Does ICT Investment Reduce Labor Demand: Evidence from OECD Countries

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Abstract: ICT investment has both a negative substitution effect and a positive compensation effect on labor demand. This paper aims to analyze the mechanism behind this relationship by constructing a labor demand model and examine the dynamic effects by using PVAR model utilizing data from 18 OECD countries spanning the period 1995-2019. The findings indicate that ICT investment initially reduces labor demand in the current period but ultimately leads to an increase in labor demand in the long run. Furthermore, the study explores the impact of three categories of ICT subtypes on labor demand. The results reveal that the negative impact in the current period presents Software and Database > Communication Technology > Internet Technology, and the positive impact in the long term presents Software and Database > Internet Technology > Communication Technology. These results suggest that Software and Database exert a more substantial influence on labor demand. These empirical findings offer valuable insights in managing the relationship between digital economy development and ensuring stable employment.

Keywords: ICT investment; Substitution effect; Compensation effect; Labor demand; PVAR analysis

1. Introduction

The question of whether automation and intelligent operations brought about by ICT will replace traditional jobs has been widely debated in society. Frey and Osborne (2017) [1]conducted an estimation of the likelihood of computerization for 702 detailed occupations, revealing that approximately 47% of total U.S. employment within the next 10-20 years is categorized as high-risk, encompassing occupations such as transportation and logistics workers, office and administrative staff, and laborers in production occupations. These occupations are considered susceptible to replacement by computer automation within a relatively short timeframe. Moreover, studies suggest that jobs in the informal employment sector are particularly vulnerable to replacement. Arntz et al. (2016)[2] conducted a comprehensive analysis across 21 OECD countries to estimate the vulnerability of jobs to automation. Their findings indicate that, on average, approximately 9% of jobs are highly sensitive to automation.

Recent advancements in artificial intelligence have sparked heightened concerns regarding job displacement. In November 2022, Open AI, an artificial intelligence research lab in the United

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States, unveiled Chat GPT, a chatbot capable of engaging in context-based conversations that mimic human communication. This development has raised public apprehensions about the potential replacement of jobs in fields such as accounting, law, news media, and software development, as Chat GPT demonstrated proficiency in tasks such as generating standardized reports, composing emails, and even coding software (Alshurafat, 2023; Shamika, 2023)[3-4].

While the conventional perspective suggests that computers are more likely to replace low- and medium-skilled jobs involving repetitive tasks (Autor et al., 2003)[5], the advent of ICT has introduced the possibility of automation encroaching upon non-programmed, high-skilled occupations. For instance, professions such as automobile driving, medical diagnostics, and computational statistics are now susceptible to potential displacement. Furthermore, computers are increasingly challenging human labor in various cognitive tasks. A study conducted by Manyika et al. (2013)[6] estimated that approximately 140 million full-time knowledge workers worldwide could be replaced by sophisticated algorithms.

In recent years, China's ICT industry has experienced remarkable growth, expanding its reach and influence to unprecedented levels. The "14th Five-Year Plan," released by the State Council, highlights China's achievement in constructing the world's largest fiber optic and 4G network. China has also emerged as a global leader in 5G commercialization, boasting an internet penetration rate exceeding 70%. The digital economy core industry's added value in China reached 7.8% of GDP in 2020, propelling the country to the second position worldwide in terms of total digital economy. As a result, the labor market in China has undergone significant transformations, influenced by the continuous and profound impact of ICT. These changes encompass shifts in employment opportunities, employment patterns, and the requisite skill sets, giving rise to both employment creation and employment substitution effects.

Whether ICT investment will lead to "computer substitution" as in developed countries, which in turn will lead to job substitution and lower labor demand, is a particularly critical research issue for China to ensure employment stability. Given that OECD countries have experienced earlier and more representative developments in ICT, this study focuses on OECD countries to investigate the impact of ICT investment on labor demand, with the aim of providing valuable insights and lessons for China.

The subsequent sections of this paper are organized as follows: Part two provides a comprehensive review of the relevant literature. Part three develops a labor demand model and offers an in-depth analysis of the substitution effect and compensation effect of ICT on labor demand. Part four presents the empirical results. Part five concludes the conclusion and policy implications.

2. Literature Review

ICT possesses the characteristics of General Purpose Technology (GPT). Nevertheless, its impact on labor demand is a double-edged sword. On one hand, it has the potential to replace certain jobs and consequently decrease labor demand, exhibiting a negative substitution effect. On the other hand, it can generate employment opportunities through avenues such as increased consumption and investment, leading to a positive compensatory effect. The net effect of ICT investment on labor demand hinges on the relative magnitudes of the substitution and compensation effects.

2.1 Attributes of ICT as a GPT

ICT exhibits the characteristics of a general-purpose technology (GPT) due to three key attributes. Firstly, it possesses universality, being applicable across multiple industrial sectors of the economy. Secondly, ICT typically undergoes technological improvement, initially demonstrating underperformance but subsequently driving continuous progress in the relevant sectors. Lastly, it displays innovative complementarity, facilitating the invention of new products and production processes (Bresnahan and Trajtenberg, 1995)[7]. It is through these attributes that ICT holds the potential to enhance overall economic productivity. However, it is important to note that the construction and operation of ICT infrastructure entail significant upfront investments, which can contribute to economic volatility. David (1990)[8], Lipsey and Bekar (1995)[9] argue that the introduction of GPTs, such as steam engines, generators, lasers, and computers, involves substantial costs related to reconstruction and adjustment. Consequently, it is unrealistic to expect a smooth process, contrary to the assumptions of real business cycle (RBC) theory. In fact, the initial effect of a significant technology shock is often a reduction in output, productivity, and employment levels. Basu and Fernald (2007) [10]further highlight that the U.S. ICT industry, consistent with GPT theory, experiences a lag of 5-15 years between capital growth and accelerated total factor productivity.

2.2 ICT and production efficiency

Firstly, ICT plays a role in reducing the impact of information asymmetry. Information and communication technology improves the internal and external communication and coordination of enterprises, thereby mitigating information asymmetry. Enterprises with advanced information technology are better equipped to conduct market research and economic analysis, enabling them to obtain more accurate information and make precise judgments (Li et al., 2011)[11]. This, in turn, helps improve "ex-ante" investment efficiency and enables effective responses to demand shocks, thereby enhancing capacity utilization and production efficiency (Wang et al., 2017)[12]. Moreover, in countries with higher information technology penetration, firms can utilize current and superior technology more effectively for production, thanks to reduced information asymmetry, leading to enhanced productivity (Roller and Waverman, 2001)[13].

Secondly, ICT facilitates the optimization of production and management processes. By promoting the optimization and upgrading of organizational and management methods, ICT enables more convenient and efficient production management. It prompts enterprises to streamline processes, reduce costs, and improve efficiency in production, sales (Kelly et al., 2017)[14], and overall business management. Goldfarb and Tucker (2019)[15] emphasize that enterprises leveraging internet-based organizational management innovations can reduce information search costs, transportation costs, and improve order tracking, ultimately enhancing the efficiency of business operations, production, and innovation activities.

Thirdly, ICT enhances the efficiency of enterprise collaboration. With information technology in place, enterprises can swiftly receive production orders and simultaneously access production instructions and allocate resources from relevant upstream and downstream entities.

Such collaborative production relationships significantly reduce transaction costs, enabling enterprise resource management to extend beyond the internal organization and encompass the entire industrial chain. Goldfarb and Tucker (2019)[15] highlight that ICT provides immediate and comprehensive supply and demand matching information for intra-regional production activities, thereby greatly improving the efficiency of division of labor in enterprise collaboration. Moreover, Du and Guan (2021)[16] argue that in the current global production system characterized by intra-product division of labor, digital technologies facilitate orderly collaboration among different countries, regions, and production segments.

2.3 Substitution effect of ICT

The substitution effect of ICT stems from the technological progress and productivity improvement within the ICT sector, leading to a decrease in the price of ICT products. This, in turn, facilitates the substitution of ICT capital for other forms of capital as well as labor (Cai et al., 2015)[17]. Firstly, ICT can substitute for labor through productivity enhancements. Cheng and Peng (2018)[18] highlight that the increase in productive efficiency resulting from information technology applications leads to a reduction in the demand for labor in enterprises, as physical labor time decreases while live labor time increases. Secondly, ICT can reduce the demand for labor by promoting mechanization and automation in enterprises. Autor et al. (2003)[5] assert that automation tends to replace low- and medium-skilled workers involved in performing programmed tasks. Cai and Chen (2019)[19] find that middle-tier jobs are particularly vulnerable to replacement during the advancement of artificial intelligence and automation, with a higher concentration of lower-educated and lower-skilled workers in the affected industries. Acemoglu and Restrepo (2020) observe that between 1990 and 2007, the addition of one robot per 1000 U.S. workers led to a decline of 0.2% in the national employment-to-population ratio. Moreover, numerous studies from an information technology bias perspective argue that ICT effectively enhances the efficiency of capital accumulation, resulting in a decreased comparative advantage of labor and a manifestation of machine substitution for human labor within the labor market (Acemoglu and Restrepo, 2020; Wang et al., 2020)[20-21].

2.4 Compensation effect of ICT

Firstly, ICT contributes to an increase in labor demand through enhanced consumption. The improved productivity and reduced product prices resulting from ICT investment lead to an increase in consumers' real income. This, in turn, stimulates consumer demand for goods and services, leading to industry expansion and a greater demand for workers. A study by PwC highlights that automated information technology enhances labor productivity, lowers product prices, raises consumers' real income levels, and drives an expansion in consumer demand. Consequently, businesses need to hire more labor to meet the increased demand, thereby creating new employment opportunities (PwC, 2018)[22].

Secondly, ICT fosters an increase in labor demand through heightened investment. By reducing production costs and product prices, ICT facilitates the expansion of consumer demand in the market. This, in turn, encourages firms to expand their production to meet the growing market demand. Bresnahan et al. (2002)[23], using firm-level data, find that lower ICT prices lead to increased investment in product and service innovation, which in turn generates a higher demand for skilled workers. Furthermore, the advancements in ICT facilitate the creation of new products, business models, and industry models, which attract firm investments in new product development and production, consequently contributing to employment growth. Yang et al. (2018)[24] argue that digital technology and the emergence of new industries such as the platform economy and the sharing economy have resulted in the creation of numerous new jobs and the absorption of a significant workforce within the tertiary sector. Additionally, ICT can also generate new job opportunities through the "fans economy" (Jiang, 2017)[25] and the "Gig economy" (Mo and Li, 2022)[26].

2.5 Comprehensive impact

ICT has both a negative substitution effect and a positive compensation effect on labor demand, and the overall net effect depends on the relative magnitude of these opposing forces. According to neoclassical labor demand theory, the impact of technological progress on employment is determined by the technological elasticity of aggregate demand. If this elasticity is greater than 1, technological progress leads to an increase in employment, whereas if it is less than 1, technological progress reduces employment. Mortensen and Pissarides (1998)[27] suggest that when the cost of technological innovation is low, the increase in production efficiency results in a job creation effect that surpasses the labor substitution effect, leading to a decrease in the unemployment rate.

Acemoglu and Restrepo (2018)[28] emphasize that technologies such as robotics and artificial intelligence have a dual effect. Automation tends to reduce employment by replacing tasks previously performed by low-skilled labor. However, the "creation of new tasks" also contributes to increased employment, particularly benefiting high-skilled labor. Consequently, inequality may increase during the transitional phase after the introduction of new technologies. However, in the long run, the "creation of new tasks" can have different effects as these tasks may later become standardized and accessible to lower-skilled labor. If the standardization effect is strong enough, it can lead to a balanced growth path in the long term.

Synthesizing previous studies, it is evident that ICT has both substitution and compensation effects on labor demand, with the combined effects influenced by factors such as technology costs and the technical elasticity of aggregate demand. Furthermore, these effects are also influenced by the time horizon considered. While many scholars have conducted in-depth analyses of the mechanisms through which ICT affects labor demand and have performed regression tests to explore these effects, there is limited literature that examines the dynamic relationship between these two interactions. Therefore, this paper aims to contribute by utilizing the PVAR model to investigate the dynamic relationship between ICT investment and labor demand, building upon the analysis of the labor demand model to explore this relationship in greater depth.

3. Labor demand model

We can develop a concise model to elucidate the underlying mechanism through which ICT influences labor demand. In the theoretical models on labor demand, the demand relationship for labor depends mainly on the production technology reflected in the firm's production function. The commonly used production functions, divided according to the elasticity of substitution of input factors, are (1) Lyontief production function, whose elasticity of substitution σ=0; (2) Cobb-Douglas (C-D) production function, whose elasticity of substitution σ=1; (3) complete substitution production function, whose elasticity of substitution $\sigma=\infty$; (4) constant elasticity of substitution (CES) production function, whose elasticity of substitution is constant ($0<\sigma<\infty$) (Bosworth et al., 1996)[29]. In general, the Lyontief production function and the perfect substitution production function are more special cases that do not exactly fit economic reality. Using the C-D production function, the derivation process is more simplified, but its drawback is that the elasticity of substitution σ in the production function is always equal to 1 and lacks universality. For this reason, this paper adopts a more general CES production function and assumes that the production technology obeys a logarithmic first-order autoregressive AR(1) process.

It is assumed that under perfectly competitive market conditions, the prices of real factors are constant and representative manufacturers pursue profit maximization. The form of the production function is as follows.

$$Y_t = A_t\left[\beta_1 K_t^{-\rho} + \beta_2 L_t^{-\rho}\right]^{\frac{-\eta}{\rho}} \tag{1}$$

where Y_t denotes total output in period t, A_t denotes broad technology level, K_t and L_t denote capital and labor, respectively, β_1 and β_2 denote the share parameters of capital and labor, $\rho \geq -1$, $\sigma = 1/(1+\rho)$ denotes the elasticity of substitution of capital and labor. η denotes the payoff of scale coefficient, when $\eta > 1$, it means increasing payoff of scale; when $\eta = 1$, it means constant payoff of scale; when $\eta < 1$ when $\eta < 1$, it means decreasing returns to scale.

From equation (1), the profit function of the manufacturer can be found as

$$\pi = Y - (r+\delta)K - \omega L \tag{2}$$

where π denotes the manufacturer's profit, the price of the final good is normalized to 1, r denotes the interest rate, δ denotes the depreciation rate of capital, $r + \delta$ denotes the rent of rented capital, and ω denotes the wage. From the first-order conditions of the manufacturer's profit maximization problem, the capital demand function and the labor demand function can be derived separately as follows.

$$\frac{\partial \pi}{\partial K} = -\frac{\eta}{\rho} A\left[\beta_1 K^{-\rho} + \beta_2 L^{-\rho}\right]^{(\frac{-\eta}{\rho}-1)} \beta_1(-\rho)K^{-\rho-1} - (r+\delta) = 0 \tag{3}$$

$$\frac{\partial \pi}{\partial L} = -\frac{\eta}{\rho} A\left[\beta_1 K^{-\rho} + \beta_2 L^{-\rho}\right]^{(\frac{-\eta}{\rho}-1)} \beta_2(-\rho)L^{-\rho-1} - \omega = 0 \tag{4}$$

Dividing equation (4) by equation (3), we get

$$\frac{\omega}{r+\delta} = \left(\frac{\beta_2}{\beta_1}\right)\left(\frac{K}{L}\right)^{\rho+1} \tag{5}$$

$$K = \left(\frac{\omega}{r+\delta}\right)^{\frac{1}{\rho+1}} \left(\frac{\beta_1}{\beta_2}\right)^{\frac{1}{\rho+1}} L \tag{6}$$

Bringing equation (6) into equation (1), the demand function for labor can be found as

$$L = \left(\frac{Y}{A}\right)^{\frac{1}{\eta}} \psi \tag{7}$$

Where $\psi = (\beta_2)^{1/\rho} \left[1 + \left(\frac{\beta_1}{\beta_2}\right)^{1/(\rho+1)} \left(\frac{\omega}{r+\delta}\right)^{-\rho/(\rho+1)} \right]^{1/\rho}$

By the constant equation of national economic accounting, we have $Y = C + I$, where C denotes consumption and I denotes investment. Equation (7) can be rewritten as

$$L = \left(\frac{C+I}{A}\right)^{\frac{1}{\eta}} \psi \tag{8}$$

Equation (8) shows that labor demand is negatively correlated with technology level A and positively correlated with consumption C and investment I. This qualitative result provides an analytical path to study the impact of ICT investment on the demand for labor. According to the above analysis: (a) ICT will cause an increase in A, which will reduce the demand for labor; (b) advances in information technology will lead to lower production costs and lower prices of final products for enterprises, which can expand consumer demand, and therefore can increase the demand for labor; (c) at the same time, enterprises will further expand their production scale to meet market consumption demand (c) At the same time, in order to meet the market consumption demand, enterprises will further expand their production scale and increase their investment, which in turn will increase the demand for labor. The above relationship can be expressed in function (9) as

$$\text{(a)}\ \frac{dL}{dA}\frac{dA}{dICT} < 0;\ \text{(b)}\ \frac{dL}{dC}\frac{dC}{dICT} > 0;\ \text{(c)}\ \frac{dL}{dI}\frac{dI}{dICT} > 0 \tag{9}$$

In equation (9), (a) indicates that ICT reduces the demand for labor by increasing productivity, i.e., ICT has a substitution effect; (b) and (c) indicate that ICT can boost the demand for labor by expanding consumption and increasing investment, i.e., ICT has a compensatory effect. Thus, on balance, whether ICT increases or decreases the demand for labor depends on the relative magnitude of the above two effects. Of course, what is actually the case needs to be further tested through empirical tests.

4. Empirical test

4.1 Model setting and data description

4.1.1 PVAR model

The objective of this study is to investigate the dynamic effect of ICT investment on labor demand. Based on the previous analysis, ICT exhibits the characteristics of General Purpose Technology (GPT), and its impact on labor demand may manifest over an extended period. In light of this, this paper proposes the utilization of a Panel Vector Autoregressive (PVAR) model to explore the dynamic effect of ICT investment on labor demand.

The PVAR model inherits the advantages of the Vector Autoregressive (VAR) model, which treats all variables as endogenous and allows for the analysis of the effects of each variable, including its lagged variables, on other variables in the model. Additionally, the PVAR model incorporates panel data, thereby effectively addressing the issue of individual heterogeneity and comprehensively considering individual and time effects. The PVAR model employed in this paper is specified as follows.

$$Z_{it} = \alpha_0 + \sum_{j=1}^{p} \alpha_{ij} Z_{it-j} + \gamma_i + \upsilon_t + \varepsilon_{it} \tag{10}$$

where Z denotes ICT investment and labor demand, i denotes country, t denotes time, p denotes the number of lags, γ_i and υ_t denote individual and time effects, and ε_{it} is a random disturbance term. The procedure used in this paper is PVAR2 (Lian and Chung, 2008)[30].

4.1.2 Data description

Compared to late-developing countries, OECD countries have experienced earlier ICT development and can provide more comprehensive insights into the impact of ICT investment on labor demand. Taking into consideration data availability and completeness, this study selects a sample of 18 OECD countries from 1995 to 2019 for analysis. The dataset used comprises various proxies for ICT and labor demand, obtained from the EUKLEMS database. ICT is further categorized into three subtypes: Internet technology (IT), communication technology (CT), and software and database technology (Soft_DB). These three categories are interconnected and closely linked; however, the societal demand for each type of technology may vary over time. Consequently, the impact resulting from the development of these technologies may also differ. For instance, as communication technology becomes faster and more convenient, the urgency for its further development decreases, while the market demand for advancements in big data, artificial intelligence, and industrial software may increase. Therefore, in addition to examining the overall impact of ICT on labor demand, this paper also investigates the dynamic effects of the segmented technologies (IT, CT, and Soft_DB) on labor demand individually. To mitigate the influence of heteroskedasticity, all the aforementioned variables are logarithmically transformed. The statistical characteristics of each variable are presented in Table 1.

4.2 Results

Firstly, unit root tests were conducted on the aforementioned five variables, and the findings revealed that all five variables exhibited non-stationarity. Consequently, differencing was applied to these variables, and unit root tests were performed on the differenced data.The results presented in Table 2 demonstrate that the differenced terms of all five variables passed the unit root test, indicating that they have become stationary variables. Based on the criteria of AIC, BIC, and HQIC, an optimal lag order of 1 was determined for all variables.

Table 1: Descriptive statistics

Variable	Definition	Obs.	Mean	Std. Dev.	Min	Max
EMP	Number of persons employed	449	9.399	2.575	6.786	18.914
ICT	Information and communication technology stock	432	7.655	0.641	5.814	8.908
IT	Computing equipment capital stock	432	6.121	0.630	4.879	7.709
CT	Communications equipment capital stock	432	6.235	0.864	3.676	8.100
Soft_DB	Computer software and databases capital stock	432	6.797	0.902	3.532	8.527

Table 2: Unit root analysis

	d_EMP	d_ICT	d_IT	d_CT	d_Soft_DB
IPS	-4.5118***	-5.4843***	-6.1479***	-6.1139***	-4.4552***
ADF	137.6972***	162.035***	146.4025***	133.1118***	179.8641***

Note: *** indicates a 1% significance level.

Figure 1 depicts the impulse response of ICT on labor demand. In Figure 1-a, it can be observed that the initial shock of ICT on labor demand is negative in the current period. However, it transitions to a positive impact in the first period, reaches its peak in the second period, and subsequently gradually diminishes before converging to zero. This pattern can be attributed to the short-term effect of ICT, whereby it reduces labor demand through labor-capital substitution while simultaneously enhancing productivity. Nevertheless, as ICT becomes more widely adopted, it lowers production costs for enterprises and leads to a decline in the prices of final products. This, in turn, indirectly stimulates consumption and investment, creating a significant number of new job opportunities. Consequently, in the long run, the compensatory effect of ICT on labor demand outweighs the substitution effect, resulting in increased labor demand.

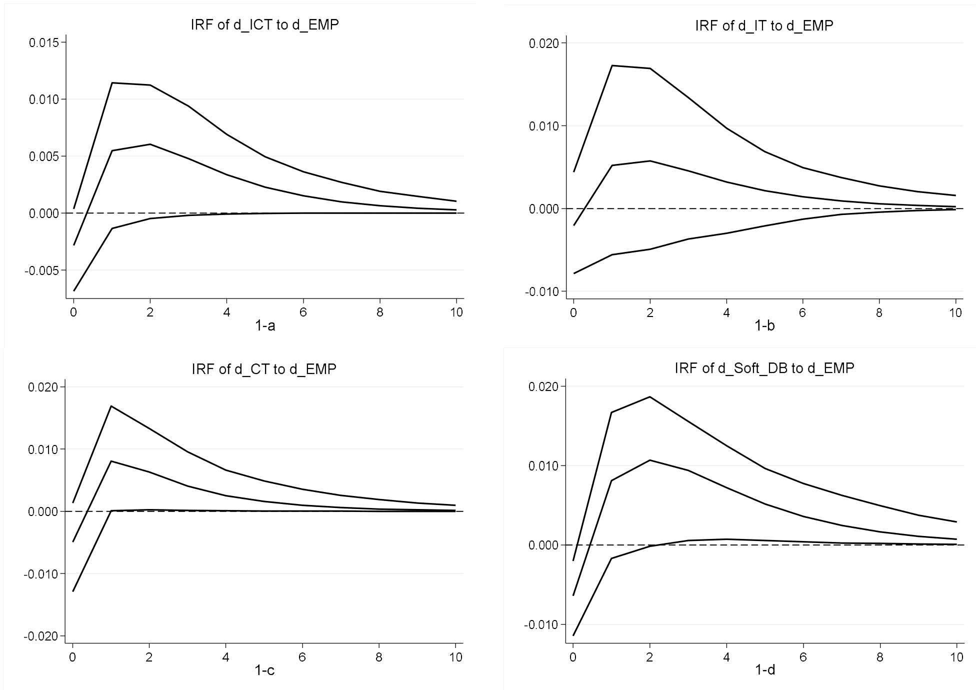

Figure 1: Impulse response diagram of ICT on labor demand

Figures 1-b, 1-c, and 1-d exhibit a similar dynamic impact of Internet technology, communication technology, and software and database on labor demand, respectively. These subcategories of ICT follow the same trend as the overall ICT, displaying a negative impact in the current period, transitioning to a positive effect, and gradually diminishing before reaching zero after reaching its maximum value. This indicates that in the short run, the influence of

Internet technology, communication technology, and software and database on labor demand is primarily driven by the substitution effect, with a stronger compensatory effect emerging in the long run. Ultimately, the compensation effect outweighs the substitution effect in the long run.

In addition, upon analyzing Figures 1-b, 1-c, and 1-d, it becomes evident that the decline in shocks to labor demand is notably slower for Soft_DB compared to IT and CT once they reach their maximum values. This discrepancy suggests that the cumulative impact of the three technology types on labor demand shocks may differ. Consequently, this paper further examines the cumulative impulse responses to gain a deeper understanding of this relationship. The results of the cumulative impulse responses for ICT and its three subdivision technologies are presented in Table 3.

The analysis reveals that the current impulse response of ICT on labor demand is -0.0028, while the cumulative impulse response over a 10-period horizon is 0.023. This finding further supports the notion that the current impact of ICT on labor demand is negative, but the long-term impact is positive. Regarding the segmented technologies, all three types exhibit negative current impulse responses on labor demand, with Soft_DB having the highest negative impact, followed by CT and IT.

Furthermore, the cumulative impulse response analysis demonstrates that the cumulative response of Soft_DB grows at a faster rate, surpassing CT and IT by period 2 and maintaining this trend thereafter. The cumulative impulse response of Internet technology matches that of communication technology in period 3 but then exceeds communication technology. Based on the 10-period cumulative impulse responses, the positive effects indicate that Soft_DB has the greatest long-term impact on labor demand, followed by IT and CT. This suggests that the long-term effects of Soft_DB on labor demand are greater than those of IT and CT. Additionally, the long-term effects of IT on labor demand are greater than CT.

Table 3: Impulse response results of ICT on labor demand

	Impulse response				Cumulative impulse response			
	（1）	（2）	（3）	（4）	（5）	（6）	（7）	（8）
Step	ICT-EMP	IT- EMP	CT-EMP	Soft_DB-EMP	ICT-EMP	IT-EMP	CT-EMP	Soft_DB-EMP
0	-0.0028	-0.0021	-0.005	-0.0064	-0.0028	-0.0021	-0.005	-0.0064
1	0.0055	0.0052	0.008	0.0081	0.0027	0.0031	0.003	0.0017
2	0.006	0.0057	0.0063	0.0107	0.0087	0.0088	0.0093	0.0124
3	0.0048	0.0045	0.004	0.0094	0.0135	0.0133	0.0133	0.0218
4	0.0034	0.0032	0.0025	0.0072	0.0169	0.0165	0.0158	0.029
5	0.0023	0.0022	0.0016	0.0052	0.0192	0.0187	0.0174	0.0342
6	0.0015	0.0014	0.001	0.0036	0.0207	0.0201	0.0184	0.0378
7	0.001	0.0009	0.0006	0.0024	0.0217	0.021	0.019	0.0402
8	0.0006	0.0006	0.0004	0.0016	0.0223	0.0216	0.0194	0.0418
9	0.0004	0.0004	0.0002	0.0011	0.0227	0.022	0.0196	0.0429
10	0.0003	0.0002	0.0001	0.0007	0.023	0.0222	0.0197	0.0436

5. Conclusion and policy implications

With the rapid development of ICT, concerns about the "computer substitution for human" have escalated. Drawing upon the labor demand model, this paper elucidates that ICT investment elicits two effects on labor demand. Firstly, it can diminish the demand for labor by enhancing productivity, thereby exhibiting a substitution effect. Secondly, ICT can bolster the demand for labor by stimulating consumption and investment, demonstrating a compensating effect. Building upon this premise, the study employs data from 18 OECD countries spanning the period 1995-2019 as the research sample and investigates the dynamic relationship between ICT investment and labor demand using the PVAR model. The findings reveal that while ICT investment curtail labor demand in the current period, they augment labor demand in the long run, signifying that the compensatory effect of ICT on labor demand outweighs the substitution effect in the long term.

Furthermore, the paper scrutinizes the dynamic effects of three types of subdivision technologies within ICT on labor demand. The negative effects in the current period follow the order of Soft_DB> CT>IT, whereas the positive effects in the long run exhibit the order of Soft_DB>IT>CT. This outcome suggests that the impact of software and database on labor demand surpasses that of Internet technology and communication technology in both the short and long term.

The policy implication of this study underscores that although ICT may replace certain jobs at the micro level and momentarily reduce labor demand, its extensive implementation can reduce production costs for enterprises and lower product prices. This, in turn, indirectly drives consumption and investment, leading to substantial job creation. Consequently, at the macro level, ICT investment elevates the demand for labor. Therefore, We need to maintain an open and cautious approach to ICT investment. This requires that governments should take into account the short-term and long-term effects of ICT on the labor market. We should steadfastly promote the long-term development and application of ICT, on the other hand, to address the issue of short-term unemployment among low and middle skilled workers resulting from ICT adoption, efforts should be directed toward issuing temporary unemployment allowances, strengthening digital skills training, and promoting re-employment.

Additionally, given the escalating significance of software and database technology in labor demand, it is imperative for governments to prioritize their development and application alongside the construction of Internet technology and communication technology.

References:

[1] Frey, C. B., & Osborne, M. A. (2017). The future of employment: How susceptible are jobs to computerisation? Technological forecasting and social change, 114, 254-280.

[2] Arntz, M., Gregory, T., & Zierahn, U. (2016). The risk of automation for jobs in OECD countries: A comparative analysis. OECD Social, Employment and Migration Working Papers, No. 189, OECD Publishing.

[3] Alshurafat, H. (2023). The Usefulness and challenges of chatbots for accounting professionals: Application On ChatGPT[J]. Available at SSRN 4345921.

[4] Shamika, N. SIRIMANNE. (2023). How artificial intelligence chatbots could affect jobs[EB/OL]. United Nations Conference on Trade and Development.
[5] Autor, D. H., Levy, F., & Murnane, R. J. (2003). The skill content of recent technological change: An empirical exploration. The Quarterly journal of economics, 118(4), 1279-1333.
[6] Manyika, J., Chui, M., Bughin, J., Dobbs, R., Bisson, P.,... Marrs, A. (2013). Disruptive technologies: Advances that will transform life, business, and the global economy (Vol. 180): McKinsey Global Institute San Francisco, CA.
[7] Bresnahan, T. F., & Trajtenberg, M. (1995). General purpose technologies 'Engines of growth'? Journal of econometrics, 65(1), 83-108.
[8] David, P. A. (1990). The dynamo and the computer: an historical perspective on the modern productivity paradox. The American Economic Review, 80(2), 355-361.
[9] Lipsey, R. G., & Bekar, C. (1995). A structuralist view of technical change and economic growth. Bell Canada Papers on Economic and Public Policy, 3(9-75), 24-82.
[10] Basu, S., & Fernald, J. (2007). Information and communications technology as a general-purpose technology: Evidence from US industry data. German Economic Review, 8(2), 146-173.
[11] Li, Y., Yao, S., & Chia, W. M. (2011). Demand uncertainty, information processing ability, and endogenous firm: Another perspective on the impact of ICT. Nankai Business Review International.
[12] Wang, Y. J., Kuang, X., & Shao, W. B. (2017). Informatization, Firm's Flexibility and Capacity Utilization. The Journal of World Economy, 40(1), 67-90.
[13] Roller, L., & Waverman, L. (2001). Telecommunications infrastructure and economic development: A simultaneous approach. American economic review, 91(4), 909-923.
[14] Kelly, T., Liaplina, A., Tan, S. W., & Winkler, H. (2017). Reaping digital dividends: Leveraging the internet for development in Europe and Central Asia: World Bank Publications.
[15] Goldfarb, A., & Tucker, C. (2019). Digital economics. Journal of Economic Literature, 57(1), 3-43.
[16] Du, C. Z., & Guan, H. F. (2021). Digital economy and export technical sophistication of China's manufacturing industry: Test based on mediating effect and threshold effect. South China J. Econ, 12, 1-20.
[17] Cai, Y., & Zhang, J. (2015). The substitution and pervasiveness effects of ICT on China's economic growth. Economic Research Journal, 50(12), 100-114.
[18] Cheng, C. P., & Peng, H. (2018). The mechanism of artificial intelligence affecting employment and China's countermeasures. China Soft Science, 10, 62-70.
[19] Cai, Y., & Chen, N. (2019). Artificial intelligence and high-quality growth & employment in the era of new technological revolution. J. Quant. Tech. Econ, 36, 3-22.
[20] Acemoglu, D., & Restrepo, P. (2020). Robots and jobs: Evidence from US labor markets. Journal of Political Economy, 128(6), 2188-2244.
[21] Wang, L. H., Hu, S. M., & Dong, Z. Q. (2020). Will artificial intelligence technology induce labor income inequality—Model deduction and classification evaluation. China Ind. Econ, 4, 97-115.
[22] PwC, U. K. (2018). Will robots really steal our jobs? An international analysis of the potential long-term impact of automation. Price Waterhouse Coopers LLP.
[23] Bresnahan, T. F., Brynjolfsson, E., & Hitt, L. M. (2002). Information technology, workplace organization, and the demand for skilled labor: Firm-level evidence. The quarterly journal of economics, 117(1), 339-376.
[24] Yang, W., Qiu, Z., & Wu, Q. (2018). A literature review on the impact of artificial intelligence on employment. Chinese Journal of Population Science, 5, 109-119.
[25] Jiang, X. (2017). Resource reorganization and the growth of the service industry in an

interconnected society. Economic Research Journal, 52(3), 4-17.
[26] Mo, Y., & Li, L. (2022). Gig Economy and Entrepreneurship: Evidence from the Entry of Food Delivery Platforms. Management World (In Chinese), 2, 31-45.
[27] Mortensen, D. T., & Pissarides, C. A. (1998). Technological progress, job creation, and job destruction. Review of Economic dynamics, 1(4), 733-753.
[28] Acemoglu, D., & Restrepo, P. (2018). The race between man and machine: Implications of technology for growth, factor shares, and employment. American Economic Review, 108(6), 1488-1542.
[29] Bosworth, D. L., Dawkins, P., Stromback, T. (1996). The economics of the labour market, Financial Times/Prentice Hall.
[30] Lian, Y., & Chung, C. (2008). Are Chinese Listed Firms Over-Investing. Available at SSRN 1296462.