Firm Innovation and Tertiary Continuing Education

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**Abstract**

In recent years tertiary level continuing education (CE) has received increased attention in

Denmark. We investigate how firms’ use of tertiary CE impacts innovation outcomes. Tertiary CE is relevant for firms’ innovation outcomes both by bringing specialized human capital to the firm and by strengthening collaborations with universities that can aid in the innovation process. We use survey data and administrative data to show that firms with employees who have participated in tertiary level CE have a higher likelihood of innovating than firms without. The study suggests that policy should attempt to make tertiary level programs more accessible.

# Introduction

The continuing education and training system has been considered an important part of the National System of Innovation (NSI) since the earliest part of the NSI literature (see e.g. Lundvall 1992, pp. 14-15). In the 1990s, the most often used formal continuing education (CE) was short-interval labor-market-oriented CE, which aimed at providing low skill workers with specific human capital skill upgrades supporting both the worker and their firm (Gregersen and Holek, 1996). In the first empirical analysis of the role of CE in the Danish Innovation System, Voxsted (1998) studied how Danish manufacturing firms used these short-interval CE programs to prepare their firms for incremental innovation through innovation, communication protocols, and quality control. Even today, these programs continue to serve as a tool to help employees achieve desirable employment outcomes (Nielsen et al., 2020 Other chapter in the book). Starting in the 2000s, however, many firms began to provide their workers with longer and more knowledge-intensive Master and Diploma level tertiary CE that focus on management skills. The increased use of tertiary level CE arguably reflects a change in the role of CE in the National System of Innovation and increased importance of human capital and networks in the innovation process.

Several prior studies have linked initial education levels and diversity, two measures of firms’ human capital base, to firm innovation (see e.g. Audretsch et al. 2018; D’Este et al. 2014; Schubert and Tavassoli 2020; Østergaard et al. 2011), but CE has received less attention. CE provides firms with human capital upgrades of particular skills after the participants have earned the initial degrees that are most often emphasized in the levels and diversity studies. This type of upgrade is particularly relevant in the face of technological change (Holm et al 2020 = another chapter).

While a few studies have linked short-interval labor-market CE to incremental product and process innovation in firms (Bauernschuster et al., 2009; Børing, 2017; Dostie, 2018; Voxsted, 1998), none have studied the relation between tertiary CE and firm innovation, to the best of our knowledge. Like short-interval CE, tertiary CE provides post-initial education skill upgrades. It differs from short-interval CE as it gives access to a specific type of human capital, managerial skills, as opposed to applied skills such as how to use specific welding equipment. Tertiary CE programs are also often longer (up to two part-time years compared to 4 days on average) and taken at a more intense pace measured in the number of hours per year. The differences between CE and initial education, and short-interval and tertiary CE, makes it particularly relevant to empirically study the role of CE in the National Innovation System.

The main hypothesis of this study is that when a firm’s employees participate in tertiary level CE, the firm becomes more likely to innovate because the firm gains managerial skills necessary to support the innovation process.

We contrast the hypothesis of the internal use of managerial skills with a network hypothesis to test alternative explanations for tertiary CE and innovation relationships. Recent studies of MBA participants (a form of tertiary CE) have shown that network influences are important determinants of participants’ subsequent behavior (Shue, 2013; Hacamo and Kleiner, 2020). One type of network effect which we can test with our available data is networks linking firms and universities. Such relations have been linked to having a higher likelihood of successfully innovating (Cohen et al., 2002; Jaffe, 1989). To test if managerial skills are likely to work internally or are based purely in network effects, the second hypothesis, we first test whether employee participation in tertiary CE predicts collaboration with universities for innovation purposes, and secondly whether this channel fully explains any relation between tertiary CE participation and firms’ likelihood of innovating.

The empirical study is based on three types of Danish administrative data and a descriptive and instrumental variable identification approach. The datasets contain information on spells of tertiary CE participation at the individual level, worker and firm characteristics, as well as linked Danish Research, Development and Innovation (RDI) surveys with information about a representative sample of firms’ R&D inputs, and whether the firms have product innovated (put a new product on the market), or process innovated (changed internal organizational routines).

We show that firms with employees who received tertiary CE training within the last two years are more likely to product and process innovate than firms without. We also confirm that the effects are plausibly causal using an instrumental variables strategy, relying on changing distances to nearest tertiary CE education institutions as instruments. Also, having former tertiary CE participants in the firm is positively associated with collaborating with universities as would be suggested under our second hypothesis. However, collaboration with universities does not fully explain the effect of tertiary CE on innovation. Tertiary CE appears to have causal effects on innovation through a collaboration channel but also through other channels that we cannot investigate in this paper.

Our study has importance from a policy perspective. Policies intending to improve the competitiveness of firms through their likelihood of innovating can readily focus on tertiary CE. Increasing access to tertiary CE, either through opening more programs or lowering participation costs, is likely to lead to higher rates of innovation in firms constrained on their managerial skills which are an input in the innovation process.

The chapter proceeds as follows. In section 2 we discuss earlier literature and the theory linking CE to firm-level innovation outcomes, and we provide a brief introduction to the Danish tertiary CE programs, contrasting the program with the short-interval CE programs. Section 3 contains a description of data sources used for the chapter and our empirical strategy to estimate the effects of tertiary CE on firms’ likelihood of innovating. Section 4 contains our empirical findings. Finally, section 5 concludes the chapter.

# Continuing Education and Innovation

In this section, we first describe the existing research linking human capital and particularly short-interval CE to innovation, as well as prior studies on individual and firm-level effects of tertiary CE participation. We then discuss theoretical foundations that describe why upskilling already highly educated tertiary CE participants is still likely to lead increase the likelihood of successful innovation.

## Existing Studies

The education level and composition of firms’ workforce have often been used as a measure of human capital in innovation studies, and are found to be an important input to the innovation process

(e.g. Audretsch et al. 2018; Østergaard et al. 2011; D’Este et al. 2014; Schubert and Tavassoli 2020). The term human capital describes the embodied productive characteristics of an individual (Becker, 1993). While often related to educational attainment at the primary, high school and post-secondary level, experience, and in-firm training (Bhuller et al. 2017; Lemieux 2006). It is also used to capture broader sets of characteristics, such as training, attitudes, motivation and job satisfaction, and has been linked to innovation within firms (Lenihan et al., 2019; McGuirk et al., 2015).

A few prior studies have investigated the relation between short-interval CE and innovation.[[1]](#footnote-1) Bauernschuster et al. (2009) use German IAB establishment surveys from 1997 to 2001 to estimate the relation between training support (either financial or through paid time off for training) and the likelihood the firm product innovates. Dostie (2018) and Børing (2017) use similar Canadian and Norwegian surveys to show that having employees with short-interval training is positively related to the likelihood of incremental product innovation.The only Danish study of the relation between short-interval CE and innovation is Voxsted (1998), who used the Danish DISKO survey data from a sample of Danish manufacturing firms to investigate firms' use of training. Voxsted found that among the participating firms, 25 percent had used the public labor market education programs to upskill their workers to prepare the firm for process innovations. In general, however, these studies suggest some effect of increasing the skills of the least educated on incremental product and process innovations.

Studies of tertiary CE are scarcer than the studies on short-interval training, and none directly investigate tertiary CE and innovation links to the best of our knowledge. Bolvig et al. (2017) investigate wage returns to tertiary CE in a Danish context, finding no income returns from tertiary CE in Denmark. Several authors have studied individual financial returns to and behavior in tertiary CE programs (e.g. Altonji and Zhong, 2020; Bertrand et al., 2010; Boneva et al., 2019). A small literature on US tertiary CE MBA participants have also investigated firm-level outcomes from hiring tertiary CE participants. These studies typically focus on the effect of peer networks on firm policies among firms hiring MBA program peers, e.g. on top management salaries, acquisitions, investment strategies, and the likelihood of successful entrepreneurship (Ahern et al., 2014; Lerner and Malmendier, 2013; Shue, 2013).

In summary, while there exists a large set of studies linking various forms of human capital and the likelihood of innovation, few have investigated CE effects on innovation. The existing studies also tend to focus on short-interval CE, leaving no empirical evidence directly on the effects of tertiary CE.

## Theoretical Links from Tertiary CE to Innovation

Tertiary CE differs from initial education in that participants already have high levels of education, and that they already have substantial work experience. Like short-interval CE it also allows firms to upgrade their employees’ skills beyond the internal knowledge base of the firm where skills and human capital more broadly can be learned through learning-by-doing.[[2]](#footnote-2) This external skill acquisition becomes increasingly important as firms will have to adapt to technological change (Holm et al. 2020, Nielsen et al. 2020 [=chapters]), which may force firms and workers to grapple with new technologies and innovation opportunities and demands. Tertiary CE also differs from the short-interval CE in that they focus not on specific applied skills, but rather on more general skills such as managerial skills.

The importance of managerial skills is emphasized in the Strategic Management literature. In the Resource-Based View of the Firm (e.g. Barney, 1991, and Peteraf, 1993), firms gain competitive advantages when their managers effectively utilize (valuable) resources idiosyncratic to the firm. The more recent Dynamic Capabilities literature (e.g. Teece 2007, Teece et al. 1997, and Winter 2003) instead focus on long-run adaptability of the firm, emphasizing how managerial capabilities allow the firm to maintain sustained competitive advantaged through change. Teece (2010, 2017) makes more direct links between management, and in particular Dynamic Capabilities, and innovation within the firm, arguing that management skills are a necessary component in the sustained innovation activity in the firm.

Alternatively, the managerial skills developed in tertiary CE may draw on networks formed during employees’ tertiary CE participation to increase the likelihood of successful innovation. A core idea in the NSI literature is that knowledge is the foundation for innovation (see e.g. Lundvall 2016), and networks between actors in the economy allow for knowledge sharing and can, in turn, lead to higher likelihoods of innovation (e.g. Bell et al. 2019; Bonaccorsi et al. 2014; Cantner and Graf 2006; Dahl and Pedersen 2004; Gonzalez-Brambila et al. 2013). The recent US MBA studies on effects of peer networks on firm policies, furthermore, underscore the importance of collaborations formed during studies for subsequent firm outcomes (Hacamo and Kleiner, 2020; Lerner and Malmendier, 2013; Shue, 2013). A potentially important type of networks may be with employees at universities, giving access to collaborations and knowledge sharing with the universities previously linked to innovation (Cohen et al., 2002; Jaffe, 1989). As we cannot distinguish between firms’ other networks, but we can investigate collaborations with universities with our available data, we, therefore, test a second hypothesis: having employees that have participated in tertiary CE leads to higher likelihoods of collaborating with universities for innovation purposes, and also that this is the main channel for tertiary CE’s effect on the likelihood of successfully innovating.

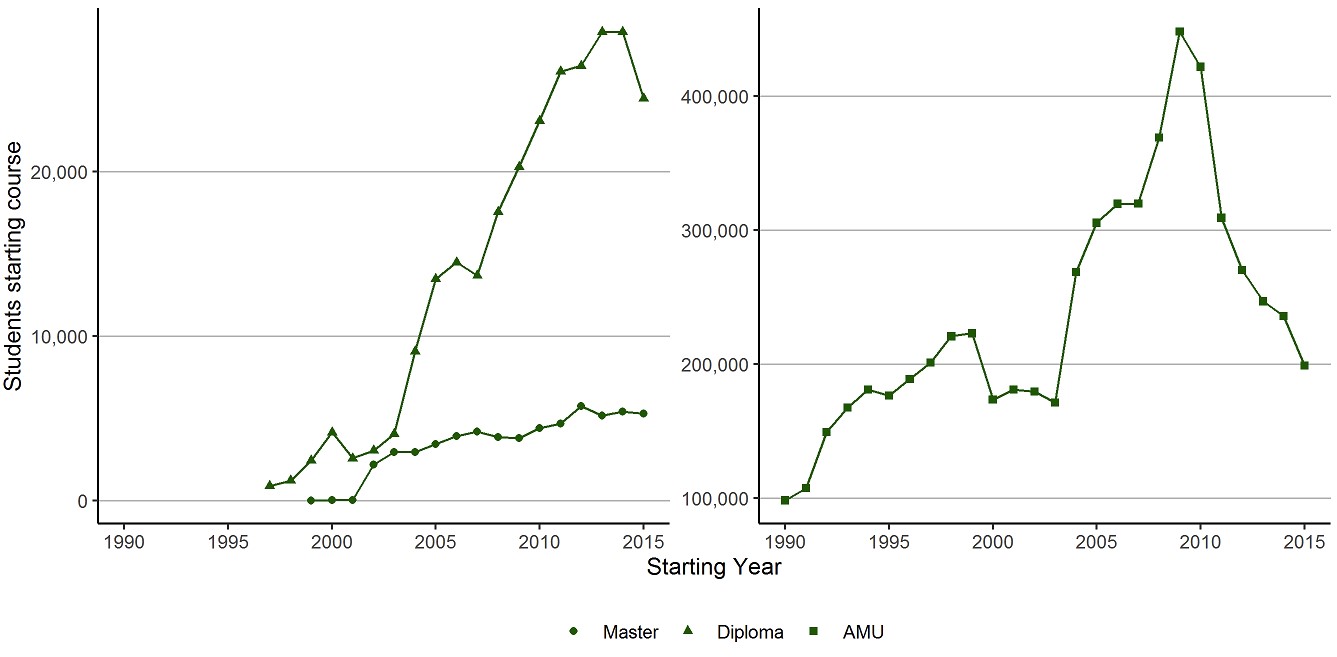
## Tertiary Continuing Education in Denmark

The Danish CE system can be divided into the short-interval labor market educations (AMU) and the longer tertiary CE Master and Diploma programs (such as MBAs, MPAs, Master in IT, and

Diploma in Pedagogy).In this section, we shortly compare the two types of *programs* to provide context for the following analysis.[[3]](#footnote-3)

The majority of Diploma and Master programs aim at providing participants with management skills. To characterize the content of the tertiary CE programs, we have collected information on program content from the Danish Ministry of Education (www.ug.dk) and individual programs’ webpages. Among Diploma tertiary CE programs, 45 percent are fully management oriented. Nearly all other programs, such as the Diploma in Pedagogy, include courses on management specified for the context the course is intended for. Similarly, 42 percent of Master programs are specifically management-oriented, including MBAs and MPAs, and most other Master programs provide some level of management skills aimed at application to the specific field. One example of the programs with specific emphasis is the Master in IT, which allows participants to update their knowledge of recent IT developments, while also gaining management-oriented skills aimed at being useful IT sections and firms. In contrast to the tertiary CE programs, AMU programs provide specialized content aimed at building narrow, applied skills including how to use specialized welding equipment (Gregersen and Holek, 1996).

Figure 1: Number of students who have started CE by year and type of program.



The figure is based on Danish administrative data on spells of CE participation at the individual-spell level. The number of students per year is the number of unique individuals pursuing a given type of program each year. The number of courses pursued will be higher for AMU participation, as some participants go to more than one course per year.

The number of CE students in Denmark has increased over time, both in the AMU programs and tertiary level Master and Diplomas. Figure 1 shows the number of individuals who have started a course, by year and type of program. From 2000 to 2015 the number of new Master students rose from five to 5,200, and the number of Diploma students rose from 4,100 to 24,400 students. This reflects the opening of many new tertiary CE programs across Danish education institutions. Over the same period, the number of AMU students increased from 173,000 in 2000 to 448,200 in 2009 during the Financial Crisis, declining then to 198,900 in 2015. The different post-Crisis trends reflect different uses of programs, where AMU programs are used as unemployment-based training programs, while tertiary CE is a more substantial time- and monetary investment with increased usage over time.

Tertiary CE programs usually last between one and two years, while the average AMU course lasts 4 days, and tertiary CE is taken at more intense levels than AMU courses (Gregersen and Holek, 1996; Undervisningsministeriet, 2010). As a result, AMU courses are taken at less intensive levels than Diploma and Master programs. As a proportion of the academic credits awarded to full-time students, Master and Diploma students achieve between 0.6 and 1.2 of a full-time equivalent study in a year on their programs, with intensity declining slightly in recent years. This likely reflects a change towards more flexible programs that allow students to spread coursework over additional years. AMU programs, in comparison, generally have a duration of a few days.

# Data and methods

To investigate the hypotheses discussed in section 1 we use the 2007 to 2015 waves of the Danish RDI surveys distributed to between 4000 and 5000 Danish companies yearly.[[4]](#footnote-4) From the survey, we collect information on innovation activities and collaboration patterns in connection with innovation, which we use as dependent variables.

Our main explanatory variable is a binary indicator for having or not having an employee who participated in tertiary CE two years prior.[[5]](#footnote-5) To create this variable we use Danish administrative data containing all individual CE spells at registered education institutions in Denmark. The dataset contains all CE spells pursued in Denmark at the individual-course level from 1974 to 2016.[[6]](#footnote-6) For each spell, we can identify the participant, start date, end date, scope in hours, the content of the program, institution, and whether the participant passed the course or not. To use this for the construction of the main explanatory variable, we also use the dataset together with information from the Danish Ministry of Education on the location of education institutions to calculate distances to the nearest tertiary CE institution. We focus on Master and Diploma level tertiary CE programs as these are the programs that employees are likely to participate in having already been in the labor market for some years.

We obtain several variables at the individual and firm-level from administrative data accessed at Statistics Denmark which is available for the full population of individuals in Denmark, as well as all firms from 1980 until 2015. For individuals, these include age, family status, education levels, income levels, and their location down to postal numbers. For firms, they include the number of employees, firm age, industry, and location. Finally, we supplement the administrative data with information on the locations of education institutions collected from the Danish Ministry of Education when the institution still exists and found e.g. in historical archives otherwise.

## Methods

Our hypothesis concerns the effect of CE on innovation. Firms award employees with tertiary CE making the firm more likely to innovate but awarding CE may be endogenous as the innovation process may require employees to participate in tertiary CE. To handle this endogeneity problem and robustly identify the causal effects of awarding CE to employees on the firm’s innovation outcome we do two things:

1. We lag the CE variable to ensure that workers are awarded CE before the firm report on innovation
2. We instrument CE as even the lagged variable may be endogenous if innovating firms use tertiary CE in anticipation of needs arising from later innovation.

## Baseline Model

We model firm-level innovation in an augmented innovation production function as is common in the innovation literature (Love et al., 2011; McGuirk et al., 2015). This entails modeling firm-level innovation outcomes as a function of characteristics that are internal to the firm and that can affect the firm’s propensity to innovate, augmented with an additional set of regressors capturing contextual factors in the firm’s environment that may affect its propensity to innovate. Equation 1 describes this framework for firm *i* at time *t*, where *firmit* are firm internal characteristics including our tertiary CE variable, and *regionalit* are firm external factors, which in our data all refer to variables defined at the regional level. We expand on these variables below.

*Innovationit* = *f*(*firmit, regionalit*) (1)

In the findings section, we first show OLS regressions according to equation 1, with an indicator for having innovated within the last year on the left-hand side, and an indicator for having an employee that has participated in tertiary CE two years prior as the main right-hand-side variable.

We show two main regressions, first controlling for year fixed effects to capture any fluctuations in overall innovation levels due e.g. to the Financial Crisis. Secondly, we control for firm and regional level factors that affect firms’ propensity for innovation separately from the effects of tertiary CE participation.

The full model with year, firm, and regional controls can be seen in equation 2. In the model, *λ* is the conditional relation between *CE* participation and firm innovation, and *CE* is either participation in Master or Diploma level tertiary CE. *Yeart* is a set of year indicators, *firmit* a vector of firm-level controls, and *regionalit* the vector of regional controls. We estimate the model using OLS as opposed e.g. to probit or logit modelling and ML estimation to get estimates of effect sizes that are readily interpretable from the regression coefficient (Angrist and Pischke, 2009, page 72).

(2)

## Controls

At the firm internal level, we control for common factors that have been found to correlate with innovation activity. We control for the firm’s main branch of economic activity as innovation is naturally more common in some industries compared to others (compare for example the pharmaceutical and construction sectors). We also control for firm size in terms of employment as larger firms have been empirically shown to be more likely to innovate than smaller firms (Cohen, 2010), and firm age in years since the firm was established as firms’ economic performance has been shown to vary with firm age (Coad et al., 2018). We also control for firm-level inputs to the innovation process by including a variable for the share of researchers in the workforce, as reported by the firm in the RDI surveys.

At the firm external level, we include two controls. The first is a control for the locally available resources for innovation: the share of the regional workforce with tertiary level education. A supply of highly educated labor benefits the firms’ innovation activities directly as a resource, and indirectly by allowing the firm increased flexibility when adapting its workforce after the innovation has taken place. We define regions as commuting zones computed from the administrative data. Commuting zones are defined according to Statistics Denmark (2016), as a function of the size of working areas, the distance employees commute, and local economic activity. Around the main cities of Denmark, there are large commuting zones combined of multiple municipalities, while in the more peripheral areas commuting zones correspond to single municipalities. This means that there are significant differences in the regional innovation systems among our 27 regions. Some are small rural regions with only a few hundred firms, while others are geographically large regions centered around metropolitan university cities with several thousand firms. These differences are likely to correlate with our measure of the locally available resources for innovation, and the share of the local workforce with a tertiary education will thus also reflect differences in regional innovation systems more broadly.

While the first regional variable captures the general conditions for innovation in the regional innovation system, the second regional control variable reflects regional spillovers that are specifically useful for the specific firm. These are the Marshall-Arrow-Romer (MAR) externalities: A thick labor market, specialized suppliers, and informal interaction (Malmberg and Maskell, 2002). To measure the potential for MAR externalities for firm *i* in region *r* at time *t* we use an index for relatedness (Hidalgo et al., 2018; Neffke et al., 2017). That is, an index capturing the relatedness between the firm’s activities and the other activities in the region-year combination. More related activities entail a thicker labor market, a greater potential for specialized suppliers, and greater scope for informal interaction with peers. The specific index follows then employment weighted relatedness index as applied in Holm and Østergaard (2018). We compute the index at the level of two-digit NACE industries and for industry-region-year *krt*. *ERkrt* is interpreted as the share of employment in the region-year, which is in industries that are related to industry *k*.

## Instrumental Variable Estimation

The OLS regression shows descriptive evidence as to whether there exists a relation between the use of tertiary CE and the firm becoming more likely to innovate. The use of CE may still be endogenous if firms that innovate simply are more likely to have employees participate in CE, for example, because they are expanding their production scale. To estimate the causal effects of tertiary CE on the innovation process we instrument the CE variable in equation 2.

The instrument for CE is the distance to institutions offering CE. One of the first uses of distances to education institutions as instruments was by Card (1993). Several authors have since extended the approach, including Mountjoy (2019). In our setting, the distance represents a cost, so firms located closer to institutions offering CE are more likely to award their workers with CE. The cost is made up of both the actual cost from transportation, but also as an information cost as firms located near such institutions are more likely to be aware of the possibilities of CE. While the pecuniary cost to the firm of an employee participating in CE is likely to be dominated by the cost of the course itself, there are also personal costs to the participants in terms of time away from home and family if participating in a program

The distance between the firm and the CE offering institution is not a perfect instrument for whether firms award CE to their employees. The distance may not be random as more knowledge-intensive firms tend to locate near educational institutions (Bonaccorsi et al., 2014). There are other ways that the distance can affect innovation outcomes: Firms located a shorter distance to educational institutions will have better access to skilled labor, and access to new knowledge produced at the institution – especially if it is a research institution such as a university. However, including the full set of controls as in the methods section will control for both relevant regional and firm characteristics.

The IV setup is a 2 stage least squares (2SLS) approach (Angrist and Pischke, 2009, Ch. 4). equation 3 is our first stage from which we obtain fitted values for CE participation at the firm level using the instrument and the remaining independent variables from the augmented innovation production function as regressors.

(3)

In the second stage, we use these fitted values in place of *CEit* in the original model in equation 2 to estimate the causal effects of CE on the likelihood of the firm innovating. For all IV regressions we also include the results from two tests. The first test is an F-test for weak instruments in the first stage, which as a rule-of-thumb should be above 10 to ensure low levels of weak-IV-bias in the IV estimate (Angrist & Pischke, 2009, Ch. 4.6.4). We report both the F-statistic and the p-value from the test. The Wu-Hausman test for endogeneity is the second test, which compares IV and OLS estimates to determine if the estimates are statistically different (Wooldridge, 2010, pp. 129-134).

# Empirical Findings

The OLS regressions presented in Table 1 show a strong positive relation between firm innovation and participation in tertiary CE by the firm’s employees. We find a strong positive relation with both Master and Diploma CE participation. Firms that have an employee who has received Master level CE, have a 19 percentage points higher likelihood of having had a product innovation conditional on year fixed effects. When we include firm- and regional level controls, the firms are 13.6 percentage points more likely to have innovated. The relationship is weaker for process innovation at 16.9 percentage points and 12.2 percentage points but remains economically substantial. Firms with employees that have taken Diploma level CE are also more likely to have had product and process innovations. In particular, their likelihood of having had a product innovation is 15.1 percentage points higher than firms without Diploma CE employees without controls and 12 percentage points with controls. The numbers are nearly similar for process innovations.

In summary, the OLS evidence is suggestive of the innovation effects of tertiary CE. Firms with employees who have taken CE are more likely to innovate. The result is robust to including several controls that can impact the firm’s innovation process. However, the OLS regressions can only be interpreted descriptively.

Next, we turn to investigate whether the effects we find on innovation can be interpreted causally. Table 2 contains Instrumental Variables estimates of the effect of tertiary CE on the likelihood that a firm has had a product or process innovation. The tertiary CE variables remain the same, as do left-hand side variables and firm and regional controls. We instrument lagged Master and Diploma education with additionally (1-3 years) lagged distances to the nearest education institution providing the relevant type of education.

Firms with Master level CE participants remain positively and statistically significantly more likely to have product and process innovations when we instrument for CE. It is noteworthy that the point estimate for both product and process innovation remain nearly the same with and without controls. For product innovation, the estimate is 1.722, while it is .82 for process innovation without controls, and 0.788 with controls. This suggests that the specification is robust to plausible confounders and that we are capturing causal effects even if the estimates have been sized disproportionately. For Diploma level CE participation and the likelihood of innovating we find mixed evidence. While the likelihood of having a product innovation remains higher for tertiary CE participation with and without controls (a point estimate of 1.5), the effect on process innovation becomes negligible and statistically insignificant when controlling for firm and regional variables. Across specifications the first stage F-statistic is above 10, suggesting that the estimates do not suffer from weak instrument bias. Additionally, for product innovation estimations we can reject equality of IV and OLS estimates, and the p-values of the test suggests that there may be less issues of endogeneity in the Process innovation models.

In total, our evidence suggests that Master level CE can positively impact a firm’s likelihood of having a product and process innovation, while Diploma level tertiary CE has a positive impact on the firm’s likelihood of having product innovations.

## Collaboration with Universities

Collaboration with universities is one potential driver of the effect of tertiary CE on the likelihood of innovation. In the RDI survey, we have access to information on firms’ participation in collaborations with universities to increase their likelihood of innovating. In this section, we investigate whether some or all of the effect of tertiary CE on the innovation likelihood can be explained by increased collaboration.

We start by showing that having tertiary CE employees correlates positively with university collaborations. Table 3 contains the estimates, where model 1 and 2 shows the results for Master participation, and model 4 and 5 for Diploma participation. Firms who have employees that have participated in CE are 12.6 percentage points more likely to collaborate with universities for innovation compared to firms with no Master participants when comparing only with year controls, and 10.4 percentage points more likely to collaborate when we include all controls. For Diploma participation, the numbers are 8.9 percentage points and 7.6 percentage points. CE participation is a statistically significant predictor of collaborations, suggesting that this can explain part of the innovation effect we found in the last section.

We also use our instrument to investigate for signs of causal effects. The results can be seen in models 3 and 6 in table 3. The estimates remain positive and statistically significant as we instrument for participation CE, suggesting that we are likely observing causal effects.

If all effects of tertiary CE on the likelihood of innovating can be explained by additional collaborations, then adding collaboration for innovation with a university as a control variable in our primary OLS and IV regressions should remove any independent effect of participation in CE on the likelihood of innovating. Therefore, we next show our main IV regressions but add collaboration with universities for innovation (*Collaboration with University*) as a control to the regressions. The results can be seen in table 4.

We start by investigating the effect of Master participation on the likelihood of having a product innovation. When controlling for university collaboration, the IV estimate drops only little from 1.739 to 1.646 and remains statistically significant. While collaboration does appear to control for some of the effects of Master participation, there still seem to be other pathways through which CE participation affects the likelihood of having a product innovation.

The effect is somewhat similar when considering the effect on process innovation. The estimate drops slightly from .796 to .676, but the effect remains statistically significant. Finally, looking at Diploma participation, our results are broadly similar. Controlling for university collaboration makes the product innovation estimate drop from 1.476 to still statistically significant 1.394, whereas controlling for university collaboration in the regression for process innovation leads to a drop from .269 to .148, both are statistically insignificant.

In summary, while it appears that a higher likelihood of university collaboration is one effect of tertiary CE participation, tertiary CE still has a separate effect on the likelihood of innovating which is largely separate from the collaboration channel.

# Conclusion

In this chapter, we have investigated how firms’ use of tertiary CE can impact their likelihood of having either product or process innovations. Participation in tertiary CE, such as Master and Diploma education has been increasing since the early 2000s. This can be relevant for firms’ product and process innovation procedures both by bringing specialized human capital to the firm and by strengthening relations and collaborations with universities that can aid in the innovation process.

We use survey data merged with firm and individual level administrative data to investigate the effects of tertiary CE on firms’ likelihood of having a process or product innovation. In descriptive regressions, we find that having at least one employee who has participated in tertiary CE increases the likelihood of having had a product or process innovation. The relation is robust to controlling for a large set of firm and regional variables that capture both size, age, industry, and knowledge appropriation characteristics, as well as year fixed effects.

We then implement IV regressions using distances to the nearest tertiary CE institution as an instrument for having employees who have participated in tertiary CE to estimate whether tertiary CE has causal effects on the likelihood of having product and process innovations. The IV regressions indicate that there is a causal effect of Master level tertiary CE on the likelihood of firms having both product and process innovations. The estimated effect of Master level CE also is greater than the estimated effect for Diploma level CE for product innovations. There appears to be no credible evidence for Diploma effects on process innovations.

Finally, to test whether the effects of tertiary CE can be explained through university-related networks and collaborations we first show that both Master and Diploma CE participation is a strong predictor of firms having collaborations with universities to innovate. However, adding university collaboration as a control in our main IV regressions does not substantially change the results. It seems that network and collaboration channels do not explain the effects of tertiary CE on firms’ likelihood of innovating, leaving further room for further research on how the specialized human capital from tertiary CE impacts innovation.

The increasing use in Denmark of tertiary level CE relative to other forms of CE appears merited as tertiary level CE increases the probability of innovation at the firm level and increases the probability of collaboration between firms and universities. The current study does not give any reason to believe that the effect of AMU-type CE on incremental shop floor innovations has lessened over time and hence cannot suggest that policy should shift focus from the AMU system to tertiary level CE. The study does, however, suggest that policy should attempt to make tertiary level programs more accessible. This can be achieved by increasing the number of places in Denmark that such programs are offered or by lowering the cost of attending the programs. However, the cost may also represent an important selection mechanism resulting in firms primarily using tertiary level CE when the expected economic benefit is substantial. Another aspect of the costs of participation in tertiary level CE is the degree to which the costs, pecuniary as well as nonpecuniary, are born by the employee and not the employer. Employees can have a strong incentive to participate in CE to remain adaptive and attractive in the labor market and thus be willing to assume part of the costs. The role of costs is thus complicated, and more research is needed before policy recommendations can be reached.

Finally, our results are only suggestive of the effects of smaller changes to the tertiary CE system, whereas more research is warranted to investigate large scale changes to the tertiary CE system.

# References

Ahern, K. R., Duchin, R., and Shumway, T. (2014). Peer Effects in Risk Aversion and Trust. *Review of Financial Studies*, 27(11):3213–3240.

Altonji, J., and Zhong, L. (2020). The Labor Market Returns to Advanced Degrees. NBER Working Paper Series, Working Paper 26959, National Bureau of Economic Research, Cambridge, MA.

Angrist, J. D. and Pischke, J.-S. (2009). *Mostly Harmless Econometrics: An Empiricist’s Companion*. Princeton University Press.

Audretsch, D. B., Hafenstein, M., Kritikos, A. S., and Schiersch, A. (2018). Firm Size and Innovation in the Service Sector. *IZA Discussion Paper Series, 12035*, (12035).

Barney, J. (1991). Firm Resources and Sustained Competitive Advantage. *Journal of Management*, 17(1):99–120.

Bauernschuster, S., Falck, O., and Heblich, S. (2009). Training and Innovation. *Journal of Human Capital*, 3(4):323–353.

Becker, G. S. (1993). *Human Capital - A Theoretical and Empirical Analysis with Special Reference to Education*. Chicago University Press, Chicago, third edition.

Bell, A., Chetty, R., Jaravel, X., Petkova, N., & Van Reenen, J. (2019). Who Becomes an Inventor in America? The Importance of Exposure To Innovation. *The Quarterly Journal of Economics*, *134*(2), 647–713.

Bertrand, M., Goldin, C., and Katz, L. F. (2010). Dynamics of the gender gap for young professionals in the financial and corporate sectors. *American Economic Journal: Applied Economics*, 2(3):228–255.

Bhuller, M., Mogstad, M., and Salvanes, K. G. (2017). Life-Cycle Earnings, Education Premiums, and Internal Rates of Return. *Journal of Labor Economics*, 35(4):993–1030.

Bolvig, I., Kristensen, N., and Skipper, L. (2017). *Effektevaluering Af Voksen- Og Efteruddannelsesindsatsen*. KORA - Det Nationale Institut for Kommuners og Regioners Analyse og Forskning.

Bonaccorsi, A., Colombo, M. G., Guerini, M., and Rossi-Lamastra, C. (2014). The impact of local and external university knowledge on the creation of knowledge-intensive firms: Evidence from the Italian case. *Small Business Economics*, 43(2):261–287.

Boneva, T., Golin, M., and Rauh, C. (2019). Can Perceived Returns Explain Enrollment Gaps in Postgraduate Education? *HCEO Working Paper Series 2019-045*.

Børing, P. (2017). The relationship between training and innovation activities in enterprises: The relationship between training and innovation activities. *International Journal of Training and Development*, 21(2):113–129.

Cantner, U. and Graf, H. (2006). The network of innovators in Jena: An application of social network analysis. *Research Policy*, 35(4):463–480.

Card, D. (1993). Using Geographic Variation in College Proximity to Estimate the Return to Schooling. National Bureau of Economic Research, Working Paper 4483, National Bureau of Economic Research.

Card, D., Kluve, J., and Weber, A. (2018). What Works? A Meta-Analysis of Recent Active Labor Market Program Evaluations. *Journal of the European Economic Association*, 16(3):894–931.

Coad, A., Holm, J. R., Krafft, J., and Quatraro, F. (2018). Firm age and performance. *Journal of Evolutionary Economics*, 28(1):1–11.

Cohen, W. M. (2010). Fifty years of empirical studies of innovative activity and performance. In Hall, B. H. and Rosenberg, N., editors, *Handbook of the Economics of Innovation*, volume 1, chapter 4, pages 129–213. North-Holland.

Cohen, W. M., Nelson, R. R., and Walsh, J. P. (2002). Links and impacts: The influence of public research on industrial R&D. *Management Science*, 48(1):1–23.

Dahl, M. S. and Pedersen, C. Ø. R. (2004). Knowledge flows through informal contacts in industrial clusters: Myth or reality? *Research Policy*, 33(10):1673–1686.

Danmarks Evalueringsinstitut (2008). *Nyt AMU: med fokus på kompetencer og fleksibilitet*. Danmarks Evalueringsinstitut, Kbh.

Danmarks Evalueringsinstitut (2012). *AMU som springbræt til fortsat uddannelse*. Danmarks Evalueringsinstitut, Kbh.

Danmarks Evalueringsinstitut (2019). *Virksomheders brug og vurderinger af AMU i 2019 - belyst gennem surveys i 2007, 2011, 2015 og 2019*. Danmarks Evalueringsinstitut, Kbh.

D’Este, P., Rentocchini, F., and Vega-Jurado, J. (2014). The Role of Human Capital in Lowering the Barriers to Engaging in Innovation: Evidence from the Spanish Innovation Survey. *Industry and Innovation*, 21(1):1–19.

Dostie, B. (2018). The Impact of Training on Innovation. *ILR Review*, 71(1):64–87.

Gonzalez-Brambila, C. N., Veloso, F. M., and Krackhardt, D. (2013). The impact of network embeddedness on research output. *Research Policy*, 42(9):1555–1567.

Gregersen, O. and Holek, L. (1996). *Arbejdsmarkedsuddannelserne - En Vidensopsamling*. Socialforskningsinstituttet, København.

Hacamo, I. and Kleiner, K. (2020). Competing for Talent: Firms, Managers and Social Networks. *Kelly School of Business Research Paper No. 17-34*, page 56.

Hidalgo, C. A., Balland, P.-A., Boschma, R., Delgado, M., Feldman, M., Frenken, K., Glaeser, E., He, C., Kogler, D. F., Morrison, A., and Others (2018). The principle of relatedness. In *International Conference on Complex Systems*, pages 451–457. Springer.

Holm, J. R., and Østergaard, C. R. (2018). *Changes in Regional Diversification: The Conditional Role of Knowledge Flows*. Working Paper presented at the Regional Innovation Policies Conference, Bergen, October 11- October 12.

Holm et al. (2020) (= another chapter)

Jaffe, A. (1989). Real Effects of Academic Research. *The American Economic Review*, 79(5):957– 970.

LaLonde, R. (2003). Employment and Training Programs. In Moffitt, R., editor, *Means-Tested* *Transfer Programs in the United States*, A National Bureau of Economic Research Conference Report, pages 517–585. University of Chicago Press, Chicago.

Lemieux, T. (2006). The ”Mincer Equation” Thirty Years after Schooling, Experience, and Earnings. In Grossbard, S., editor, *Jacob Mincer - A Pioneer of Modern Labor Economics*. Springer.

Lenihan, H., McGuirk, H., and Murphy, K. R. (2019). Driving innovation: Public policy and human capital. *Research Policy*, 48(9):103791.

Lerner, J., and Malmendier, U. (2013). With a little help from my (random) friends: Success and failure in post-business school entrepreneurship. *Review of Financial Studies*, 26(10):2411–2452.

Love, J. H., Roper, S., and Bryson, J. R. (2011). Openness, knowledge, innovation, and growth in UK business services. *Research Policy*, 40(10):1438–1452.

Lundvall, B.-Å. (1992). Introduction. In Lundvall, B.-Å., editor, *National Systems of Innovation Toward a Theory of Innovation and Interactive Learning*, chapter 1, pages 1–19. Pinter, London.

Lundvall, B.-Å. (2016). *The Learning Economy and the Economics of Hope*. Anthem Press.

Malmberg, A., and Maskell, P. (2002). The elusive concept of localization economies: Towards a knowledge-based theory of spatial clustering. *Environment and Planning A: Economy and Space*, 34(3):429–449.

McGuirk, H., Lenihan, H., and Hart, M. (2015). Measuring the impact of innovative human capital on small firms’ propensity to innovate. *Research Policy*, 44(4):965–976.

Mountjoy, J. (2019). Community Colleges and Upward Mobility. *Working Paper*.

Neffke, F. M. H., Otto, A., and Weyh, A. (2017). Inter-industry labor flows. *Journal of Economic Behavior & Organization*, 142:275–292.

Nielsen et al. (2020). (= another chapter)

Østergaard, C. R., Timmermans, B., and Kristinsson, K. (2011). Does a Different View Create Something New? The Effect of Employee Diversity on Innovation. *Research Policy*, 40(3):500– 509.

Pedersen, V. H., Andresen, S., and Lassen, M. (2012). *En Fortælling Om AMU: Arbejdsmarkedsuddannelserne i En Verden Af Forandring*. Aalborg University Press, Aalborg.

Peteraf, M. A. (1993). The cornerstones of competitive advantage: A resource-based view. *Strategic Management Journal*, 14(3):179–191.

Schubert, T., and Tavassoli, S. (2020). Product Innovation and Educational Diversity in Top and Middle Management Teams. *Academy of Management Journal*, 63(1):272–294.

Shue, K. (2013). Executive networks and firm policies: Evidence from the random assignment of MBA peers. *Review of Financial Studies*, 26(6):1401–1442.

Statistics Denmark (2016). Pendlingsområder – metode. *Metode Papir af 22. November 2016*.

Teece, D. J. (2007). Explicating dynamic capabilities: The nature and microfoundations of (sustainable) enterprise performance. *Strategic Management Journal*, 28(13):1319–1350.

Teece, D. J. (2010). Technological Innovation and The Theory of The Firm: The Role of Enterprise Level Knowledge, Complementarities, and (Dynamic Capabilities). In *Handbook of the Economics of Innovation*, volume 1 of *Handbooks in Economics*, pages 679–730. Elsevier B.V.

Teece, D. J. (2017). Towards a capability theory of (innovating) firms: Implications for management and policy. *Cambridge Journal of Economics*, 41(3):693–720.

Teece, D. J., Pisano, G., and Shuen, A. (1997). Dynamic Capabilities and Strategic Management. *Strategic Management Journal*, 18(7):509–533.

Undervisningsministeriet (2010). *AMU 50 År Jubilæum*.

Voxsted, S. (1998). Efteruddannelses-systemets Rolle og Muligheder i Det Danske Innovationssystem. *Notat, Erhvervsudviklingsr*å*det, DISKO-Projektet: Rapport Nr. 3*.

Winter, S. G. (2003). Understanding dynamic capabilities. *Strategic Management Journal*, 24(10):991–995.

Wooldridge, J. M. (2010). *Econometric Analysis of Cross Section and Panel Data* (2nd ed.). MIT Press.

Table 1: OLS Regression of Innovation outcomes on having former tertiary CE participants among employees.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Product Innovation | | | | Process Innovation | | | |
|  | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Master (-2Y) | .190\*\*\* | .141\*\*\* |  |  | .169\*\*\* | .125\*\*\* |  |  |
|  | (.010) | (.010) |  |  | (.010) | (.010) |  |  |
| Diploma (-2Y) |  |  | .151\*\*\* | .124\*\*\* |  |  | .149\*\*\* | .121\*\*\* |
|  |  |  | (.008) | (.008) |  |  | (.008) | (.008) |
| Employees |  | .00004\*\*\* |  | .00004\*\*\* |  | .0001\*\*\* |  | .0001\*\*\* |
|  |  | (.00001) |  | (.00001) |  | (.00001) |  | (.00001) |
| Firm age |  | .0004\* |  | .0004\* |  | -.0001 |  | -.0001 |
|  |  | (.0003) |  | (.0003) |  | (.0003) |  | (.0003) |
| R&D empl. (pct) |  | .493\*\*\* |  | .497\*\*\* |  | .257\*\*\* |  | .260\*\*\* |
|  |  | (.036) |  | (.037) |  | (.020) |  | (.020) |
| Regional pct. w. tertiary ed. |  | .402\*\*\* |  | .392\*\*\* |  | .213\*\*\* |  | .202\*\*\* |
|  |  | (.058) |  | (.058) |  | (.061) |  | (.061) |
| ERirt |  | .414\*\*\* |  | .424\*\*\* |  | .159\*\*\* |  | .168\*\*\* |
|  |  | (.044) |  | (.044) |  | (.045) |  | (.045) |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Industry FE |  | Yes |  | Yes |  | Yes |  | Yes |
| N | 36,995 | 36,995 | 36,995 | 36,995 | 36,995 | 36,995 | 36,995 | 36,995 |
| Note: \*p<0.1; \*\*p<0.05; \*\*\*p<0.01 | |  |  |  |  |  |  |  |

Table 2: IV Regression of Innovation outcomes on having former tertiary CE participants among employees.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | |  | |  | |  | |  | |  | |  | |  | |
|  | Product Innovation | | | | | | | | Process Innovation | | | | | | | |
|  | (1) | | (2) | | (3) | | (4) | | (5) | | (6) | | (7) | | (8) | |
| Master (-2Y) | 1.722\*\*\* | | 1.739\*\*\* | |  | |  | | .820\*\*\* | | .796\* | |  | |  | |
|  | (.234) | | (.453) | |  | |  | | (.238) | | (.468) | |  | |  | |
| Diploma (-2Y) |  | |  | | 1.650\*\*\* | | 1.476\*\*\* | |  | |  | | .579\*\*\* | | .269 | |
|  |  | |  | | (.160) | | (.251) | |  | |  | | (.210) | | (.344) | |
| Year FE | Yes | | Yes | | Yes | | Yes | | Yes | | Yes | | Yes | | Yes | |
| Industry FE |  | | Yes | |  | | Yes | |  | | Yes | |  | | Yes | |
| Firm Controls |  | | Yes | |  | | Yes | |  | | Yes | |  | | Yes | |
| Region Controls |  | | Yes | |  | | Yes | |  | | Yes | |  | | Yes | |
| Stage-1 F-stat | 42.47 | | 11,20 | | 49.48 | | 18,00 | | 42.47 | | 11,20 | | 49.48 | | 18,00 | |
| Stage-1 F p-value | <0.001 | | <0.001 | | <0.001 | | <0.001 | | <0.001 | | <0.001 | | <0.001 | | <0.001 | |
| Wu-Hausman p-value | <0.001 | | <0.001 | | <0.001 | | <0.001 | | 0.005 | | 0.141 | | 0.039 | | 0.667 | |
| N | 36.468 | | 36.468 | | 36.468 | | 36.468 | | 36.468 | | 36.468 | | 36.468 | | 36.468 | |
| Note: \*p<0.1; \*\*p<0.05; \*\*\*p<0.01 | |  | |  | |  | |  | |  | |  | |  | |

Table 3: OLS and IV regressions of indicator for collaboration with a university on having an employee with tertiary CE degree

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | |  | |  | |  | |  | |  | |
|  | OLS | | OLS | | IV | | OLS | | OLS | | IV | |
|  | (1) | | (2) | | (3) | | (4) | | (5) | | (6) | |
| Master (-2Y) | .126\*\*\* | | .104\*\*\* | |  | |  | |  | |  | |
|  | (.005) | | (.005) | |  | |  | |  | |  | |
| Diploma (-2Y) |  | |  | |  | | .089\*\*\* | | .076\*\*\* | |  | |
|  |  | |  | |  | | (.004) | | (.004) | |  | |
| IV Master (-2Y) |  | |  | | .372\*\* | |  | |  | |  | |
|  |  | |  | | (.157) | |  | |  | |  | |
| IV Diploma (-2Y) |  | |  | |  | |  | |  | | .325\*\*\* | |
|  |  | |  | |  | |  | |  | | (.100) | |
| Year FE | Yes | | Yes | | Yes | | Yes | | Yes | | Yes | |
| Industry FE |  | | Yes | | Yes | |  | | Yes | | Yes | |
| Firm Controls |  | | Yes | | Yes | |  | | Yes | | Yes | |
| Region Controls |  | | Yes | | Yes | |  | | Yes | | Yes | |
| Stage-1 F-stat |  | |  | | 11,20 | |  | |  | | 18,00 | |
| Stage-1 F p-value |  | |  | | <0.001 | |  | |  | | <0.001 | |
| Wu-Hausman p-value |  | |  | | 0,087 | |  | |  | | 0,009 | |
| N | 36.995 | | 36.995 | | 36.468 | | 36.995 | | 36.995 | | 36.468 | |
| Note: \*p<0.1; \*\*p<0.05; \*\*\*p<0.01 | |  | |  | |  | |  | |  | |

Table 4: IV regressions of Innovation outcomes on having former participants in CE among employees and controlling for collaboration with Universities for innovation purposes.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | |  | |  | |  | |  | |  | |  | |  | |
|  | Product Innovation | | | | | | | | Process Innovation | | | | | | | |
|  | (1) | | (2) | | (3) | | (4) | | (5) | | (6) | | (7) | | (8) | |
| Master (-2Y) | 1.739\*\*\* | | 1.646\*\*\* | |  | |  | | .796\* | | .676 | |  | |  | |
|  | (.453) | | (.466) | |  | |  | | (.468) | | (.485) | |  | |  | |
| Diploma (-2Y) |  | |  | | 1.476\*\*\* | | 1.394\*\*\* | |  | |  | | .269 | | .148 | |
|  |  | |  | | (.251) | | (.258) | |  | |  | | (.344) | | (.359) | |
| Collab. w. Uni. |  | | .253\*\*\* | |  | | .253\*\*\* | |  | | .306\*\*\* | |  | | .373\*\*\* | |
|  |  | | (.067) | |  | | (.046) | |  | | (.068) | |  | | (.059) | |
| Year FE | Yes | | Yes | | Yes | | Yes | | Yes | | Yes | | Yes | | Yes | |
| Industry FE | Yes | | Yes | | Yes | | Yes | | Yes | | Yes | | Yes | | Yes | |
| Firm Controls | Yes | | Yes | | Yes | | Yes | | Yes | | Yes | | Yes | | Yes | |
| Region Controls | Yes | | Yes | | Yes | | Yes | | Yes | | Yes | | Yes | | Yes | |
| Stage-1 F-stat | 11,20 | | 10,25 | | 18,00 | | 16,38 | | 11,20 | | 10,25 | | 18,00 | | 16,38 | |
| Stage-1 F p-value | <0.001 | | <0.001 | | <0.001 | | <0.001 | | <0.001 | | <0.001 | | <0.001 | | <0.001 | |
| Wu-Hausman p-value | <0.001 | | 0,112 | | <0.001 | | 0,008 | | 0,141 | | 0,112 | | 0,667 | | 0,008 | |
| N | 36.468 | | 36.468 | | 36.468 | | 36.468 | | 36.468 | | 36.468 | | 36.468 | | 36.468 | |
| Note: \*p<0.1; \*\*p<0.05; \*\*\*p<0.01 | |  | |  | |  | |  | |  | |  | |  | |

1. Unlike studies investigating short-interval training and innovation, a substantial literature investigates effects e.g. on individual employment and wage. LaLonde (2003) and Card et al. (2018) survey the extensive international literature, and Gregersen and Holek (1996) and Danmarks Evalueringsinstitut (2008, 2012, 2019) survey Danish studies focusing also on participants’ and firms’ experience of the short-interval AMU programs. [↑](#footnote-ref-1)
2. The upgrade to skills not already available within firms was, in fact, the main purpose for the development of the Danish short-interval CE in 1960 (Pedersen et al., 2012; Undervisningsministeriet, 2010). [↑](#footnote-ref-2)
3. Nielsen et al. 2020 ( = other chapter) provide a more in-depth introduction to the short interval CE programs. [↑](#footnote-ref-3)
4. This survey is the Danish version of the Community Innovation Survey run by Statistics Denmark. A full description of the survey is available at [https://www.dst.dk/da/Statistik/dokumentation/statistikdokumentation/ forskning-og-udvikling-i-erhvervslivet.](https://www.dst.dk/da/Statistik/dokumentation/statistikdokumentation/forskning-og-udvikling-i-erhvervslivet) [↑](#footnote-ref-4)
5. The binary indicator for CE participation is a simple threshold indicator. An alternative to the binary indicator is a continuous measure of tertiary CE participation, such as the share of employees who have received tertiary CE, which could capture the intensity of tertiary CE effects on innovation. However, our data on innovation outcomes do not allow us to distinguish between low and high levels of innovation output as we only observe whether a firm has innovated or not. As a result, to avoid unnecessarily complicated functional specifications, we simplify the analysis by focusing on binary indicators on both the left and right-hand side of regression models we specify in section 5. [↑](#footnote-ref-5)
6. The data covers all educations that are officially recognized by the Danish government as CE. Examples of program spells not contained in the register are degrees pursued in foreign countries and online certificates. [↑](#footnote-ref-6)