Enabling the Visible Hand: Organizational and Technological Innovation and the Supply of Skilled Workers

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Preliminary and Incomplete

Abstract

In this paper, the relationship between the adoption of a new organizational structure, associated with the movement towards more concentrated industries, and the movement of women into clerical positions is investigated. Input demand equations derived from generalized Leontief cost functions are estimated using industry specific data from a sample of Ohio manufacturing industries in 1933, 1935 and 1937. By disaggregating the data by both gender and type of employment (production or administration), I find that female clerical workers were substitutes for the physical capital employed by Ohio manufacturers and that technology adoptions saved on the employment of capital, male labour, and female production labour, and increased their use of female clerical labour. This evidence suggests that technological change in the U.S. during the early 20th century may have been biased in favour of female clerical labour. In order to test the hypothesis that firms reorganized in order to take advantage of the increase in skilled workers, I divide the sample into three groups of industries, identified by their degree of vertical integration, and find that industries that were fully integrated took advantage of the availability of skilled female workers in the way characterized by the change in organizational structure described in my model. The preliminary results presented in this paper are consistent with the view that U.S. manufactures responded to the increase in educated female labour in a way in which simultaneously expanded the demand for those workers.

"The ninth and last division groups all the clerical occupations, the writing of letters, the keeping of books and record. When there were not so many large scale establishments, and the carpenter kept his own books, and the shoemaker both made shoes and kept the record of it, this was an unimportant division, because it was merely part of many occupations; but as business has become more concentrated, this record keeping and letter writing end of the work has become more and more an occupation in itself, and I find clerical occupations increasing by leaps and bounds." (Ohio Council in Industry, 1928)

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1 Introduction

In 1920, the rubber industry in Ohio consisted of 86 establishments hiring an average of 634 workers per establishment (U.S. Department of Labor, 1932). At that time less than 7% of their labour force could be categorized as either bookkeepers, stenographers or clerical workers, 31% of which were female (U.S. Department of Labour Women's Bureau, 1932). By 1937, the number of establishments manufacturing tires in Ohio had fallen to 29, the average number of workers was 1532 and the proportion of those workers classified as bookkeeper, stenographers or clerical workers has risen to over 15%. In less than 20 years, the number of establishments had been reduced by 65%, the average number of workers per establishment had increased almost 2.5 times and the fraction of administrative workers had more than doubled. As the number of establishments fell, and the average firm size increased, a handful of firms came to dominate the market. By 1935, over 80% of the output from the American rubber industry was produced by the 4 leading manufactures (Chandler, 1990).

This movement toward a more concentrated, and more complex, industry was typical of the reorganization of American industry that heralded in the first thirty years of the twentieth century. This transition, characterized by the reorganization of firm structure, is well described by authors such as Chandler (1977), Nelson (1995) and Williamson (1981): industries which could benefit from economies of scale, and profitably take control over other areas of production and distribution, choose to vertically integrate. Authorities of the vertical integration movement consider the increase in the employment of clerical workers as a by-product of this movement, stemming from an increased need for record keeping and communication as the hierarchy of managers grew and corporations became more complex. Clerical workers, however, required a level of skill far above that of the average worker at turn of the century. If this movement had taken place 30 years previously, when less than 2% of the population had completed a high school education, firms would have been faced with a short supply of literate and numerate workers to fill these positions. It seems reasonable to ask the question, if the take-off in high school enrollment and graduation rates had not taken place when it did, would industries, such as rubber producers in Ohio, still have found it profitable to adopt new, complex, organization structures? Did industries which chose to vertically integrate in this period take advantage of the rise in the supply of skilled workers in a way in which others did not?

There is no doubt that the rise of the large enterprise led to the creation of thousands of previously non-existent jobs, both for highly educated workers, as managers, and for less skilled workers, as clerical workers. Alfred Chandler (1977) describes the modern business enterprise as "many distinct operating units managed by a hierarchy of salaried executives."(p.g. 3) He writes:

> Such units did not exist in the United States in 1840. By World War I this type of firm had become the dominant business institution in many sectors of the American economy. By the middle of the twentieth century, these enterprises employed hundreds and even thousands of middle and top managers who supervised the work of dozens and often hundreds of operating units employing tens and often hundreds of thousands of workers(*Visible Hand*, 1977).

In fact, by 1930, 14,320,000 workers in the US were categorized as white-collar workers, almost 30% of the work force, an increase of 60% from thirty years previously (*Historical Statistics* Series D 182-232).

High school graduation and enrollment rates took off at the turn of the twentieth century. In 1880 only 2.5% of 17 year olds completed high school (U.S. Department of Education). By 1910 almost 10 times as many students graduated from high school. In the following 30 years the percentage of students with high school diplomas grew to 51%, and the percentage with at least some high school education increased to 73%. This precipitous rise in high school graduation and enrollments rates was, at this time, a uniquely American experience. Other developed countries lagged US growth of secondary schooling by thirty years or more (see Goldin 1994). High school enrollment rates in Britain, France and Germany were below US levels throughout most of the twentieth century (Ringer 1979). Likewise, the rise of big business through vertical integration began much earlier in the US than in European countries. Whereas large industries sprang up in the US as early as 1890, big business did not become common place in Britain until the late 1920's or early 1930's, and in France until after W.W.II (Chandler 1980). The rise in big business in Germany took place coincident with that in the US. Big business in Germany, however, was very different from that in the US. American big business took the form of an single incorporated business run from a central office, big business in Germany was more likely to be a group of individual businesses taking advantage of cartels and, presumably, faced lower accounting and communication costs than a multiunit incorporated firm.

In Adshade (2003) I develop a model in which profit considerations determine whether a firm chooses to adopt new organizational structures requiring the labour input of skilled, administrative workers. According to the model, when the supply of skilled workers is low, the profitability of adopting the new organizational structure falls below the profitability of using the old; no firm adopts the new organization structure and no clerical-type workers are employed. As the over-all supply of skilled workers grows, however, adoption of the new organizational structure becomes profitable. This increasing profitability arises as the result of two factors: growth in manufacturing output and decreasing average supervision costs of administrative workers. Where manufacturing and administration are complements in the production of a final good, increases in productivity in manufacturing induces an increase in demand for administrative output. Increased demand for administrative output, in turn, increases the wage producers are willing to pay to administrative workers. Educated individuals, that might otherwise have chosen to stay out of the labour market, increased their labour force participation. The second factor which increases the profitability of adopting the new organizational structure is related to the increase in the level of available labour input. For low levels of available labour input, per technology, entrepreneurs find it profitable to administer the firm themselves. Since the profitability of using the new organizational structure is increasing in the labour input when the supply of skilled workers increases they might find it profitable to assume the role of supervisor and employ a clerical workforce. As male workers have a comparative advantage in manufacturing employment, the majority of this increase in employment comes in the form of skilled, female, workers.

In this paper I undertake an empirical study in which the relationship between the adoption of a new organizational structure (associated with movement towards more concentrated industries) and the movement of women into clerical positions is investigated. As part of this investigation I test the hypothesis that the adoption of the new organizational structure among a sample of manufacturing industries in Ohio was a response to the growing pool of literate and numerate female workers. Input demand equations derived from a generalized Leontief cost function are estimated using industry specific data from a sample of Ohio manufacturing industries in 1933, 1935 and 1937. Labour inputs have been disaggregated into four types of workers: male clerical workers, female clerical workers, male production workers, and female production workers. Using the full sample of 133 four digit product groups, representing ten industries, I find that, unlike their male colleagues and female production workers, female clerical workers were substitutes for the physical capital employed by Ohio manufacturers. It also appears that technology adoptions among the industries saved on the employment of capital, male labour, and female production labour, but used female clerical labour. This suggests that the model accurately predicts that technological adoptions in the U.S. during the early 20th century was biased in favour of female clerical labour. To investigate organizational changes I divide the sample into three groups of industries, identified by their degree of vertical integration as described in Chandler (1969). Re-estimating the input demand equations using the three data sub-samples, I find that the unique attributes of female clerical workers are most obvious among the industries that were fully vertically integrated, and hence, characterized by the organizational innovations described in my model. The empirical evidence, therefore, is consistent with the view that the presence of a pool of educated female labour induced innovations in the method and the mode of production among U.S. manufacturers, which in turn simultaneously expanded the demand for these workers.

The paper proceeds as follows, the following section discusses the relationship between the move to big business in the United States at the turn of the twentieth century and the creation of the clerical sector. Section three presents the data and methods used in the empirical analysis and discusses the results. The final section concludes the paper and discusses future work.

2 The Role of the Clerical Workforce in Integrated Industries

The rise of big business, and the movement to vertically integrated industries, was accommodated by the reorganization of production, on both the factory floor and in administrative offices. The principles of the Scientific Method, heralded by thinkers such as Frederick Taylor at the turn of the century, promoted the specialization of tasks. Prior to this movement, the firm was often administered by one or two managers, usually the owners of the firm, and the organization of the labour force (including hiring and the distribution of wages), the purchasing of material and the manufacture of goods was often left to the factory foreman. One of the founding principles of the scientific movement was the creation of an accounting system that allowed the managers to divide the tasks of the foreman in to specialized tasks performed by many "functional" foremen and closely monitored by the managers themselves

(see Nelson 1995). This process of accounting produced a large amount of record keeping that was well beyond the scope of the functional foreman's responsibility. As the level of output of individual firms grew, more and more often the responsibility for keeping these records was passed on to clerical workers (Chandler, 1977).

With the decline in responsibility of the individual foreman, and the growth in number workers per firm, came the need for a unit within the firm to manage the workforce. The responsibilities of these units went beyond simple hiring and training of workers. One of the tenants of the Scientific Method was the introduction of an efficiency wage. Workers were often paid for piece work, and workers who produced more were often rewarded more per unit produced than were workers who produced less (Nelson 1995). The introduction of this wage system meant that on the shop floor clerical workers were required to keep detailed records of inputs to production and the output of all workers. These records were used to calculate both the flow of goods through the production process and determine the return to inputs. Workers were paid accordingly.

In addition to taking control over production within their own factory, managers began to render greater control over both the production of their inputs (backwards integration) and the marketing and distribution of their products (forward integration). What was once a single unit enterprise became an association of many units, each with a distinct task. This growth in the complexity of firm structures led to a greater need for communication between units, communications made possible by the growing pool of typists, stenographers and switchboard operators.

As large firms came to dominate, public pressure, beginning as early as 1900, led to increased legislation at the state level for independently audited annual reports and improved record keeping. In 1902 the United States Industrial Commission recommenced the introduction of federal legislation requiring that large corporation publish verifiable reports of profits and loss. The Taft Commission in 1911 effected changes in state government budgeting practises and eventually led to the Budgeting and Accounting Act of 1921, that lead to increased record keeping for both governments and businesses. The introduction of a corporate income tax (in 1909), personal income taxes (1913) and excess profits tax (in 1918) meant that corporations were required to adopt standard cost accounting measures that could be upheld by an independent audit. With changing government reporting, stockholder pressure for accountability and banking reform came the introduction of financial departments and increased centralized control of recording keeping throughout the organization (see Strom 1992). All these factors led to the creation of an army of workers whose skill levels were sufficiently high to manage detailed bookkeeping and communication practices.

3 Empirical Analysis

The estimation used in this analysis is derived from that used by Parks (1971). Parks suggests a factor demand model that can be used to measure various elasticities of substitution while

not imposing the restriction that intermediate materials enter the production function in fixed proportions. The generalized linear cost function is convenient for this purpose in that the functional form is consistent with tiered production technology used in the basic model and allows for specification of non-homothetic input demand functions.

At this time, the analysis is limited by the availability of data. While the state of Ohio collected detailed wage and employment figures over the period 1914 to 1937,[2] the results presented here are for a fraction of that time (1933, 1935,1937) and for a limited number of industries. Until the data for the earlier period comes available it is not feasible to undertake a cross sectional analysis and to explicitly test for induced technical change. Given the data that I do have, however, it is possible to see if the evidence suggested by the various input elasticities are consistent with the story I present; that is that industries chose to adopt complex management structures were responding to an increase in skilled, female, workers. To this end I have included a proxy for productivity and can determine if the estimations are at least consistent with the hypothesis that technical change was biased towards female clerical workers, if not evidence of it.

3.1 The Data

I have selected industries for this sample based on Chandler's (1969) categorization of U.S. manufacturers. Chandler groups two digit manufacturing industries on the basis of their degree of vertical integration;[3] Type A groups nonintegrated industries, Type B groups partially integrated industries and Type C groups fully integrated industries (see Table 4.1). Industries represented in this sample are: Leather Goods, Printing and Publishing, and Lumber Products (Group A); Textiles, Paper, Machinery and Fabricated Metals[4] (Group B); Chemicals, Rubber Products, Transportation Vehicles, and Tobacco (Group C).

Virtually all data for this analysis comes from two sources, The Biennial Census of Manufactures and The Bulletin of the Bureau of Labor Statistics in Ohio, and covers three years: 1933, 1935 and 1937. Information on the number of establishments, total number of employees, total wage bill, gross value of production, and value added was collected for each Ohio industry from the Biennial Census. A capital proxy was determined, using total horsepower employed in each product group in 1929, changes in gross fixed capital in the manufacturing sector as a whole, and changes in the contribution of each product group to aggregate manufacturing value added. The Moody's AAA corporate bond yields reported in *The Historical Statistics of the United States* is used as a proxy for the user cost of capital. Using bond yields as a proxy for capital costs implicitly assumes that there was a competitive market for capital in Ohio during the 1930s, and purchase prices, depreciation rates and tax treatments were approximately equal across product groups.

[2]Only a fraction of which was ever published and is still available.

[3]Defined as the percentage of concentrated industries within industrial groups.

[4]Machinery and Fabricated Metal Industries are best represented in the Ohio Data under the industry heading "Iron and Steel and their Products" and are treated in the sample as one industry.

Type A Groups	Type B Groups	Type C Groups
Leather Products	**Textiles**	**Rubber**
Publishing & Printing	**Paper**	**Chemicals**
Lumber & Wood	**Fabricated Metals**	**Transportation Equipment**
Furniture	**Machinery**	**Tobacco**
Apparel	**Food**	**Primary Metal**
		Electrical Machinery
		Stone, Clay and Glass
		Instruments
		Petroleum

Table 1: Industry Grouping by Concentration of Industry

The second source is collected from The Bulletin of the Bureau of Labor Statistics in Ohio published in 1939. From 1914 onwards all employers of 5 or more (3 or more post-1924) workers in Ohio were required to report monthly on the level of employment and the rates of wages for three types of employment; waged (all production workers), clerical (bookkeepers, stenographers and office clerks) and salespeople (not traveling). Total wage payments to supervisors and managers were also collected. Information on the employee's age and gender was included such that the data consists of the total number of establishments, weekly wage rate distributions, payroll totals for individual industries (down to the 4-digit level), for both men and women over and under the age of 18. For this sample, in 1931, Croxton estimates that these figures represent 95.2% of wage earners represented in the Census of Manufactures and 96.4% of the wage payments (Croxton, 1935 p.g. 4). Table 2[5] contains summary statistics on wages and employment for years and industries in the sample.

After matching the census data, the capital proxy and wage and employment data, the sample consists of a set of eleven variables defined over 133 four digit product groups covering the years 1933, 1935 and 1937, and representing ten industries.

3.2 The Estimation of Input Demand Systems

The information derived from the Biennial Census of Manufacturing and The Bulletin of the Bureau of Labor Statistics in Ohio is adequate for the estimation of input demand systems derived from non-homothetic in output generalized Leontief cost functions. These systems are used to investigate the relationship between female clerical employment, technical change and organizational innovation. The generalized Leontief cost function is desirable for this purpose as it is a second order approximation of any arbitrary cost function. Each input demand function derived from this specification is linear in input prices and facilitates the direct estimation of input specific scale effects, input specific biases in technical change, and the complete range of input relationships. As an example, Sheppard's Lemma applied to a two input generalized Leontief cost function, derives an input demand system of the form:

[5]Wages are mean weekly. Waged workers are production workers. # are mean employment in 4 digit product group. Wages and number of workers from Ohio Division of Labor Statistics (1939).

		Full Sample		Group A		Group B		Group C	
		Wage	#	Wage	#	Wage	#	Wage	#
Male Clerks	1933	33.33	473.3	32.23	354.8	33.71	529.3	33.65	486.4
	1935	33.99	503.5	32.41	346.9	33.88	547.3	65.64	577.1
	1937	36.03	568.3	35.42	379.8	35.96	602.2	36.58	641.6
Female Clerks	1933	20.05	324.6	20.30	400.8	20.00	288.8	19.95	316.1
	1935	20.15	347.8	20.49	397.5	20.86	315.7	18.66	354.4
	1937	21.82	358.4	19.94	468.8	22.37	315.9	22.16	355.5
Male Waged	1933	22.26	4735.9	22.02	2818.9	22.21	5048.7	22.14	5975.3
	1935	24.39	4088.7	24.33	2225.6	24.46	4640.0	24.33	5417.1
	1937	27.51	6108.6	26.89	2702.3	27.83	8037.7	27.54	5871.1
Female Waged	1933	12.07	1017.3	13.08	894.1	12.45	1161.0	10.60	840.5
	1935	14.25	989.7	15.45	715.9	14.21	1244.3	12.83	878.6
	1937	16.18	1105.2	18.09	991.0	16.50	1249.9	13.68	945.9

Table 2: Summary Statistics of Wages and Employment in Ohio

$$\frac{L_{jt}}{Q_{jt}} = \delta_{LL} + \delta_{LK}\left(\frac{w_{K,jt}}{w_{Ljt}}\right)^{0.5} + \alpha_L t + \beta_L Q_{jt} + \gamma_{LK} f_{jt} + e_{L,jt} \quad (1)$$

$$\frac{K_{jt}}{Q_{jt}} = \delta_{KK} + \delta_{KL}\left(\frac{w_{L,jt}}{w_{K,jt}}\right)^{0.5} + a_K t + \beta_K Q_{jt} + \gamma_{LK} f_{jt} + e_{K,jt} \quad (2)$$

Where: Q = Value Added; L = Labour Input; K = Capital Proxy; w_X = Nominal Price for Input X; t = Productivity Proxy (1933, 1935, 1937); f = Matrix of Industry Specific Fixed Effects Dummies (controlling for cross-panel heteroskedasticity); and j = Industry Identifier. The signs on the parameter estimates indicate characteristics of the technology employed. For example: $\delta_{LK} > 0$ implies that K and L are substitutes in production; $\delta_{LK} < 0$ implies that K and L are compliments in production; $\alpha_L > 0$ implies that the bias in technical change is using L; $\alpha_L < 0$ implies that the bias in technical change is saving L; $\beta_L > 0$ implies that there are decreasing returns in the use of L; and $\beta_L < 0$ implies that there are increasing returns in the use of L. In this study the γ_{LK} parameters have been constrained to be equal across equations in each system so that the fixed effects controls for cross-panel heteroskedasticity are applied to the cost functions, rather than the individual input demand equations.

Input demand equations have been estimated as a series of seemingly unrelated regressions. The additive disturbance terms included in each equation are assumed to be independently and identically distributed with a non-singular, non-diagonal covariance matrix. The parameter estimates and independent variables from each of the systems have been used to determine the extent to which the cost functions implied by the estimations satisfy the theoretical definition of a cost function, that is; decreasing and concave in input prices.

As a benchmark, two equation systems are estimated comprising of capital and all types of labour aggregated into a single input (see equations (1) and (2)). I have estimated these

systems using the full sample, and by data sub-samples, defined by group (where groups are identified by the degree of vertical integration among the included industries). Because labour can be disaggregated into gender and occupation type, the benchmark two equation systems, with all labour aggregated into a single input, is used merely for illustrative purposes. The systems that contain five input demand equations (capital, male production labour, female production labour, male clerical labour, and female clerical labour) are the main focus of this exercise. Again, these are systems estimated using the full sample and by sub-sample.

There are four types of workers, Type 1 workers are male clerical, Type 2 workers are female clerical, Type 3 workers are male production and Type 4 workers are female production workers. An labour input demand equation in the five equation system is of the form

$$\begin{aligned}\frac{L2_{jt}}{Q_{jt}} &= \delta_{L1L1} + \delta_{L2K}\left(\frac{w_{K,jt}}{w_{L2jt}}\right)^{0.5} + \delta_{L2L1}\left(\frac{w_{L2,jt}}{w_{L1jt}}\right)^{0.5} + \delta_{L2L3}\left(\frac{w_{L3,jt}}{w_{L2jt}}\right)^{0.5} \\ &\quad + \delta_{L2L4}\left(\frac{w_{L4,jt}}{w_{L2jt}}\right)^{0.5} + \alpha_L t + \beta_{L2} Q_{jt} + \gamma_{LK} f_{jt} + e_{L,jt}, \end{aligned} \tag{3}$$

and the input demand equation for capital is of the form:

$$\begin{aligned}\frac{K_{jt}}{Q_{jt}} &= \delta_{KK} + \delta_{KL1}\left(\frac{w_{L1,jt}}{w_{K,jt}}\right)^{0.5} + \delta_{KL2}\left(\frac{w_{L2,jt}}{w_{K,jt}}\right)^{0.5} + \delta_{KL3}\left(\frac{w_{L3,jt}}{w_{K,jt}}\right)^{0.5} \\ &\quad + \delta_{KL4}\left(\frac{w_{L4,jt}}{w_{K,jt}}\right)^{0.5} + a_K t + \beta_K Q_{jt} + \gamma_{LK} f_{jt} + e_{K,jt}. \end{aligned} \tag{4}$$

$L2_{jt}$ is the labour input of a female clerical worker in time period t and industry j. The sign of parameter δ_{L2L1} will determine whether or not female clerical and male clerical workers are substitutes or complements in production. The sign of parameter δ_{L2K} will indicate whether or not female clerical workers are compliments or are substitutes in production. The sign of parameter α_{L2} indicates whether or not technology is female clerical labour saving or female clerical labour using. The sign of parameter β_{L2} will indicate if the returns to increasing the input of female clerical labour is increasing or decreasing.

3.3 Results

Using a single aggregate labour input, the estimated cost functions for manufacturers in Ohio during the 1930s exhibit common characteristics to their counterparts in other industries and regions at this time. More specifically, capital and labour were compliments in production, technical change saved on both capital and labour, and increases in output were associated with greater than proportional increases in capital (decreasing returns) and less than proportional increases in labour (increasing returns) (see Table 3). These results are consistent with other studies of U.S. manufacturing during the early 20th century (for examples see Cain and Paterson, 1986, Woolf, 1984, Wylie, 1989). These effects, particularly with respect to the biased technical change in favour of capital savings and the returns to scale estimates,

are more significant in a statistical and economic sense as I move towards more vertically integrated industries. In other words, in moving from Group A (least integrated) to Group C (most integrated) p values tend to fall and parameter estimates rise (in absolute value) on the technical change and scale parameters in the capital input demand equation. These results are consistent with Chandler's categorization of the industries by degree of vertical integration.

The standard approach, with all workers measured as a single labour input, masks considerable idiosyncratic detail. The results of the of estimation with labour disaggregated by gender and occupational type show that male and female clerical workers are substitutes in production, and male and female production workers are substitutes, but clerical workers and production workers are compliments (see Table 3). Additionally, increases in output are associated with greater than proportional increases in capital (decreasing returns) and less than proportional increases in all four labour types (increasing returns). Although these results are intuitively appealing and they reveal the type of additional detail I can identify with disaggregate labour inputs, it is the unique features of female clerical labour that are most interesting. There were two main technological characteristics that were specific to female clerical workers. First, female clerical labour was a substitute for capital, while all other labour inputs were compliments to capital. Second, technical change was biased towards the use of female clerical labour, while all other labour inputs and capital were saved as a result of technical change. Clearly, female clerks were different, and among the industries in my sample innovations in the method of production (technological change) were directed towards the exploitation of female clerical labour, rather than any other occupation types or physical capital.

In order to investigate the relationship between female clerical workers and organizational innovations I estimate separate input demand systems with disaggregated labour types for the three groups of industries. Similar to the two equation systems, I find that the industries that had the greatest degree of vertical integration (Group C) had the most significant scale effects in both a statistical and economic sense. This same group of industries had the most significant female clerical labour using bias in their technological changes, and both male and female clerks were substitutes for capital among the industries in this group of fully vertically integrated producers. This implies that the industries with the strongest tendency to exploit female clerks in their technological innovations were the same industries that had adopted organizational innovations used these very same workers. These findings are consistent with the presence of induced innovations in the method and mode of production. As such they may characterize a simultaneous shift in the supply and the demand for educated female workers during the early 20th century, increased female labour force participation with muted changes in female relative to male wages.

4 Conclusion

It appears that among the sample of Ohio manufacturing industries, during the 1930s, female clerical labour was unique in its impact on the technology and evolution over time. Only female clerical workers were substitutes for physical capital and technological change was using only these workers. These idiosyncrasies were increasingly obvious for more vertically integrated

	Full	Group A	Group B	Group C
2 Equation System	$n = 133$	n=32	n=62	n=39
δ_{LK}	-5.92e-12 (0.999)	-1.29e-8 (0.000)	3.67e-9 (0.743)	-1.32e-9 (0.564)
α_K	-1.34e-3 (0.222)	-1.05e-4 (0.774)	-2.64e-3 (0.255)	-5.34e-4 (0.134)
α_L	-2.94e-4 (0.114)	-1.48e-4 (0.316)	-1.09e-4 (0.111)	-6.43e-4 (0.285)
β_K	1.46e-11 (0.853)	5.47e-11 (0.650)	-9.11e-12 (0.946)	-2.64e-11 (0.372)
β_L	-6.48e-12 (0.470)	9.44e-13 (0.984)	-1.45e-12 (0.566)	-3.96e-11 (0.197)
5 Equation System				
δ_{L1K}	-1.16e-4 (0.401)	-9.06e-5 (0.706)	2.43e-4 (0.233)	6.41e-5 (0.744)
δ_{L2K}	3.71e-4 (0.06)	-7.93e-5 (0.851)	-6.64e-5 (0.807)	3.332e-4 (0.142)
δ_{L3K}	-3.14e-4 (0.005)	-1.99e-4 (0.375)	-1.25e-4 (0.480)	-5.38e-4 (0.005)
δ_{L4K}	-7.87e-5 (0.497)	-3.09e-5 (0.917)	-3.07e-4 (0.175)	-1.17e-5 (0.920)
δ_{L1L2}	3.30e-4 (0.011)	-6.47e-5 (0.386)	3.36e-4 (0.005)	2.10e-5 (0.894)
δ_{L1L3}	-4.66e-4 (0.034)	1.36e-4 (0.334)	-5.40e-4 (0.107)	-6.74e-5 (0.690)
δ_{L1L4}	-1.11e-4 (0.468)	-7.65e-5 (0.403)	-5.86e-4 (0.111)	5.80e-5 (0.480)
δ_{L2L3}	-2.67e-4 (0.118)	4.12e-5 (0.787)	-2.36e-4 (0.091)	-1.53e-4 (0.651)
δ_{L2L4}	-1.57e-4 (0.179)	1.53e-5 (0.870)	-2.65e-4 (0.056)	-4.01e-5 (0.750)
δ_{L3L4}	6.38e-5 (0.769)	-4.49e-5 (0.858)	5.45e-4 (0.276)	-1.89e-5 (0.892)
α_K	-1.02e-5 (0.964)	4.63e-4 (0.283)	2.54e-5 (0.929)	-2.32e-4 (0.597)
α_{L1}	-6.65e-6 (0.594)	-4.16e-6 (0.792)	-8.32e-6 (0.727)	-6.28e-6 (0.708)
α_{L2}	9.10e-6 (0.375)	-4.80e-6 (0.805)	-3.92e-6 (0.744)	3.04e-4 (0.195)
α_{L3}	-2.55e-4 (0.127)	-1.03e-4 (0.309)	-5.82e-5 (0.185)	-6.62e-4 (0.224)
α_{L4}	-5.36e-5 (0.133)	-3.45e-5 (0.292)	-6.61e-5 (0.146)	-8.42e-5 (0.374)
β_K	2.29e-11 (0.001)	-7.26e-11 (0.421)	3.29e-11 (0.000)	-6.92e-12 (0.681)
β_{L1}	-2.15e-13 (0.694)	-3.07e-13 (0.951)	-9.93e-14 (0.901)	-8.24e-13 (0.309)
β_{L2}	-4.19e-13 (0.356)	-2.31e-12 (0.705)	-1.15e-13 (0.772)	-9.69e-13 (0.379)
β_{L3}	-3.78e-12 (0.602)	-5.63e-13 (0.986)	1.84e-13 (0.902)	-1.91e-11 (0.444)
β_{L4}	-1.67e-12 (0.281)	2.88e-12 (0.779)	-1.50e-12 (0.321)	-3.48e-12 (0.424)

Table 3: Econometric Results and P-Values

industries. These findings are consistent with the notion that the presence of an available pool of literate and numerate female workers induced firms to adopt vertically integrated organizational structures and technological innovations used by workers who provide specialized clerical services. They also suggest that the expansion in the supply of female labour induced a nearly simultaneous increase in demand for this labour type, such that labour force participation increased substantially but relative wages remained stable.

The results suggest two more general conclusions. First, Chandler's categorization of manufacturing industries appears consistent with the technological characteristics I have estimated. More specifically, the industries Chandler identified as fully vertically integrated tended to have more significant returns to scale, and they employed their clerical labour (both male and female) differently than other industries. Second, the aggregation of all labour types into a single input obscures some important differences in the way industries use their workers. In particular, the labour types that were a smaller share of total employment were swamped in aggregate measures of labour inputs. The economic experiences of female clerical workers were different from the experiences of their male colleagues (even their male in clerical employment), but any investigation of this variation is lost in most studies that rely exclusively on aggregate census data.

Future empirical work in this area is warranted. By extending the data set to include more years, a cross-sectional estimation method can be used to test for induced technical change. Including more industries (as the results for Group B) suggest, should improve the power of the tests and make hypothesis testing possible. Using the resulting own price elasticities, it would be possible to break down the specific effects on female clerical wages that result from increases to supply and demand to see which effect dominated. Effectively this would allow me to undertake tests suggested by Mincer (1962) and Goldin (1990) to determine if the demand side effects outweighed the supply side effects in influencing female labour force participation, as I have suggested here.

Finally, and perhaps most importantly, work need to be done to accurately measure the adoption of technologies specific to female clerical workers. Ideally this would be in the form of office appliance adoption rates and would be industry specific, so that a test could be undertaken that specifically tests for induced technical change in administration and the level of substitutability of female clerical labour and office technology.

References

[1] Altman, Morris; Lamontagne, Louise."On the Natural Intelligence of Women in a World of Constrained Choice: How the feminization of Clerical Work Contributed to Gender Pay Equity in Early Twentieth Century Canada." Forthcoming: Journal of Economic Ideas.

[2] Berndt, Ernest."The Practice of Econometrics: Classic and Contemporary." Toronto:Addison Wesley. (1991)

[3] Cain, Louis; Donald G. Paterson (1986), " Biased Technological Change, Scale and Factor Substitution in American Industry, 1850-1919" , Journal of Economic History, Vol. 46, Pg. 153-164.

[4] Chandler, Alfred D. Jr.. "The Structure of American Industry in the Twentieth Century: A Historical Overview." Business History Review, Vol. XLIII, No. 3. (Autumn 1969)

[5] Chandler "The Visible Hand The Managerial Revolution in American Business." Cambridge, MA: Harvard University Press. (1977)

[6] Chandler "Scale and Scope The Dynamics of Industrial Capitalism." Cambridge, MA: Harvard University Press. (1990)

[7] Chandler, Alfred D. Jr.. "The United States: Seedbed of Managerial Capitalism." In Alfred D. Chandler and Herman Daems, eds., *Managerial Hiearchies: Comparative Perspectives on the Rise of the Modern Industrial Enterprise.* Cambridge, MA: Harvard Press: 9-40. (1980)

[8] Costa, Dora L. "From Mill Town To Board Room: The Rise of Women's Paid Labor." NBER Working Paper Series, No. 7608. (March 2000)

[9] Croxton, Fred. C.; Croxton, Frederick E; Croxton, Frank C. U.S. Department of Labor Bureau of Labour Statistics."Average Annual Wage ans Salary Payments in Ohio 1916 to 1932." Bulletin of the U.S. Bureau of Labor Statistics No. 613. (1935)

[10] Diewert, W.E. (1971), " An Application of the Sheppard Duality Theorem: A Generalized Linear Production Function" Journal of Political Economy, Vol. 79, Pg. 482-507.

[11] Goldin, Claudia."America's Graduation from High School: The Evolution and Spread of Secondary Schooling in the Twentieth Century." Journal of Economic History 58 (June1998).

[12] Ohio's Women Workers, Ohio Council in Industry, page 12. (Wage Rates, Earnings and Fluctuation of Employment: Ohio, 1914-1926 (inclusive)) 1928

[13] Ohio Division of Labor Statistics. "Rates of Wages and Fluctuations in Employment; wage and salary payments in Ohio 1930 to 1937 inclusive." Danner Press Inc., Akron, Ohio. 1939

[14] Parks, R.W. (1971), " Price Responsiveness of Factor Utilization in Swedish Manufacturing: 1870-1950" , Review of Economics and Statistics, Vol. 53, Pg. 129-139.

[15] Ringer, Fritz K."Education and Society in Modern Europe." Bloomington: Indiana University Press, 1979.

[16] U.S. Bureau of the Census. "Census of Manufactures, 1933." Washington, Government Printing Office, 1934.

[17] U.S. Bureau of the Census. "Census of Manufactures, 1935." Washington, Government Printing Office, 1936

[18] U.S. Bureau of the Census. "Census of Manufactures, 1937." Washington, Government Printing Office, 1938..

[19] U.S. Department of Commerce. Bureau of the Census. "Historical Statistics of the United States Colonial Times to 1970." Bicentennial Edition, Part 1. Washington, D.C. (1975)

[20] United States Department of Labor. "Fluctuation in Employment in Ohio 1914-1929." Bulletin of the United States Bureau of Labor Statistics No. 55. United States Government Printing Office, Washington. 1932.

[21] U.S. Department of Labour Women's Bureau. "Bookkeepers, Stenographers and Office Clerks in Ohio 1914 to 1929." Prepared by Amy Maher. Bulletin of the Women's Bureau, No. 95. US Government Printing Office. (1932)

[22] U.S. Department of Labour Women's Bureau. "The Employment of Women in Offices." Prepared by Ethel Erickson. Bulletin of the Women's Bureau, No. 129. US Government Printing Office. (1934)

[23] U.S. Department of Labor. "Fluctation in Employment in Ohio 1941-1929." Bulletin of the U.S. Bureau of Labor Statistics No. 553. (March, 1932)

[24] Woodland, A. (1975), " Substitution of Structures, Equipment and Labour in Canadian Production" , International Economic Review, Vol. 16, Pg. 171-187.

[25] Woolf, A. (1984), " Electricity, Productivity and Labour Saving: American Manufacturing, 1900-1929," Explorations in Economic History, Vol. 21, Pg. 176-191.

[26] Wylie, Peter (1989), " Technological Adaptation in Canadian Manufacturing, 1900-1929" , Journal of Economic History, Vol. 49, Pg. 569-591.