Technology and the Future of Work
Aggregate Employment Effects of Digitization*

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Extended Abstract

Although the discussion on labor market consequences of automation technologies and the induced automation anxiety are not new (Mokyr et al., 2015; Autor, 2015), recent advances in the fields of robotics and artificial intelligence have revived the debate once more. For producing firms, such technologies ("4.0 technologies") include production facilities up to Smart Factories, Cyber-Physical Systems and Internet of Things. For service providers, innovations have brought forward analytic tools for Big Data, Cloud Computing systems, internet platforms, shop systems or online marketplaces. All these advances have raised the question of whether machines and algorithms will at some point make human labor obsolete (Brynjolfsson and McAfee, 2011). The debate has been fuelled by a recent series of "future of work" studies according to which about half of the workforce faces a high risk of automation in coming decades (Frey and Osborne, 2017). Although other studies have put forward reasons to believe that these studies may be overstating the risk of automation (Arntz et al., 2017), there does not yet seem to exist a clear view on how modern technologies impact employment.

Existing empirical evidence on the industry level suggests that industrial robots had no detrimental effect on aggregate employment in developed countries (Graetz and Michaels, 2015).

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Studies on the firm-level suggest no employment losses in firms specialized in routine tasks (Cortes and Salvatori, 2015). Further evidence on the level of US local labor markets suggest that labor markets specialized in routine tasks did not experience employment declines (Autor et al., 2015) or even experienced a positive impact on labor demand as for the case of European regions (Gregory et al., 2016). A somewhat different result has recently been put forward for the US suggesting that regions using more robots experienced a negative effect on employment (Acemoglu and Restrepo, 2017). A recent study by Dauth et al. (2017) finds negative employment effects of robots in the German manufacturing sector, which are off-set by induced positive employment effects in the service sector. In line with this, Acemoglu and Restrepo (2017) highlight that the employment effects of robots apparently differ strongly from those of other types of technology as, e.g. computerization.

A major shortcoming of existing empirical assessments is that they use either indirect measures of technology such as the degree of routinization of work tasks (Routine Replacing Technological Change, RRTC) or specific technologies such as industrial robots. In case of routinization measures, studies rely on the assumption that all jobs involving routine (non-routine) tasks actually become automated (are safe from automation), which might not be realistic, especially in an era of technologies that increasingly enter domains previously preserved for human labor. Using robot data provides a more direct approach in measuring technological adaption, although the results are restricted to producing firms and neglect the important role of service providers which use algorithms and data rather than robots. Besides, up to the authors knowledge, none of the studies looks at the impact of "4.0 technologies" on employment, although they are attributed to fundamental changes on the labor market compared to former technologies. Finally, the underlying mechanisms through which technology affects employment are only partly understood. Most studies focus on job destruction channels such as capital-labour substitution and neglect beneficial channels of technology including positive product demand effects or capital-labour complementarities. The aim of this study is to fill these research gaps by making at least three major contributions.

First, to better understand the underlying mechanisms of technology impacting jobs, we set up a labor demand model that is able to explain technology adaption. The model links technology to occupational labor demand directly and explains the main job creation and job destruction channels arising from technology including substitution and product demand effects. Substitution effects arise as machines substitute (or complement) for certain work tasks. Product demand

effects arise as machines allow firms to operate more cost efficient, leading to lower product prices and, hence, higher sales and labor demand. The model provides testable predictions for total labor demand as well as its subsequent transmission channels. The effects thereby depend on the substitution elasticity between job tasks as well as the elasticity of substitution between goods bundles across industries. In addition, we also model wage and labor supply respones to a changing labour demand in order to capture all relevant mechanisms through which technological change affects employment.

Second, we conduct a representative "IAB-ZEW Labour Market 4.0" firm survey among 2032 producing firms and service providers in Germany. Within the survey, we ask firms about their technology investments between 2011 and 2016. Among others, we gathered technology use data for producers (production equipment) and service providers (electronic office and communication equipment) and distinguish between different degrees of automation in order to identify technologies of the "Industry 4.0" (fourth industrial revolution). We then link the survey data to employment biographies from social security records (BeH) of all workers employed in the surveyed firms. We thus establish a unique linked employer-employee panel data set among German firms in a recent period of rapid technology improvements which allows us to (1) draw a first and detailed representative picture on the extent and change in modern automation technologies and to (2) relate these changes to changes in the level and structure of employment at the firm-level.

Third, based on the theoretical framework, we assess the impact of modern technology on total employment as well as the contributions of the key transmission channels via a decomposition by estimating the key parameters of the theoretical model: (1) task-specific labor demand as a function of technology investment yields the elasticity of substitution between job tasks and allows conclusions on whether modern technologies substitute (or complement) for certain tasks/occupations; (2) product demand as a function of technology investments yields the elasticity of substitution between goods bundles across industries which tells us to what extent firm's product demand profits from technology through lower product prices; (3) wages in a particular occupation-industry-cell as a function of the cell-specific employment rate; (4) labor supply shifts across industry-occupation cells in response to employment rates and wages. In the demand-side estimates, the unique linked employer-employee panel data set allows holding constant a rich set of firm characteristics and controlling for endogenous changes in capital, wages and revenues within an instrumental variables (IV) approach. For the supply-side estimations,

we use rich administrative employment records and apply fixed effects and IV approaches to take account of potential endogeneities.

Our preliminary results suggest that the net effects of these technologies is actually positive, but small. Contrary to existing results for the effects of robots, this is driven by positive labor demand effects. On net, complementarity dominates worker-machine substitution. In addition, we find net positive technology-induced product demand effects. While the net effects remain small, we do find huge reallocations of workers between industries and occupations. Technologies have mostly substituted for routine manual and cognitive workers while raising employment in interactive, abstract and non-routine manual jobs. Moreover, the technologies have accelerated structural change towards service industries, although those manufacturing sectors that produce the new technologies diverge from this picture and experience technology-induced employment growth.

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