

MACROECONOMIC IMPLICATIONS OF AUTOMATION: THEORY AND EVIDENCE

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**DEPARTMENT OF HUMANITIES AND SOCIAL SCIENCES
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MACROECONOMIC IMPLICATIONS OF AUTOMATION: THEORY AND EVIDENCE

BY:

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DEPARTMENT OF HUMANITIES AND SOCIAL SCIENCES

**IN THE FULFILLMENT OF THE REQUIREMENTS OF THE DEGREE OF
DOCTOR OF PHILOSOPHY**

TO THE



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JULY 2026**

*“Chitto jetha bhoysgunyo, uchcho jetha shir,
Gyan jetha mukto, jetha griher prachir;
Apon pranganete dibos-sarborir dhara,
Bistrilo hoye jay ananta akasher majhe.”*

– Rabindranath Tagore, “Chitto Jetha Bhoysgunyo”, Gitanjali.

*“Where the mind is without fear and the head is held high,
Where knowledge is free;
Where the world is not broken up into narrow walls of division,
But the clear stream of reason flows into the vast open sky.”*

– Rabindranath Tagore, Gitanjali.

Dedicated to *maa* and *baba*

CERTIFICATE

This is to certify that the thesis titled “*Macroeconomic Implications of Automation: Theory and Evidence*”, submitted by *Subhrasil Chingri* to the Indian Institute of Technology Delhi, for the award of the degree of *Doctor of Philosophy*, is a bonafide record of research work carried out by him under my supervision. The content of this thesis, in full or in parts, has not been submitted to any other Institute or University for the award of any degree or diploma.

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Subhrasil Chingri

ABSTRACT

This thesis investigates the macroeconomic implications of automation from three complementary perspectives: the labor share, environmental outcomes, and inequality across gender and skills. In the first chapter, we study whether human capital accumulation can mitigate the adverse effects of automation on the global labor share. We develop an automation- and human-capital-augmented growth model in which we first treat human capital as exogenous and then endogenize human capital formation. The analysis shows that automation exerts downward pressure on the labor share, but this effect can be partially offset through greater investment in human capital. Using data on industrial robot adoption and years of schooling, we find that fully stabilizing the labor share would require unrealistically large and persistent increases in educational investment. The results highlight the value of human capital as a policy instrument in the age of automation, while also showing that education alone cannot counteract its long-run distributional consequences.

The second chapter examines the environmental dimension of automation by analyzing its impact on aggregate emissions of CO₂ and NO₂ in a growth framework that incorporates robots as a production factor. The model predicts that the use of industrial robots raises aggregate emissions and delays the timing of the emissions peak relative to a robot-free economy. These predictions are evaluated empirically using a balanced international panel dataset. The estimates indicate that countries with greater demand for industrial robots experienced faster growth in GDP per capita alongside higher average growth in CO₂ emissions per capita. Although the direct contribution of automation to emissions is modest in magnitude, it is statistically significant and consistent with the theoretical mechanism in which automation slows the arrival of the Environmental Kuznets Curve turning point.

The third chapter explores how automation shapes inequality between men and women and between high- and low-skilled workers in the United States. We construct an R&D-based growth model in which automation substitutes for routine workers and complements high-skilled workers, while education choices endogenize skill and gender differences. The model predicts that automation increases demand for high-skilled labor and raises female participation in innovation, but it also widens inequality both within gender groups and across skill levels. Policy experiments show that redistributive transfers financed by robot taxation compress inequality but reduce innovation and growth, whereas education subsidies expand the skilled workforce and stimulate growth at the cost of greater inequality.

Together, the three essays provide a unified perspective on how automation reshapes labor markets, environmental dynamics, and social inequalities, offering guidance for policies that seek to balance innovation, equity, and sustainability in an increasingly automated economy.

सार

यह शोधप्रबंध स्वचालन (ऑटोमेशन) के व्यापक आर्थिक प्रभावों का तीन प्रमुख दृष्टिकोणों से अध्ययन करता है: श्रम हिस्सेदारी, पर्यावरणीय परिणाम, तथा लिंग और कौशल के आधार पर असमानता। पहले अध्याय में, हम यह जाँचते हैं कि क्या मानव पूंजी का संचय वैश्विक श्रम हिस्सेदारी पर स्वचालन के प्रतिकूल प्रभावों को कम कर सकता है। हम एक स्वचालन- तथा मानव-पूंजी-वर्धित वृद्धि मॉडल विकसित करते हैं, जिसमें पहले मानव पूंजी को बाह्य माना जाता है और फिर मानव पूंजी निर्माण को अंतर्जात किया जाता है। विश्लेषण से पता चलता है कि स्वचालन श्रम हिस्सेदारी पर नकारात्मक दबाव डालता है, लेकिन मानव पूंजी में अधिक निवेश के माध्यम से इस प्रभाव को आंशिक रूप से संतुलित किया जा सकता है। औद्योगिक रोबोट अपनाए और स्कूली शिक्षा के वर्षों के आँकड़ों का उपयोग करते हुए, हम पाते हैं कि श्रम हिस्सेदारी को पूरी तरह स्थिर करने के लिए शैक्षिक निवेश में अवास्तविक रूप से बड़े और निरंतर इजाफ़े की आवश्यकता होगी। ये परिणाम स्वचालन के युग में मानव पूंजी को एक नीति उपकरण के रूप में महत्वपूर्ण बताते हैं, साथ ही यह भी दर्शाते हैं कि केवल शिक्षा ही इसके दीर्घकालिक वितरणात्मक परिणामों का प्रतिकार नहीं कर सकती।

दूसरा अध्याय स्वचालन के पर्यावरणीय आयाम की जाँच करता है, जिसमें रोबोटों को उत्पादन कारक के रूप में शामिल करने वाले वृद्धि ढाँचे में CO₂ और NO₂ के समग्र उत्सर्जन पर इसके प्रभाव का विश्लेषण किया गया है। मॉडल यह भविष्यवाणी करता है कि औद्योगिक रोबोटों का उपयोग समग्र उत्सर्जन को बढ़ाता है और रोबोट-रहित अर्थव्यवस्था की तुलना में उत्सर्जन के शिखर के समय को आगे खिसका देता है। इन भविष्यवाणियों का अनुभवजन्य परीक्षण एक संतुलित अंतरराष्ट्रीय पैनल डाटासेट के माध्यम से किया गया है। अनुमान बताते हैं कि जिन देशों में औद्योगिक रोबोटों की मांग अधिक थी, वहाँ प्रति व्यक्ति GDP की वृद्धि तेज रही, साथ ही प्रति व्यक्ति CO₂ उत्सर्जन की औसत वृद्धि भी अधिक रही। यद्यपि उत्सर्जन में स्वचालन का प्रत्यक्ष योगदान परिमाण में सीमित है, फिर भी यह सांख्यिकीय रूप से महत्वपूर्ण है और उस सैद्धांतिक तंत्र के अनुरूप है जिसके अनुसार स्वचालन पर्यावरणीय कूज़नेट्स वक्र के मोड़ बिंदु के आगमन को धीमा करता है।

तीसरा अध्याय संयुक्त राज्य अमेरिका में पुरुषों और महिलाओं के बीच तथा उच्च और निम्न-कुशल श्रमिकों के बीच असमानता पर स्वचालन के प्रभावों की पड़ताल करता है। हम एक अनुसंधान एवं विकास-आधारित वृद्धि मॉडल का निर्माण करते हैं, जिसमें स्वचालन नियमित कार्य करने वाले श्रमिकों का स्थान लेता है और उच्च-कुशल श्रमिकों का पूरक बनता है, जबकि शिक्षा संबंधी विकल्प कौशल और लिंग के अंतर को अंतर्जात रूप से निर्धारित करते हैं। मॉडल यह भविष्यवाणी करता है कि स्वचालन उच्च-कुशल श्रम की मांग बढ़ाता है और नवाचार में महिलाओं की भागीदारी को बढ़ाता है, लेकिन साथ ही यह लिंग समूहों के भीतर और कौशल स्तरों के बीच असमानता को भी बढ़ाता है। नीति प्रयोग दर्शाते हैं कि रोबोट कर के माध्यम से वित्तपोषित पुनर्वितरणात्मक हस्तांतरण असमानता को कम करते हैं, लेकिन नवाचार और वृद्धि को घटाते हैं; जबकि शिक्षा सब्सिडी कुशल कार्यबल का विस्तार करती है और वृद्धि को प्रोत्साहित करती है, किंतु अधिक असमानता की कीमत पर।

समग्र रूप से, ये तीन निबंध इस बात का एकीकृत दृष्टिकोण प्रस्तुत करते हैं कि स्वचालन किस प्रकार श्रम बाजारों, पर्यावरणीय गतिशीलता और सामाजिक असमानताओं को पुनः आकार देता है, और ऐसी नीतियों के लिए मार्गदर्शन प्रदान करता है जो बढ़ती स्वचालित अर्थव्यवस्था में नवाचार, समानता और स्थिरता के बीच संतुलन स्थापित करना चाहती हैं।

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