Eastern Journal of European Studies
DOI: 10.47743/ejes-2025-0101 • June 2025 • VOLUME 16, ISSUE 1

Differential investment in an AI-based technology and economic growth: a tale of two regions

Amitrajeet A. Batabyal[a], **Hamid Beladi**[b]
[a] Rochester Institute of Technology, USA; [b] University of Texas at San Antonio, USA

Abstract: In this paper, we analyze a dynamic model in which two stylized regions, A and B, use an artificial intelligence (AI)-based technology $\alpha(t)$ to produce a knowledge good $Q(t)$. Even though the initial value of the AI-based technology $\alpha(0)$ is identical in both regions, region A saves and hence invests more than region B to make the existing AI-based technology more powerful. We show that this differential investment means that the ratio of the output of the knowledge good in region A to region B or Q_A/Q_B is continually rising. In other words, without targeted policy, region A will become a "leading region" that experiences economic growth and innovation ahead of region B which will become a "lagging region" that innovates less and hence tends to grow more slowly.

Keywords artificial intelligence, dynamics, economic growth, region, technology

Introduction

Artificial intelligence (AI) has become a driving force behind economic growth, revolutionizing industries and reshaping traditional business models (Aghion et al., 2019). One key aspect contributing to this growth is the increased efficiency and productivity achieved through the implementation of AI-based technologies. Automation of routine tasks, predictive analytics, and intelligent decision-making systems now enable businesses to streamline operations, reduce costs, and enhance overall productivity (Brynjolfsson et al., 2019). This heightened efficiency not only improves the competitiveness of individual companies but also contributes to macroeconomic growth by fostering a more dynamic and resilient business environment (Wang et al., 2021).

AI-based technologies play a crucial role in innovation, sparking the development of novel products and services. The ability of AI-based technologies to analyze vast amounts of data quickly and derive valuable insights has led to breakthroughs in various sectors of the regional economy including, but not limited to, healthcare, finance, and manufacturing (Tawalbeh et al., 2016). This innovation not only drives regional economic growth by creating new markets and industries,

✉ Professor, Department of Economics and Sustainability, Rochester Institute of Technology, USA; e-mail: aabgsh@rit.edu.

but also enhances the overall quality of life through improved products, services, and solutions. Governments and businesses that invest in AI research and development are positioning themselves at the forefront of technological advancements, fostering an environment conducive to sustained regional economic growth (Fofano et al., 2023).

Given the documented connections between the use of AI-based technologies and regional economic growth, it is instructive to see what regional scientists and other researchers have said about this topic. In this regard, Chain et al. (2019) point out that the frontier of knowledge in regional science has changed from an emphasis on what these authors call “traditional methods” to an increased focus on alternate areas such as AI. Agrawal et al. (2019) first explain how AI-based technologies improve prediction which is a key input into many economic activities. They then discuss the implications for labour productivity and economic growth, highlighting both opportunities and uncertainties.

Xiao and Boschma (2023) study how a regional knowledge base of information and communication technologies influences the emergence of AI-based technologies in Europe. Finally, Crowley and Doran (2023) concentrate on future automation and study how the use of AI-based technologies will impact labor markets in different towns across Ireland.

The purpose of this review of the literature is to emphasize the point that, to the best of our knowledge, there are *no* theoretical studies in the literature that formally analyse how the use of AI-based technologies affects regional economic growth. Given this lacuna in the literature, our objective in this paper is to study a dynamic model in which two stylized regions, A and B, use an AI-based technology denoted by $\alpha(t)$ at time t to produce a knowledge good whose output at time t is given by $Q(t)$. To illustrate the dominance of AI-based technologies, we concentrate on the case in which the initial value of the AI-based technology $\alpha(0)$ is identical in both regions but region A saves and therefore invests more than region B to make the existing AI-based technology more powerful. In this setting, we show that this differential investment means that the ratio of the output of the knowledge good in region A to region B or Q_A/Q_B is continually rising.

The remainder of this paper is arranged as follows. Section 1 delineates the theoretical framework. Section 2 demonstrates the main result of the paper, first diagrammatically and then formally. The last section concludes and then discusses four ways in which the research described in this paper might be extended.

1. The theoretical framework

We begin with a few general observations. New technologies have frequently acted as a catalyst for economic growth by enhancing productivity, creating new industries, and reshaping labour markets. Innovations such as artificial intelligence, advanced robotics, and biotechnology are driving significant gains in efficiency and enabling businesses to offer new products and services, thereby expanding economic output (Brynjolfsson & McAfee, 2014). Moreover, digital platforms and improved communication technologies facilitate global trade and investment, breaking down barriers and increasing market access for firms of all sizes (World Bank, 2016).

However, while technological advancement often boosts overall economic performance, it can also lead to increased income inequality and job displacement if appropriate policies are not implemented to support workforce transitions (Autor, 2015). As such, the net impact of new technologies on economic growth depends not only on innovation itself but also on how societies adapt to and manage these changes.

That said, we now specialize our theoretical discussion and focus on an aggregate economy of two regions denoted by A and B, respectively. Each region uses an AI-based technology to produce a knowledge good such as a smartphone, a camera, or a laptop computer. The output of the knowledge good at any time t and in region $i, i = A, B,$ is denoted by $Q_i(t)$. Similarly, the AI-based technology at any time t and in region i is represented by $\alpha_i(t)$.

Since the focus of this paper is on the nexus between the use of the AI-based technology $\alpha_i(t)$ and output growth, in what follows, we shall abstract away from the other inputs that are used to produce $Q_i(t)$. Alternately, we could keep these other inputs fixed at some level but this latter assumption will not change our basic result.

Let the output of the knowledge good in each region be given by the production function

$$Q_i(t) = \{\alpha_i(t)\}^{\zeta}, \tag{1}$$

where the parameter $\zeta > 1$. The law of motion describing the evolution of the AI-based technology over time is given by the differential equation

$$\frac{d\alpha_i(t)}{dt} \equiv \dot{\alpha}_i(t) = \sigma_i Q_i(t), \tag{2}$$

where σ_i is the constant fraction of the output $Q_i(t)$ in each region i that is saved and hence invested to make the existing AI-based technology more powerful.

When our analysis begins at time $t = 0$, both regions A and B in the aggregate economy have the *same* AI-based technology with which they produce the knowledge good. In symbols, this means that $\alpha_A(0) = \alpha_B(0)$. However, because we want to show how *differential* saving and hence, investment rates in the two regions, designed to make the existing AI-based technology more powerful, have a significant impact on output growth in these same two regions, we suppose that $\sigma_A > \sigma_B$. In words, region A saves and hence invests *more* than region B to make the available AI-based technology in its region more powerful. Our next task is to show that the ratio of the output of the knowledge good in region A to region B or Q_A/Q_B is continually rising.

2. Analysis

2.1. The diagrammatic approach

We shall show this result about the ratio Q_A/Q_B in two ways. In the more intuitive approach that involves the use of a diagram, we begin by substituting the production function in equation (1) into the law of motion for the AI-based technology given in equation (2). This gives us

$$\dot{\alpha}_i(t) = \sigma_i\{\alpha_i(t)\}^{\zeta} \quad (3)$$

and we already know that $\zeta > 1$. Now, dividing both sides of equation (3) by the AI-based technology $\alpha_i(t)$ gives us an expression for the growth rate of the stock of the AI-based technology. Let us denote this growth rate by $g_{\alpha,i}(t)$. Then, the specific equation of interest is

$$g_{\alpha,i}(t) \equiv \frac{\dot{\alpha}_i(t)}{\alpha_i(t)} = \sigma_i\{\alpha_i(t)\}^{\zeta-1}. \quad (4)$$

Next, we want to obtain a closed-form expression for the growth rate of the growth rate of the AI-based technology. To obtain this expression, we differentiate the logarithm of both sides of equation (4) with respect to time. Let us proceed in two steps. First, taking the logarithm of both sides of equation (4), we get

$$\log\{g_{\alpha,i}(t)\} = \log(\sigma_i) + (\zeta - 1)\log\{\alpha_i(t)\}. \quad (5)$$

Second, let us differentiate both sides of equation (5) with respect to time. This gives us

$$\frac{d}{dt}[\log\{g_{\alpha,i}(t)\}] = \frac{d}{dt}[\log(\sigma_i) + (\zeta - 1)\log\{\alpha_i(t)\}]. \quad (6)$$

Because σ_i is constant, it follows that its logarithm is also constant, and therefore, the derivative of the logarithm of σ_i with respect to time is zero. Using this last result in equation (6), we get

$$\frac{d}{dt}[\log\{g_{\alpha,i}(t)\}] = \frac{d}{dt}[(\zeta - 1)\log\{\alpha_i(t)\}]. \quad (7)$$

Now, by definition, it follows that

$$\frac{d}{dt}[\log\{\alpha_i(t)\}] = \frac{1}{\alpha_i(t)}\frac{d}{dt}\{\alpha_i(t)\} = g_{\alpha,i}(t). \quad (8)$$

Using the preceding two steps and equations (4) through (8), we can write an expression for the growth rate of the growth rate of the AI-based technology or $\dot{g}_{\alpha,i}(t)/g_{\alpha,i}(t)$. That equation is

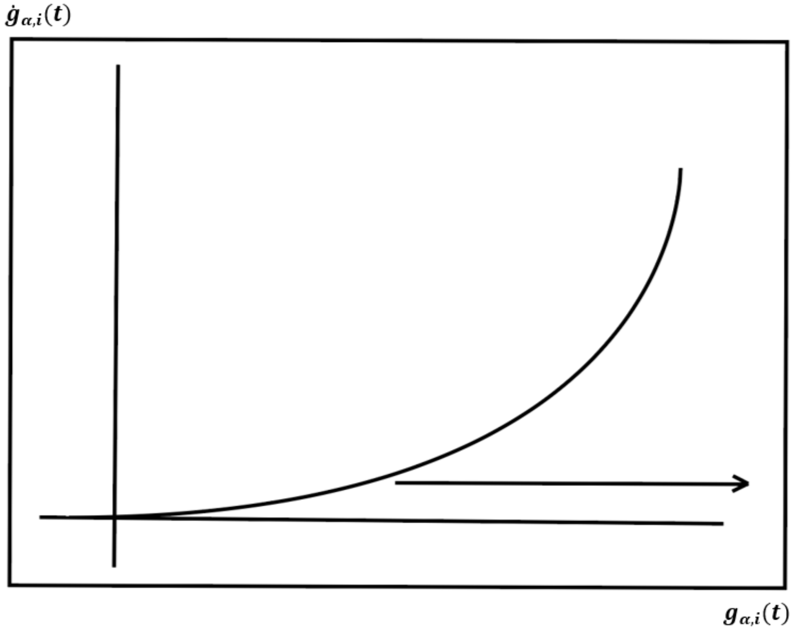
$$\frac{\dot{g}_{\alpha,i}(t)}{g_{\alpha,i}(t)} = (\zeta - 1)g_{\alpha,i}(t). \quad (9)$$

Cross-multiplying both sides of equation (9) with $g_{\alpha,i}(t)$ yields

$$\dot{g}_{\alpha,i}(t) = (\zeta - 1)\{g_{\alpha,i}(t)\}^2. \quad (10)$$

Equation (6) is plotted in figure 1. We plot the growth rate of the growth rate of the AI-based technology or $\dot{g}_{\alpha,i}(t)$ on the vertical axis and the growth rate of the AI-based technology or $g_{\alpha,i}(t)$ on the horizontal axis. The reader will observe that because $\zeta > 1$, inspection of equation (6) tells us that $g_{\alpha,i}(\cdot)$ will always be *rising*. In addition, the initial value of $g_{\alpha,i}(\cdot)$ is determined by the initial value of the stock of the AI-based technology and the saving rate σ_i as shown in equation (4).

Figure 1. Growth in the stock of the AI-based technology



Source: authors' representation

Observe that because the economies of the two regions, A and B, have the same initial value of the AI-based technology or $\alpha_i(0)$ but different saving rates $(\sigma_A > \sigma_B)$, from equation (4) it follows that the region with the higher saving rate, which is region A, will also have the higher initial growth rate or $g_{\alpha,i}(0)$.

Equation (9) tells us that the growth rate of $g_{\alpha,i}(\cdot)$ is increasing in $g_{\alpha,i}(\cdot)$. Therefore, the growth rate of the stock of the AI-based technology in region A, which is the high saving and investing region, will always be *greater* than the growth rate of the stock of the AI-based technology in the low saving and investing region B. In Figure 1 symbols, we have just reasoned that $g_{\alpha,A}(t) > g_{\alpha,B}(t), \forall t \geq 0$.

Finally, observe that the gap between these two growth rates will tend to *widen* over time.

2.2. The formal approach

The result that the ratio of outputs Q_A/Q_B is continually rising can also be illustrated without recourse to a diagram such as figure 1. To see this, observe that using the production function or equation (1), we can express the ratio of output in the high saving and investing region A to output in the low saving and investing region B as

$$\frac{\{Q_A(t)\dot{/}Q_B(t)\}}{Q_A(t)/Q_B(t)} = \zeta\left\{\frac{\dot{\alpha}_A(t)}{\alpha_A(t)} - \frac{\dot{\alpha}_B(t)}{\alpha_B(t)}\right\}. \tag{11}$$

Now observe that the right-hand-side (RHS) of equation (11) can be rewritten using the growth rate notation or $g_{\alpha,i}(t)$ introduced earlier. Specifically, using this growth rate notation, we can write

$$\zeta\left\{\frac{\dot{\alpha}_A(t)}{\alpha_A(t)} - \frac{\dot{\alpha}_B(t)}{\alpha_B(t)}\right\} = \zeta\{g_{\alpha,A}(t) - g_{\alpha,B}(t)\} > 0. \tag{12}$$

We have already explained above that $g_{\alpha,A}(t)$ will exceed $g_{\alpha,B}(t), \forall t \geq 0$. This means that the gap between these two growth rates will be rising over time. Therefore, the growth rate of the output ratio will be both positive and increasing over time. Put differently, the ratio of output of the knowledge good in the high saving and investing region A to output of the knowledge good in the low saving and investing region B will be *continually rising*, and moreover, this ratio will be rising at an increasing rate. The policy implication of this finding is that despite starting with the same AI-based technology $\{\alpha_A(0) = \alpha_B(0)\}$, when it comes to output growth, region A will be the "leading region" and region B will be the "lagging region."

This saturnine conclusion should not be interpreted to mean that there is nothing a region, such as region B, can do to improve its economic growth prospects.

In this regard, it is possible to help a region catch up in the adoption and use of AI-based technologies by utilizing a judicious combination of policies that address infrastructure, education, incentives, governance, and ecosystem development. Specifically, investments in digital infrastructure, education and skills development, and innovation and entrepreneurship incentives are likely to help the process of "catching up".

The reader will see that our central result in this paper depends on the assumption that the production function parameter $\zeta > 1$. If $\zeta \in (0, 1]$ then our central result does not hold. Given that we are studying an AI-based technology in this paper, we do not consider the case where $\zeta \in (0, 1)$ to be interesting. That said, in the knife-edge case where $\zeta = 1$, equation (4) tells us that there is no or zero growth in the stock of the AI-based technology. Hence, it naturally follows from either equation (9) or (10) that the growth rate of the growth rate of the AI-based technology is also zero. This completes our two-region analysis of how differential investment in an AI-based technology influences regional economic growth.

Conclusions

In this paper, we have studied an intertemporal model in which two stylized regions, A and B, used an AI-based technology $\alpha(t)$ to produce a knowledge good $Q(t)$. Even though the initial value of the AI-based technology $\alpha(0)$ was identical in both regions, region A saved and hence, invested more than region B to make the existing AI-based technology more powerful. We showed that this differential investment meant that the ratio of the output of the knowledge good in region A to region B or Q_A/Q_B was always increasing. This means that, in the absence of policy intervention, region A will always be the leading region and region B the lagging region.

The analysis in this paper can be extended in several different directions. Here are four potential extensions. First, it would be useful to study the conditions that must prevail or be created in a lagging region for it to become innovative from the standpoint of the use of AI-based technologies. Second, suppose two regions A and B are both supported equally from both private and public sources to develop AI-based technologies. In such a scenario, it would be interesting to analyze whether these two regions might evolve along different growth trajectories. Third, it would be interesting to study the case where the low saving and investing region is able to alter the saving rate in response to its observation of the output of the knowledge good in this region. Finally, one could analyze the interaction between regions A and B in a game-theoretic setting in which the two regions compete with each other and hence, strategic considerations are involved. Studies that analyze these aspects of the problem will provide additional insights into the nexuses between the use of AI-based technologies, on the one hand, and regional economic growth on the other.

References

Aghion, P., Jones, B.F., & Jones, C.I. (2019). Artificial intelligence and economic growth. In A. Agrawal, J. Gans & A. Goldfarb (Eds.), *The Economics of Artificial Intelligence* (pp. 237-282). Chicago: University of Chicago Press.

Agrawal, A., Gans, J., & Goldfarb, A. (2019). Artificial intelligence: The ambiguous labor market impact of automating prediction. *Journal of Economic Perspectives, 33*, 31–50. https://doi.org/10.1257/jep.33.2.31

Autor, D. (2015). Why are there still so many jobs? The history and future of workplace automation. *Journal of Economic Perspectives*, *29*, 3-30. https://doi.org/10.1257/jep.29.3.3

Brynjolfsson, E., & McAfee, A. (2014). *The Second Machine Age*. New York: W.W. Norton and Company.

Brynjolfsson, E., Rock, D., & Syverson, C. (2019). Artificial Intelligence and the modern productivity paradox: A clash of expectations and statistics. In A. Agrawal, J. Gans, & A. Goldfarb (Eds.), *The Economics of Artificial Intelligence* (pp. 23-57). Chicago: University of Chicago Press. https://doi.org/10.7208/chicago/9780226613475.003.0001

Chain, C.P., dos Santos, A.C., de Castro, L., Gonzaga, J., & do Prado, J.W. (2019). Bibliometric analysis of the quantitative methods applied to the measurement of industrial clusters. *Journal of Economic Surveys*, *33*, 60-84. https://doi.org/10.1111/joes.12267

Crowley, F., & Doran, J. (2023). The geography of job automation in Ireland: What urban areas are most at risk? *Annals of Regional Science*, *71*, 727-745. https://doi.org/10.1007/s00168-022-01180-4

Fofano, F., Scantamburlo, T., & Cortés, A. (2023). Investing in AI for social good: An analysis of European national strategies. *AI and Society*, *38*, 479-500. https://doi.org/10.1007/s00146-022-01445-8

Tawalbeh, L.A., Mehmood, R., Benkhlifa E., & Song, H. (2016). Mobile cloud computing model and big data analysis for healthcare applications. *IEEE Access*, *4*, 6171-6180. https://doi.org/10.1109/ACCESS.2016.2613278

Wang, L., Sarker, P.K., Alam, K., & Sumon, S. 2021. Artificial intelligence and economic growth: A theoretical framework. *Scientific Annals of Economics and Business*, *68*, 421-443. https://doi.org/10.47743/saeb-2021-0027

World Bank. (2016). *World Development Report 2016*. Washington DC: World Bank.

Xiao, J., & Boschma, R. (2023). The emergence of artificial intelligence in European regions: The role of a local ICT base. *Annals of Regional Science*, *71*, 747-773. https://doi.org/10.1007/s00168-022-01181-3