Productivity, Broadband Connectivity and Technological Innovations: Firm-level Evidence for Ten European Countries.

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Technological innovations, such as information and communication technology (ICT), have long since been identified as important drivers of productivity in firms. Studies of manufacturing firms based on data from the European Community Innovation Survey (CIS) show a significant correlation between productivity and technological innovations (Crépon, Duguet & Mairesse, 1998; Griffith et al., 2006, Mansury & Love, 2008; see Hall, 2011 and Mohnen & Hall, 2013 for recent surveys), while the association with process innovations is more ambiguous.

Another strand of literature demonstrates the significant link between investments in ICT (measured as ICT capital or ICT usage) and firm productivity (Greenan & Mairesse, 2000; Black & Lynch, 2001; Bresnahan, Brynjolfsson & Hitt, 2002; Brynjolfsson & Hitt, 2003; Arvanitis, 2005; Hempell, 2005; Badescu & Garcés-Ayerbe 2009; for a survey see Cardona et al., 2013). In contrast, Acemoglu et al. (2014) find poor productivity effects in US ICT intensive manufacturing industries for the period 1980-2009, by measuring ICT as the ratio of industry computer expenditures to total capital expenditures. Firm-level analyses of the association between productivity and specific ICT usages such as broadband internet (or e-commerce applications) are less common (for exceptions see Bertschek, Cerquera & Klein, 2013; Colombo, Croce & Grilli, 2013; Hagsten, 2016; Bartelsman, van Leeuwen & Polder, 2017). In this study the relationship between innovations (technological and non-technological) and productivity is investigated, taking into account the ICT intensity of firms, measured as broadband internet connected employees. The analysis is based on multi-linked and internationally comparable firm-level data for ten European countries for the period 2002-2010 and the innovation variables follow the definitions of the Oslo manual distinguishing between technological, organisational and marketing innovations (OECD/Eurostat, 2005). Robust regressions are used to estimate the parameters of the augmented Cobb-Douglas production function.

Linked firm-level data are increasingly available. Changes in the statistical laws have made it legally possible to link data across data sources, but there are still many limitations. Previous studies have linked the Eurostat ICT usage in enterprise survey with production statistics (Hagsten, 2016), Dutch CIS with production data (Klomp & van Leeuwen, 2001), Estonian CIS data with the Business register (Masso & Vahter, 2012), Italian CIS with balance sheets information (e.g. Barbieri, Piva & Vivarelli, 2016), Swedish CIS with production and other firm-level data (Baum et. al., 2017) and United Kingdom CIS

with the annual business inquiry (Criscuolo, Haskel & Martin, 2003). Linked firm-level datasets offer several advantages and possible new research insights compared to single surveys (see Wagner, 2012 for Germany), because they include more information about firm characteristics and firm behaviour. The disadvantage of linked firm-level data often originates from measures to ease the response burden of firms (Hagsten & Sabadash, 2017). This means that different surveys do not necessarily overlap each other and that there is a high degree of panel attrition over time (Raymond et al., 2015) restricting the choice of estimation method that can be used. The main contribution of this study is the inclusion of ICT intensity of firms in the estimation of the association between four types of innovations and productivity based on comparable data for manufacturing and services firms in a large group of European countries. Another strength of the study is the uniquely multi-linked datasets, covering several surveys as well as well as an uninterrupted time period. Research based on linked firm-level data is not uncommon, although the inclusion of more than two surveys, preferably register- or census-based, is rare, as are longer periods of time or more than one wave (three-year average) of innovation data.

Robust regression estimations show that there is indeed a direct, positive and significant relationship between innovation activities and productivity in manufacturing as well as services firms in a majority of countries. However, this is only valid for product innovations, while no obvious pattern appears for the remaining kinds of innovations. In contrast, the proportion of broadband internet connected employees is clearly related to productivity across industries and all but one countries, with a magnitude distinctly larger than that of product innovations. The inclusion of the ICT intensity variable also diminishes the magnitude and significance of the innovation variables. This could follow from the fact that broadband connected employees are capable to make use of additional unmeasured intangible assets. Although the approach does not allow causal effects to be interpreted, the results may indicate that ICT intensity, or the ability to use innovations is more important for productivity than the innovative process in firms. Alternatively, there might be indirect links between innovation activities and productivity, or the innovations may need some time to establish the association. The direct significant negative effect of organisational innovations across industries in some countries could indicate that firms need a phase of adjustment before the operations benefit from the changes.