The Emergence of Wage Discrimination in US Manufacturing

Joyce Burnette
Wabash College
Crawfordsville, Indiana 47933
burnettj@wabash.edu
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In spite of the large body of research on labor market discrimination, we are just beginning to map out where and how discrimination operated in the past. One simple answer does not suffice; we must carefully map out what forms discrimination did or did not take for each time and place. In this paper I present evidence on wage discrimination in nineteenth-century US manufacturing, and then examine this evidence as part of a larger picture of the history of discrimination. The results provide further support for Claudia Goldin's claim that wage discrimination emerged around 1900.

Economists do not always mean the same thing when they talk about "discrimination." Fortunately, "discrimination" generally does mean one of a few clearly defined types of discrimination. The two most important models of discrimination are Becker's wage discrimination model, Bergmann's occupational crowding model. This paper examines wage discrimination, which occurs if the relative wage paid to females is less than their relative productivity:

$$\frac{w_f}{w_m} < \frac{MP_f}{MP_m}.^{1}$$

Even if there is no wage discrimination, other forms of discrimination may exist. Barbara Bergmann's crowding model provides a model of discrimination that implies no wage discrimination. In the crowding model, women are allowed to enter occupation B, but not occupation A. Women are then "crowded" into occupation B, where the supply of workers is large relative to the demand. Because the marginal product of labor is declining, the large supply

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[1] Becker defined the market discrimination coefficient as $\frac{\pi_w}{\pi_n} - \frac{\pi_w^0}{\pi_n^0}$, where π_i is the market wage and π_i^0 represents "the equilibrium wage rates without discrimination." Becker (1971), p. 17.

of worker in occupation B leads to a low marginal product of labor and thus a low wage. In occupation A, where the supply of worker is small relative to the demand, marginal product and wage are both high. In this model wages are equal to marginal product, so there is no wage discrimination, but women workers have a low marginal product because they are crowded into "female" jobs. The method I use will test for wage discrimination, but cannot detect the presence of occupational crowding. Other studies will be need to test for occupational crowding.[2]

While the fact that women earned less than men in nineteenth-century US manufacturing is evident to all, observers have interpreted this fact in very different ways. Some historians claim that female factory workers were underpaid. Layer (1952, p. 4, 167, 175) claimed that the labor market for textile workers was not competitive, and that both immigrants and females earned wages below the competitive level. Gitelman (1967, p. 233) claimed that female cotton factory workers were paid "a discriminatory wage rate." Other historians, however, claim that wages were not discriminatory. In her study of the Amoskeag Co., Hareven (1982, p. 282) claimed that "Textile work offered significant employment opportunities for women without wage discrimination." Paul David (1970, p. 550, 578) suggested that firms did have monopsony power, but assumed that the female-to-male wage ratio equaled the productivity ratio. Nickless (1976, p. 107) assumed no monopsony power, and suggested that wages were set at the competitive level. Some historians suggest that during the late nineteenth century wages were set at competitive rather than discriminatory levels. Rosenbloom and Sundstrom (2009) suggest that during the period between the Civil War and World War I labor markets were competitive. Claudia Goldin (1990, p. 89) concluded that wage discrimination by gender was not important in nineteenth-century manufacturing, but "emerged sometime between 1890 and 1940 in the white-collar sector of the economy."

Most studies that claim to measure wage discrimination do not measure the marginal product of male and female workers, but use an Oaxaca decomposition to determine whether the wage gap can be explained by observable characteristics. To calculate the Oaxaca decomposition, the researcher uses individual-level data on wages to estimate separate wage equations for men and women. The coefficients from these equations can be used to decompose

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[2] I have tested for occupational crowding in eighteenth-century English agriculture. I did not find any evidence of crowding there. See Burnette (1996).

the difference in wages into an explained portion and an unexplained portion.[3] The explained portion of the wage gap is the difference in observed characteristics, weighted by the coefficients of either the male or female wage equation. The remainder of the wage gap is unexplained. Using this method Goldin (1990, p. 117) found that the unexplained portion of the wage gap rose from at most 20 percent of the difference in male and female earnings in manufacturing in 1890, to 55 percent in office work in 1940."

Unfortunately, the Oaxaca decomposition is a poor measure of wage discrimination. The unexplained portion of the wage gap is often interpreted as wage discrimination, though, as Altonji and Blank (1999, p. 3156) note, "This is misleading terminology . . . because if any important control variables are omitted that are correlated with the included Xs, then the B coefficients will be affected." The unexplained portion of the wage gap contains not only wage discrimination, but also the effects of any omitted variables. If there are any unobserved variables that affect wages and are correlated with sex, then the unexplained portion of the wage gap will overestimate wage discrimination. Since the explanatory variables cannot include all individual characteristics that might be important for productivity, a large portion of the wage gap may be unexplained simply because we do not have sufficient data to measure productivity, rather than because of discrimination. Often the unexplained portion of the wage gap is fairly large, suggesting a wide range of possible levels of wage discrimination, including no wage discrimination.[4]

Fortunately, there is a more accurate way to measure wage discrimination. Cross-sectional firm data can be used to estimate production functions, and to directly estimate the productivity of female workers relative to male workers. This more accurate measure of productivity ratio can be compared to the wage ratio to test for wage discrimination. There is now a small but important body of literature that tests for wage discrimination using productivity estimates from production functions. Some of these studies are historical, and some use more recent data.[5] Some data sets include information on average male and female wages, and in

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[3] $\ln \overline{w}_m - \ln \overline{w}_f = (\overline{X}_m - \overline{X}_f)'\beta_m + \overline{X}_f'(\beta_m - \beta_f)$

[4] Joyce Jacobsen (1994), p. 317, reports that, in 1990, 71 percent of the gender wage gap was unexplained for whites, and 70 percent for nonwhites.

[5] Cox and Nye (1989) examine nineteenth-century France, and McDevitt, Irwin and Inwood (2009) examine Canada in 1870, while Hellerstein and Neumark (1999), Hellerstein, Neumark and Troske (1999) and Haegeland and Klette (1999) examine recent data.

some cases the wage gap must be estimated.[6] Some studies conclude that there is wage discrimination, and some studies conclude that there is no wage discrimination.[7] Repeating such studies for different times and locations will allow us to begin to map historical changes in both relative female productivity and wage discrimination.

When Claudia Goldin found that wage discrimination increased between the nineteenth and twentieth centuries, she attributed this change the rise of internal labor markets. She described the nineteenth century as characterized by spot markets: "Manufacturing jobs and many others in the nineteenth century were part of what I shall terms the 'spot market.' Workers were generally paid their value to the firm at each instant, or what economists call the value of labor's marginal product."[8] This changed in the twentieth century as internal labor markets replaced spot markets, and women in occupations such as clerical work found their wages limited by the lack of opportunity for advancement. This hypothesis nicely connects the emergence of wage discrimination to changes in the economy that seem to have resulted from the increased importance of firm-specific human capital.

Using a more accurate measure of wage discrimination, this paper confirms Goldin's findings that there was little wage discrimination in the nineteenth century. I find no evidence of wage discrimination between 1833 and 1880. Relative female productivity was increasing in the textile industry, but wages kept pace with productivity so there is no evidence of wage discrimination in the antebellum period.

Model

If we assume a Cobb-Douglas production function with homogenous labor, we could estimate the parameters of the production function by regressing the log of value added on the logs of the inputs. If labor were homogenous, the production function would be

$$VA = AK^{a_1}L^{a_2} \qquad (1a)$$

or

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[6] Cox and Nye (1989) use wages reported in the data set, while Hellerstein and Neumark (1999), Hellerstein, Neumark and Troske (1999), Haegeland and Klette (1999), and McDevitt, Irwin and Inwood (2009) must estimate relative wages.

[7] Hellerstein, Neumark and Troske (1999) and McDevitt, Irwin, and Inwood (2009) find evidence of wages discrimination, while Cox and Nye (1989) and Hellerstein and Neumark (1999) and Haegeland and Klette (1999) do not.

[8] Goldin (1990), p. 114.

$$\ln VA = \ln A + a_1 \ln K + a_2 \ln L \tag{1b}$$

where VA is value added (the value of output less the value of raw materials), K is capital, and L is labor. If labor is not homogenous, however, we need a production function that includes more than one labor input. One possible way to incorporate different kinds of labor into the production function is to treat each type of labor as a separate input in the Cobb-Douglas production function. This was the method used by Cox and Nye (1989) to estimate productivity in nineteenth-century French manufacturing. They estimated a production function of the form

$$\ln Y = \ln A + \beta_1 \ln M + \beta_2 \ln F + \beta_3 \ln K$$

where M is the number of male workers and F is the number of female workers.[9] Carden (2004) used this same model to estimate relative productivity in nineteenth-century US manufacturing. This production function assumes that the elasticity of substitution between male and female labor is one. It also assumes that both male and female workers are necessary for production; if the firm hires zero units of either type of labor, then it cannot produce any output. Because this second assumption is obviously violated at many firms, I prefer a specification that allows male and female workers to be perfect substitutes for each other, though not necessarily at a ratio of one-to-one.

Leonard (1984) included a linear combination of two types of labor as the aggregate labor input in the Cobb-Douglas production function. He assumed the production function was of the form

$$Y = e^{\alpha_1} K^{\alpha_2} (L_A + CL_B)^{\alpha_3} \tag{2}$$

In this production function the two types of labor are perfect substitutes. The parameter C measures the ratio of the marginal products of the two types of labor, which is a constant and does not depend on how many workers of each type are employed. While this nested Cobb-Douglas production function has many advantages, it cannot be estimated by a simple linear regression.

Various authors have used different techniques to estimate the nested model. Leonard used a Taylor-series approximation to make the non-linear equation (2) into the linear equation

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[9] Cox and Nye (1989), p. 907.

$$\ln Y = \alpha_1 + \beta_1 \ln K + \beta_2 \ln L + \beta_2 (C-1)P \tag{3}$$

where L is the total number of workers employed, and P is the proportion that are female. Hellerstein and Neumark (1999) use the same approach to examine relative female productivity in Israeli manufacturing, and McDevitt, Irwin, and Inwood (2009) use this method to estimate relative female productivity in Canadian clothing factories. As Leonard notes, this approximation is closer to the true relationship when P is small and C is close to one. Since women were a large portion of the workforce in my data set, and I do not expect the productivity ratio to be close to one, equation (3) is probably not a good approximation of the non-linear relationship in this case. An alternative is to estimate equation (2) directly using non-linear regression or maximum likelihood. Other studies have used variants of this approach. Hellerstein and Neumark (1995) estimate an expanded version of (2) with twelve kinds of labor categorized by age and occupation. Haegeland and Klette (1999) use maximum likelihood to estimate the parameters of a nested translog production function.

In this paper I use a nested Cobb-Douglas production function, where the aggregate labor input is a linear combination of the different types of labor. For the case where there are two types of labor, M and F, the aggregate labor input is

$$L^* = M + b_1 F \tag{4}$$

where L* is the aggregate labor input, M is the number of men, F is the number of women. The production function is:

$$VA = CK^{a_1}(M + b_1 F)^{a_2} \tag{5a}$$

or

$$\ln VA = \ln C + a_1 \ln K + a_2 \ln(M + b_1 F). \tag{5b}$$

This specification makes it easy to test whether female-male productivity ratio was equal to the wage ratio. The parameter b_1 measures the ratio of the marginal product of a female to the marginal product of an male:

$$\frac{dVA/dF}{dVA/dM} = b_1.$$

While equation (5) can be used for the 1850 and 1860 censuses, the other data sets require a specification that allows for three categories of labor. In this case the aggregate labor input is

$$L^* = M + b_1 F + b_2 B \tag{6}$$

where B is the number of boys for the McLane Report, and the number of children for the 1870 and 1880 censuses. The production function in this case is:

$$VA = CK^{a_1} (M + b_1 F + b_2 B)^{a_2} \tag{7a}$$

or

$$\ln VA = \ln C + a_1 \ln K + a_2 \ln(M + b_1 F + b_2 B). \tag{7b}$$

In this specification the parameter b_1 measures the ratio of the marginal product of a female or adult women to the marginal product of an adult male, and b_2 measures the ratio of the marginal product of a boy, or child, to the marginal product of an adult male.

$$\frac{dVA/dF}{dVA/dM} = b_1$$

$$\frac{dVA/dB}{dVA/dM} = b_2$$

Both specifications assume that men and women are perfect substitutes, though not necessarily at a one-for-one ratio. This is reasonable if women and men can be used for the same tasks, but men produce more output per hour, or can tend a greater number of machines, than women.

The economic history literature has generally favored this specification of the production function, though usually the parameters b_1 and b_2 are assumed rather than estimated. Most studies that have estimated production functions for nineteenth-century manufacturing calculate an aggregate labor measure by weighting each type of labor by its relative wage, under the assumption that wages are an accurate measure of productivity. When aggregating the amount of labor used by manufacturing firms, Sokoloff (1986, p. 702-3) counts an adult woman as the equivalent of half an adult man because women's wages were about half of men's wages.

> Females and boys have been treated as equal, in terms of their labor input, to one-half of an adult male employee, with these weights having been drawn from evidence on the relative wages of the groups prevailing near the end of the period.

In a comment on this article, Jeffrey Williamson (1986) questions whether assuming a constant productivity ratio over time is valid, but does not question the assumption that the wage ratio is an accurate measure of the productivity ratio. Similarly, Atack, Bateman, and Margo (2003) assume, based on the wage ratio, that an adult female worker is equal to 60 percent of an adult male worker in US manufacturing in 1880.[10] Ulrich Dorazelski (2004) also constructed a composite labor measure using the wage ratios to weight female and child labor in his study of French manufacturing. By estimating the productivity weights, the current paper tests the assumption that the wage ratio matches to productivity ratio.

Following Aigner, Lovell, and Schmidt (1977), the error term for a production function is often assumed to have two components, a random error term and an inefficiency term:

$$y_i = f(x_i;\beta) + v_i + u_i \tag{8}$$

where v_i is a normally distributed error term (such as measurement error) and u_i is a nonnegative error term that indicates if a firm is operating below the production frontier. While (8) can be estimated by maximum likelihood if an assumption is made about the distribution u, only the constant term will be biased if the function is estimated by OLS.[11] Since I am not concerned with either the constant term or the efficiency of a particular firm, OLS is sufficient for my purposes.

1833 McLane Report

The earliest data used in this paper is from a 1833 report to the U.S. House of Representatives titled *Documents relative to the Manufactures in the United States*, also known as the McLane Report because the Secretary of the Treasury Louis McLane collected the returns. The report was published in 1833, but the data was submitted in the spring of 1832, so the data set refers to manufacturing in 1831-32. Sokoloff (1986) used data from the McLane Report and from the 1850 and 1860 censuses to estimate total factor productivity in manufacturing. Goldin and Sokoloff (1982) the McLane Report and the 1850 census to examine the employment and wages of female manufacturing workers.

The McLane report includes data on smaller workshop-type establishments, as well as the more modern factories, though smaller firms are under-represented. Goldin and Sokoloff (1982,

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[10] See also Atack, Bateman, and Margo, 2005.

[11] "if estimation of β alone is desired, all but the coefficient in b corresponding to a column of ones in X is estimated unbiasedly and consistently by least squares." Aigner, Lovell, and Schmidt, 1977, p. 28.

p. 745) report that the main defect of the data source is that it is not a representative sample of firms either geographically or in terms of firm size. Neither issue is likely to bias my estimates of relative female productivity. For the purposes of this paper I have collected two different samples from this report. The first sample includes all industries, but covers only Massachusetts, and has 1398 observations. The second sample covers all the states in the McLane report, but includes only textile firms, and has 427 observations. Each data set includes only firms with complete information on the output, capital, raw materials, and labor. Massachusetts tended to give more complete information than other states, leading to an uneven geographical representation (see Table 1).[12] Thus my samples should not be used to draw conclusions about industry aggregates.

Table 2 provides descriptive statistics for each of these samples. In some cases the McLane report lists more than one factory together. For example, in Adams, Massachusetts, "2 calico factories" together produced 1.15 million yards of cloth and hired 38 men, 14 boys, and 10 women and girls. In this case the observation includes the aggregate for both firms. The "singles" samples include only observations that are clearly for one firm only, and the full sample includes all observations. I test for constant returns to scale before using the full sample. Output is the dollar value of annual production. Firms reported domestically produced raw materials separately from imported raw materials, and these are combined into one "Materials" variable. I will use Value Added, which is equal to Output minus Materials, as my dependent variable. Capital is the sum of the values of "real estate, buildings, and fixtures", "tools, machinery, and apparatus", and "average stock on hand."

The McLane Report lists the number of workers employed in three categories; these categories are: "Average number of males over 16 years old employed", "Average number of boys under 16 years of age", and "Average number of women and girls employed." This allows me to estimate the productivity of three separate categories of workers: men, boys, and females. The "female" category includes both adult women and girls, which may affect the relative productivity of this group. Female workers in textile factories were relatively young. In the 1830s sixty percent of female workers were under age 20, and 86 percent were under age 25.[13] In the full Massachusetts sample 41 percent of the labor force was female. In the textile industry

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[12] I have also excluded firms which report negative value added or zero capital.

[13] Only 14 percent were under age 15, though. Thomas Dublin (1979), p. 31.

about two-thirds of the workers were female. The greater employment of females in textiles is consistent with other evidence; Thomas Dublin's study of Hamilton Manufacturing Company in Lowell found that 85 percent of the workforce was female.[14]

Wages are reported separately for men, boys, and females, and explicitly state that they are wages for workers "boarding themselves." Wages are not reported for every firm in every category because not every firm hired all three types of labor. The average wage for each type of labor, then, is based on data collected from less than the full sample of firms. I calculate the female-to-male wage ratio for each observation that reports both wages. The average of these in the Massachusetts sample is 0.41, which is the same as wage ratio that Goldin and Sokoloff report for the McLane Report.[15] The wage ratio in the textile industry is slightly higher (0.43). In the Massachusetts sample boys earned 43 percent as much as men. Unlike females, boys earned relatively less in the textile industry (0.35).

I use this data to estimate the equation

$$\ln VA_i = \ln C + a_1 \ln K_i + a_2 \ln(M_i + b_1 F_i + b_2 B_i) + \varepsilon_i$$

using non-linear regression. Table 3 presents the results for the Massachusetts sample, including all industries. The first column presents the results for the singles sample, which includes only observations known to be for single firms. The results suggest that females were 47 percent as productive as adult males, and boys were 35 percent as productive. I test for constant returns to scale by imposing the restriction that $a_1 + a_2 = 1$, and I cannot reject the null hypothesis that the restriction is appropriate.[16] Since I cannot reject constant returns to scale, I estimate the production function on the full sample, which also includes observations which aggregate multiple firms. This estimate suggests that females were 45 percent as productive as men, and that a boy was half as productive as a man. The estimation in the third column includes an adjustment for entrepreneurial labor. Sokoloff (1986, p. 686) calculated the aggregate labor input (total employment) as:

$$TE = M + 0.5\,(F+B) + E$$

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[14] Thomas Dublin (1979), p. 26.

[15] Goldin and Sokoloff (1982), p. 760. Note that the average of the ratios (0.41) is different from the ratio of the average wages (0.38/1.00=0.38) because fewer observations are used for the former.

[16] F(1, 733)=1.26.

where M is the number of men, F is the number of females, B is the number of boys, and E is equal to one. This equation adds one male-equivalent worker for the contribution of the entrepreneur, who presumably worked at the firm but was not counted as an employee. I used this variation, with one adjustment: for observations representing multiple firms I added multiple entrepreneurs. For example, if the observation was listed as "2 calico firms", then I added two entrepreneurs. This adjustment does not substantially change the results; in this estimation females were 48 percent as productive as adults males, while boys were 49 percent as productive.

All of the coefficients suggest that both females and boys were less productive than adult males. To test for wage discrimination, we need to compare the estimated productivity ratios to the observed wage ratios. Table 3 reports p-values for the one-tail test of the hypothesis that the productivity ratio is less than or equal to the wage ratio. If the productivity ratio is significantly greater than the wage ratio, then there is wage discrimination. Using a 5% level of significance we cannot reject the null hypothesis in any case. Using the 10% significance level would lead us to reject the null for female workers in the third column. I also test the joint hypothesis that $b_1 = 0.41$ and $b_2=0.43$. I estimate a restricted model with aggregate labor equal to

$$L^* = \text{men} + \text{entrepreneurs} + (0.41*\text{females}) + (0.43*\text{boys}).$$

I cannot reject the null hypothesis that the restricted model is a good fit.[17] This is essentially a test of whether the standard method of measuring aggregate labor, which is to use relative wages to weight the different labor inputs as in equation (8):

$$M + \frac{w_f}{w_m}F + \frac{w_b}{w_m}B \tag{8}$$

is justified. My findings suggest that such a measure of aggregate labor is a good measure of labor input.

Altonji and Blank (1999, pp. 3197-8) criticize the estimates of Hellerstein, Neumark, and Troske by noting that firms may choose different gender division of labor as a result of differences in technology: "the variation across establishments in the makeup of the work force, particularly in the gender and skill mix, is likely to result mainly from heterogeneity in production technology." If being more productive causes firms to hire fewer females, then females might appear to be less productive than they really are. To check for a relationship

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[17] F(2, 1393)=1.40.

between productivity and the gender mix of the labor force, I regress the percentage of the firm's labor force that is female on residuals from the third regression in Table 3. More productive firms would have higher-than-expected output, and thus would have positive residuals. Regression yields the following result:

$$\underset{}{\text{Percent female}} = \underset{(0.0075)}{0.1981} + \underset{(0.0134)}{0.0005} * \text{Residual} \qquad R^2 = 0.00$$

The R-squared suggests that there is no relationship between the residuals and the percentage of the labor force that is female, which suggests that there is no systematic relationship between firm productivity and the gender mix of the labor force.

Table 4 presents the results from the textile industry. Again, the singles sample includes only observations that are clearly for a single firm. An F-test cannot reject the hypothesis of constant returns to scale, so I also use the full sample.[18] As above, the third column adds to the number of men one entrepreneur for each firm in the observation. The estimates suggest that females were between 40 and 47 percent as productive as adult men, and that boys were between 40 and 44 percent as productive. In no case can we reject the null hypothesis of no wage discrimination.

The tests above do not provide evidence of wage discrimination, but they also do not tell us why females were less productivity than adult men. There were many factors contributing to low female productivity. No doubt the females' lower average age contributed to the difference, but differences in skill and strength probably mattered as well. Another characteristic of female labor affecting their productivity was high turnover. Dublin calculated that 26 percent of females entered or left employment in a five-week pay period, compared to 21 percent for males. Because of the high turnover, about one-fifth of the female employees were "spare hands" who were learning the job. Dublin (1979, pp. 71-2) described the work of the spare hand as basically a trainee:

> the newcomer worked with an experience operative who instructed her in the intricacies of the job. She spelled her partner for shirt stretches of time and occasionally took the place of an absentee. . . After the passage of some weeks or months, when she could handle the normal complement of machinery . . . the sparehand moved into a regular position.

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[18] F(1, 372)=0.13.

If one-fifth of the female workers were not yet assigned their own machines, this would lead to a relatively low average output per worker. Differences in the occupations of men and women also contributed to differences in productivity. Dublin finds that men mainly worked as overseers, in the repair shop, or tending machines for picking and carding. Men dominated these positions because of their skills, or, in the case of carding and picking, because they "demanded considerable strength and endurance and exposed workers to risk of personal injury."[19] Women tended all the other machines.

Because male workers are divided by age and females are not, the productivity ratios estimated thus far compare females of all ages to adult males. Boys are clearly less productive than adult men, and we would expect girls to be less productive than adult women. Unfortunately, the McLane report does not provide the information necessary to divide females into two categories. I can, however, combine boys and men into a single category, so that there are only two kinds of labor, male and female. In the fourth column of Tables 3 and 4 I combine men and boys into a single category of male workers, and estimate equation (5b) by non-linear least squares. The female-to-male productivity ratio increases because females are now being compared to all males, not just adult men. Of course this productivity ratio is influenced by the fact that the female workers were still relatively young. However, an advantage of the methodology used here is that I do not have to try to correct for the different characteristics of the male and female workers. I simply measure the relative productivity of the workers employed, and check whether the relative productivity of a particular group matched the relative wage of the same group of workers.

1850 and 1860 Census of Manufacturing

In addition to the McLane Report, I use data from the national samples of the nineteenth-century censuses of manufacturing compiled by Atack, Bateman and Weiss. Data from the manufacturing censuses have been used by economic historians to study firm productivity. Craig and Field-Hendrey (1993) used the 1860 census of to compare productivity in Northern and Southern manufacturing to productivity in agriculture. Atack, Bateman, and Margo (2003) used the 1880 census to examine the relationship between output and the length of the working day, and Atack, Bateman, and Margo (2004) showed that skill intensity (as measured by average

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[19] Thomas Dublin (1979), p. 65.

wage) decreased with firm size. Because the categories used to report labor change between 1860 and 1870, I will discuss the results from the manufacturing censuses in two parts. This section will report the results for 1850 and 1860, and the next section will report the results for 1870 and 1880.

The censuses report the value of output, the value of raw materials used, the total capital invested, and the number of workers. The 1850 and 1860 censuses report the number of workers in only two categories, men and women. Table 5 shows descriptive statistics for 1850 and 1860, for all firms, and for textile firms only. Textiles firms were larger than the average manufacturing firm, and employed a larger portion of women. While the average firm employed only 9 workers in 1850, the average textile firm employed 41 workers. While the manufacturing labor force was only 26 percent female, the labor force in textiles was 57 percent female.

The manufacturing censuses do not report a daily or weekly wage, but they do report a monthly wage bill for male and female workers. I calculate the average monthly wage for each type of worker by dividing the monthly wage bill by the number of workers at the firm. The result is noisier than a direct measure of wages, but does give an average wage ratio for the same firms as are used to estimate productivity. The average ratio of female-to-male wages was 0.49 in 1850 and 0.54 in 1860. Relative female wages were higher in the textile industry, where females earned 64 percent of the male wage in 1850 and 60 percent in 1860.

To estimate the relative productivity of female workers in 1850 and 1860, I estimate the following equation by non-linear least squares:

$$\ln VA_i = \ln C + a_1 \ln K_i + a_2 \ln(M_i + b_1 F_i) + \varepsilon_i. \tag{9}$$

Results are given in Tables 6 through 9. Each table contains four different estimations. The first column provides the basic estimation described by equation (9). In the second column I add one to the number of men, to account for the labor of the entrepreneur. The third column includes dummy variables for the use of steam or water power.

$$\ln VA_i = \ln C + a_1 \ln K_i + a_2 \ln(M_i + b_1 F_i) + a_3 Steam + a_4 Water + \varepsilon_i.$$

The fourth column is similar, except that it includes dummy variables for states rather than for type of power.

Tables 6 and 7 provides estimates for the full sample. For 1850 the estimated productivity ratio is always below the wage ratio of 0.49. Similarly, the estimated productivity ratios for 1860 are always below the wage ratio of 0.54. Table 8 and 9 examine the textile industry only. Sample sizes are smaller, so the estimates are less precise. In Table 8 three of the four estimates of the productivity ratio are below the wage ratio, and there is no evidence of wage discrimination. In Table 9 the estimated productivity ratios are above the wage ratio, but the productivity ratios are so imprecisely measured that I cannot reject the hypothesis that b_1 is less than or equal to the wage ratio. Overall the estimates for 1850 and 1860 provide no evidence of wage discrimination.

1870 and 1880 Censuses of Manufacturing

National samples from the census of manufacturing are also available for 1870 and 1880.[20] Unfortunately, these samples do not contain enough observations from the textile industry to study that industry separately. These censuses also present additional challenges in the way that labor and wages are reported. The 1870 and 1880 censuses report labor in three categories, adult men and women, and children. Males over age 16 are included in the category "men", and females over age 15 are included in the category "women." "Children" includes younger workers of both sexes. The 1870 and 1880 censuses report an aggregate wage bill, but not wage bills by gender, so wage ratios can only be estimated.

Table 10 reports descriptive statistics for the 1870 and 1880 samples. Firms are somewhat larger, increasing from 9.6 workers per firm in 1860 to 13.6 in 1870. The percentage female is not directly comparable across the samples because the category "women" contains all females in 1850 and 1860, and only females over age 15 in 1870 and 1880. Females over age 15 were 18.8 percent of the labor force in 1870 and 19.5 percent in 1880. Women and children together were 30 percent of the labor force in 1870 and 24 percent in 1880. The employment of children fell from 11.6 percent of the labor force in 1870 to 5 percent in 1880. The 1870 census reports the number of months of operation, and the 1880 census reports the number of months the firms operated at fill-time, three-quarters time, two-thirds time, and half-time. Since a firm operating for six months should produce only half the output of a firm with the same capital and labor operating a full year, I adjust the value added to a full-year equivalent by dividing value added by the percentage of the year the firm is in operation. The 1880 census also reports the number of hours of work per day. The usual number of hours per day is 10, so I adjust the each

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[20] Atack, Bateman, and Weiss (2004).

labor input to the equivalent of a ten-hour day. Thus, the number of men is the number of men reported by the census times hours per day divided by ten.

Because these data sets have three categories of workers, I modify slightly the equation that I estimate. I use non-linear least squares to estimate the equation:

$$\ln VA_i = \ln C + a_1 \ln K_i + a_2 \ln(M_i + b_1 F_i + b_2 C_i) + \varepsilon_i$$

C is the number of children, and the other variables are defined as above. Table 11 gives the results of estimating this equation for 1870 and 1880. As above, I add a male worker to represent the entrepreneur, and include state dummies. The results are fairly consistent across different functional forms. The estimates for 1870 suggest that women were about 78 percent as productive as adult men, and children only about 17 percent as productive. For 1880 the estimate of relative female productivity is still about 78 percent, but the estimate of children's productivity jumps up to 78 percent. The relative productivity of children may rise because of a reduction in the employment of very young children, but I do not place much weight on the estimates of child productivity because the number of children employed was very low in both years.

Unfortunately the 1870 and 1880 census samples do not contain estimates of male and female wages. They do contain a total wage bill, so I attempt to estimate wages by regression the total wage bill on the number of workers of each type. If firms were price-takers, wages would be constant across firms, and I should be able to reconstruction wages by examining the relationship between the number of workers of each type and the total wage bill. Since errors from the wage equation are likely to be correlated with errors from the production function, I jointly estimate the following equations using seemingly unrelated regression:

$$\ln VA = a_0 + a_1 \ln K + a_2 \ln L + a_2(b_1 - 1)\ln P_f + a_2(b_2 - 1)\ln P_c$$

$$\ln w = \alpha + \beta P_f + \gamma P_c$$

where L is the total number of workers, P_f is the percentage of the workforce that is female, and P_c is the percentage of the workforce that are children, and w is the average wage per worker (total wage bill/number of workers). I also add dummy variables for states and for two-digit industries. Table 12 shows the coefficients for these estimations, and the wage and productivity ratios that they imply. The coefficient on the percentage female in the production function is $a_2(b_1-1)$, so to calculate the female-male productivity ratio, I divide the coefficient on P_f by the coefficient on *lnL* and add one. A firm that hired only men should have an average wage of α, and a firm that hired only women would have an average wage of α + β, so

$$\ln w_f - \ln w_m = \ln \frac{w_f}{w_m} = \beta$$

and

$$e^{\beta} = \frac{w_f}{w_m}.$$

The regressions with neither location nor industry controls have very low R-squareds, suggesting that gender alone explain little of the variation in wages.

The female-to-male productivity ratios in Table 12 are similar to the estimates in Table 11 for 1880, and slightly higher for 1870. In Table 12 the child-to-male productivity ratios for 1870 are negative, implying that hiring children reduced a firm's total output. However, these point estimates are not significantly different from zero. Adding state and industry controls reduces the female-to-male productivity ratio in 1880, but it also reduces the estimated wage ratio, so I cannot reject the equality of productivity and wages for females relative to males. Estimates in Table 12 do suggest that children were under-paid in 1880, but the results for children are not robust enough to create great confidence in this result. While female productivity seems to have risen relative to male productivity in the decades after the Civil War, there is still no evidence of wage discrimination against women.

Translog Production Function

So far this paper has used a Cobb-Douglass production function. Would the results change if a different production function were used? To answer this question I re-estimate the production functions using a nested translog production function. The translog production function is

$$\ln Q = a_0 + a_1 L + a_2 L^2 + a_3 K + a_4 K^2 + a_5 LK$$

If aggregate labor contains male and female workers,

$$L^* = M + b_1 F,$$

then the nested function is

$$\ln Q = a_0 + a_1(M + b_1 F) + a_2(M + b_1 F)^2 + a_3 K + a_4 K^2 + a_5(M + b_1 F)K \qquad (10)$$

Estimating (10) by non-linear least squares gives estimates of b_1. Table 13 gives the productivity ratios estimates from these estimations for all of the data sets used in this paper. The translog results tell the same story as the Cobb-Douglass results: there is no evidence of wage discrimination, except for children in 1880.

Trends

Unfortunately, the differing categories of labor make it difficult to compare productivity ratios across time. For 1832, 1850, and 1860 the category "female" contained females of all ages, including girls. Males are separated into men and boys in 1832, but they can easily be re-combined, producing a female/male productivity ratio comparable to those for 1850 and 1860. For 1870 and 1880, however, the category "children" contains both boys and girls, so we cannot re-classify these children. However, we could make different assumptions about the percentage of children that were female in order to estimate the female-to-male productivity ratio. The two possible extremes are that all children were boys, and that all children were girls. In Table 14 I re-estimate the production functions making both of these extreme assumptions. The first and third columns assume that all children were girls, and add the number of children to the number of women. The second and fourth columns assume that all children were boys, and adds the number of children to the number of men. The estimates of relative female productivity under both of these assumptions should provide bounds for the possible values of the female-to-male productivity ratio. For 1870, these two assumptions give productivity ratios of 0.60 and 0.74. For 1880 the two estimates are quite close together, 0.779 and 0.784. These estimates suggest that relative female productivity in manufacturing increased substantially during the nineteenth century.

The production functions estimated here reveal interesting differences between textiles and other industries, and changes over time. In 1850, and particularly in 1860, relative female productivity was higher in textiles than in manufacturing as a whole, which probably explains why female employment was so high in textiles. Relative female productivity also increased over time. Figures 1 and 2 graph the ratios over time. Figure 1 shows wage and productivity ratios in the textile industry, which are only available until 1860. Figure 2 shows the ratios for all manufacturing from 1832 to 1880. For 1870 and 1880 I graph the female-male productivity ratios that result from assuming all children were female, and the ratios that results from assuming all children were male. Figure 1 shows a pronounced upward trend in relative female productivity.

The large literature on labor productivity in textiles may provide some clues about why rising productivity ratio. During the mid-nineteenth century there was an increase in overall labor productivity in textiles. Lazonick and Brush (1985) attribute this increase to intensification of work. They note that the native "farmgirls" employed in the 1830s could easily quit in response to unfavorable working conditions, while the immigrant workers that became more common in the 1850s did not have the same outside opportunities and were less able to quit.

Reports from female textile workers do suggest that those employed later in the century seem to have worked harder than those earlier in the century. Harriet Robinson, who wrote a memoir at the end of the nineteenth century, remembered that when she worked in the mills in the 1840s the job was not overly taxing:

> Though the hours of work were long, they were not over-worked; they were obliged to tend no more looms and frames than they could easily take care of, and they had plenty of time to sit and rest. I have known a girl to sit idle twenty to thirty minutes at a time. They were not driven, and their work-a-day life was made easy.[21]

However, the factory workers that she interviewed later in the century did not find their job so easy:

> The hours of labor are now less, it is true, but the operatives are obliged to do a far greater amount of work in a given time. They tend so many looms and frames that they have no time to think. They are always on the jump; and so have no opportunity to improve themselves.[22]

Robinson's impression is that the work of a female factory hand was greatly intensified.

James Besson, however, does not think the power of the employers changed that much, and attributed most of the increase productivity between 1835 and 1855 to increases in human capital. More skilled workers could achieve higher utilization rates, because the could attend to stops more quickly and effectively. In the 1830s each weaver attended two looms, but over the course of the century this increased, and by 1902 the average worker attended seven looms.[23] Bessen concludes that, while some of this increase was the result of innovations, some of it was the result of the increased skills of the workers. Because it might take workers up to a year to

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[21] Robinson (1976), p. 43.

[22] Robinson (1976), p. 121-2.

[23] Bessen (2008), Figure 2.

reach the highest possible utilization rates for the machines, turnover was an important part of workers productivity.

Do these theories of labor productivity have any implications for the ratio of female productivity to male productivity? If the increase in labor productivity occurred among production workers, then they occurred mainly in the female labor force. In the early period production workers were almost exclusively female. If productivity increase faster among female weavers than among male overseers and mechanics, either due to intensification of work or to human capital acquisition, then we would expect the female/male productivity ratio to rise.

In the middle of the century the gender division of labor changed, as immigrant men were hired as weavers, a job which had previously been all-female. Gitelman (1967, p. 251) suggests that this employment pattern, and the lower wage or Irish men, was a result of discrimination. He claims that Irish males "were more strongly discrimination against within the firm than were females. Most were consigned to the lowest paying, dirtiest jobs." While discrimination is one possible explanation for this pattern, it is also possible that Irish men were hired for the lower-paying jobs because they had fewer skills than native men. If this were so, then an increase in the percentage of male workers that were immigrants would reduce average male productivity and increase the female-male productivity ratio.

Relative female productivity seems to have risen in manufacturing as a whole as well as in the textile industry. As in the textile industry, both rising female skills and the influx of unskilled male immigrants may have contributed to this increase.

Conclusion

Since men and women were not equally productive, we can only test for wage discrimination if we are able to measure the productivity ratio. The estimates of relative productivity provided in this paper add to a small body of evidence on the male-female productivity ratio. Table 15 compares the wage and productivity ratios in this paper to results from various other papers that estimate relative female productivity. The new evidence generally supports Goldin's claim that wage discrimination emerged sometime around 1900. I have tested for wage discrimination and have not found evidence of wage discrimination against women. Of course, even when there was no wage discrimination, there may have been discrimination in other forms. Occupational crowding reduces women's wage without wage discrimination.

By the later twentieth century, though. wage discrimination had come to US manufacturing. In contrast to Norway and Israel, where there is no evidence of wage discrimination, US women do seem to have been underpaid in late twentieth-century US manufacturing. Hellerstein, Neumark, and Troske find evidence of wage discrimination in 1990, and Leonard finds evidence of wage discrimination in 1966 and 1977.[24] Unfortunately, there is still no evidence for the period between 1860 and 1966, and data limitations make it difficult to find data for this period. Manuscripts returns of the 1890-1920 censuses of manufacturing do not survive, and more recent censuses of manufacturing do not report labor by gender. However, it does appear that wage discrimination appeared in US manufacturing sometime between 1880 and 1966.

Knowing when wage discrimination appeared may help us to understand what caused it. For most of the nineteenth century, manufacturing employees were paid piece-rate wages and had short job tenures. These job characteristics led to a spot market, where each worker was paid his or her current marginal product. As we entered the twentieth century, however, firms became more anxious to reduce turnover. Owen suggests that technological change, specifically the automated machinery, increased the importance of firm-specific human capital. More people were hired into jobs which

> required knowledge of particular machines as they were operated in the production process of a given plant; knowledge that constituted firm-specific skills. . . This shift in the skill composition of the work-force toward workers with more firm-specific skills should have led to an increase in the cost of labor turnover to the employer.[25]

Since turnover was more costly, firms introduced various incentives to discourage workers from quitting. Firms were successful; quit rates fell from 101 per 100 employees in 1920 to 26 in 1928.[26]

One of the incentive systems used to reduce turnover was delayed compensation. If firms paid workers less when first hired, but increased their wages with tenure, workers would have more incentive to stay with the firm. An increased emphasis on turnover may have led to statistical discrimination against women, who were expected to have shorter tenures. Firms may also have decided that men needed greater incentives to stay. Owen finds that male quits were

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[24] While he does not report the p-value, Leonard does claim that the gender earnings ratio is “significantly less than the productivity ratio.” Leonard (1984), p. 162.

[25] Owen (1995), p. 505.

[26] Owen (1995), p. 499.

more responsive to market conditions, so firms may have felt more of a need to develop incentives to keep their male workers. There is some evidence from other the industries that, when internal labor market policies were in place, women did not have the same opportunities for advancement as men. Goldin (1990, p. 108) finds that, among American clerical workers "Each year of total experience augmented male earnings more than female earnings." Men were assigned to jobs with promotion possibilities and women were not. Similarly, Seltzer and Frank (2008) find that, among employees of Williams Deacon's Bank in the early twentieth century, men and women were paid approximately the same salary when first hired, but after about eight years at the firm a substantial wage gap appeared. Examining Swedish workers in the 1930s, Svensson (2008) finds that women were assigned to dead-end jobs will little prospect for wage increases, while men were assigned to jobs with increasing wage profiles.

The change from piece-rate to time-rate payments may have increased wage discrimination if it was easier to discriminate with time-rate wages. Piece rates were usually the same for both genders, and any differences would be immediately obvious. However, since male and female productivity differed, time-rate wages would differ by gender even if there were no wage discrimination. This would have made wage discrimination less obvious, and perhaps easier to institute. Evidence on Swedish tobacco workers in 1898 is consistent with the hypothesis that time-rate wages included more wage discrimination than piece-rate wages. Stanfors and Karlsson (2008, Table 7) find that, controlling for individual and firm characteristics, women paid piece-rate wages earned significantly more than women paid time-rate wages, while for men there was no difference between the two payment types. While more work remains to be done, it appears that the emergence of wage discrimination was the result of changes in labor market institutions.

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Table 1: Distribution of Textile Firms in the McLane Textile Sample

	Percent of Obs.
Massachusetts	55.4
New York	19.8
New Hampshire	16.3
Maine	3.7
New Jersey	3.4
Connecticut	0.7
Vermont	0.7

Table 2: Descriptive Statistics, McLane Report

A. Massachusetts Singles

	Mean	Std.Dev.	Min	Max	N
Output ($)	23,442	49,560	300	500,000	738
Materials ($)	12,565	26,644	0	367,300	738
Value Added ($)	10,877	22,768	31	251,155	738
Capital ($)	20,240	61,513	120	920,086	738
Men	12.5	20.3	0	200	738
Females	15.6	47.2	0	672	738
Boys	2.9	8.3	0	141	738
Men’s Wage ($)	0.97	0.24	0.33	2.25	716
Female Wage ($)	0.37	0.13	0.02	1.20	369
Boys’ Wage ($)	0.40	0.14	0.11	1.00	260
Wage Ratio F/M	0.41	0.13	0.03	1.15	359
Wage Ratio B/M	0.43	0.15	0.13	1.00	252

B. Massachusetts Full Sample

	Mean	Std.Dev.	Min	Max	N
Output ($)	33,939	136,445	180	4,180,000	1398
Materials ($)	17,238	55,204	0	1,190,000	1398
Value Added ($)	16,701	107,631	31	3,863,500	1398
Capital ($)	20,889	57,950	100	920,086	1398
Men	19.2	44.2	0	562	1398
Females	15.9	52.1	0	672	1398
Boys	3.7	12.5	0	200	1398
Men’s Wage ($)	1.00	0.26	0.33	3.5	1346
Female Wage ($)	0.38	0.12	0.02	1.2	553
Boys’ Wage ($)	0.43	0.14	0.11	1.0	467
Wage Ratio F/M	0.41	0.12	0.03	1.2	524
Wage Ratio B/M	0.43	0.14	0.01	1.2	456

C. Textile Singles

	Mean	Std.Dev.	Min	Max	N
Output ($)	44,732	86,592	600	800,000	377
Materials ($)	22,566	46,246	60	425,693	377
Value Added ($)	22,166	43,318	297	387,035	377
Capital ($)	71,168	272,332	650	4,200,000	377
Men	17.5	32.2	0	312	377
Females	50.3	114.6	0	1050	377
Boys	8.0	18.0	0	141	377
Men's Wage ($)	0.96	0.32	0.17	5.00	365
Female Wage ($)	0.39	0.09	0.11	0.83	345
Boys' Wage ($)	0.33	0.12	0.11	0.87	215
Wage Ratio F/M	0.43	0.15	0.06	1.94	342
Wage Ratio B/M	0.35	0.14	0.13	1.00	212

D. Textile Full Sample

	Mean	Std.Dev.	Min	Max	N
Output ($)	49,003	95,553	240	900,000	427
Materials ($)	26,185	58,384	0	720,530	427
Value Added ($)	22,818	43,103	210	387,035	427
Capital ($)	70,386	257,848	250	4,200,000	427
Men	18.6	34.6	0	312	427
Females	49.6	110.6	0	1050	427
Boys	8.2	18.1	0	141	427
Men's Wage ($)	0.96	0.31	0.17	5.00	413
Female Wage ($)	0.39	0.08	0.11	0.83	383
Boys' Wage ($)	0.33	0.12	0.11	0.97	242
Wage Ratio F/M	0.43	0.15	0.06	1.94	379
Wage Ratio B/M	0.35	0.14	0.13	1.01	238

Table 3: Production Functions for Massachusetts, 1832

Parameter	Singles	Full Sample	Add Entrepreneur	Combine Males
Constant	4.214	4.057	3.701	3.698
	(0.126)	(0.088)	(0.086)	(0.087)
a_1	0.313	0.328	0.332	0.332
	(0.018)	(0.013)	(0.013)	(0.013)
a_2	0.666	0.685	0.760	0.748
	(0.025)	(0.017)	(0.019)	(0.019)
b_1	0.470	0.449	0.480	0.488
	(0.072)	(0.046)	(0.049)	(0.052)
b_2	0.346	0.502	0.492	
	(0.129)	(0.113)	(0.128)	
Females				
Wage Ratio	0.41	0.41	0.41	0.42
p-value	0.20	0.20	0.08	0.10
Boys				
Wage Ratio	0.43	0.43	0.43	
p-value	0.74	0.26	0.31	
R^2	0.85	0.87	0.86	0.86
N	738	1398	1398	1398

“p-value” is the p-value for a one-tail test of the null hypothesis $b \geq$ wage ratio. Wage discrimination occurs if $b >$ wage ratio, so rejection of the null is evidence of discrimination.

Wage ratio for the “combine males” column is the average female wage divided by a weighted average of the men’s and boys’ wages.

Table 4: Production Functions for the Textile Industry, 1832

Parameter	Singles	Full Sample	Add Entrepreneur	Combine Males
Constant	4.215	4.249	3.996	3.817
	(0.361)	(0.338)	(0.320)	(0.315)
a_1	0.284	0.282	0.278	0.301
	(0.053)	(0.051)	(0.050)	(0.050)
a_2	0.706	0.707	0.764	0.711
	(0.062)	(0.059)	(0.063)	(0.061)
b_1	0.404	0.403	0.471	0.563
	(0.082)	(0.073)	(0.084)	(0.101)
b_2	0.404	0.404	0.440	
	(0.145)	(0.137)	(0.146)	
Females				
Wage Ratio	0.43	0.43	0.43	0.51
p-value	0.62	0.64	0.31	0.30
Boys				
Wage Ratio	0.35	0.35	0.35	
p-value	0.35	0.35	0.27	
R^2	0.82	0.83	0.83	0.83
N	377	427	427	427

Table 5: Descriptive Statistics, Census of Manufactures, 1850 and 1860

	Mean	Std.Dev.	Min	Max	N
ALL FIRMS					
1850					
Output ($)	9197	28,156	100	1,025,000	6017
Materials ($)	4632	16,956	12	569,740	6017
Value Added ($)	4565	14,985	10	455,260	6017
Capital ($)	4825	27,763	10	1,200,000	6017
Men	6.71	47.94	0	3500	6017
Women	2.32	27.03	0	1600	6017
Male Monthly Wage	25.30	23.65	0.04	350	5975
Female Monthly Wage	10.56	5.81	0.8	108	825
Wage Ratio (F/M)	0.489	0.306	0.04	5.4	802
1860					
Output ($)	14,077	47,258	125	1,680,000	6495
Materials ($)	7621	29,066	8	905,100	6495
Value Added ($)	6457	22,583	16	774,900	6495
Capital ($)	7255	35,301	15	1,500,000	6495
Men	7.10	20.51	0	500	6495
Women	2.48	32.30	0	1760	6495
Male Monthly Wage	28.55	16.23	0.5	351	6431
Female Monthly Wage	12.96	9.09	0.6	150	756
Wage Ratio (F/M)	0.535	0.420	0.03	6.1	725
TEXTILES ONLY					
1850					
Output ($)	33,323	82,661	400	1,025,000	235
Materials ($)	20.247	50,434	0	28.270	235
Value Added ($)	13,076	34,486	70	455,260	235
Capital ($)	30,996	98,935	150	1,200,000	235
Men	17.74	34.17	0	320	235
Women	23.53	72.45	0	870	235
Male Monthly Wage	19.42	7.64	1.75	66.67	234
Female Monthly Wage	11.99	9.55	1	108	156
Wage Ratio (F/M)	0.64	0.53	0.15	5.4	155
1860					
Output ($)	67,464	161,281	500	1,680,000	181
Materials ($)	38,683	92,195	210	905,100	181
Value Added ($)	28.781	75,924	20	774,900	181
Capital ($)	45,352	145,989	100	1,500,000	181
Men	24.64	45.74	0	400	181
Women	41.88	171.04	0	1760	181
Male Monthly Wage	22.97	8.89	1.3	60	177
Female Monthly Wage	12.84	6.22	0.95	50	122
Wage Ratio (F/M)	0.60	0.22	0.13	1.42	121

Table 6: Production Functions for All Manufacturing, 1850

	All Firms	Add Entrepreneur	Power Controls	State Controls
C	4.637	4.147	4.483	4.546
	(0.056)	(0.053)	(0.060)	(0.070)
a_1	0.259	0.261	0.299	0.245
	(0.009)	(0.009)	(0.010)	(0.008)
a_2	0.729	0.886	0.676	0.721
	(0.014)	(0.013)	(0.015)	(0.013)
b_1	0.416	0.349	0.415	0.449
	(0.050)	(0.051)	(0.053)	(0.048)
Steam Power			0.056 (0.044)	
Water Power			-0.261 (0.027)	
State Dummies				Yes
F/M Wage Ratio	0.49	0.49	0.49	0.49
p-value	0.93	1.00	0.92	0.80
R^2	0.61	0.60	0.61	0.70
N	6017	6017	6017	6017

Table 7: Production Functions for All Manufacturing, 1860

	All Firms	Add Entrepreneur	Power Controls	State Controls
C	4.539	4.003	4.436	4.655
	(0.058)	(0.055)	(0.061)	(0.067)
a_1	0.290	0.294	0.316	0.278
	(0.009)	(0.009)	(0.010)	(0.009)
a_2	0.730	0.876	0.693	0.739
	(0.013)	(0.016)	(0.013)	(0.013)
b_1	0.517	0.439	0.525	0.536
	(0.051)	(0.048)	(0.055)	(0.052)
Steam Power			0.003 (0.029)	
Water Power			-0.202 (0.025)	
State Dummies				Yes
F/M Wage Ratio	0.54	0.54	0.54	0.54
p-value	0.68	0.98	0.61	0.53
R^2	0.67	0.60	0.67	0.69
N	6495	6495	6495	6495

Table 8: Production Functions for Textiles, 1850

	All Firms	Add Entrepreneur	Power Controls	State Controls
C	3.793	3.372	3.467	3.901
	(0.341)	(0.331)	(0.340)	(0.470)
a_1	0.331	0.348	0.313	0.286
	(0.053)	(0.055)	(0.061)	(0.056)
a_2	0.673	0.728	0.769	0.684
	(0.064)	(0.074)	(0.079)	(0.067)
b_1	0.457	0.474	0.421	0.652
	(0.171)	(0.188)	(0.167)	(0.249)
Steam Power			0.191 (0.157)	
Water Power			0.166 (0.117)	
State Dummies				Yes
F/M Wage Ratio	0.64	0.64	0.64	0.64
p-value	0.86	0.82	0.91	0.48
R^2	0.86	0.85	0.85	0.86
N	235	235	235	235

Table 9: Production Functions for Textiles, 1860

	All Firms	Add Entrepreneur	Power Controls	State Controls
C	5.093	4.620	5.065	4.579
	(0.392)	(0.382)	(0.394)	(0.606)
a_1	0.186	0.204	0.189	0.170
	(0.057)	(0.060)	(0.060)	(0.063)
a_2	0.798	0.845	0.793	0.816
	(0.071)	(0.085)	(0.074)	(0.078)
b_1	0.763	0.929	0.830	1.032
	(0.264)	(0.334)	(0.295)	(0.371)
Steam Power			0.119	
			(0.167)	
Water Power			-0.063	
			(0.137)	
State Dummies				Yes
F/M Wage Ratio	0.60	0.60	0.60	0.60
p-value	0.27	0.16	0.22	0.12
R^2	0.83	0.82	0.83	0.83
N	181	181	181	181

Table 10: Descriptive Statistics, Census of Manufactures, 1870 and 1880

	Mean	Std.Dev.	Min	Max	N
1870					
Output ($)	27,405	138,161	45	4,532,422	2484
Materials ($)	15,597	90,712	0	3,050,937	2484
Value Added ($)	11,808	55,780	20	1,481,485	2484
Capital ($)	13,606	85,825	10	3,000,000	2484
Men	9.45	54.76	0	2267	2484
Women	2.56	20.67	0	600	2484
Children	1.58	25.51	0	1200	2484
Wage Bill	5709	29,787	1	936,473	1902
1880					
Output ($)	21,434	113,319	100	6,000,000	7512
Materials ($)	14,095	97,208	0	5,600,000	7512
Value Added ($)	7339	26,481	4	1,055,000	7512
Percent of Year	0.85	0.23	0.08	1.00	7512
Adjusted VA	8558	28,717	4	1,055,000	7512
Capital ($)	9111	41,530	10	1,500,000	7512
Men	8.26	29.67	0	1018	7512
Women	2.16	32.87	0	2400	7512
Children	0.54	4.29	0	200	7512
Men, adjusted	8.28	29.79	0	1018	7512
Women, adjusted	2.15	32.98	0	2400	7512
Children, adjusted	0.54	4.30	0	190	7512
Wage Bill	3705	15,152	2	422,530	7246

Adjusted VA is valued added divided by the percent of the year that the factory is in operation. Employment figures are adjusted to a ten-hour day. Adjusted men = men*(hours/10)

Table 11: Estimated Production Functions, 1870 and 1880

	1870			1880		
	All Firms	Add Entrepreneur	State Dummies	All Firms	Add Entrepreneur	State Dummies
C	5.188	4.624	5.193	5.245	4.769	5.097
	(0.087)	(0.079)	(0.145)	(0.045)	(0.041)	(0.096)
a_1	0.249	0.257	0.238	0.234	0.231	0.232
	(0.014)	(0.014)	(0.014)	(0.007)	(0.007)	(0.007)
a_2	0.759	0.910	0.757	0.709	0.871	0.708
	(0.022)	(0.028)	(0.022)	(0.010)	(0.012)	(0.010)
b_1	0.783	0.750	0.764	0.780	0.680	0.758
	(0.118)	(0.114)	(0.116)	(0.059)	(0.053)	(0.056)
b_2	0.168	0.002	0.179	0.777	0.652	0.776
	(0.083)	(0.025)	(0.087)	(0.092)	(0.096)	(0.091)
State Dummies			Yes			Yes
R^2	0.72	0.71	0.73	0.73	0.73	0.74
N	2300	2300	2300	7509	7509	7509

Table 12: Joint Estimation of Production Functions and Wage Equations, 1870 and 1880

	1870	1870	1870	1880	1880	1880
Production Function						
a_0	5.616	5.743	7.153	5.647	5.434	6.192
	(0.022)	(0.166)	(0.221)	(0.042)	(0.096)	(0.150)
a_1	0.200	0.199	0.161	0.180	0.185	0.168
	(0.015)	(0.015)	(0.017)	(0.006)	(0.007)	(0.007)
a_2	0.746	0.744	0.772	0.723	0.719	0.724
	(0.023)	(0.023)	(0.024)	(0.009)	(0.009)	(0.010)
$a_2(b_1-1)$	–0.104	–0.140	–0.078	–0.160	–0.192	–0.320
	(0.120)	(0.119)	(0.144)	(0.050)	(0.050)	(0.059)
$a_2 (b_2-1)$	–0.793	–0.827	–1.027	–0.216	–0.211	–0.313
	(0.179)	(0.181)	(0.180)	(0.077)	(0.142)	(0.075)
State Dummies		Yes	Yes		Yes	Yes
Industry Dummies			Yes			Yes
R^2	0.70	0.72	0.73	0.72	0.74	0.75
Wage Equation						
α	5.543	5.527	4.498	5.479	5.049	4.233
	(0.022)	(0.152)	(0.218)	(0.011)	(0.105)	(0.168)
β	0.141	–0.088	–0.414	–0.198	–0.342	–0.647
	(0.129)	(0.124)	(0.151)	(0.060)	(0.057)	(0.067)
γ	–1.885	–1.813	–1.793	–0.821	–0.821	–0.885
	(0.194)	(0.189)	(0.189)	(0.094)	(0.088)	(0.086)
State Dummies		Yes	Yes		Yes	Yes
Industry Dummies			Yes			Yes
R^2	0.05	0.18	0.24	0.01	0.13	0.21
Productivity Ratios						
F/M	0.86	0.81	0.90	0.78	0.73	0.56
(SE)	(0.16)	(0.16)	(0.19)	(0.07)	(0.07)	(0.08)
C/M	-0.06	-0.11	-0.33	0.70	0.71	0.57
(SE)	(0.23)	(0.24)	(0.23)	(0.11)	(0.10)	(0.10)
Wage Ratios						
F/M	1.15	0.92	0.66	0.82	0.71	0.52
C/M	0.15	0.16	0.17	0.44	0.44	0.41
p-value of test for equality of ratios						
F/M	0.13	0.56	0.20	0.53	0.73	0.66
C/M	0.35	0.24	0.03	0.01	0.01	0.11
N	1902	1902	1902	7246	7246	7246

Table 13: Productivity Ratios Estimated from Translog Production Functions

Date	Comparison	Productivity Ratio	Wage Ratio
1833, Massachusetts	Female/Men	0.409 (0.046)	0.41
	Boys/Men	0.525 (0.113)	0.43
1833, Textiles	Female/Men	0.417 (0.074)	0.43
	Boys/Men	0.409 (0.137)	0.35
1850, Mfrg.	Female/Male	0.497 (0.059)	0.49
1850, Textiles	Female/Male	0.411 (0.149)	0.64
1860, Mfrg.	Female/Male	0.584 (0.056)	0.54
1860, Textiles	Female/Male	0.781 (0.264)	0.60
1870, Mfrg.	Women/Men	0.821 (0.125)	1.15
	Children/Men	0.235 (0.101)	0.15
1880, Mfrg.	Women/Men	0.779 (0.059)	0.82
	Children/Men	0.780 (0.094)	0.44

Table 14: Sensitivity Checks for Female/Male Productivity Ratio

	1870		1880	
	Assume All Children Are		Assume All Children Are	
	Female	Male	Female	Male
C	5.165	5.134	5.245	5.233
	(0.087)	(0.087)	(0.045)	(0.044)
a_1	0.253	0.258	0.234	0.236
	(0.014)	(0.014)	(0.007)	(0.007)
a_2	0.750	0.729	0.709	0.705
	(0.022)	(0.022)	(0.010)	(0.010)
b_1	0.596	0.740	0.779	0.784
	(0.082)	(0.125)	(0.049)	(0.059)
R^2	0.72	0.72	0.73	0.73
N	2300	2300	7509	7509

Table 15: A Summary of Studies of Female-Male Productivity Differences

Study	Location	Wage Ratio	Productivity Ratio
Current Study	US textile industry		
	1832	0.51	0.56
	1850	0.64	0.46
	1860	0.60	0.76
	US manufacturing		
	1832	0.42	0.49
	1850	0.49	0.42
	1860	0.54	0.52
	1870		0.78
	1880		0.78
Cox and Nye (1989)	French mfrg, 1849-45		
	Cotton spinning	0.54	0.63
	Wool spinning	0.49	0.43
	Cotton weaving	0.60	0.59
	Wool weaving	0.48	0.37
	French mfrg, 1860-65		
	Cotton	0.52	0.72
	Wool	0.50	1.11
Craig and Field-Hendrey (1993)	US, 1860		
	Northern Agriculture		
	Teenagers		0.94
	Age 19-54		0.61
	Southern Agriculture		
	Free labor, age 19-54		0.72
	Slaves, age 20-54		0.60
	Northern Manufacturing		0.50
	Southern Manufacturing		0.44
McDevitt, Irwin, and Inwood (2009)	Canadian manufacturing, 1870	0.38	0.49*
Leonard (1984)	US manufacturing, 1966	0.53	0.75*
	1977	0.54	1.01*
Haegeland and Klette (1999)	Norwegian mfrg., 1986-93	0.82	0.83
Hellerstein and Neumark (1999)	Israeli mfrg., 1989	0.77	0.82
Hellerstein, Neumark, Troske (1999)	US 1990	0.55	0.84*

* = productivity ratio is significantly above the wage ratio, indicating wage discrimination

Figure 1: Productivity and Wage Ratios in Textiles

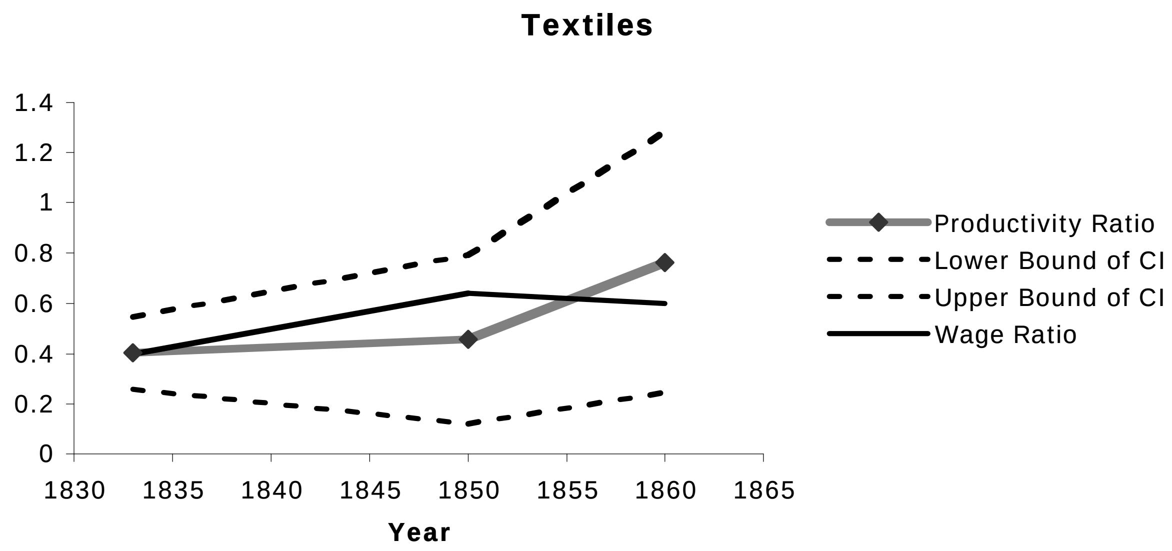

Figure 2: **Productivity and Wage Ratios Manufacturing**