Diffusion of Information and Communication Technologies and the Demand for ICT workers*

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Abstract

This paper investigates the impact of relative (quality-adjusted) computer prices on the industry employment in information technology (IT) occupations for a sample of 28 industries in West Germany. We build on static labour demand functions and incorporate relative computer prices in a panel framework from 1987-2000. We find that a drop in computer prices relative to value added prices increases the level of IT workers. Almost 90 percent of the increase in IT workers can be attributed to the drop in computer prices. Wage and output effects, however, have been less important in explaining the demand for IT workers. Finally, a shift-share analysis indicates that 78 percent of the increase in the IT worker share can be explained by within industry changes using data on 96 industries for the period 1987-1998.

Keywords: information technology workers, skill-biased technological change

JEL Classification: J23, O33

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1. Introduction

IT occupations are among the fastest growing occupations in Germany. Between $1980 - 2000$ employment in five IT-related occupations (computer scientists, system analysts, software developers/computer programmers, IT marketing specialists and other computer scientists) has grown on average by 6.4 percent per year in West Germany. For IT occupations with a university degree the employment growth rate is even higher with about 9.7 percent per year. At the same time computer power exploded and prices of computers fell greatly (see Jorgenson, 2001). For the U.S., the total stock of quality adjusted computing equipment in constant prices grew rapidly with average growth rates between 20 and 30 percent per year (Jorgenson, 2001). German figures show similar tendencies. Despite reports of job cutting in many IT firms, IT workers are still in demand.

On the theoretical side, Saint-Paul (2001) examines the effects of information technology on the demand of labour in the knowledge production. The author finds that both unskilled and skilled IT workers could be benefit from computerization. This paper presents new empirical estimates of the determinants of the labor demand of IT/computer professions. In particular, we estimate static fixed effects models and random coefficients models. While international trends in the employment of IT workers are well documented (see Cooke 2002 for the U.S and Dostal 2000 for Germany), few studies investigate the determinants of employment growth of IT related workers. To our knowledge, this paper presents the first empirical evidence on the link between computer prices and employment of IT occupations. The data consists of panel data on 98 or 28 two-digit industries for the period $1987 - 2000$.

The paper proceeds as follows. Section 2 outlines the specification of the labour demand function and the formulation of the hypothesis, while section 3 describes and summarizes the data. Section 4 presents the empirical results and section 5 concludes.

2. Empirical model and hypothesis

Within-industry shifts versus between-industry shifts

A standard way of evaluating the contribution of changes in the industrial structure is decomposing the employment change in IT occupations into changes that occurred between industries and changes that occurred within industries. The shift-share analysis is carried out using data drawn from the Employment

Register of the Federal Labor Office. Following the framework used by Autor et al. (1998), the change in the aggregate employment share of IT workers can be decomposed into two parts. Let IT be the total number of IT workers and L be total employment. Let l_i be employment in sector i and it_i be the number of IT workers in sector i. Then the aggregate employment share of highly skilled workers can be written as:

$$\frac{IT}{L} = \sum_{i=1}^{S} \frac{it_i}{l_i} \cdot \frac{l_i}{L}. \tag{2.1}$$

Taking first differences with respect to time yields

$$\Delta \frac{IT}{L} = \sum_{i=1}^{S} \Delta \frac{it_i}{l_i} \cdot \frac{\overline{l}_i}{L} + \sum_{i=1}^{S} \frac{\overline{it}_i}{l_i} \Delta \frac{l_i}{L}, \tag{2.2}$$

where Δ denotes the time difference operator and the upper bar denotes the variable's mean over time. $\frac{it_i}{l_i}$ measures the employment share of IT workers in sector i, $\Delta \frac{IT}{L}$ is the change in the employment share of IT workers in the economy as a whole and $\frac{l_i}{L}$ is the sectoral employment share. The above equation thus decomposes the change in the employment share of highly skilled workers into two effects. The first term measures the contribution to the total change which results from employment shifts between sectors of different skill intensities. If there is a substantial reallocation of labor to the skill-intensive sectors, this effect should be large. The second term measures the contribution to the total change which results from the shift towards skilled workers within a sector.

Labour demand model augmented by computer prices

To quantify possible employment gains resulting from computer related technological change we adopt a regression approach grounded in a simple labour demand function. We derive a standard labour demand function based on a CES cost function where for the representative firm in industry i in period t:

$$\ln L_{it} = \alpha_0 + \alpha_1 \ln(W_{it}/P_{it}^Y) + \alpha_2 \ln Y_{it} + \alpha_3 t + e_{it} \tag{2.3}$$

where the variables are defined as follows:

L	employment in IT occupations (alternatively IT occupations with university degree)
W	earnings of IT workers
P^Y	value
Y	output (=value added) in constant prices
t	trend

One might expect that computer related technological change increases the technical efficiency over time. This implies:

$$\ln L_{it} = \alpha_0 + \alpha_1 \ln(W_{it}/P_{it}^Y) + \alpha_2 \ln Y_{it} + \alpha_3 \ln(P_t^C/P_{it}^Y) + e_{it}, \qquad (2.4)$$

where P^C denotes quality adjusted computer prices. The expected signs are positive for α_2 and negative for both α_1 and α_3. The labour demand function will be estimated by fixed effects with heteroscedasticity consistent standard error and the random coefficient model. Furthermore, we will run separate regression for manufacturing and non-manufacturing industries. The main hypothesis to be tested is that technological change associated with reductions in the relative prices of computers increases the demand for IT workers. This can be explained by the fact the IT workers are directly related to introduction of new information technologies. IT workers, for instance, design, manufacture, operate, repair and maintain the IT infrastructure necessary for e-commerce, Internet or other network related activities. Furthermore, less skilled IT workers face a greater chance of being disabled by rapidly evolving computer technologies. In contrast, highly skilled IT workers (those with a university degree) enjoy a strong demand for their services. This may be justified by the fact that highly skilled workers have a comparative advantage in implementing new technologies. Therefore, we expect a stronger impact of computer prices on the demand for workers with a university degree than on the demand for IT workers in general.

3. Data

The data sample used consists of panel data on 28 West German industries for the period 1987−2000. Value added and the value deflator are provided by the national accounts. Wages are measured as average annual salaries (plus fringe benefits and non-wage labor costs) paid to medium-skilled workers in the office and computing machinery and are drawn from the wage and salary statistics.

Price indices for computers and peripheral equipment are taken from the NIPA Table 7.8 published by the U.S. Bureau of Economic Analysis (BEA). Starting

from 1985, BEA has used hedonic price indices for computer equipment to deflate its national accounts output and investment data (BEA, 2001, Whelan, 2000). It provides estimates for the quality-adjusted price index of computers and peripheral equipment for the period 1966 −2000. The measured decline is 16.3 percent per year for computer and peripheral equipment for the period 1970 −1999. For Germany, quality adjusted computer prices are not available. The computer price index is adjusted for exchange rates movements between US-$ and DM.

The number of IT workers is drawn from the employment register of Social security. Following the official classification of the Federal Statistical Office Germany only the core IT professions can be clearly defined. Occupations in this area include software engineers, computer support specialists, database administrators, computer systems analysts, technical support representatives and network specialists (see Table 1). Telecommunication and electrical professions are not included. Since there are no changes to the occupational system, it is possible to construct time series of employment of IT workers.

IT occupations are among the fastest growing occupations in Germany. While in 1970 hardly 60,000 workers could be found in this profession, by 2000 there were 380,000 IT occupations in West Germany (see Table 7 in appendix). This corresponds to 1.4 percent of all West German workers in 1998 (see Table 9 in appendix). In 2000, there were 418,000 IT occupations in Germany (East and West). About one third (34 percent) of the workers with IT occupations were in jobs that generally need an university degree. Since the beginning of 2001, however, as the economy has weakened, employment growth of IT industries has slowed considerably.

Service industries, with the exception of financial intermediation, have enjoyed higher than average rates of employment growth in IT occupations. From 1980 to 2000 IT jobs in business services (including data processing and software services) grew almost twice as fast (11.6 percent per year) as the sector average (6.4 percent per year) (see Table 8 in appendix). Manufacturing industries, however, have seen little job growth in IT occupations. Some industries such as mining and quarrying, textiles, leather and wearing apparel and office and computing machinery have even lost IT jobs in the 1990s. The employmemt growth rate of IT workers with a university degree is about 9.7 percent per year (see Table 10 in appendix).

4. Empirical results

Table 2 shows the result of the shift-share analysis using 96 industries for the period 1987-1998. The last column shows the within shift as a proportion of the total change. For IT workers, 78 percent of the total 0.6 percentage point increase can be attributed to within industry changes during the period between 1987 and 1997. Thus, nearly all industries have experienced increases in the share of IT occupations. Note that self-employed workers and workers who earn less than a minimum threshold are not covered by this data base. Therefore the industry share of some service industries may be underestimated to some extent.

The results of the labour demand models are presented in Table 3-5. Table 3 reports four sets of estimates: the base specification (i) with time effects or (ii) with a time trend, (iii) the base specification augmented by the relative computer prices and (iv) and for the latter also the estimates based on a random coefficients model. Output and wages have the expected impacts but the wage elasticity, in absolute values, seems to be rather high. The output elasticity of IT workers is between 0.82 and 0.95. The coefficient on the time trend indicates that teh employment in IT occupations increases by 3.7 percent per year given the impact of output and wages. Column iii reports the results of introducing relative computer prices into the base employment equation. Since both relative computer prices and real wages do not vary much across industries, time effects or the time trend are highly collinear with computer prices. Therefore, it is difficult to separate time effects from the impact of computer prices.

Turning the impact of computer prices we see that the effect is negative, as expected, and significant at the 1 percent level. The final specification allows the coefficients to be variable across the industries. The coefficient on the relative computer prices remains negative when we go from the fixed effects to the random coefficients specification, but the effects are not statistically significant at conventional levels.

In Table 4 we investigate the effects of computer prices on the derived labour for IT occupations with a university degree. We find stronger effects of computer prices on IT workers with a university degree than on IT workers in general. In Table 5 we present results for two split samples: manufacturing and services industries. Again, we find a significantly negative effect of the computer prices on the demand for both IT workers and IT workers with a university degree. For IT workers we find some evidence that the impact of computer prices is stronger in service industries than in manufacturing.

What are the employment implications of these results? Over the period 1987-2000 employment in IT occupations increased by 4.4 percent (unweighted average). Our results indicate that the technological change associated with the drop in computer prices accounts for 88 percent of the increase of 4.4 percent per year over the period (see Table 6).

5. Conclusions

This paper investigates the impact of relative (quality-adjusted) computer prices on the industry employment in information technology (IT) occupations for a sample of 28 industries in West Germany. We estimated static labour demand functions and incorporate relative computer prices in a panel framework from 1987-2000. We find that a drop in computer prices relative to value added prices increase the level of IT workers. Almost 90 percent of the increase in IT workers can be attributed to the drop in computer prices. Wage and output effects, however, have been less important in explaining the demand for IT workers. Finally, a shift-share analysis indicates that 78 percent of the increase in the IT worker share can be explained by within industry changes using data on 96 industries for the period 1987-1998.

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Table 1: Professional Classification of Computer Professions

774		Data processing specialists, computer scientists
	7741	Data processing (DP) specialists
	7742	Computer Scientists
	7743	Mathematical-technical assistants
	7744	Computer Scientists assistants
	7745	DP managers
	7749	Other data processing specialists
775		Software developers, general
	7750	Software developers, general
	7751	Application software developers
	7752	System software developers
	7753	Managers software developers
776		DP Organizers and related professions
	7761	DO organizers
	7762	System analyzers
	7763	DP coordinators
	7764	Managers DP organization/system analysists
777		DP advisors and marketing specialists
	7771	DP advisors
	7772	DP marketing specialists
778		Computing centre and DP user service specialists
	7780	Computing centre specialists
	7781	Operators
	7782	Production schedulers and reworkers
	7783	EDP administrators
	7784	Computing centre managers
	7789	Other computing centre managers
779		
	7791	Data processing businessmen
	7792	Economic informaticians/computer scientists
	7793	Medical informaticians/computer scientists
	7794	DP auditors, DP controllers

Table 2: Shift-share analysis of the change in employment in IT occupations, 1987-1998

number of IT workers (1000s)		IT worker share in percent		total change	between change	within change	within change in percent
				percentage points			
1987	1998	1987	1998	1987/1998			
165	379	0.8	1.4	0.63	0.14	0.49	78.2

Notes: Number of industries is 96. Source: Employment Register of Social Security, Federal Employment Office, own calculations.

Table 3: Labour demand function for IT occupations: fixed effects and random coefficients results:

	Fixed effects model			RCM
	time effects (i)	time trend (i)	comp. prices (i)	(iv)
output, $\ln Y$	0.82 (12.82)	0.83 (9.89)	0.86 (9.83)	0.95 (4.99)
real wages, $ln(W/P^Y)$	−1.09 (−12.44)	−1.07 (−13.18)	−0.80 (−10.49)	0.22 (0.58)
computer prices, $ln(P^C/P^Y)$			−0.21 (−12.12)	−0.10 (−1.32)
time trend		0.037 (13.73)		
time effects	yes	no	no	no
fixed effects	yes	yes	yes	yes
constant	0.095 (9.39)			0.003 (0.18)
nobs	392	392	392	392
Adj-R^2	0.66	0.66	0.64	0.33

Table 4: Labour demand function for IT occupations with a university degree: Fixed effects and random coefficients results:

	Fixed effects model			RCM
	time effects	time trend	comp prices	
	(i)	(ii)	(iii)	(iv)
$\ln Y$	0.65	0.68	0.74	1.52
	(9.28)	(7.52)	(7.43)	(5.34)
$ln(W/P^Y)$	−1.32	−1.29	−0.76	0.65
	(−13.90)	(−14.52)	(−8.48)	(2.10)
$ln(P^C/P^Y)$			−0.41	−0.16
			(−8.48)	(−2.62)
time trend	no	0.073	no	no
		(21.83)		
time effects	yes	no	no	no
fixed effects	yes	yes	yes	yes
constant	0.15			−0.001
	(13.57)			(−0.08)
nobs	392	392	392	392
Adj. R^2	0.76	0.74	0.68	0.12

Table 5: Labour demand function for IT occupations: split sample estimates

	$\ln Y$	$ln(W/P^Y)$	$ln(P^C/P^Y)$	nobs	adj-R^2
Dep variable: IT workers					
manufacturing, construction	0.40	−0.66	−0.12	266	.56
	(6.87)	(−9.46)	(−7.03)		
services	1.12	−0.05	−0.25	126	.76
	(4.39)	(−0.12)	(−5.23)		
Dep variable: IT workers with a university degree					
manufacturing, construction	0.29	−0.63	−0.33	266	.58
	(2.93)	(−7.06)	(−12.41)		
services	1.50	−0.38	−0.31	126	.84
	(6.25)	(−1.18)	(−6.47)		

Table 6: decomposition analysis (percentages in parentheses)

	IT workers	IT workers with a university degree
output effect	0.019 (58)	0.016 (29)
wage effect	−0.015 (46)	−0.014 (25)
computer price effect	0.028 (88)	0.053 (96)
predicted employment	0.032 (100)	0.056 (100)
actual employment	0.044	0.076

Table 7: Employment in IT/computer professions across industries (West Germany)

NACE		1980	1990	2000
01-05	Agriculture, forestry & fishing	48	104	134
10-14	Mining & quarrying	215	411	268
15-16	Food, drink & tobacco	2,350	2,761	2,529
17-19	Textiles, leather, footwear & clothing	1,598	1,815	1,419
20	Wood & products of wood & cork	136	164	256
21-22	Pulp, paper, printing & publishing	2,482	4,705	8,187
23	Mineral oil refining, coke & fuel	466	577	565
24	Chemicals	3,443	6,738	6,823
25	Rubber & plastics	1,151	2,102	2,358
26	Non-metallic mineral products	956	1,244	1,421
27-28	Basic metals & fabricated metal prod.	4348	6,224	6,367
29	Mechanical engineering	4672	9,619	10,152
30	Office & computing machinery	7414	9,995	7,217
31-33	Electrical & electronic equip., instrum.	12,670	20,916	23,408
34-35	Transport equipment	5,355	9,942	9,487
36-37	Furniture, miscellaneous, recycling	691	865	1,075
40-41	Electricity, gas & water supply	2243	3,460	3,314
45	Construction	486	844	1,177
50-52	Wholesale & retail trade, repairs	13,379	25,703	43,447
55	Hotels & catering	77	270	493
60-64	Transport & communications	2,444	6,434	15,612
65-67	Financial intermediation	9,226	16,797	20,283
70	Real estate activities	892	2113	5,891
71-74	Business services	19,925	58,697	178,525
90-99	Other services	262	810	1,565
75-85	Non-market services & public sector	12,230	17,828	26,593
	Total	109,159	211,138	378,566

Source: Employment Register of Social Security, Federal Employment Office, own calculations.

Table 8: Employment growth of IT/computer professions across industries (West Germany)

NACE		'80/'90	'90/'00	'80/'00
01-05	Agriculture, forestry & fishing	8.0	2.6	5.3
10-14	Mining & quarrying	6.7	−4.2	1.1
15-16	Food, drink & tobacco	1.6	−0.9	0.4
17-19	Textiles, leather, footwear & clothing	1.3	−2.4	−0.6
20	Wood & products of wood & cork	1.9	4.6	3.2
21-22	Pulp, paper, printing & publishing	6.6	5.7	6.1
23	Mineral oil refining, coke & nuclear fuel	2.2	−0.2	1.0
24	Chemicals	6.9	0.1	3.5
25	Rubber & plastics	6.2	1.2	3.7
26	Non-metallic mineral products	2.7	1.3	2.0
27-28	Basic metals & fabricated metal prod.	3.7	0.2	1.9
29	Mechanical engineering	7.5	0.5	4.0
30	Office & computing machinery	3.0	−3.2	−0.1
31-33	Electrical & electronic equip., instrum.	5.1	1.1	3.1
34-35	Transport equipment	6.4	−0.5	2.9
36-37	Furniture, miscellaneous, recycling	2.3	2.2	2.2
40-41	electricity, gas & water supply	4.4	−0.4	2.0
45	Construction	5.7	3.4	4.5
50-52	Wholesale & retail trade, repairs	6.7	5.4	6.1
55	Hotels & catering	13.4	6.2	9.7
60-64	Transport & communications	10.2	9.3	9.7
65-67	Financial intermediation	6.2	1.9	4.0
70	Real estate activities	9.0	10.8	9.9
71-74	Business services	11.4	11.8	11.6
90-99	Other services	11.9	6.8	9.3
75-85	Non-market services & public sector	3.8	4.1	4.0
	Total	6.8	6.0	6.4

Source: Employment Register of Social Security, Federal Employment Office, own calculations.

Table 9: Employment share of IT/computer professions across industries (West Germany) (percentages)

	1980	1990	1998
Agriculture, forestry & fishing	0.0	0.0	0.1
Mining & quarrying	0.1	0.2	0.3
Food, drink & tobacco	0.3	0.4	0.4
Textiles, leather, footwear & clothing	0.2	0.4	0.5
Wood & cork	0.1	0.2	0.3
Pulp, paper, printing & publishing	0.5	0.8	1.4
Mineral oil refining, coke & nuclear fuel	1.5	2.4	2.2
Chemicals	0.6	1.1	1.3
Rubber & plastics	0.3	0.5	0.5
Non-Metallic mineral products	0.3	0.4	0.5
Basic Metals & Fabricated Metal Products	0.3	0.5	0.6
Mechanical Engineering	0.5	0.9	1.1
Office and computing machinery	9.7	11.9	11.2
Electrical and Electronic Equipment; Instruments	1.0	1.6	1.9
Transport Equipment	0.7	1.1	1.1
Furniture. Miscellaneous Manufacturing; recycling	0.2	0.2	0.3
electricity. gas and water supply	1.0	1.4	1.5
Construction	0.0	0.1	0.1
wholesale and retail trade. repairs	0.4	0.7	1.0
Hotels & Catering	0.0	0.0	0.0
Transport and communications	0.2	0.6	1.9
Financial Intermediation	1.2	1.9	2.1
Real Estate Activities	0.7	1.3	2.0
Business Services	2.8	5.4	8.0
Other Services	0.1	0.2	0.2
Non-Market Services	0.4	0.5	0.6
total	0.5	0.9	1.4

Table 10: Employment in IT/computer professions with a university degree across industries (West Germany)

	employment			employment growth		
sector	1980	1990	2000	'80/'90	'90/'00	'80/'00
manufact., constr., etc.	11,025	25,679	30,790	8.8	1.8	5.3
....Office & computing mach.	3,109	4,134	2,961	2.9	−3.3	−0.2
....Electrical industry	4,163	9,185	11,567	8.2	2.3	5.2
Trade & transport, comm.	2,215	6,411	12,584	11.2	7.0	9.1
Financial Intermediation	698	3,561	6,912	17.7	6.9	12.1
Business Services	5,060	20,593	69,251	15.1	12.9	14.0
Other	1,444	4,381	10,237	11.7	8.9	10.3
Total economy	20,442	60,625	129,774	11.5	7.9	9.7

Source: Employment Register of Social Security, Federal Employment Office, own calculations.