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The Impact of AI On Economic Growth Between China and The United States During the Period 2011—2021

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Abstract: With the introduction of the concept of Industry 4.0 and the widespread use of artificial intelligence in various fields, this paper explores whether the development of artificial intelligence in China and the United States has affected economic development within the last decade. The results show that AI development in both China and the US will impact economic development and that there is a positive relationship between AI and economic development. Meanwhile, comparing the effects of AI on economic growth in these two countries, it is found that the United States would gain more benefits from the higher level of development of AI.

Keywords: artificial intelligence, gross domestic product, economic growth, human labor

1. Introduction

It is well known that technological innovation has played a landmark role in the prosperity of nations throughout history. Thanks to the steam engine, Britain began the first generation of the Industrial Revolution and became the Empire of the Sunset. In turn, the world moved on to the second and third generations. Today, artificial intelligence is kicking off Industry 4.0, pushing technological innovation into a whole new realm. Since the beginning of time, practitioners have been looking for ways to improve productivity and product quality and reduce costs [1], and AI has emerged to meet this demand. Artificial intelligence includes robotics, neural networks, and signaling systems. Robots can be simply programmed to perform specific tasks, which has changed the structure of labor and the skills required for the job; with many traditional jobs being replaced, it has also created new jobs. Artificial intelligence is not only a breakthrough in technology but also profoundly impacts human society's development and economic growth. However, AI as a rapidly developing frontier technology is too new too quickly for the relevant research to be comprehensive. This article examines the economic impact of AI, using two countries as examples and considering that the United States and China are both significant players, both emerging economies and representatives of developed and developing countries. This paper will use the United States and China as examples to study artificial intelligence's different impacts and magnitude on emerging and developed economies'

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economic development. There are various measures of economic progress, such as GDP. In the work, we will use empirical data combined with the annual GDP trend to study different elements of AI and see whether GDP growth is closely related to AI. These include GDP and R&D investment, the number of patents, private investment, the number of papers published on arXiv, and the number of STEM doctoral students.

2. Literature Review

Based on the sample of 283 Chinese cities, Li found that technological innovation contributes to industrial transformation and upgrading that pushes sustainable and high-quality economic development [2]. The research based on the data from 269 Chinese firms pointed out that open innovation enhances sustainable competitiveness directly as it could motivate study in exploration [3]. Moreover, the formation of competitive advantage is indirectly influenced by the mediating mechanism, which is agreed upon by Carmona-Lavadoa [4]. The study focused on the relationships between the level of AI and the economic growth in 28 Chinese provinces from 2015-2018. Supporting the rapid development of AI by supporting that Industrial structure upgrading is an influential mediating variable for artificial intelligence to promote China's economic growth. Like other authors, this author also said that the Chinese policymaker has been one of the most significant issues programmers and engineers face [5]. Anton & Joseph suggest that AI may exacerbate poverty and inequality in developing countries and that AI would be more beneficial to the development of developed countries [6]. As the analysis deepens, scholars find that AI represents both a challenge and an opportunity for developing countries. AI Index is an independent Human-Centered Artificial Intelligence (HAI) initiative at Stanford University [7]. The report provides data on AI by country. Actual data show that China and the US rank first in the world in the number of AI papers published together, despite severe political issues. At the same time, the author hopes that decision-makers can make more meaningful decisions by analyzing the data.

3. Hypothesis

AI has gradually become the core driving force for sustainable economic growth since AI not only directly contributes to regional development and avoids industrial over-upgrading. Even though AI potentially causes a lower level of rationalization, the impacts of AI on economic growth are significantly positive in total [5]. Pradhan provided evidence from 49 European countries to support the hypothesis that technological innovation and financial development are critical factors of per capita economic growth for European countries in the short and long run [8]. Therefore, we put forward the first hypothesis:

H1: Artificial Intelligence Makes a Contribution to Economic Growth in China and America. (1)

Wei pointed out that the competition between China and the United States in AI has been fierce since the status and role of AI are increasingly important [9]. Alonso concluded that the new technological revolution regarding artificial intelligence (AI) and robotics, which is analyzed by the productivity of robots, is raising the level of divergence of advanced and developing economies [10]. To compare the difference in the influence of AI between China and the United States, the outstanding representatives of developing and developed economies, respectively, the second hypothesis is proposed:

H2: The Contributions Made by AI Are Greater In America Than That In China. (2)

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4. Model Constructor

4.1. Model

To research the effects of AI on economic growth, we refer to the model structure of Li [2] on the impact of science and technology innovation and industrial design upgrading on the sustainable and high-quality development of economies, installation of Fan [5] on the relationship between AI and sustainable economic growth and build a new model based on that.

$$GDP_t = \sum_{i=1}^{5} \alpha_i \times \chi_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (1)$$

GDP_t is the gross domestic product of year t, representing economic growth; χ_{it} is a series of independent variables χ_{it} of year t, which are R&D investment, patent, private investment, arXiv article publication, and the number of Ph.D. in STEM. STEM contains four subjects, science, technology, engineering, and mathematics, and is an essential source of scientific and technical personnel in AI. We predict that these five independent variables are the factors that affect the development of AI, indicating the development of AI. $\mu_i$are individual effects, λ_t are time effects, and ε_{it} are random error terms. The α_i corresponding to $\chi_i$represents the magnitude of the effects of independent variables on the dependent variable, economic growth: if $\alpha_i < 0$, there is a negative relationship between the independent variable and economic development; if $\alpha_i > 0$, there is a positive relationship between the independent variable and economic growth; $\alpha_i = 0$ means that AI has no significant effects on economic growth. We used Stata 17.0 for the benchmark regression and model analysis during the research.

4.2. Variable and Measurements

Table 1: Variable and measurements.

Variable	Unit	Description	Country
GDP	$ billion	Gross Domestic Product is the sum of the total value added of all residential and institutional units engaged in production and services.	United States
R&D	$	The amount of money invested in AI research and development per year.	United States
Patent		The number of AI-related patents granted per year in the country	United States
Investment	$ billion	the amount of private investment in AI companies per year.	United States
ArXiv		The number of AI-related papers published in arXiv per year.	United States
PhD		The number of Ph.D. students graduating in STEM per year.	United States
G	$ billion	Gross Domestic Product is the sum of the total value added of all residential and institutional units engaged in production and services.	China
R	$	The amount of money invested in AI research and development per year.	China
P		The number of AI-related patents granted per year in the country	China

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Table 1: (continued).

I	$ billion	The amount of private investment in AI companies per year.	China
A		The number of AI-related papers published in arXiv per year.	China
D		The number of Ph.D. students graduating in STEM per year.	China

Table 2: Basic regression result of China.

Linear regression

g	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
r	.049	.117	0.41	.7	-.277	.374	
p	130.685	48.337	2.70	.054	-3.521	264.891	*
i	128.969	52.745	2.45	.071	-17.475	275.413	*
a	11.338	13.617	0.83	.452	-26.467	49.144	
d	1.463	1.801	0.81	.462	-3.537	6.462	
Constant	-89.436	44075.262	-0.00	.998	-122461.98	122283.11	

Mean dependent var	113632.500	SD dependent var	24438.769
R-squared	0.994	Number of obs	10
F-test	130.120	Prob > F	0.000
Akaike crit. (AIC)	190.426	Bayesian crit. (BIC)	192.242

*** $p<.01$, ** $p<.05$, * $p<.1$

Table 3: Basic regression result of the United States.

gdp	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
rd	.264	.029	9.22	0	.198	.33	***
Constant	44741.87	15405.914	2.90	.02	9215.768	80267.972	**

Mean dependent var	185559.700	SD dependent var	20581.589
R-squared	0.914	Number of obs	10
F-test	85.017	Prob > F	0.000
Akaike crit. (AIC)	205.435	Bayesian crit. (BIC)	206.040

*** $p<.01$, ** $p<.05$, * $p<.1$

gdp	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
rd	-.021	.059	-0.36	.752	-.273	.231	
patent	3.657	.364	10.05	.01	2.092	5.223	***
investment	35.979	7.903	4.55	.045	1.974	69.984	**
arxiv	23.324	4.877	4.78	.041	2.34	44.309	**
phd	4.245	.33	12.86	.006	2.824	5.665	***

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Table 3: (continued).

Constant	40118.653	18425.537	2.18	.161	-39160.035	119397.34	

Mean dependent var	178987.375	SD dependent var	17205.760
R-squared	1.000	Number of obs	8
F-test	2787.060	Prob > F	0.000
Akaike crit. (AIC)	118.889	Bayesian crit. (BIC)	119.366
*** *p<.01*, ** *p<.05*, * *p<.1*			

Table 4: Correlation matrix.

Matrix of correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) gdp	1.000											
(2) rd	0.983	1.000										
(3) patent	-0.712	-0.777	1.000									
(4) investment	0.650	0.697	-0.587	1.000								
(5) arxiv	0.951	0.981	-0.749	0.608	1.000							
(6) phd	0.964	0.917	-0.719	0.555	0.858	1.000						
(7) g	0.992	0.961	-0.633	0.661	0.918	0.958	1.000					
(8) r	0.996	0.969	-0.704	0.605	0.938	0.974	0.988	1.000				
(9) p	0.386	0.253	-0.112	0.154	0.101	0.568	0.446	0.420	1.000			
(10) i	0.803	0.854	-0.622	0.769	0.877	0.649	0.781	0.773	-0.151	1.000		
(11) a	0.952	0.986	-0.737	0.706	0.990	0.847	0.928	0.932	0.106	0.914	1.000	

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Table 4: (continued).

(12) d	0.990	0.993	-0.751	0.629	0.981	0.935	0.969	0.986	0.282	0.832	0.975	1.000

5. Results and Analysis

5.1. Contributes to Economic Growth for China

Table 2 shows the correlations between GDP as the dependent variable and the five sets of independent variables. R&D investment, the number of patents, the amount of private investment, the number of an article published in arXiv, and the number of PhDs in STEM. All other things being equal, the p-values for these factors are more significant than 0.1 for R&D costs, arXiv, and STEM and are, therefore, not statistically significant. In turn, the impact of these three factors on GDP is not statistically significant. For patents, the p-value is less than 0.1 and is statistically significant. This further suggests that all the above factors statistically impact China's GDP at the 10% confidence level. Secondly, the coefficient on the number of patents is 130.6852, on average; all else being equal, one unit increase in the number of AI patents is associated with a corresponding rise in China's GDP of US$130.6852 billion.

Chinese patents are distributed in various fields, such as natural language processing, big data, intelligent cloud, intelligent recommendation, and robotics. The robot includes robot motion control, robot arm control, robot multi-mode operation, and so on. With the development of the times, the 2017 Report on the Work of the Chinese Government pointed out that the rapid growth of artificial intelligence will change human life and the world. China should seize the significant strategic opportunity of AI development, build the first mover advantage of AI development and speed up the construction of China [11]. The intervention of artificial intelligence in the accounting industry overturns the traditional development mode and brings innovation to the accounting industry. The support of relevant policies and the introduction of regulations means that the combination of artificial intelligence and the accounting industry is an inevitable trend in the future [12]. Traditional accounting work is very tedious, but applying artificial intelligence can avoid accounting errors, long-time and personal emotional problems, and avoidance of accounting crime. The company can put the funds into the development of the enterprise, drive the growth of the market economy, and thus have positive help to the economic development of the whole country. The downside is that there will be purchase costs in the short term, but in the future, this is one of the critical factors for the business's success. Alibaba's face recognition technology in payment and financial services and intelligent robot customer services on shopping platforms have driven the transformation and upgrading of business and services through the specific application of these artificial intelligence technologies [12]. Artificial intelligence has become a new hotspot for enterprises to enhance their core competitiveness. Therefore, enterprises should cooperate with cloud computing and extensive data analysis technology to fully use resources.

For private investment, the P-value is less than, 0.1which means that it is statistically significant at a 10% significant level. Second, the coefficient of the number of patents is 128.9687; on average, all other things being equal, every $1 billion increase in AI private investment in China would result in a corresponding rise in GDP by $128.9687 billion. Private investment in AI in China increased from $188.48 million in 2010 to $10.621 billion in 2019, a growing cliff. With the appeal of the Chinese government and the lead of enterprises, Chinese individuals also understand the importance

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of AI. They are willing to invest their funds in AI research, development, and use. The surge in private investment in China has coincided with a nationwide AI boom. The boom has promoted the development of artificial intelligence in China, dramatically increasing China's GDP even under the premise of innate technological deficiency.

5.2. Contributes to Economic Growth for the United States

Table 3 shows the results of the relationship between AI and economic growth in 5 dimensions involving R&D investment, patent, private investment, arXiv article publication, and the number of Ph.D. in STEM. It is shown that the coefficient of R&D investment is -0.0212, and it is not significant, which means that the more R&D investments are made, the less healthy economic growth would be and conflicts with our first hypothesis. One of the reasons may be COVID-19. Back to the data collection of American GDP and R&D investment in 2020 and 2021, GDP is 214332 in 2020 and 209366 in 2021, showing a decreasing trend, and R&D investment is 632654.6 in 2020 664065.7 in 2021. Combining these data shows a negative relationship between GDP and R&D investment in 2020-2021. In the system of fictional accounts, R&D investment is a kind of expenditure that keeps rising during COVID-19. However, the R&D investment could not play the expected roles because the capital of labor in the whole economy becomes much less than before, manifesting that R&D investment is relatively meaningless in contributing the economic growth.

At the same time, we are concerned that the decreasing GDP, an infection point in 2020-2021, results from COVID-19. Xiang stated that the overbreak of COVID-19 has a bad influence on labor supply and output, directly leading to significant adverse effects on economic growth [13]. Therefore, R&D investment is not a good variable when researching the relationship between AI development and economic growth in the United States. The coefficient of the patent is 3.6574, which is significant at a significant level of 1%, standing for that the 1-unit patent increase brings GDP to rise by 3.6574 units of measures. The coefficient of arXiv article publication in AI is 23.3241 at a significant level of 10%, which is substantial. In addition, the coefficient of the number of Ph.D. majoring in STEM is 4.2449, and it is statistically significant at a significant level of 1%. The constant 40118.65 is the amount of GDP if all five variables have the amount of zero. The increase in R&D investment, patents, and scientific knowledge reflects the improvement of the intensity of science and technology in the whole economy [14]. Sachs explained that before the investment took, people, especially workers, started to improve their educational level, and after the R&D investment, the change in academic level became more significant. It can be represented by the rising patent, arXiv article publications, and the number of Ph.D. in STEM since the development of AI reduces the demand for low-skilled labor, meaning that the quantity of work is enhanced. It benefits critical industries like manufacturing, business services, and the high-technological sector in terms of remarkably improved productivity and economic growth, representing the rising GDP. The private investment in AI has a relatively higher coefficient than the other independent variables, 35.9790, significant at a significant level of 5%. Private investment could also provide an impetus for economic growth, lining the abovementioned aspects. The difference is that return on private investment is higher than the social return [15], meaning that personal bring higher contributions to economic growth. That is why the coefficient is higher than the other variables. Therefore, AI enables economic growth to be enormous.

5.3. Comparison

Sachs suggests that the impact of AI on future development is significant and complex [16]. AI can help low-income countries to be able to leapfrog in a few areas, including e-government, e-finance, e-health, and e-education. Artificial intelligence will also lead to automation, reducing the need for labor, especially unskilled labor. Labor-intensive industries such as clothing, for example, will

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provide fewer jobs. American labor costs are expensive, and the workforce is scarce, which is an excellent opportunity for the United States to develop its economy. However, Nedelkoska & quilting find that developing countries are more vulnerable to automation due to differences based on industrial structure [17]. China has a non-negligible part of its economy that comes from many processing and primary manufacturing industries, so there is a high demand for labor. Nowadays, artificial intelligence replaces work, mitigating the disadvantages of labor presence and considerably boosting production and, consequently, economic development. China and the United States similarly apply AI to a wide range of simple tasks to reduce costs, independent of people and circumstances, such as an aging population and COVID. The same advantages apply depending on the country's situation.

In the last decade, China has paid more and more attention to technological development, and the output of Ph.D. and dissertations is increasing. Empirical data also show that the GDP of both China and the US is positively correlated with these two factors. The coefficients of PhD. and arXiv in China are 1.462 and 11.338, while those in the United States are 4.244 and 23.324, among which China's growth rate is slower than that of the United States. Given the field research conducted in collaboration with Tsinghua University in 2019, success in artificial intelligence doesn't just require data and algorithms. It also requires advanced, dedicated AI chips that offer higher computing and storage power and reduced energy consumption. China is almost dependent on the United States to import such advanced AI chips, but tensions are growing between the US and China. China's access to these AI chips has been interrupted in the interim. China started its research in AI later than the US, so its access to AI technology is still limited [18]. Without essential support, there is no way to complete the development of the entire application, and our AI development will become water without a source. Therefore, necessary hardware and software are the "fundamental technologies" of AI development. China is slowly realizing, for example, that big companies like Baidu are now rolling out their chip technology. As China's foundation strengthens, future technological ideas will be increasingly applied to real life, and there will be more significant economic growth.

6. Conclusion

Under the background of technological innovation becoming an increasingly critical state in the economic development and widespread application of AI, focusing on the development of AI and the process of the impacts of AI on economic development is more and more necessary. This research aims to discover AI's effects on the economic growth in China and the United States from 2011-2021 in five dimensions: R&D investment, patent, private investment, arXiv article publication, and the number of Ph.D. in STEM. The empirical results demonstrate a positive correlation between the development of AI and economic growth in both countries. Contrary to the hypothesized association in R&D investment, the relationship between R&D investment and American economic growth is negative. It provides a new version of the impact of R&D investment in different periods to explore. AI-augmented R&D has the potential to drive economic growth.

In a comparison of the influence on China and the United States, the contributions brought by AI to the United States are more than that to China, with a higher level of AI development. Increasing the speed of AI development in China may facilitate economic growth and accelerate competition between China and the United States. COVID-19, a significant turning point, plays a role in medicine, pharmaceutical research, the labor market, and so on and arouses interest in exploring the relationship between the pandemic and AI and the development of AI in the post-epidemic period and future, which could be done in further studies in several years with more accurate databases.

Although this study explores the impacts of AI on economic growth in China and the United States, some aspects still need to be improved. Due to the lack of data on the patent in 2020 and 2021, it cannot confirm that the regression result behaves as how should with accurate data. The reliability of

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this research is affected by the multicollinearity of GDP and R&D investment, representing a linear regression between GDP and R&D investment and a high correlation.

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