Applications for Digital Economics and AI Tutorial: Guang-Xuan Zhou

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- Courses in my second year: Advanced International Trade (1 year), Advanced Macroeconomics (1 semester), AI Economics (1 semester), International Finance (1 semester), Financial Economics (1 semester), Numerical Methods in Economics (1 semester), Time Series in Economics (1 semester)

- Research interests: The interaction between AI technology and trade patterns, supply chains, and fragmentation.

- Research projects: Automation and Offshoring: the Role of Input-Output Linkages

- Committee members: James Harrigan, Kerem Cosar

- Abstract of Automation and Offshoring: the Role of Input-Output Linkages:

This paper examines the impact of automation on employment and offshoring across different sectors. The findings reveal that automation displaces labor and leads to reshoring within the same sector, while increasing employment and offshoring in its upstream and downstream sectors. To explain these mechanisms, I develop a Ricardian trade model that incorporates input-output linkages and trade in tasks. Automation lowers production costs, driving greater demand for upstream goods and reducing the costs of downstream goods. These findings highlight the heterogeneous sectoral effects of automation and offer new insights into the ongoing debates in existing research.

Automation and Offshoring: the Role of Input-Output Linkages

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1 Introduction

Recent studies begin to focus on how automation in developed countries impacts other countries with few robots, especially focus on the relationship between automation and reshoring (or offshoring). Bonfiglioli et al. (2022) and Krenz et al. (2021) argue that automation has led to reshoring in the U.S. and Europe, as robots and digital technologies replace low-skilled workers abroad. Similarly, Carbonero et al. (2020) and Faber (2020) suggest that automation reduces employment in emerging markets such as Brazil and Mexico. On the other hand, automation can boost productivity, increasing the demand for tasks that are not automated. This can result in more offshoring or greater imports of goods from emerging economies by producers in developed countries (Wang, 2022; Artuc et al., 2023).

These studies emphasize that the impact of automation on offshoring depends on the relative magnitude of two opposing forces: the *reshoring effect* and the *productivity effect*. However, input-output linkages become an important feature in the international trade. I argue that automation may cause reshoring within sector, but increase offshoring of upstream and downstream sectors.

To understand the the impact of automation across sectors, I develop a Ricardian trade model with input-output linkages to analyze the reshoring, productivity, and linkage effects of automation. Following Caliendo and Parro (2015), I allow trade in intermediate goods. Production functions for intermediate goods exhibit constant returns to scale and consist of composite tasks and composite intermediate goods. Composite tasks are generated by a continuum of complementary tasks, and composite intermediate goods are nontraded and produced by a continuum of intermediate goods.

The task-based framework for modeling robotic technology builds on Acemoglu and Restrepo (2018) and Acemoglu and Restrepo (2020). Labor can perform all tasks, but robots are limit to a

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subset of tasks. Following insights from Grossman and Rossi-Hansberg (2008) and Rodríguez-Clare (2010), the model also allows for trade in tasks. A domestic country can import labor services to perform these tasks. Producers have three options for completing tasks: hiring domestic workers, offshoring to foreign workers, or using robots. They select the lowest-cost option to complete composite tasks. Automation, introduced as an exogenous shock, enables robots to perform a greater range of tasks, thereby affecting labor markets and offshoring.

The model predicts that when robots can perform low-skilled tasks previously completed by foreign workers at a lower cost, these tasks will be reshored and performed by robots — this is referred to as the *reshoring effect*. Automation also lowers the unit cost of goods, which increases the demand for high-skilled tasks that cannot be automated and for composite intermediate goods. The increased demand for high-skilled tasks represents the *productivity effect*, while the higher demand for composite intermediate goods reflects the *backward linkage effect*.

The reshoring effect reduces wages for foreign workers, while the productivity effect raises wages for both domestic and foreign workers. However, the relative domestic wage increases, incentivizing producers to offshore more high-skilled tasks. This aligns with the trends where, despite the reshoring of some low-skilled tasks due to automation, tech companies have increasingly offshored the higher-skilled tasks to countries like India. As a result, the net effect on offshoring within a sector depends on the relative strength of the reshoring and productivity effects.

The backward linkage effect drives higher demand for intermediate goods, thereby increasing offshoring and labor demand in upstream sectors. Additionally, automation reduces the price of intermediate goods used in downstream production. This costs reduction, termed the *forward linkage effect*, enhances offshoring and labor demand in downstream sectors. Together, these mechanisms demonstrate the complex interplay of automation in reshaping global labor and trade patterns.

I test the model's predictions by constructing a panel data with sector-country pairs as the unit of analysis, where imports of intermediate goods serve as a proxy for offshoring. Sector-level robot stocks are sourced from the International Federation of Robotics (IFR) dataset (IFR, 2023). To capture input-output linkages, I calculate the upstreamness and downstreamness using data from the World Input-Output Database (WIOD), and construct upstream and downstream exposure to robots using a Bartik-style measure.

I regress sector imports on sector robot density, finding a significantly negative relationship. This suggests that the negative reshoring effect is greater than the positive productivity effect within sectors. When I add the upstream and downstream exposure to robots, both variables are positively associated with imports, while robot density remains negatively associated with imports.

To test the effect of automation on labor market across sectors, I use sector wage and employment as new outcome variables with the same specification. The results indicate a negative relationship between robot density and labor market outcomes within sectors, but positive relationships between

downstream and upstream exposure to robots and these labor market outcomes. These findings align with the predictions of the model: while automation displaces labor within sectors, it increases labor demand in downstream and upstream sectors due to the input-output linkages. This highlights the nuanced effects of automation across the broader supply chain.

My findings contribute to the literature on the economic effects of automation in several ways. First, robots are unevenly distributed across countries and sectors, but they can influence labor markets globally by affecting offshoring. I point out that the mechanism is input-output linkages. Second, most single-country studies using IFR data on robots calculate exposure to automation at the subnational level due to data restrictions (e.g. Artuc et al., 2019; Acemoglu and Restrepo, 2020; Faber, 2020; Bonfiglioli et al., 2022; Stemmler, 2023), which may lead to significant measurement errors. In contrast, I use actual robot data at the sector-country level in my empirical analysis, avoiding this issue. Finally, many cross-country studies focus on automation's impact at the national level (e.g. Graetz and Michaels, 2018; Carbonero et al., 2020; Artuc et al., 2023), but I account for sectoral heterogeneity — specifically the upstream and downstream relationships — to reveal the nuanced effects of automation across sectors.

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