ICT capital and employment of information workers: are they related?

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Abstract: This paper examines the relationship between information and communication technology (ICT) related capital assets and employment of information workers in the private non-farm sector of the US economy. The results from our empirical analysis based on annual data for 59 industries from 2002 to 2007 indicate that, after controlling for relative wages of information workers and other industry-specific factors, an increase in net stock of ICT capital assets decreases the employment of information workers. This finding suggests that the effects of ICT capital assets on the employment of information workers through ICT-enabled business process innovations such as automation and outsourcing dominate over the complementarity effects on high-skilled information workers. Of the three main categories of ICT assets, communications equipment provides more definitive evidence of reducing the employment share of information workers.

Keywords: ICT capital; information workers; information intensity; software; computer and peripheral equipment; communications equipment.

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1 Introduction

An important, and perhaps the most interesting, structural change that has taken place in the US economy (and other advanced economies around the world) in recent decades is that it has evolved from being predominantly a physical or material to an information economy. According to Apte et al. (2011a), since the late 1990s more than 60% of the gross national product (GNP) has been generated in the information sector of the economy.[1] Another significant aspect of this structural shift is the growth of information workers.[2] According to Wolff (2006), information workers increased from 37% of the workforce in 1950 to 59% in 2000. Using a different conceptual framework, Apte et al. (2008) show that information workers constituted about 45% of total employment in the USA in 1999. Updating this study, Apte et al. (2011a) further shows that the employment share of information workers has increased to more than 47% by 2007. The unprecedented advances in information and communication technology (ICT) have been the most prominent driving force behind these changes. These technological changes have also entailed investment in ICT related capital assets such as computer hardware and software, and various communications equipment. In recent years, the net stock of ICT capital assets accounted for about one-fourth of the total stock of fixed assets (equipment and software) in the private non-farm sector of the US economy.[3]

The objective of the current study is to examine if there is a systematic relationship between ICT capital assets and the employment of information workers. In particular, this paper investigates the effects of ICT capital assets on the employment of information workers. There are at least three major channels through which ICT capital assets can potentially affect the employment of the workers who are engaged in information intensive jobs.[4] The first channel is the automation of information intensive jobs. For example, the bank teller's job is being replaced by an automated teller machine (ATM) or the airline ticket reservation clerk's job is being replaced by software. Thus, one would expect that installation of ICT capital assets will reduce the employment of information workers. Second, the ICT has enabled the companies to outsource some of their information intensive jobs to other companies located both in and out of the country. For example, McDonald's outsourced its drive-through order-taking to another location.[5] Or a major publisher in the USA outsourced its typesetting job to a Desktop Publishing (DTP) firm in India. In these cases, outsourcing involves potential reduction in the employment of information workers by the firm that has outsourced and increase in employment of information workers by the firm receiving the outsourcing contracts. In case of offshore outsourcing, this is likely to decrease the employment of information workers in the economy whereas in case of domestic outsourcing the effect on employment in the economy is ambiguous. However, both firms are likely to increase the stock of their ICT capital assets. Finally, investment in ICT capital requires employment of high-skilled workers to work with the high-tech ICT machinery. For example, installation of ICT capital assets may require employment of high-skilled programmers. In this case, there is a complementary relationship between ICT capital assets and information workers. That is, the larger is the stock of ICT capital, the higher will be the employment of information workers.

There is a literature that discusses the labour market effects of skill-biased technological changes (SBTC). For example, Wolff (2002) shows that computerisation is associated with skill changes and occupational restructuring. Autor et al. (2003) show that computerisation is associated with reduced labour input of routine manual and routine cognitive tasks and increases labour input of non-routine cognitive tasks. Wolff (2006) further shows that the growth of information workers is partially attributable to changes in production technology that make it possible to substitute goods and service workers for information workers and partly to differential rates of productivity movements among the industries of the economy. Machin and Reenen (1998) and Berman et al. (1998) examine the labour market implications of SBTC in an international context. The relationship between ICT capital assets and information workers has also been examined in the context of increasing wage gap between low-skilled and high-skilled workers. For example, Autor et al. (1998) argue that increased use of computers and skill-upgrading account for the growth in demand for and wages of skilled workers. Focusing on IT professionals, Mithas and Krishnan (2008) further document that investment in human capital and IT-intensity of firms lead to substantially higher compensation for these workers.

Using annual data for 59 industries from 2002 to 2007, this paper estimates a panel regression model to examine the relationship between ICT capital assets and employment of information workers in the private non-farm sector of the US economy. The estimation results indicate that, after controlling for relative wages of information workers and other industry-specific factors, an increase in net stock of ICT capital assets decreases the employment of information workers. This finding indicates that the effects of ICT capital assets on the employment of information workers through automation and outsourcing are dominant over their complementarity effects on the employment of high-skilled information workers. Furthermore, among the three major categories of ICT capital assets, communications equipment has consistently significant negative effects on the employment of information workers.

The rest of the paper is organised as follows. Section 2 describes the data and the empirical methodology. The estimation results and their analysis are presented in Section 3. Section 4 includes a summary and a few concluding remarks.

2 Data and methodology

2.1 Data

This study uses two sets of data. The first dataset includes occupational employment and wage data by detailed industry and the second set comprises industry-level data on various fixed assets.

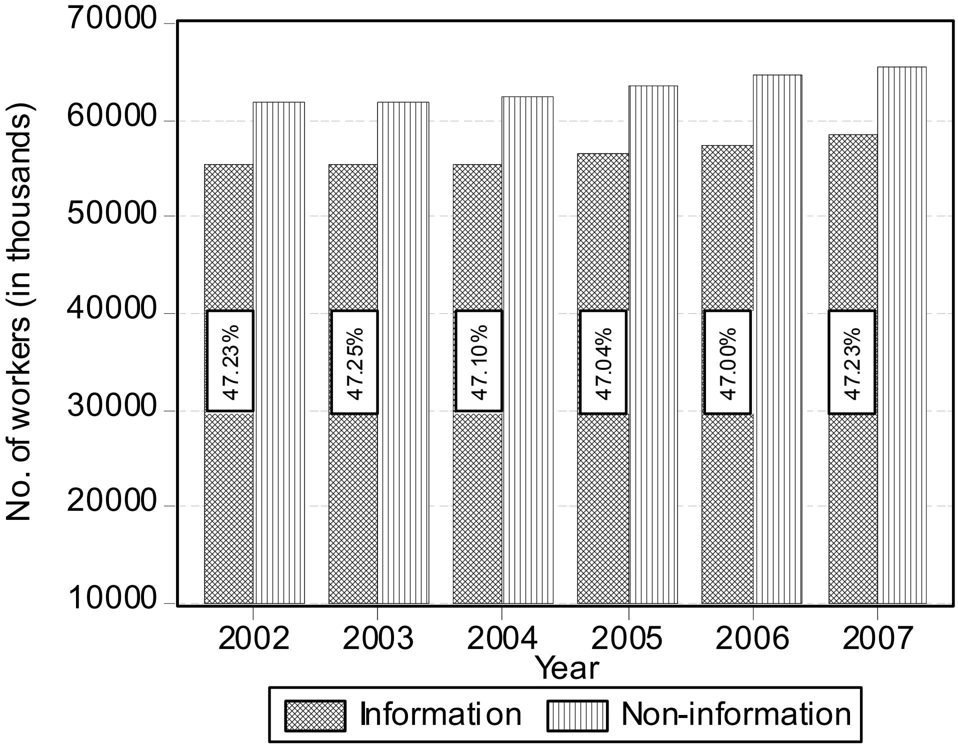
Annual industry-level data on employment and annual mean wages for over 800 occupations by three-digit and four-digit North American Industrial Classification System (NAICS) industries for the period between 2002 and 2007 are obtained from the archived data files available at the Bureau of Labor Statistics (BLS) (2010) website (http://www.bls.gov/oes/oes_arch.htm). These data are used to calculate the fulltime equivalent (FTE) employment and average wages for information and non-information workers. For consistency, employment and wage data are consolidated for the same 59 private non-farm industries as those for which ICT capital assets data are available. The selection of the sample period, 2002 to 2007, is dictated by two considerations. *First*, the data for 1999 through 2001 are available by erstwhile Standard Industrial Classification (SIC) industries while, for 2002 through 2007, they are available by new NAICS industries and these two industrial classifications are not quite comparable at the disaggregate industry level.[6] *Second*, the years between 2002 and 2007 represent a period of business cycle expansion between two recent recessions in the USA.[7]

The construction of data on employment and wages of information workers follows the methodology described in Apte et al. (2008, 2011a, 2011b) and is based on the recognition of the fact that every occupation uses information at various intensities. *Information intensity* of an occupation is defined as the fraction of time spent in dealing with informational actions (i.e., in creating, processing, and communicating information). Apte et al. (2008, 2011b) classified occupations according to five levels of information intensity: 100% information and no physical (non-information); 75% information and 25% physical; 50% information and 50% physical; 25% information and 75% physical; and no information and 100% physical.[8,9] Thus, by applying the weights: 100%, 75%, 50%, 25% and 0%, to employment numbers for various occupations within an industry and aggregating for the industry, the total employment is decomposed into two broad categories, information and non-information (physical) for each disaggregate industry. These weights are further applied to total wages for different occupations (obtained by multiplying annual mean wage by the number of workers in each occupation) to decompose the industry wage bill into information and non-information. For each industry, the average wage for information workers is calculated by dividing total information wages by the FTE number of information workers. Thus, the occupational employment data obtained from BLS are used to construct the FTE employment and average wage data by information and non-information classification for 59 industries between 2002 and 2007.[10]

Annual data on current-cost net capital stock for 12 different types of ICT-related fixed assets for 59 three-digit NAICS industries for the period from 2002 to 2007 are obtained from the Fixed Assets Accounts Tables at the Bureau of Economic Analysis (BEA) (2010) website (http://www.bea.gov/national/FA2004/index.asp)[11]. These ICT fixed assets include three types of software (prepackaged, custom, and own account), eight types of hardware (mainframes, PCs, DASDs, printers, terminals, tape drives, storage devices, system integrators), and communications equipment.[12] The BEA also provides data on chained-type quantity indexes for net capital stock, which are used to convert current-cost net capital stock into 2005 constant-cost net capital stock. Since some of these assets are relatively small in quantity (as measured by constant cost value), they are combined into three major categories: software, computer and peripheral equipment, and communications equipment. The aggregation methodology as described by the BEA is used to construct aggregate chained-type quantity indexes for these broad categories, which are then used to convert the current cost values into constant cost values.[13]

Figure 1 presents a bar diagram of the total employment of information and non-information workers in the private non-farm sector of the US economy for 2002 through 2007. The FTE number of information workers accounted for around 47% of total non-farm employment in the private sector of the US economy and it remained fairly constant during this period. Although the employment of information workers grew faster than that of non-information workers between 2002 to 2003, the growth was rather sluggish (0.23% for information workers and 0.14% or non-information workers).[14] The employment growth of information workers was slower than that of non-information workers during 2003 to 2006, the period of job market recovery after the 2001 recession. However, between 2006 and 2007, the employment growth rate for information workers jumped to about 2% and it exceeded the employment growth rate for non-information workers by almost one percentage point.

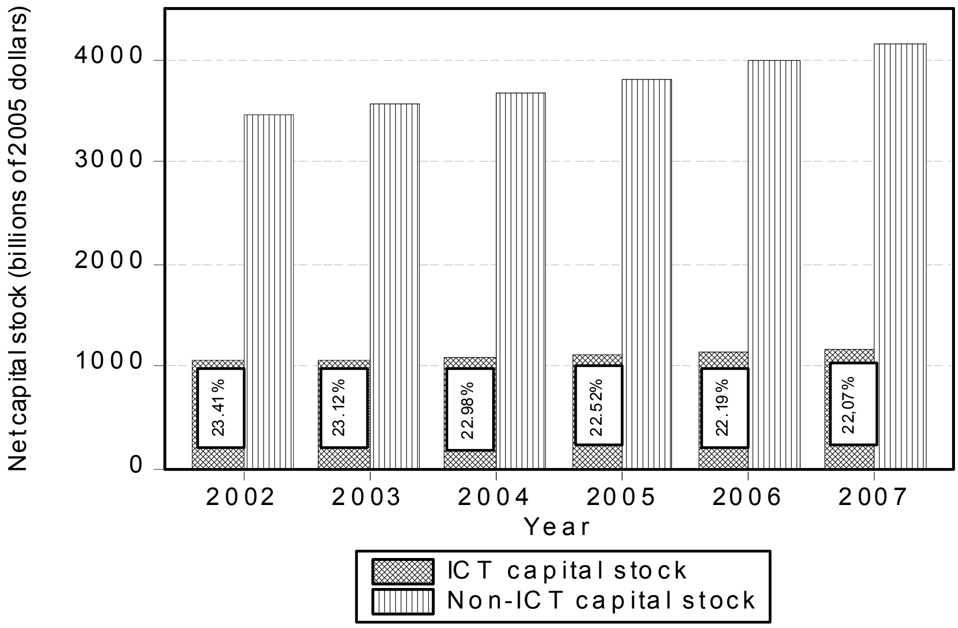
Figure 1 Information and non-information workers in the private non-farm sector of the US economy: 2002 to 2007



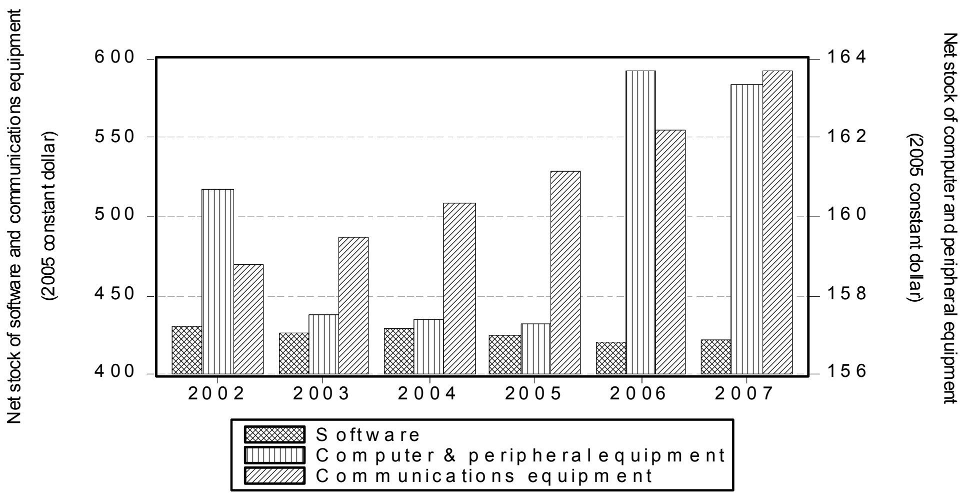
Note: The percentages on the information bars represent percentage shares of information workers in total employment.

Figure 2(a) presents a bar diagram of the constant-cost value (in 2005 USD) of net stock of ICT and non-ICT capital assets for 2002 through 2007. The ICT net capital stock accounted for more than 23% of total net stock of equipment and software (that includes all ICT fixed and other fixed assets) in private non-farm sector of the US economy and this share steadily declined to about 22% in 2007. The ICT capital stock grew at an average annual rate of 2.1% during 2002 to 2003 whereas the growth of net stock of all fixed assets exceeded 3% during this period indicating a much slower rate of net investment in ICT capital assets than in non-ICT assets. Figure 2(b) presents a bar diagram of three major categories of ICT capital assets: software, computer and peripheral equipment, and communications equipment. The share of software in total ICT capital stock steadily declined from about 41% in 2002 to about 35% in 2007. The share of net stock of computer and peripheral equipment fell from more than 15% of total ICT capital stock to about 14% in 2005 and then it rose to about 14.4% (much larger in absolute value). In contrast, the share of communications equipment steadily increased from about 44% to more than 50%.

Figure 2 (a) Net stock of ICT and non-ICT capital assets in private non-farm sector f the US economy: 2002 to 2007* (b) net stock of software, computer and peripheral equipment, and communications equipment in private non-farm sector f the US economy: 2002 to 2007



(a)



(b)

Note: *The percentages on the ICT capital stock bars represent percentage shares of net ICT capital stock in total net capital stock of equipment and software.

At the industry-level, however, there are wide variations in the employment of information workers and ICT capital assets. Table 1 presents summary statistics of a panel dataset that includes data on employment share of information workers, capital shares of three categories of ICT capital assets separately and of all ICT capital assets together for 59 industries between 2002 and 2007. This table illustrates that there exist wide differences in the employment of information workers and ICT capital assets across industries.[15]

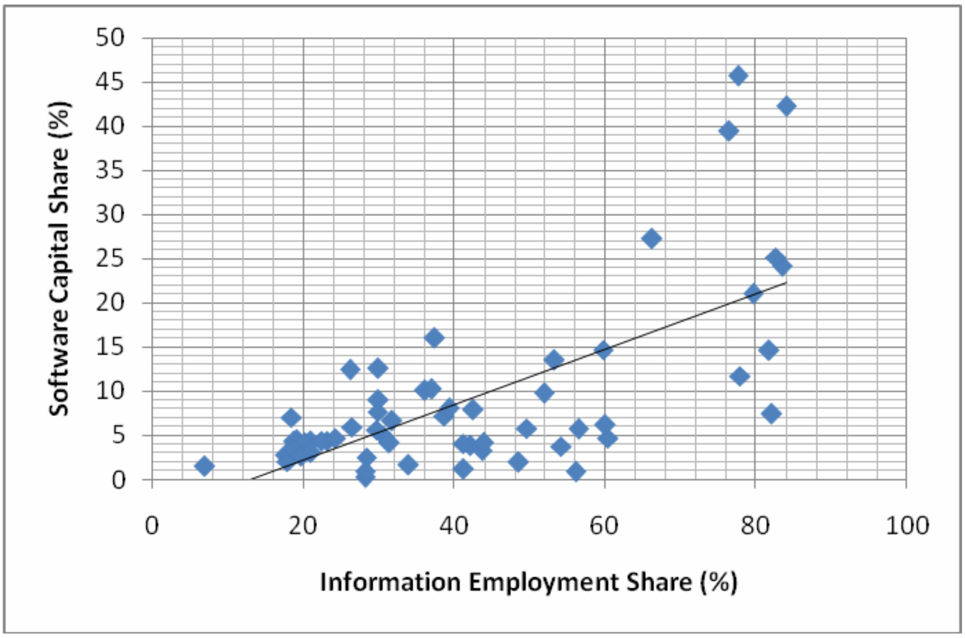
Table 1 Summary statistics of employment shares and net capital stock shares for 59 industries between 2002 and 2007 (in percentages)

	Employment share of information workers	*Net capital stock share of software*	*Net capital stock share of computer and peripheral equipment*	*Net capital stock share of communications equipment*	*Net capital stock share of all ICT capital assets*
	1	*2*	*3*	*4*	*5*
Mean	41.67	9.04	2.90	8.53	20.46
Maximum	84.94	55.95	16.08	70.40	88.52
Minimum	5.92	0.19	0.26	0.41	2.49
Std. dev.	21.07	9.97	3.16	13.02	18.81
Observations	354	354	354	354	354

Figure 3 Scatter plot of employment shares of information workers and net capital stock shares of ICT capital assets, (a) correlation coefficient = 0.67 (b) correlation coefficient = 0.68 (c) correlation coefficient = 0.79 (d) correlation coefficient = 0.27 (see online version for colours)

(a)

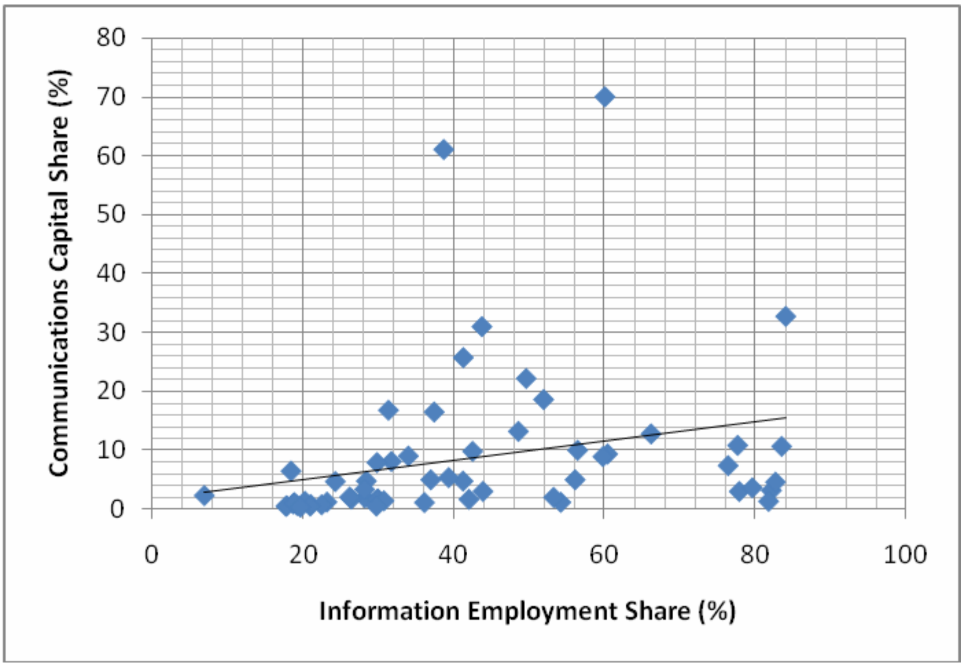
Figure 3 Scatter plot of employment shares of information workers and net capital stock shares of ICT capital assets, (a) correlation coefficient = 0.67 (b) correlation coefficient = 0.68 (c) correlation coefficient = 0.79 (d) correlation coefficient = 0.27 (continued) (see online version for colours)



(b)

(c)

Figure 3 Scatter plot of employment shares of information workers and net capital stock shares of ICT capital assets, (a) correlation coefficient = 0.67 (b) correlation coefficient = 0.68 (c) correlation coefficient = 0.79 (d) correlation coefficient = 0.27 (continued) (see online version for colours)



(d)

Since this paper is intended to examine if there exists any systematic relationship between the employment of information workers and ICT capital assets, Figure 3 presents the scatter plots of average employment shares of information workers (averaged over the sample period) and capital shares of various ICT assets. The estimated correlation coefficient for each pair of variables is presented at the bottom of each scatter plot. These coefficients indicate that there are strong positive relationships between employment share of information workers and capital shares of all ICT capital assets, software, and computer and peripheral equipment. The relationship with the capital share of communications equipment is, although positive, relatively weak. However, these scatter plots and correlations coefficients do not imply any causal relations. Furthermore, these bivariate correlations completely ignore the fact that there may be other factors that affect the relationship between the two variables under consideration. Therefore, it is important to have a fully developed model that incorporates hypothesised relationship with appropriate controls that can be tested.

2.2 Methodology

This paper uses a panel data estimation technique for the empirical analysis. By pooling time-series and cross-section, this method produces more reliable parameter estimates.[16] As discussed above, ICT capital assets may affect the employment of information workers through three different channels: automation, outsourcing, and high-skilled information worker complementarity. Since it is plausible that all three mechanisms are at work in an industry, it is a priori not clear what will be the net effect of a change in the stock of ICT capital assets on the number of information workers employed. Furthermore, there are additional factors that may affect the employment of information workers. For example, there may be changes in demand or/and supply conditions, unrelated to ICT capital assets, in the market for information workers, that lead to a change in their employment. Furthermore, industry-specific characteristics may have an impact on the employment of information workers. However, due to the limited number of observations, it is important to be parsimonious in the specification of the empirical model. Thus, the empirical model to be estimated is specified as follows:

$$infemp_{it} = \mu_i + \beta_1 relwag_{it} + \beta_2 ictcap_{it} + \varepsilon_{it} \quad (1)$$

where $infemp_{it}$ is the employment share of information workers in industry i in year t; μ_i is the time-invariant industry-specific fixed effect; $relwag_{it}$ is relative mean wage of information workers (relative to mean wage for all workers) in industry i in year t; and $ictcap_{it}$ is the net capital stock share of ICT capital assets in industry i in period t; and ε_{it} is the error term; $i = 1, 2,\ldots,59$ indexes industry and $t = 2002, 2003,\ldots,2007$ indexes year. Since the current study uses annual data for 59 private industries between 2002 and 2007, a total of 354 (= 59 × 6) observations are used for the estimation of the above model.

The use of ratios, instead of levels, of employment, wage, and ICT capital stock helps address several issues. *First*, since these ratios represent shares in total employment, average wage, and total net capita stock of equipment and software for each industry, changes in these variables subsume the effects of overall growth of the industry. In effect, by definition, they control for the growth of the industry, without having to include additional explanatory variable(s) in the regression equation. However, one needs to be careful in interpreting the results. Because changes in these ratios would only reflect relative or net changes in the respective variables. For example, an increase in the employment share of information workers does not necessarily reflect an increase in absolute number of information workers. This may happen due to one of the following:

a the number of information workers increases but the total employment decreases or remains the same

b both the number of information workers and total employment increase but the employment of information workers increases faster than does the employment of non-information workers

c the number of information workers does not change but total employment decreases

d both the number of information workers and total employment decrease but the employment of information workers decreases slower than does the employment of non-information workers.

Second, by reducing the number of variables to be included in the regression model, it helps achieve parsimony in model specification. *Finally*, some of the variables in levels may exhibit stochastic trending properties thus creating the possibility of spurious relationship. The shares are by definition stationary and therefore there is no need to worry about non-stationarity.

Although the baseline specification of the model in equation (1) includes net capital stock share of all ICT capital assets, alternative specifications include capital stock shares of three major categories of ICT capital assets separately and in combinations. One potential concern about the model specification in equation (1) could be over the direction of causality running from ICT capital to the employment of information workers. One can argue that ICT capital stock is not an exogenous variable. It is plausible that the stock of ICT capital assets and the employment of information workers are jointly determined. Alternatively, it is also likely that the employment of information workers determines the stock of ICT capital. However, in the above specification, the maintained assumption, not unrealistically, is that firms within an industry first accumulate capital assets and then hire workers. The accumulation of capital assets usually involves long-term planning whereas employment can be adjusted on a short-term basis. To test the validity of this assumption, the net capital stock share of all ICT capital assets and of three categories separately are regressed on information employment share. The estimated coefficients are found to be statistically insignificant except for the case when the capital stock share of communications equipment is used as the dependent variable. These results provide overwhelming evidence in support of the assumption about the direction of causality.

Like any other price, wage is determined by the joint forces of demand and supply in the labour market. Thus, by including relative wage of information workers, we expect to capture the effects of changes in demand and supply conditions in the market for information workers. There are two potential issues regarding the inclusion of this variable on the right hand side of the equation. First, it is plausible that wage is an endogenous variable. That is, it is determined jointly with the number of workers employed. However, by including it as an explanatory variable in this model, it is implicitly assumed as if individual firms within an industry take the industry wage as given and decide how many workers they would hire at the given wage rate.[17] Second, the channels through which ICT capital assets are hypothesised to have affected the demand for information workers are likely to influence their wages as well. Therefore, as a robustness check, equation (1) is estimated in two stages. In the first stage, the fixed effects panel regression technique is used to regress relative wage on the relevant ICT capital assets variable and the residuals are obtained. In the second stage, these residuals are used instead of relative wages to estimate equation (1). Note that these residuals represent relative wages after controlling for the effects of ICT capital assets and time-invariant industry-specific factors on these wages and, therefore, any changes in them would be due to changes in demand and supply conditions in the information labour market, not related to ICT capital assets.

Finally, the industry-specific fixed effects in equation (1) are expected to capture all time-invariant industry characteristics. Intuitively, one would like to include a time fixed effect to control for the effects of macroeconomic events. To verify if these fixed effects are relevant, redundant variables tests for industry-specific fixed effect as well as for time fixed effects are conducted.[18] The test results suggest that while industry-specific effects are relevant, time fixed effect is redundant.[19] Therefore, it is decided to retain industry-specific fixed effects and to drop the time fixed effect. The model is estimated using feasible generalised least square (FGLS) method with cross-sectional weights that take care of the heteroscedasticity, likely to be present in the data.

Table 2 Fixed effects panel estimate results for 59 private non-farm industries in the USA: 2002 to 2007

Independent variables	*Feasible generalised least square estimates*							
	Model 1	*Model 2*	*Model 3*	*Model 4*	*Model 5*	*Model 6*	*Model 7*	*Model 8*
Annual mean wage for information workers as a percentage share of annual mean wage for all workers (*relwag*)	0.057*** (0.012)	0.057*** (0.013)	0.057*** (0.013)	0.053*** (0.018)	0.057*** (0.012)	0.051*** (0.018)	0.053*** (0.018)	0.050*** (0.018)
Net stock of ICT capital as a percentage share of total net stock of all fixed capital assets (*ictcap*)	–0.026*** (0.004)							
Net stock of software as a percentage share of total net stock of all fixed capital assets (*sofcap*)		–0.009 (0.006)			–0.002 (0.010)	–0.044*** (0.005)		–0.047*** (0.012)
Net stock of computer and peripheral equipment as a percentage share of total net stock of all fixed capital assets (*comcap*)			–0.060** (0.030)		–0.038 (0.044)		–0.164*** (0.015)	0.014 (0.044)
Net stock of communications equipment as a percentage share of total net stock of all fixed capital assets (*ceqcap*)				–0.108** (0.054)		–0.194*** (0.049)	–0.148*** (0.048)	–0.192*** (0.052)
Standard error of regression	0.937	0.940	0.940	0.940	0.940	0.931	0.933	0.925
No. of observations	354	354	354	354	354	354	354	354

Notes: White's robust cross-section standard errors are in parentheses. ***Significant at 1% level; **significant at 5% level; * significant at 10% level.
Dependent variable: employment share of information workers.

3 Empirical results

3.1 Fixed effects panel regression estimates

Table 2 presents the fixed effects panel regression results. For each model specification, we include coefficient estimates along with standard errors and other relevant statistics estimates from the FGLS method. Note that standard errors are estimated using White's heteroscedasticity consistent variance-covariance estimates that are robust to general heteroscedasticity. Column 1 presents estimates for our baseline model. Relative wage of information workers has a significant positive effect on the employment share of information workers. This indicates that as the real mean wage of information workers increases relative to the industry mean wage, the industry hires relatively more information workers (of course, after controlling for the effects of industry-specific factors and ICT capital stock). The share of ICT capital stock in an industry has a significant negative effect on the employment share of information workers in that industry. That is, a relatively higher level of ICT capital stock leads to a relatively lower employment of information workers. Thus, this result suggests that as an industry increases the stock of information capital assets relative to that of other assets, it hires relatively less information workers.

Next, the ICT capital assets are divided into three major categories, software, computer and peripheral equipment, and communications equipment, and the model is reestimated with one or more of these three categories of ICT capital as explanatory variables. In all specifications, the industry-specific fixed effects and relative wages of information workers are included. The main observations from these estimation results can be summarised as follows. First, the positive significant effect of relative wage on the employment share of information workers is robust across various model specifications. Second, when only one category of ICT capital assets is included in the regression equation, software does not have a significant effect on the employment of information workers (model 2). Both computer and peripheral equipment and communications equipment have significant negative effects on the employment share of information workers. Third, when a combination of two categories of ICT capital assets is included, with the combination of software and computer and peripheral equipment (model 5), none of these two types of assets has any significant effect on the employment share of information workers. Further, when all three categories of assets are included, the estimated coefficient for computer and peripheral equipment is positive but statistically insignificant. Finally, that the net capital stock share of communications equipment has a significant negative effect on the employment share of information workers is a robust result.

3.2 Comparative static analysis

In order to have a better understanding of the estimated coefficients, we present the results of a comparative static analysis based on the estimated regression model in Table 3. We first increase the mean real wage of information workers, holding everything else constant, in such a way that relative wage of those workers increases by one percentage point. Thus, the mean wage of non-information workers does not change but the mean wage for the industry as a whole goes up. According to the estimated model, the employment share of information workers should go up by 0.057 percentage point. We then calculate the resultant net increase in the employment of information workers by holding the number of non-information worker constant. The results of this exercise for all 59 industries are shown in column 1 of Table 3. As we can see, education services, which employs the largest share of information workers, experiences the largest increase in employment of information workers: an increase of 33,842 workers as a result of one percentage point increase in relative wage of information workers. If relative wage of information workers increases by one percentage point in every industry, the total employment of these workers rises by 168,887. We do a similar exercise to examine the effect of a one percentage point increase in the net capital stock share of ICT fixed assets. The results are reported in column 2 of Table 3. Each and every industry experiences a decrease in the employment of information workers and total employment decreases by 76,825.

Table 3 Comparative static analysis results: effects on the employment of information workers

Sl. no.	*Industry*	*Effect of a one percentage point increase in relative wage of information workers*	*Effect of a one percentage point increase in net capital stock share of ICT assets*
		1	*2*
1	Forestry, fishing, and related activities	300	–137
2	Oil and gas extraction	155	–71
3	Mining, except oil and gas	149	–68
4	Support activities for mining	152	–69
5	*Utilities*	554	–252
6	*Construction*	5014	–2,285
7	Wood products	384	–175
8	Non-metallic mineral products	377	–172
9	Primary metals	328	–150
10	Fabricated metal products	1,116	–509
11	Machinery	949	–432
12	Computer and electronic products	1,636	–745
13	Electrical equipment, appliances, and components	348	–159
14	Motor vehicles, bodies and trailers, and parts	1,369	–624
15	Furniture and related products	400	–182
16	Miscellaneous manufacturing	538	–245
17	Food, beverage, and tobacco products	1,210	–552
18	Textile mills and textile product mills	285	–130
19	Apparel and leather and allied products	228	–104
20	Paper products	358	–163

Table 3 Comparative static analysis results: effects on the employment of information workers (continued)

Sl. no.	*Industry*	*Effect of a one percentage point increase in relative wage of information workers*	*Effect of a one percentage point increase in net capital stock share of ICT assets*
		1	*2*
21	Printing and related support activities	545	–248
22	Petroleum and coal products	93	–43
23	Chemical products	792	–361
24	Plastics and rubber products	573	–261
25	*Wholesale trade*	7,520	–3,424
26	*Retail trade*	21,992	–10,010
27	Air transportation	523	–238
28	Railroad transportation	171	–78
29	Water transportation	55	–25
30	Truck transportation	1,191	–543
31	Transit and ground passenger transportation	334	–152
32	Pipeline transportation	36	–17
33	Other transportation and support activities	1108	–505
34	Warehousing and storage	574	–262
35	Publishing industries (including software)	1,548	–704
36	Motion picture and sound recording industries	435	–198
37	Broadcasting and telecommunications	1,947	–886
38	Information and data processing services	1,692	–768
39	Federal Reserve Banks	55	–25
40	Credit intermediation and related activities	9,003	–4,087
41	Securities, commodity contracts, and investments	2,729	–1,239
42	Insurance carriers and related activities	7,055	–3,203
43	Funds, trusts, and other financial vehicles	271	–123
44	Real estate	1,690	–770
45	Rental and leasing services and lessors of intangible assets	865	–394
46	Legal services	17,741	–8,062

Table 3 Comparative static analysis results: effects on the employment of information workers (continued)

Sl. no.	*Industry*	*Effect of a one percentage point increase in relative wage of information workers*	*Effect of a one percentage point increase in net capital stock share of ICT assets*
		1	*2*
47	Management of companies and enterprises	4,247	–1,931
48	Administrative and support services	7,029	–3,202
49	Waste management and remediation services	278	–127
50	Educational services	33,842	–15,374
51	Ambulatory healthcare services	5,096	–2,321
52	Hospitals	4,737	–2,158
53	Nursing and residential care facilities	2,301	–1,049
54	Social assistance	2,934	–1,336
55	Performing arts, spectator sports, museums, and related activities	566	–258
56	Amusements, gambling, and recreation industries	1,053	–480
57	Accommodation	1,345	–613
58	Food services and drinking places	5,478	–2,497
59	Other services, except government	3,588	–1,634
	Total	*168,887*	*–76,825*

3.3 Robustness check

As discussed Section 2, ICT capital assets may have an effect on relative wages of information workers and, therefore, it was proposed to estimate the model in two stages. The two-stage estimation results are reported in Table 4. As one can see from the table, the estimated coefficients for relative wage of information workers are almost identical with the results from one-stage estimation reported in Table 3. Although the coefficient estimates for various ICT capital shares are slightly different in magnitude there is no qualitative difference. The coefficient estimates from the first stage estimation, in which various capital asset shares are regressed on relative wage of information workers, are not reported here. It may be mentioned that net capital stock shares of all ICT capital assets, software, and computer and peripheral equipment have significant positive effects and net capital stock share of communications equipment has significant negative effect on the relative wage of information workers.

Table 4 Two-stage fixed effects panel estimate results for 59 private non-farm industries in the USA: 2002 to 2007

Independent variables	*Feasible generalised least square estimates*							
	Model 1	*Model 2*	*Model 3*	*Model 4*	*Model 5*	*Model 6*	*Model 7*	*Model 8*
Annual mean wage for information workers as a percentage share of annual mean wage for all workers (*relwag**)	0.057*** (0.012)	0.057*** (0.013)	0.057*** (0.013)	0.053*** (0.018)	0.057*** (0.012)	0.051*** (0.018)	0.053*** (0.018)	0.050*** (0.018)
Net stock of ICT capital as a percentage share of total net stock of all fixed capital assets (*ictcap*)	–0.025*** (0.004)							
Net stock of software as a percentage share of total net stock of all fixed capital assets (*sofcap*)		–0.007 (0.006)			–0.001 (0.010)	–0.043*** (0.005)		–0.047*** (0.013)
Net stock of computer and peripheral equipment as a percentage share of total net stock of all fixed capital assets (*comcap*)			–0.053* (0.029)		–0.037 (0.044)		–0.164*** (0.015)	0.013 (0.044)
Net stock of communications equipment as a percentage share of total net stock of all fixed capital assets (*ceqcap*)				–0.123** (0.050)		–0.209*** (0.046)	–0.163*** (0.044)	–0.206*** (0.048)
Standard error of regression	0.937	0.940	0.940	0.936	0.940	0.931	0.933	0.925
No. of observations	354	354	354	354	354	354	354	354

Notes: The variable *relwag** is the residual from an estimated fixed effects panel regression of relative wage on ICT capital assets. White's robust cross-section standard errors are in parentheses. ***Significant at 1% level; **significant at 5% level; * significant at 10% level. Dependent variable: employment share of information workers.

3.4 Summary discussion

That relative wages of information workers have a significant positive effect on the employment of information workers seems to suggest that in the market for these workers demand-side conditions are dominant over supply-side conditions. However, it needs further exploration of specific demand and supply conditions, which is outside the scope of the current study. That ICT capital has a significant negative impact on the employment of information workers is indicative of the fact that, in general, ICT-enabled business process innovations such as automation and outsourcing (including offshore outsourcing) of information workers are the dominant channels through which ICT capital assets affect the employment of information workers. As some studies (for example, Bardhan and Kroll, 2003) show, the aftermath of 2001 recession witnessed a spur in offshore outsourcing. The results reported in this study seem to reflect those observations. Of the three main categories of ICT assets, communications equipment provides more definitive evidence of reducing the employment share of information workers. However, these results do not necessarily contradict the findings of some other studies that show that computerisation increases the demand for high-skilled information workers (for example, Autor et al., 2003). First, we define information workers more broadly and do not make any distinction according to their skill levels. Second, in our ICT capital assets, we not only include computer but also include software and communications equipment. Thus, it will be interesting to see if different types of ICT capital assets have differential effects on the employment of information workers who are further categorised according to their specific skills. But it will be outside the scope of this current study.

4 Concluding remarks

In this paper, we examine the relationship between ICT capital assets and employment of information workers in the private non-farm sector of the US economy. Using annual data for 59 industries from 2002 to 2007 we estimate a panel regression model. The estimation results indicate that, after controlling for relative wages of information workers and other industry-specific factors, an increase in net stock of ICT capital assets decreases the employment of information workers. Although more micro-level studies are warranted to confirm it, this finding seems to support the hypothesis that the effects of ICT capital assets on the employment of information workers through ICT-enabled business process innovations such as automation and outsourcing are dominant over their complementarity effects on high-skilled information workers. Among the three major categories of ICT capital assets, communications equipment have more consistently significant negative effects on the employment of information workers.

The unprecedented advances in ICT (mostly embodied in ICT capital assets) during the last two decades have facilitated a flurry of innovations, particularly in services. This trend is likely to continue in near future. These innovations may take place in small scale at the firm level or in much large scale at the industry or economy level. In this dynamic environment, it is very difficult to predict how ICT capital is going to affect the employment of information workers. It will be worthwhile to examine these effects at the micro level to derive management implications for more specific industries and firms. Furthermore, at the industry level it will be interesting to see how ICT capital affects affect the employment of different categories of information workers. Such a study will have useful implications for public policy on education and employment.

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Notes

1 When this material-information dichotomy of the economy is combined with the conventional product-service dichotomy, a very interesting perspective on the structural changes emerges. Karmarkar (2002, 2007) and Apte et al. (2008) discussed these changes and their implications in detail.

2 An information worker is defined as one who is primarily involved in creating, processing, and communicating information.

3 Author's calculation based on the data available at the Bureau of Economic Analysis (BEA) website: http://www.bea.gov.

4 These are only a few in a stream of innovations that have been and will be triggered by ICT advances. For a discussion on how these technologies have revolutionised services and will continue to do so, see Karmarkar (2004). The importance of ICT-enabled service innovations I a more dynamic context and various aspects (good, bad, ugly and self-destructive) of these innovation from a policy perspective have been recently emphasised by Ezell and Atkinson (2010).

5 For example, KITV reports on June 28, 2008 that "more than half of the McDonald's restaurants in Hawaii with drive-through are now using what are called 'emote order takers' – people taking your order from a call centre in El Paso, Texas." (http://www.kitv.com/print/16607424/detail.html)

6 SIC was a product-based classification system that classifies firms (companies) into an industrial category according to the similarity of products. SIC was replaced in 1997 by NAICS that classifies firms according to the similarity of processes.

7 According to the National Bureau of Economic Research (NBER), the 2001 recession began in March 2001 and ended in November 2001 and the latest recession began in November 2007 and ended in June 2009.

8 By physical, they mean physical presence or physical action by a worker.

9 As examples, Apte et al. (2011b) mention, "… while a chief executive spends almost all of her time creating, processing, and communicating information, a surgeon has to devote about half of his time to information actions and other half to physical actions. Similarly, an economist's time is entirely invested in creating, processing, and communicating information whereas a biologist has to devote a significant amount of her time to physical actions in her laboratory or outside." It is almost impossible to come up with a precise number to reflect information intensity and, therefore, this somewhat ad hoc classification scheme is subject to criticism.

10 For a detailed discussion and documentation of the method, see Apte et al. (2008, 2011b).

11 The BEA provides data on current-cost net capital stock by types of fixed assets for a period from 1947 to 2009 under private non-residential fixed assets. These assets are broadly divided into two categories: equipment and software, and structures. However, data on certain categories of fixed assets, particularly ICT fixed assets, are not available for earlier years. Furthermore, software were not considered capital assets.

12 Stiroh (2002) defined information technology (IT) capital to include these 13 types of fixed assets. We will call them ICT capital or ICT capital assets or ICT fixed assets interchangeably.

13 This aggregation methodology is discussed with an example in a companion spreadsheet that comes with the dataset available at the BEA website: http://www.bea.gov/national/FA2004/Details/Index.html.

14 In fact, total non-farm employment fell through most of 2002 and the first three months of 2003, then it levelled off and started growing sharply from August 2003. See BLS monthly data at http://www.bls.gov/.

15 Although it is not clear from this summary statistics table, the differences in these shares over time within each industry are negligible.

16 For a discussion on the benefits and limitations of the panel data techniques, see Baltagi (2005).

17 In fact, a labour demand function derived from the cost minimisation problem that is subject to a given production technology provides the theoretical underpinning for this specification.

18 In order to conduct these tests, restricted models with time fixed effects and industry-specific fixed effects set equal to zero respectively are estimates and corresponding F-statistics are calculated. Rejection of the null hypothesis suggests that the variable is relevant and should be included in the regression model.

19 Since they are not central to the question addressed here, the detailed test results are not reported here to save space. Interested reader may obtain the results directly from the author.