Impact of Automation on Employment and Productivity: A Nonlinear Input â€“ Output Model

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Impacts of automation, digitalization and artificial intelligence for the economic and social developments are the main challenges nowadays and in the focus of intensive debates and scientific theoretical and empirical research. The new technologies offer both new opportunities as well as new challenges. Fundamental implications can be expected for the labour market by substitution of machines for labour. To which extent will the expected productivity growth generated by automation and digitalization substitute the use of labour? Is society running out of jobs or can the reduced size of working population in EU countries be compensated by new technologies?
Given that the performance of an economy is not determined by the simple addition of the activities of its sectors but by the complex interrelationships between them, the aim of this paper is to contribute to the recent discussion by extension of the input-output models postulating substitution possibilities between the employment (human workers), traditional physical capital (machines, assembly lines etc.) and automation capital (industrial robots, 3D printers, etc.), covering a â€žprogrammableâ€œ type of labour. Using the Cobb-Douglas production function with all three production factors for each sector of the economy, we extend the model by SCHUMANN (1968, pp. 138-164), LUPTACIK (1977, pp. 53-61) and LUPTACIK (2010, pp.16-17). Under the objective of labour input minimization for an exogenously given final demand subject to the constraints for the disposable physical and automation capital for each sector in the economy we obtain a special class of the nonlinear optimization problems called geometric programming problems (LUPTACIK, 2010, chapter 6.). As an alternative model variant, which can be formulated as multiobjective geometric programming problem, we examine a model that maximises the welfare function described as a nonlinear combination (via the power function) of the final demand for commodities produced in an economy under the disposability constraints for labour, physical and automation capital. The solutions of the primal geometric programming models yield the optimal combination of labour, physical and automation capital in each sector and, consequently, in the economy.
The core of our contribution lies on the solution of the dual problem, which is a problem with nonlinear objective function and a system of linear equations as the constraints. The dual variables are related to each term in the primal problem, in the objective function as well as in the constraints with clear economic interpretation as elasticity coefficients (LUPTACIK, 1977, LUPTACIK, 2010, chapter 6). The dual variables related to the terms in the primal constraints indicate the percentage change of the employment in the economy when the disposable physical (or automation) capital in sector j increases by 1% as well as the impact of the changes in final demand. Using the dual relationships the lower bound for the total employment change due to the increasing automation capital can be analytically derived (the employment multiplier of automation) and the results can be decomposed in the multiplicative way into technological and the interindustry effects.
We illustrate the analytical possibilities of the models using a model with two sectors (without loss of generality), providing deeper insight into the substitution processes between the primary factors, considering the sectoral interdependencies in the economy. Several propositions concerning the relationships between the parameters of the model and the impact for the employment in the economy (and consequently for productivity) can be derived from the dual problem.

In an application to real world, we use data on industrial robots from IFR (International Federation of Robotics) and combine them with the input-output table from Austria aggregated to nine IO-sectors. We discern three manufacturing sectors that result from a classification in high, medium and low usage of industrial robots and six remaining IO-sectors and use partly estimated, partly calibrated parameters of the production function. We report the empirical results both on the primal and the dual model, thus demonstrating the propositions derived in the theoretical part of the paper and shedding light on the real-world impact of automation on employment and productivity.

References

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