Automation, Human Task Innovation, and Labor Share

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Abstract

This study examines the impact of robotic and human innovation on labor share across nine European Union countries. Using a general equilibrium model, I derive a reduced-form specification for empirical analysis. The study employs patent records and a cognitive task index spanning 2005~2019. To address endogeneity concerns, I utilize shift-share instruments based on US patents and the cognitive task index. The findings reveal that increased robotic innovation significantly reduces labor share, indicating substantial labor-automation substitution. Conversely, human task innovation demonstrates a positive relationship with labor share, though slowing innovation rates during the sample period have led it to contribute to a decline in labor share.

Introduction

The global labor share has been on a downward trend since the early 1980s; as observed by Karabarbounis and Neiman (2014) and Autor et al. (2020), it has fallen by roughly 5 percentage points on average. Figure 1, based on data compiled by Gutierrez and Piton (2020), compares the manufacturing-sector labor share across the nine European Union countries examined in this study. Substantial declines are observed in countries such as Sweden, Denmark, Portugal, and Austria, whereas more moderate decreases are reported elsewhere. These differences point to considerable heterogeneity in labor-share trajectories across countries and underscore the importance of examining cross-country and cross-industry variation in order to account for the decline.[1]

This study examines how Robot Innovation (RI) and Human Innovation (HI) affect the labor share across nine European Union countries. The central research question is how RI and HI influence the labor share within each country and industry. Two main hypotheses are proposed: first, that RI lowers the labor share by replacing labor with automated processes; and second, that HI raises the labor share by creating tasks that lie beyond the capabilities of robots.

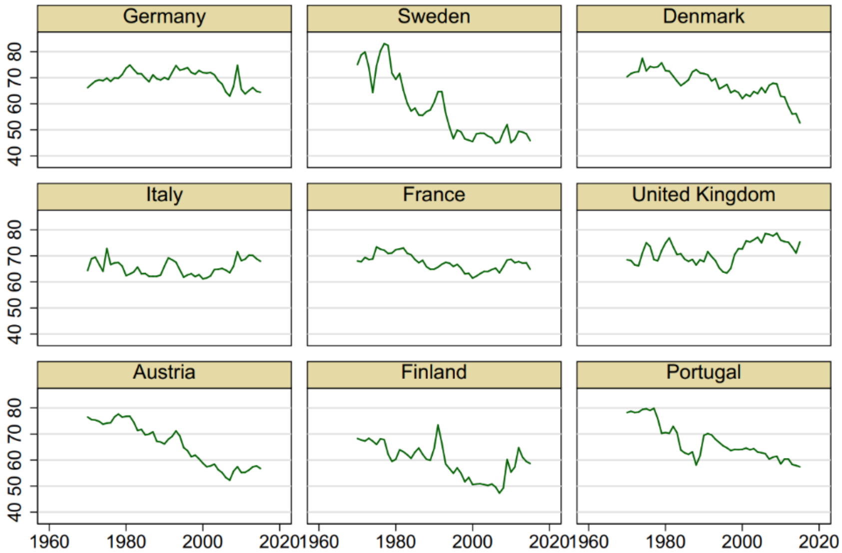
To test these hypotheses, this study employs a general equilibrium model that uniquely incorporates both RI and HI. The model addresses endogeneity using shift-share instrumental variables, and it analyzes data from the International Federation of Robotics, U.S. patent records,

[1] In this respect, this study is aligned with Graetz and Michaels (2018), who evaluate 17 EU countries, although their work focuses primarily on productivity gains rather than on the decline in the labor share.

and a Cognitive Tasks Index to provide empirical evidence for the model's predictions.

The precise causes of the declining labor share remain a subject of academic debate, with the advance of robotic automation emerging as a potential key driver. Analysis from this perspective is of growing importance as automation and artificial intelligence technologies continue to accelerate. For instance, Tesla's goal of deploying "genuinely useful humanoid robots" in its factories by 2025 (Elon 2024), together with the release of Large Language Models (LLMs) that mark breakthrough advances in AI reasoning, vividly illustrates the potential for rapid evolution of robotic systems.

Figure 1: Labor shares



The effect of robotic automation on the labor share is an active area of research. Acemoglu and Restrepo (2020), Acemoglu et al. (2020), Dauth et al. (2021), and Martinez (2018) find that robotic automation reduces the labor share. In contrast, De Vries et al. (2020) and Gregory et al. (2016) find that it instead raises the labor share. Humlum (2019) and Hubmer and Restrepo (2021) further show that the effect of robotic automation on the labor share varies across demographic groups and industry sectors.

Another potential factor affecting the labor share is "human innovation" —the emergence of tasks that lie beyond the capabilities of robots and must therefore be performed by humans. Autor (2015) argues that whether human labor will remain necessary in the future depends largely on whether human innovation can outpace robot innovation. To my knowledge, Autor et al. (2024) is the only study to measure human innovation with empirical data, constructing a proxy for human innovation from the Census Alphabetical Index of Occupations and Industries together with patent information.

Yet few studies have measured multiple factors simultaneously within a unified framework (Bergholt et al. 2022). Bergholt notes that an extensive prior literature has discussed the effect of each factor on the labor share individually, but that no empirical analysis has included all of them together within a single model. Similarly, Grossman and Oberfield (2022), stressing the importance of general equilibrium analysis, write that many authors have presented different sides of the same coin, and that even when various mechanisms are all at work, it is difficult to distinguish which part of a mechanism estimated in one study has already been captured by the mechanism in another. To address these concerns, this study adopts a general equilibrium model, and in doing so makes an academic contribution.

Following Autor et al. (2024) and Acemoglu and Restrepo (2018), this study incorporates Robot Innovation (RI) and Human Innovation (HI) simultaneously into a general equilibrium model.[2] The model builds on Acemoglu and Restrepo (2022) but differs in that it separately introduces "robot capital" and "non-robot capital" as production inputs. This specification makes it possible to analyze how robot capital and non-robot capital differentially affect the labor share in relation to the two types of innovation.

This study uses the following proxy variables to measure RI and HI. For RI, it uses a similarity score capturing how closely the textual content of each country's patents registered in the United States relates to robotic automation technology; the more patents closely related to robotics are registered, the more robot innovation is taken to have occurred. To measure the similarity of patent text, this study leverages the semantic understanding made possible by recently developed sentence-to-sentence embedding techniques.

For HI, this paper uses a "cognitive task score" that it computes directly. Cognitive ability refers to activities requiring mental processes, skills, and capacities, including perception, thinking, reasoning, memory, learning, decision-making, and other aspects of information processing. O*NET, which operates under the U.S. Department of Labor, provides numerous textual task descriptions specifying the tasks each occupation must perform, organized by the detailed Standard Occupational Classification (SOC). As with the patents, these task descriptions are given as text; this paper uses the large language models (LLMs) GPT-4 and Opus-3 to rate, on a continuous scale from 0 to 1, whether each corresponds to a "cognitive task." The resulting occupation-level (SOC) cognitive task scores are then merged into the U.S. CPS and the European EU-LFS to compute a cognitive task score by country, industry, and year. For example, if the employment share of occupations that require many cognitive tasks rises, the cognitive task score for that country, industry, and year rises accordingly. Through this approach, this study examines how RI and HI affect the labor share across countries and industries. This comprehensive analysis constitutes a further academic contribution of the study.

This study derives a reduced-form regression equation from the general equilibrium model. Empirical estimation using this equation shows that RI has a statistically significant negative effect on the labor share, whereas HI has no significant effect. Potential endogeneity in RI and HI is addressed with two shift-share instrumental variables. Other price factors —wages, robot prices, and non-robot capital prices— are used as control variables.

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[2] A closely related study is Acemoglu and Restrepo (2022). They likewise employ a general equilibrium model, but their main focus is wage inequality rather than the decline in the labor share. The present model builds on Acemoglu and Restrepo (2022) but is distinguished by separately introducing robot capital and non-robot capital as production inputs. This specification is important because it makes it possible to analyze, in conjunction with the several types of innovation, how robot capital and non-robot capital differentially affect the labor share.

This study makes two contributions to the literature. First, whereas Autor et al. (2024) focus solely on the U.S. case, this study examines the European Union context. The economic structures of the United States and the European Union differ substantially: the United States, for example, has flexible labor-market institutions, whereas Europe has rigid, labor-protective legislation. Examining the EU case is therefore worthwhile. Second, the use of instrumental variables for robot innovation and human innovation is novel relative to Autor et al. (2024). Despite several differences in setup from that study, the findings are broadly consistent with those of Autor et al. (2024).

The remainder of the paper is organized as follows. The next chapter explains the definitions used in this study. Chapter 3 presents the general equilibrium model that forms the theoretical basis of the analysis. Chapter 4 describes the data and variables used. Chapter 5 reports descriptive statistics. Chapter 6 applies the data to the reduced-form regression equation derived from the general equilibrium model to analyze how various factors affect the labor share. Chapter 7 conducts a factor decomposition analysis to identify the mechanisms that primarily explain the decline in the labor share across countries and industries. Finally, Chapter 8 discusses the conclusions and their implications.