WHEN DOES AI PAY OFF?

By Yong Suk Lee, Taekyun Kim, Sukwoong Choi, Wonjoon Kim

IN THIS BRIEF

This paper examines how business performance varies with the intensity of artificial intelligence (AI) adoption at a sampling of high-tech Korean ventures.

Specifically, we explored two research questions: Is AI adoption positively associated with high-tech venture performance, such as increased revenue and the development of new products and services? And if so, how do complementary technologies and research and development (R&D) strategies moderate this relationship?

We find that revenue increases only after sufficient, intense investment in AI. Low levels of AI adoption do not suggest significant revenue growth. Instead, as the intensity of AI adoption increases, revenue growth follows.

Further, the benefits of AI adoption are greatest at firms that also invest in complementary technologies, including cloud computing and database systems.

Additional gains are seen at firms that pursue an internal R&D strategy specific to their AI efforts rather than an external R&D strategy. Such strategies can include hiring AI researchers, investing capital in related research projects, collaborating with universities, and even outsourcing R&D to a third party.

As with many new technology breakthroughs, artificial intelligence (AI) advancement is a multifaceted process that can be viewed from many perspectives. From an economics point of view, a growing number of research papers have examined how AI could affect the global economy (including Acemoglu et al., 2020; Brynjolfsson et al., 2017; Chalmers et al., 2020).

However, we still know surprisingly little about whether AI has boosted productivity at high-tech firms where adoption is greatest—and if so, when or why.

The potential benefits from AI include the automation of cognitive tasks—such as categorization, perception, and problem solving—which have widespread applications in a variety of business and government settings. Banks have applied AI techniques to better manage risks by predicting fraud and the likelihood of loan defaults (Deloitte, 2018; Manser Payne et al., 2021).

AI could enhance productivity in at least three important ways: liberating routine tasks, reducing human errors and biases, and helping to discover new business opportunities. Accordingly, we predict that AI adoption is positively associated with increases in firm performance.

At the same time, merely introducing AI in existing businesses is unlikely to generate productivity gains. New technologies such as AI best realize their productive market potential when both tangible investments (e.g., equipment, software, and infrastructure) and intangible investments (e.g., business and technology development processes, organizational restructuring, and worker training) are made (Brynjolfsson et al., 2019). Productivity growth may initially be underestimated, and the benefits will occur later, when corresponding and necessary business transformations are realized.

While we understand that complementary assets are critical to adopting and leveraging new technologies (Rothaermel, 2001; Thomke & Kuemmerle, 2002), less is known about how these complementary assets affect the relationship between AI adoption by high-tech ventures and financial performance at those firms (Kim et al., 2021). To what extent does AI drive revenue and productivity?

Our research provides empirical evidence of the effects of AI adoption on the performance of high-tech ventures. We developed three hypotheses regarding the potential benefits of AI adoption and complementary investments:

Hypothesis 1, Productivity Gains Lag Adoption: AI adoption is positively associated with firm performance. However, the positive association may occur with some delay. During the early stages of adoption, AI may not improve productivity. Benefits generally accrue if and when adoption rates climb higher.

Hypothesis 2, Complementary Technologies Matter: The positive relationship between AI adoption and firm productivity is stronger when firms invest in complementary technologies, especially those related to big data and high-performance computing (HPC). While the notion that complementary assets are crucial to technology adoption is not new (Felten et al., 2019), different technologies may require different complements.

Hypothesis 3, The Strength of Internal R&D: The positive relationship between AI adoption and firm productivity is stronger when a firm pursues an internal R&D strategy rather than a strategy that is external and collaborative. Supporting our hypothesis, recent research (McKinsey, 2017) finds that large technology companies spend 90% of their AI budgets on internal R&D and hiring, and only 10% on AI acquisitions.

What's more, AI can improve productivity through multiple mechanisms such as enabling workers to focus more on core tasks, reducing error and bias, and discovering new business opportunities.

RESEARCH METHODOLOGY

To test our hypotheses, we conducted a survey in 2019 of high-tech ventures in Korea. Korea is an important indicator because of its mature IT structure and active adoption of AI. In addition, our sample includes several industries such as software, pharmaceuticals, and mobile IT. We selected these organizations from a list of 1,248 companies that were randomly selected and provided by the Korean Ministry of SMEs and Startups. We then sent surveys to all companies on the list. We received responses from 300 companies, giving us a response rate of approximately 24%.

Our survey examined firms' AI adoption rates and related business strategies. Importantly, the survey covered the extent to which firms have adopted AI technologies for the production or development of goods and services, a topic that previously has been mostly overlooked. The survey also asked about the level of AI adoption in terms of three key technologies: natural language processing, computer vision, and machine learning. We also asked to what degree a firm had adopted related technologies such as database systems and cloud computing. In addition, the survey posed a set of questions aimed at evaluating how firms perceive the benefits of AI adoption in areas such as product development, marketing, and customer service. Finally, the survey collected information on whether firms pursue their R&D internally on their own or in collaboration with others.

We then filtered the 300 responses to include only those that were formed in 2015 or earlier because firms began to consider adopting AI after 2015. This reduced the sample

> ***"AI adoption is positively associated with firm performance. However, the positive association may occur with some delay."***

to 211 firms. From that list, we eliminated 37 companies due to missing responses in important sections of the survey, as well as 14 companies whose revenue was not observable due to business closure. This left a final sample of 160 firms.

Of these firms, over half (53%) were in technology-related businesses. More specifically, about 26% of all companies were in the software business, 17% in pharmaceuticals, and 10% in mobile IT. The average age of a responding firm was 3.6 years, and the stage of most firms fell somewhere between early profit generation and growth. Also, slightly more than half the companies (54%) had already adopted at least one type of AI technology.

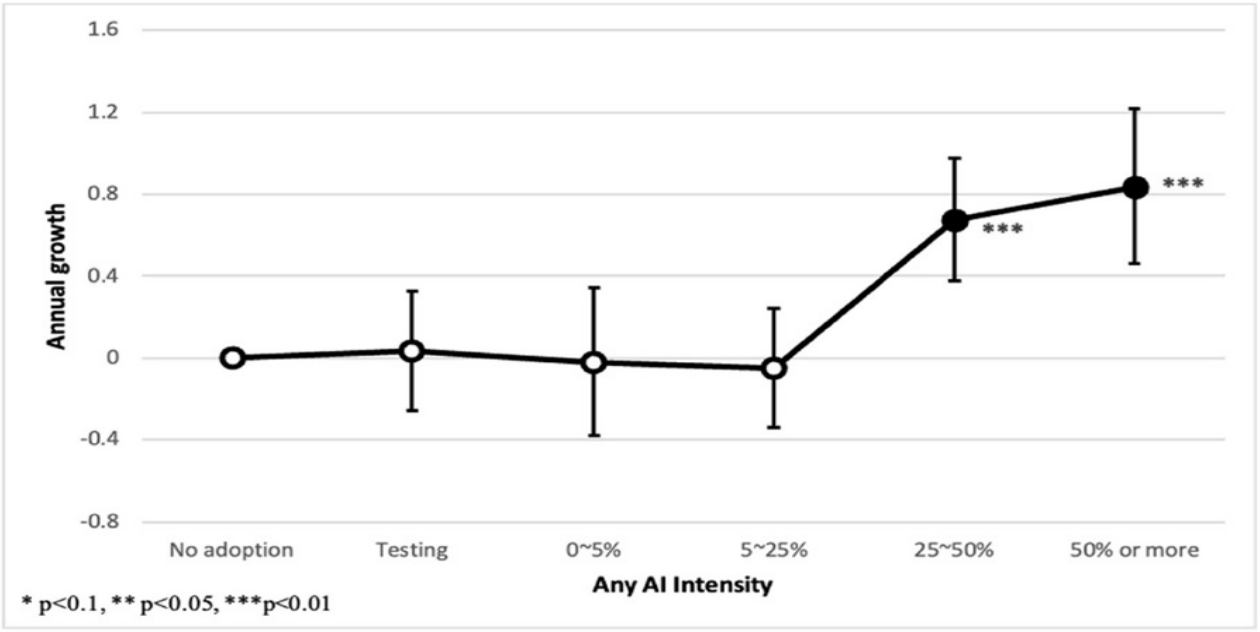
RESULTS

One important trend revealed by the survey data is that with potential for growth and more established firms.

We also find that firm type is significantly related to AI-adoption intensity. Spinoffs from other companies are less likely to adopt AI, while spinoffs from laboratories are more likely. In addition, firms led by serial entrepreneurs are more likely than others to adopt AI intensively, as are those that have already adopted database systems and cloud computing.

The data also shows that a firm's revenue growth is correlated with AI investment. That is, average annual revenue growth rate generally increases with higher levels of AI adoption (Figure 1). What's more, the relationship becomes even more significant at higher levels of adoption—when a firm has adopted 25% or more of the available AI technologies.

Figure 1: Higher average annual revenue growth collerates with AI intensity



Higher levels of AI adoption correlate with higher rates of annual revenue growth. IT intensity percentages reflect the scope of adoption; a 100% intensity would mean a company has adopted every possible form of AI. Robust standard errors are marked with asterisks (***) with statistical significance at the 1% level.

both firms with relatively low valuations ($1 million to $5 million) and firms with relatively high valuations ($10 million or more) are more likely to adopt AI more intensively than firms with mid-level valuations. This suggests that two groups adopt AI intensively: newer firms

Conversely, neither low levels of AI adoption nor the testing stages of AI generate revenue growth. That data suggests that AI adopters experience delayed productivity gains. The reasons could include the need to reorganize business practices, as well as the need to make complementary

investments in supporting technologies such as database systems and cloud computing.

About half the companies we surveyed (83 of the 160) have invested in other complementary technologies. We find the relationship between AI adoption-intensity and revenue growth occurs only among these firms (Figure 2). The jump at 25% adoption or higher is evident only at firms that have invested in these complementary technologies. This percentage indicates that of all available AI technologies , at least a quarter of them have been adopted by firms at this level.

Our data also supports a complementarity between AI adoption and R&D strategy. Revenue growth is significant among firms that adopt more firm-specific internal R&D strategies, as opposed to those that adopt R&D strategies that are more open and collaborative.

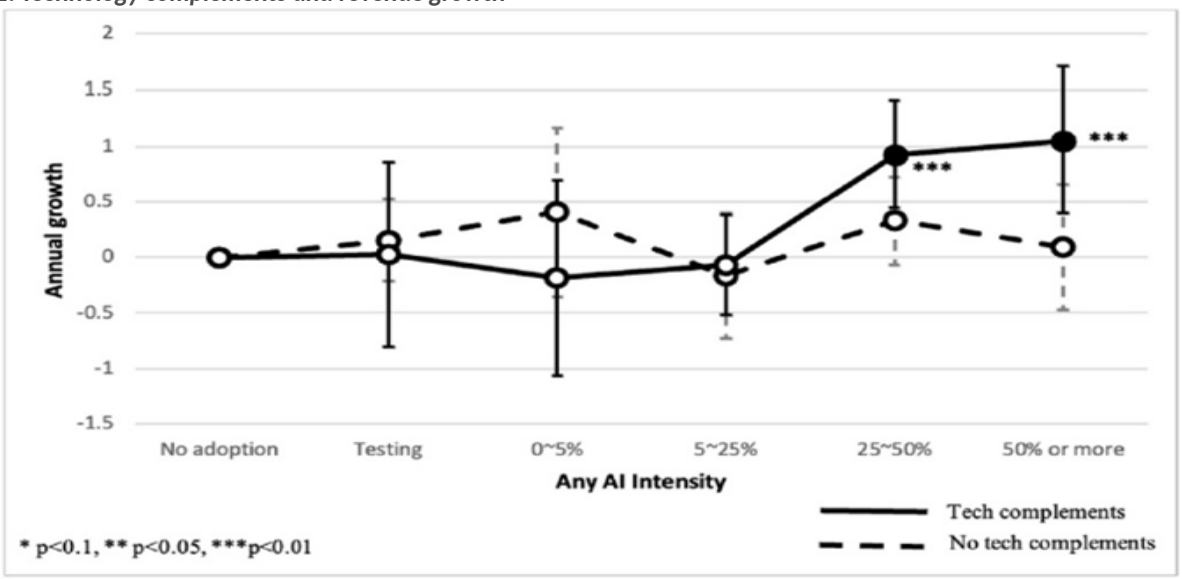
Finally, the data suggest that AI adoption may contributeto revenue growth by improving a firm's products and services, sales and marketing, and customer support. Managers at firms that adopt AI at higher levels told us they expected improvements in these areas. Though we are unable to test their assertions, the data suggests that they are correct.

CONCLUSIONS

Our study has important practical implications for managers. The findings suggest that when managers adopt and utilize AI, they may not derive benefits from the technology immediately. However, patient managers will eventually reap concrete benefits from their AI investments.

Managers also need to understand that AI investments alone may be insufficient. It's important to invest in complementary data systems and cloud computing, and to realign AI-related R&D investments.

Figure 2: Technology complements and revenue growth



Higher levels of complementary—technology adoption correlate with higher rates of annual revenue growth. Intensity percentages reflect the scope of adoption; a 100% intensity would mean a company has adopted every possible complementary technology. Robust standard errors are marked with asterisks (***) with statistical significance at the 1% level.

In the future, the impact of AI will likely become even more nuanced and widespread. AI as a general-purpose technology is still in its nascent stage and, as previously shown (Agrawal et al., 2018), AI today is primarily used as a prediction machine. Our analysis is based on an AI system whose primary role in business is to assist managers and workers through prediction.

Nonetheless, AI has already started to permeate non-business contexts, such as government agencies,

schools, and hospitals. Future research on these non-business sectors will further contribute to our overall understanding of the power of AI.

REPORT

Read the full research paper **here**.

ABOUT THE AUTHORS

Yong Suk Lee is an Assistant Professor of Technology, Economy, and Global Affairs at the University of Notre Dame's Keough School of Global Affairs.

Taekyun (T-K) Kim is a Ph.D. candidate in the Graduate School of Innovation and Technology Management at the Korea Advanced Institute of Science and Technology (KAIST).

Sukwoong Choi is a postdoctoral scholar at the MIT Sloan School of Management and MIT Computer Science & Artificial Intelligence Laboratory (CSAIL), and a postdoctoral associate at the MIT Initiative on the Digital Economy (IDE).

Wonjoon Kim is a Professor in KAIST's School of Business and Technology Management, and Director of KAIST's Center for Innovation Strategy and Policy, Social Big Data Science Research Group, and Center for Overseas Development.

REFERENCES

Acemoglu, D., et al., 2020. AI and jobs: evidence from online vacancies. National Bureau of Economic Research Working Paper 28257.

Agrawal, A., et al., 2019. Artificial intelligence: the ambiguous labor market impact of automating predictions. Journal of Economic Perspectives, vol. 33, no. 2, pp. 31-50.

Brynjolfsson, E., et al., 2017. Artificial intelligence and themodern productivity paradox: a clash of expectations and statistics. National Bureau of Economic Research Working Paper 24001.

Chalmers, D., et al., 2020. Artificial intelligence and entrepreneurship: implications for venture creation in the fourth industrial revolution. Entrepreneurship Theory and Practice, vol. 45, issue 5. **https://doi.org/10.1177/1042258720934581**

Deloitte, 2018. In: State of AI in the Enterprise, 2nd ed. **https://www2.deloitte.com/us/en/insights/focus/cognitive-technologies/state-of-ai-and-intelligent-automation-in-business-survey.html**

Felten, E.W., et al., 2019. The occupational impact of artificial intelligence: labor, skills, and polarization. NYU Stern School of Business. **https://ssrn.com/abstract=3368605**.

Kim, T., Park, Y., 2021. Artificial intelligence and firm performance. Academy of Management Proceedings, vol. 2021, no. 1. **https://journals.aom.org/doi/abs/10.5465/AMBPP.2021.291**

Manser Payne, E.H., et al., 2021. Digital servitization value co-creation framework for AI services: a research agenda for digital transformation in financial service ecosystems. Journal of Research in Interactive Marketing, 15, pp. 200–222.

McKinsey, 2017. Artificial intelligence: the next digital frontier? McKinsey Global Institute discussion paper. **https://www.mckinsey.com/~/media/McKinsey/Industries/Advanced%20Electronics/Our%20Insights/How%20artificial%20intelligence%20can%20deliver%20real%20value%20to%20companies/MGI-Artificial-Intelligence-Discussion-paper.ashx**

Rothaermel, F.T., 2001. Incumbent's advantage through exploiting complementary assets via interfirm cooperation. Strategic Management Journal, vol. 22, no. 6-7, pp. 687-699.

Thomke, S., Kuemmerle, W., 2002. Asset accumulation, independence, and technological change: evidence from pharmaceutical drug discovery. Strategic Management Journal, vol. 23, no. 7, pp. 619-635.

MIT INITIATIVE ON THE DIGITAL ECONOMY

MIT Initiative on the Digital Economy
MIT Sloan School of Management
245 First St., Room E94-1521
Cambridge, MA 02142-1347
617-452-3216

Our Mission: The MIT IDE is solely focused on the digital economy. We conduct groundbreaking research, convene the brightest minds, promote dialogue, expand knowledge and awareness, and implement solutions that provide critical, actionable insight for people, businesses, and government. We are solving the most pressing issues of the second machine age, such as defining the future of work in this time of unprecendented disruptive digital transformation.

Contact Us: David Verrill, Executive Director
MIT Initiative on the Digital Economy
MIT Sloan School of Management
245 First St., Room E94-1521
Cambridge, MA 02142-1347
617-452-3216
dverrill@mit.edu

Become a Sponsor: The generous support of individuals, foundations, and corporations help to fuel cutting-edge research by MIT faculty and graduate students, and enables new faculty hiring, curriculum development, events, and fellowships.

View all of our Sponsors