Employment by Region:
Data from the Census Manuscripts (percentage)

	1850	1860	1870	1880
United States	43.6%	54.2%	45.5%	70.1%
New England	39.7	42.4	30.4	69.8
Middle Atlantic	46.8	69.2	59.6	77.1
East North Central	37.0	36.7	35.7	71.5
West North Central	54.9	45.1	38.2	65.1
South Atlantic	52.7	62.6	13.0	58.7
East South Central	33.9	29.2	62.7	43.6
West South Central	6.0	33.6	26.1	27.9
Mountain	-	-	-	-
Pacific	73.6	54.2	59.8	51.7

Sources: See Atack and Bateman (1999).

Table 3

Share of Urban Manufacturing Establishments by Industry:
Data from the Census Manuscripts
(percentage)

	1850	1860	1870	1880
20 Food	19.9%	27.6%	16.6%	34.7%
21 Tobacco	47.5	70.6	39.9	80.0
22 Textiles	14.1	31.1	23.0	70.8
23 Apparel	59.2	70.1	42.6	83.3
24 Lumber	11.3	14.7	10.7	20.4
25 Furniture	36.2	39.9	33.9	63.9
26 Paper	28.1	41.9	29.6	67.9
27 Printing	76.1	60.5	40.6	91.2
28 Chemicals	33.9	39.4	33.8	67.8
29 Petroleum	-	-	-	-
30 Rubber	-	-	-	-
31 Leather	23.2	33.9	21.2	46.2
32 Stone	36.7	38.3	32.1	38.3
33 Primary	16.9	45.2	28.6	61.7
34 Fabricated	41.7	48.0	38.5	80.2
35 Machinery	35.4	37.2	33.9	53.0
36 Electrical	-	-	-	-
37 Transportation	20.6	28.9	21.4	41.7
38 Instruments	57.1	-	-	81.5
39 Miscellaneous	70.0	63.4	40.0	80.6
All Manufactures	26.1	33.1	23.5	47.2

Sources: Atack and Bateman (1999).

Table 4

Share of Urban Manufacturing Employment by Industry:
Data from the Census Manuscripts
(percentage)

	1850	1860	1870	1880
20 Food	40.3%	55.1%	49.8%	63.1%
21 Tobacco	62.8	69.4	61.2	89.0
22 Textiles	32.4	47.2	38.9	81.2
23 Apparel	79.2	81.7	55.0	86.1
24 Lumber	22.1	38.3	16.9	31.5
25 Furniture	52.6	49.4	56.3	72.7
26 Paper	43.1	59.2	27.5	75.0
27 Printing	85.3	84.3	74.8	98.3
28 Chemicals	45.9	54.3	20.7	42.5
29 Petroleum	-	-	-	-
30 Rubber	-	-	-	-
31 Leather	38.7	42.8	37.0	69.2
32 Stone	51.2	54.6	45.1	46.6
33 Primary	12.1	57.1	49.7	73.3
34 Fabricated	53.4	66.7	45.7	73.1
35 Machinery	79.6	65.7	60.4	66.0
36 Electrical	-	-	-	-
37 Transportation	29.4	43.3	32.7	82.4
38 Instruments	41.9	-	-	95.5
39 Miscellaneous	84.7	77.1	72.7	88.3
All Manufactures	43.6	54.2	45.5	70.1

Sources: Atack and Bateman (1999).

Table 5

Power Capacity by Region for All Manufacturers
(thousand horsepower)

	1870			1880		
	Water	Steam	Steam (percent)	Water	Steam	Steam (percent)
United States	1,130	1,216	52%	1,225	2,185	64%
New England	362	153	30%	423	320	43%
Middle Atlantic	376	380	50%	357	710	67%
East North Central	150	381	72%	158	650	80%
West North Central	37	89	70%	71	150	68%
South Atlantic	140	70	33%	146	149	51%
East South Central	41	68	62%	43	110	72%
West South Central	4	42	91%	5	53	91%
Mountain	7	10	59%	9	8	47%
Pacific	14	22	61%	15	36	71%

Source: Fenichel (1966).

Table 6

Data from Census Manuscripts: Power Usage by Region

	1870 (number of firms)				1880 (thousand horsepower)		
	Water	Steam	Steam (percent)		Water	Steam	Steam (percent)
United States	702	816	54%		30.1	55.8	65%
New England	179	76	30%		7.0	6.1	47%
Middle Atlantic 248	201	45%		10.9	14.6	57%	
East North Central	103	329	76%		4.5	17.1	79%
West North Central	29	95	77%		2.4	5.3	69%
South Atlantic	98	37	27%		3.5	5.8	62%
East South Central	40	58	59%		1.2	3.0	71%
West South Central	5	12	71%		0.1	1.6	94%
Mountain	-	-	-		-	-	-
Pacific	10	13	57%		0.5	2.3	82%

Sources: Atack and Bateman (1999).

Table 7

Ratio of Water and Steam Power to Labor, 1880
(horsepower per worker)

	Census of Manufactures		Sample from the Manuscript Census	
	water/labor (1)	steam/labor (2)	water/labor (3)	steam/labor (4)
20 Food	2.14	1.84	4.44	1.76
21 Tobacco	-	0.06	0.05	0.02
22 Textiles	0.54	0.62	1.05	0.67
23 Apparel	0.01	0.04	0.03	0.02
24 Lumber	1.16	2.43	1.95	2.17
25 Furniture	0.11	0.35	0.33	0.30
26 Paper	2.09	0.86	1.81	1.03
27 Printing	0.01	0.17	0.01	0.69
28 Chemicals	0.12	0.88	0.35	0.70
29 Petroleum	-	0.70	-	-
30 Rubber	0.18	0.67	-	-
31 Leather	0.04	0.12	0.09	0.13
32 Stone	0.03	0.27	0.30	0.24
33 Primary	0.11	2.41	0.09	0.27
34 Fabricated	0.12	0.42	0.28	0.38
35 Machinery	0.14	0.61	0.40	0.66
36 Electrical	-	-	-	-
37 Transportation	0.04	0.25	0.22	0.17
38 Instruments	0.05	0.16	0.01	0.14
39 Miscellaneous	-	-	0.07	0.13
All Manufactures	0.47	0.83	1.51	0.97

Sources: Data for the Census of Manufactures (1) and (2) are from Fenichel (1979). Data for manuscript census (3) and (4) are from Atack and Bateman (1999).

Table 8

Descriptive Data on Firms from the Manuscript Censuses, 1850-1880
(mean values)

All Firms	1850	1860	1870	1880
Output	9,806	15,575	25,339	25,388
Input	5,363	8,888	14,505	16,843
Labor	9.4	10.6	11.9	15.5
Men	6.8	7.6	8.6	9.4
Women	2.6	2.8	2.2	2.7
Capital	5,417	7,351	13,103	10,853
Wage	281	300	343	246
Waterpower	0.29	0.26	0.18	0.15 (5.1)
Steampower	0.08	0.16	0.21	0.24 (9.4)
Hand	0.49	0.27	0.43	-
Animal	0.05	0.03	0.02	-
Combo	0.03	0.02	0.02	0.02
Waterpower/Labor	-	-	-	1.51
Steampower/Labor	-	-	-	0.97
Capital/Labor	741	962	1,220	839
Input/Labor	918	1,306	1,577	1,350
Men/Labor	0.94	0.94	0.92	0.77
Women/Labor	0.06	0.06	0.06	0.05
Number of Firms	4,582	4,778	3,890	5,920

*Note: Output, input, capital, and wage are in current dollars. Labor, men and women are numbers of employees. The values for water, steam, hand, animal, and combination power sources represent the share of firms that use these respective sources of power; in 1880, the figures in parenthesis represent mean horsepower.

Sources: Atack and Bateman (1999).

Table 8 - continued

Descriptive Data on Firms from the Manuscript Censuses, 1850-1880
(mean values)

Rural Firms	1850	1860	1870	1880
Output	6,908	10,294	16,785	12,918
Input	3,997	5,813	9,813	8,689
Labor	7.2	7.2	8.5	8.8
Men	5.3	5.5	6.3	6.0
Women	1.9	1.7	1.3	0.8
Capital	4,097	4,910	9,702	6,519
Wage	255	287	301	179
Waterpower	0.38	0.35	0.22	0.27 (7.5)
Steampower	0.07	0.16	0.20	0.25 (9.3)
Hand	0.39	0.23	0.40	-
Animal	0.06	0.03	0.02	-
Combo	0.03	0.02	0.02	0.02
Waterpower/Labor	-	-	-	2.6
Steampower/Labor	-	-	-	1.4
Capital/Labor	807	1,034	1,251	889
Input/Labor	923	1,362	1,602	1,346
Men/Labor	0.96	0.97	0.93	0.80
Women/Labor	0.04	0.03	0.05	0.02
Number of Firms	3,384	3,197	2,975	3,127

*Note: Rural areas are defined as places having population less than 2,500. Output, input, capital, and wage are in current dollars. Labor, men and women are numbers of employees. The values for water, steam, hand, animal, and combination power sources represent the share of firms that use these respective sources of power; in 1880, the figures in parenthesis represent mean horsepower.

Table 8 - continued

Descriptive Data on Firms from the Manuscript Censuses, 1850-1880
(mean values)

Urban Firms	1850	1860	1870	1880
Output	17,992	26,251	53,152	39,349
Input	9,224	15,107	29,759	25,972
Labor	15.6	17.4	23.1	23.1
Men	11.2	11.6	16.2	13.3
Women	4.5	5.1	5.1	4.9
Capital	9,161	12,284	24,106	15,706
Wage	352	326	468	321
Waterpower	0.07	0.09	0.04	0.03 (2.3)
Steampower	0.11	0.15	0.24	0.21 (9.6)
Hand	0.75	0.35	0.53	-
Animal	0.02	0.02	0.02	-
Combo	0.02	0.02	0.02	0.01
Waterpower/Labor	-	-	-	0.31
Steampower/Labor	-	-	-	0.46
Capital/Labor	554	815	1,117	784
Input/Labor	902	1,193	1,499	1,355
Men/Labor	0.88	0.90	0.88	0.73
Women/Labor	0.12	0.10	0.08	0.07
Number of Firms	1,198	1,581	915	2,793

*Note: Urban areas are defined as places having population greater than or equal to 2,500. Output, input, capital, and wage are in current dollars. Labor, men and women are numbers of employees. The values for water, steam, hand, animal, and combination power sources represent the share of firms that use these respective sources of power; in 1880, the figures in parenthesis represent mean horsepower.

Table 9

Determinants of Urban Location of Manufacturing Establishments, 1850-1880
(Logit regression reported in odds-ratio with z-statistics in parentheses)

	1850 (1)	1860 (2)	1870 (3)	1880 (4)	1880+ (5)
Input/Labor	1.00	1.00	1.00	1.00	1.00
	(5.9)	*(7.1)*	*(3.1)*	*(3.9)*	*(5.9)*
Capital/Labor	1.00	1.00	1.00	1.00	1.00
	(-0.2)	*(1.2)*	*(0.3)*	*(2.6)*	*(5.1)*
Men/Labor	0.21	0.12	0.39	0.39	0.45
	(-5.8)	*(-8.2)*	*(-4.3)*	*(-8.8)*	*(-7.5)*
HP/Labor	0.85	0.91	0.91	-	-
	(-1.3)	*(-3.3)*	*(-5.4)*		
Steam	3.00	1.04	0.94	0.62	0.82+
	(5.2)	*(0.3)*	*(-0.5)*	*(-7.0)*	*(-11.1)*
Water	0.21	0.16	0.21	0.08	0.77+
	(-6.1)	*(-11.9)*	*(-7.0)*	*(-19.3)*	*(-15.7)*
Hand	4.10	1.21	1.16	-	-
	(8.9)	*(1.8)*	*(1.1)*		
Full	-	-	-	1.13	1.12
				(14.5)	*(13.3)*
Fixed effects					
County	yes	yes	yes	yes	yes
Industry	yes	yes	yes	yes	yes
Pseudo R^2	0.16	0.11	0.11	0.14	0.14
Observations	2783	3067	2743	5920	5917

+ Except for equations (5), the power sources are dummy variable indicators which take on a value of 1 or 0 depending upon whether that power source was used by manufacturing firm. However, for equation (5) water and steam represent the amounts of horsepower divided by labor for each sources of power.

Table 10

Determinants of Urban Location of Manufacturing Employment, 1850-1880
(Logit regression reported in odds-ratio with z-statistics in parentheses)

	1850 (1)	1860 (2)	1870 (3)	1880 (4)	1880[+] (5)
Input/Labor	1.00	1.00	1.00	1.00	1.00
	(7.0)	*(12.1)*	*(16.2)*	*(12.0)*	*(19.5)*
Capital/Labor	1.00	1.00	1.00	1.00	1.00
	(7.5)	*(8.1)*	*(-1.4)*	*(3.2)*	*(13.2)*
Men/Labor	0.74	0.42	0.61	0.31	0.44
	(-5.2)	*(-17.4)*	*(-11.2)*	*(-41.2)*	*(-28.5)*
HP/Labor	0.73	0.88	0.75	-	-
	(-4.5)	*(-9.3)*	*(-27.5)*		
Steam	1.78	1.13	1.56	1.18	0.78[+]
	(11.2)	*(4.0)*	*(12.1)*	*(10.1)*	*(-37.6)*
Water	0.37	0.11	0.53	0.18	0.70[+]
	(-17.5)	*(-53.4)*	*(-14.2)*	*(-50.5)*	*(-42.4)*
Hand	2.24	1.39	2.11	-	-
	(16.8)	*(9.4)*	*(16.4)*		
Full	-	-	-	1.18	1.16
				(71.0)	*(60.6)*
Fixed effects					
County	yes	yes	yes	yes	yes
Industry	yes	yes	yes	yes	yes
Pseudo R^2	0.09	0.13	0.10	0.11	0.12
Observations	23,115	32,879	36,083	92,021	91,694

[+] Except for equations (5), the power sources are dummy variable indicators which take on a value of 1 or 0 depending upon whether that power source was used by manufacturing firm. However, for equation (5) water and steam represent the amounts of horsepower divided by labor for each sources of power.

Table 11

Determinants of Urban Location, 1850-1880
(Logit regression reported in odds-ratio with z-statistics in parentheses)

	1850-1870 Estab. (6)	1850-1870 Emp. (7)	1850-1880 Estab. (8)	1850-1880 Emp. (9)
Input/Labor	1.00	1.00	1.00	1.00
	(6.8)	*(22.6)*	*(11.2)*	*(13.1)*
Capital/Labor	1.00	1.00	1.00	1.00
	(0.6)	*(2.4)*	*(-11.9)*	*(14.4)*
Men/Labor	0.22	0.60	0.22	0.36
	(-10.9)	*(-18.6)*	*(-19.4)*	*(-66.9)*
HP/Labor	0.92	0.79	-	-
	(-6.6)	*(-30.1)*		
Steam	1.21	1.27	0.88	1.18
	(2.3)	*(11.7)*	*(-2.2)*	*(13.1)*
Water	0.18	0.25	0.14	0.37
	(-15.7)	*(-55.0)*	*(-28.3)*	*(-70.3)*
Hand	1.64	1.59	-	-
	(7.2)	*(20.0)*		
1860	1.58	1.74	1.46	1.71
	(6.9)	*(28.6)*	*(8.2)*	*(41.1)*
1870	1.32	1.70	0.69	1.17
	(3.9)	*(26.3)*	*(7.4)*	*(11.6)*
1880	-	-	3.62	5.96
			(17.6)	*(75.9)*
County	yes	yes	yes	yes
Industry	yes	yes	yes	yes
Pseudo R^2	0.11	0.10	0.11	0.08
Observations	8,593	92,077	23,234	239,187

Table 12

Decomposing Locational Fixed-effects
(Logit regression reported in odds-ratio)

Urban Employment	1850	1860	1870	1880
Input/Labor	1.00*	1.00*	1.00*	1.00*
Capital/Labor	1.00*	1.00*	1.00*	1.00*
Men/Labor	0.67*	0.38*	0.64*	0.36*
HP/Labor	0.72*	0.87*	0.74*	-
Steam	1.76*	1.16*	1.31*	1.23*
Water	0.38*	0.12*	0.46*	0.18*
Hand	2.14*	1.51*	2.11*	-
Full	-	-	-	1.17*
New England	6.71*	4.04*	1.34	5.65*
Middle Atlantic	15.7*	13.0*	5.55*	5.63*
East North Central	8.10*	2.85*	1.44	5.27*
West North Central	18.3*	3.53*	2.27*	4.15*
South Atlantic	18.3*	9.32*	0.35*	3.24*
East South Central	7.53*	1.81*	4.61*	1.53*
West South Central	+	+	+	+
Mountain	-	-	-	-
Pacific	36.2*	2.67*	3.06*	2.55*
Fixed effects				
Industry	yes	yes	yes	yes
Pseudo R^2	0.12	0.19	0.17	0.13
Observations	23,115	32,879	36,083	92,021

+ Omitted category.
* z-statistics greater than or equal to 2.0.

Table 13
Decomposing Industry Fixed-effects (Logit regression reported in odds-ratio)

Urban Employment	1850	1860	1870	1880
Input/Labor	1.00*	1.00*	1.00*	1.00*
Capital/Labor	1.00*	1.00*	1.00	1.00*
Men/Labor	1.18	1.30*	0.48*	0.79*
HP/Labor	0.83*	0.91*	0.82*	-
Steam	1.89*	1.14*	1.49*	1.49*
Water	0.35*	0.10*	0.52*	0.19*
Hand	2.49*	1.37*	2.07*	-
Full	-	-	-	1.12*
20 Food	0.86	0.74*	1.88*	2.06*
21 Tobacco	0.81	1.64*	0.95	6.49*
22 Textiles	0.46*	1.82*	0.41*	5.65*
23 Apparel	1.91*	2.98*	1.01	5.14*
24 Lumber	0.30*	0.40*	0.28*	0.52*
25 Furniture	0.85	0.97	1.33*	2.83*
26 Paper	0.92	15.3*	0.46*	3.29*
27 Printing	2.28*	3.85*	2.77*	42.3*
28 Chemicals	0.42*	0.97	0.25*	0.79*
29 Petroleum	-	-	-	-
30 Rubber	-	-	81.8*	-
31 Leather	0.35*	0.69*	0.51*	1.99*
32 Stone	+	+	+	+
33 Primary	0.19*	1.57*	0.94	2.37*
34 Fabricated	1.54*	1.82*	1.18	2.09*
35 Machinery	8.43*	1.55*	1.26*	1.78*
36 Electrical	-	-	-	-
37 Transportation	0.29*	0.56*	0.48*	4.09*
38 Instruments	1.79	-	-	41.7*
39 Miscellaneous	2.17*	2.18*	2.29*	9.26*
Fixed effects				
County	yes	yes	yes	yes
Pseudo R^2	0.23	0.18	0.16	0.19
Observations	23,051	32,851	35,934	91,077

+ Omitted category.
* z-statistics greater than or equal to 2.0

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