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Capital incentive policies in the age of cloud computing: an empirical case study

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The following paper assesses whether current policy environments are appropriate for the emergence of cloud computing technology. In particular, this research uses firm level data for Germany and the United Kingdom to examine the impact of capital incentive programmes (a common policy present in most OECD countries) on cloud adoption. The design for many of these policies target investments in physical capital while excluding digital services like the cloud. Firms view digital investments and digital services as substitutes, therefore narrowly defined incentive programmes may actually discourage the use of emerging tools like cloud computing, which are found to enable the growth and performance of young entrants. Overall, the results find that while capital incentive policies encourage firm investments in ICT and other forms of capital, they actually reduce the probability of cloud adoption. Policy makers may therefore need to reconsider the design of capital incentive programmes within their jurisdictions.

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Chapter 1. Introduction

Over the last ten years, a fundamental shift has occurred in the manner with which firms access digital technology. In the past, the acquisition of ICT required businesses to make considerable upfront sunk investments in hardware infrastructure and software in order to establish and maintain IT departments. Recently however, there has been a change in the nature of ICT use, where firms are increasingly acquiring their storage, processing and software needs as a service through what is typically referred to as "cloud computing" (Van Ark, 2016; OECD, 2015). Third party IT providers offer such services "on demand" or through "pay as you go" subscriptions. As a result, firms no longer need to invest and own digital technologies, thereby avoiding many of the sunk costs previously associated with ICT use, while at the same time reducing their reliance on centralised IT departments (OECD, 2015; OECD, 2014; OECD, 2019).

The growth in this new way of accessing IT has been rapid. Amazon Web Services first introduced cloud in 2006 and two years later released more advanced cloud services allowing for greater capacity in storage and processing power. From around 2010, more cloud providers entered the market resulting in increased competition and considerable declines in the price of cloud services (Barr, 2009a; Barr, 2009b). The decline in prices were followed by a dramatic increase in the adoption of cloud computing by businesses. For example, between 2009-2017 cloud expenditures by firms grew 4.5 times faster than traditional IT investment expenditure (Lesser, 2017). By 2016, 30% of firms used cloud across the OECD, with expenditure on cloud services representing 25% of firms' IT budgets (Eurostat, 2018b; Deloitte, 2017). Moreover, global expenditures of cloud services are expected to reach USD 173 billion by 2026 (Columbus, 2016).

The diffusion of cloud coincides with the trend of firms becoming increasingly more reliant on intangible assets such as data, research and development (R&D), branding and less on tangible assets such as machines, equipment, factories (Corrado & Hulten, 2010; Haskel & Westlake, 2017). Cloud is expected to further enable the use of intangibles, in particular data, since it is a less expensive and a more flexible substitute for traditional storage and processing hardware technologies. This has ushered in a new age of business models based on data collection and analysis, referred to as big data (McKinsey, 2011; Niebel, Rasel, & Viete, 2019). This shift towards data based business models is indeed reflected in the fact that the accumulated sum of globally stored data will increase from 33 zettabytes in 2018 to 175 zettabytes by 2025, representing an annual growth rate of 61%. Moreover, most of this data will be stored in the cloud (Patrizio, 2018). Looking forward, the diffusion of cloud will further facilitate emerging technologies including artificial intelligence and other predictive technologies (Columbus, 2018; OECD, 2019).[1]

On the one hand, policy makers are interested in fostering the diffusion of emerging technologies like cloud. However, there is good reason to believe that some policies currently in place across OECD economies may actually be discouraging cloud use. Notably, programmes that are narrowly targeted towards encouraging investment in physical capital including investments in digital technology. Such policies are therefore likely to lower the marginal cost of eligible investments, incentivizing firms to adopt one type of technology versus another. Microeconomic investment theory for example purports that firms make capital investments so as to adjust to an optimal level of capital, contingent upon optimal output and cost of capital. Therefore, a capital incentive scheme lowers the user cost of capital for eligible businesses, incentivizing new investment. As such, Criscuolo et al. (2019) show that a regionally targeted investment subsidy is successful in raising capital investments and employment in the United Kingdom. Since firms view cloud services and ICT investments as substitutes, policies, which specifically target capital investments are likely to discourage the use of cloud services. It is important to note that many of these policies targeting traditional capital investments require firms to pay the government back for support received if the business subsequently sells the asset (OECD, 2019). This may act as a barrier for a firm's ability to experiment and adjust, particularly for entrants and those located in volatile sectors.

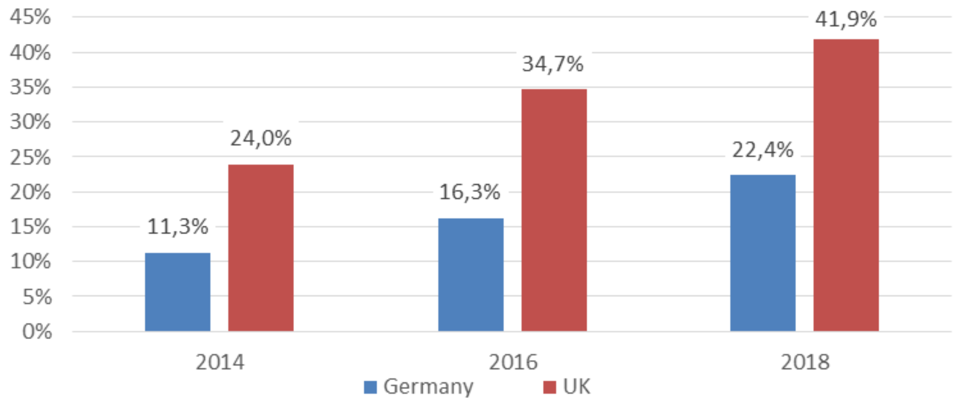
There are a number of different capital incentive policies currently present across OECD economies, targeted towards promoting the digital transformation of firms. However, such programmes often incentivise investments rather than the procurement of digital services. These include tax allowances, subsidies and targeted grants geared towards investments in digital and/or more general capital investments (OECD, 2019). Italy and the United Kingdom for example have used tax allowances to encourage the adoption of particular types of capital and/or "Industry 4.0" technologies (Menon, DeStefano, Manaresi, Soggia, & Santoleri, 2018; Maffini, Xing, & Devereux, 2019; Spengel, et al., 2015). In Germany, examples are the "'Digital Now - Investment Promotion for SMEs", an investment grant currently planned by the Federal Ministry for Economic Affairs and Energy, or the "ERP-digitalisation loan" by the government-owned development bank (KfW). One potential reason why countries use capital incentive policies is that investments are easy to measure and demonstrate policy success while cloud use is difficult to see by the policy maker or even by offices of national statistics; cloud use is typically listed as an operating expense on firm balance sheets. To our knowledge, few policies target cloud use explicitly. One notable example is a programme introduced in Spain, which provides EUR 40 million in funds to promote cloud computing services for small and medium enterprises (SMEs) (OECD, 2019).[2]

The objective of this paper is to understand the extent to which capital incentive programmes affect the adoption of cloud services. This paper will focus on two distinct policies rolled out separately in the United Kingdom and Germany known as the *Annual Investment Allowance* (AIA), which is a tax allowance policy and the "*Gemeinschaftsaufgabe Verbesserung der regionalen Wirtschaftsstruktur*" (GRW),[3] which is an investment grant scheme. The results in this paper are based on analysis from Andres et al (2019) and DeStefano et al (2020).The analysis relies on novel firm level data and is the first study to our knowledge, which examines cloud adoption at the firm level for multiple countries.[4],[5] The reliance on cross-country firm level data is particularly useful as it enables one to control for a host of unobservable characteristics, which may also be linked to cloud adoption, allowing for more robust estimation. The use of micro cross-country data also enables the identification of firm heterogeneity and provides insights as to whether or not the estimation of the effects of a policy is externally valid across different regions. One of the drawbacks however is that we are unable to pool the two datasets since they can only be accessed from secure data labs within their respective countries.

The adoption of cloud is taking place quite rapidly, however at considerably different rates across countries (OECD, 2017). The two countries assessed in this study, Germany and the United Kingdom, exhibit increases in adoption over the sample period, however as of 2018, 22.4% of firms in Germany adopted cloud versus 41.9% in the United Kingdom (see Figure 1).[6] This raises the question whether policy settings in different countries may be playing a role in determining the rate of adoption. One possible explanation may be that some policy environments are targeted more towards encouraging traditional ICT investments rather than digital services, such as capital incentive programmes (OECD, 2019). Another explanation may be the quality and availability of fast broadband, as it is a technological prerequisite for cloud use (DeStefano, Kneller, & Timmis, 2019). In fact, for many OECD countries the provision of higher quality broadband is a key pillar in their overall digital strategy (OECD, 2015). Other barriers to adoption may include general reluctance by firms to store information with a third party provider, particularly those with considerable intellectual property (OECD, 2014). Moreover differences in the rate of adoption across countries may be influenced by a number of factors such as the size, age, levels of trust and industrial composition of firms within respective countries. Since this paper is unable to pool firm level data for the UK and Germany, the analysis cannot test for the statistical differences between the policies across these economies. The analysis does however look at how policies within each jurisdiction influence how firms adopt cloud, which represents the main contribution of this paper.

Figure 1. Cloud adoption rate by country and year

Share of firms employing ten or more persons



Note: This figure shows the percentage of firms employing ten or more persons, which use cloud computing in the years 2014, 2016 and 2018 in Germany (blue) and the United Kingdom (red).
Source: Eurostat (2018a)

Countries have long been interested in the degree with which firms adopt digital technology. This is motivated by the empirical findings that ICTs are found to influence the nature of production and enhance economic performance. For example, a substantial body of research demonstrates that ICT enables firm productivity, reduces production time, increases innovation and specialization, improves accuracy and enables firms to replicate processes faster (Pilat, Lee, & van Ark, 2003; Bresnahan, Brynjolfsson, & Hitt, 2002; Hubbard, 2003; Bartel, Ichniowski, & Shaw, 2007; Brynjolfsson, McAfee, Sorell, & Zhu, 2008). Moreover, the usage of digital technology not only increases firm performance but can also influence differences in aggregate productivity between countries. A seminal paper by van Ark, O'Mahony and Timmer (2008) for example, find that the productivity gap between Europe and the US was partly explained by the slower arrival of the knowledge economy to Europe. Not only did the US invest in more IT but their firms were able to achieve greater multifactor productivity growth from these investments.

Similarly, understanding what drives cloud adoption is particularly important to policy makers because unlike previous ICTs, cloud computing is more accessible to small young firms, potentially levelling the playing field between firms. Bloom and Pierri (2018) suggests that cloud computing is "democratized computing" enabling the access of digital tools to the masses. Their results demonstrate that the adoption of cloud is occurring relatively earlier and more comprehensively by young and small entities than for previous ICTs (like E-commerce applications and PCs). Jin and McElheran (2017) find evidence that ICT services are statistically linked to higher survival and growth among young plants.

Moreover, cloud adoption leads to employment and productivity growth for young firms and the reorganisation of older firms through closing plants and moving employment further from the headquarters (DeStefano, Kneller, & Timmis, 2019).

The rest of the paper is structured as follows: Section 2 discusses the nature of cloud and the potential determinants for the adoption of these services. Section 3 introduces the policy context, data, empirical strategy and results for the capital incentive programmes in the United Kingdom and Germany, respectively. Comparisons between the two programmes will be made in Section 4 followed by some policy considerations.

Chapter 2. Understanding cloud and what enables adoption

2.1. What is cloud computing

Until recently, in order for a firm to benefit from digitalisation, significant investments in hardware and software were required. However, recently, there has been a shift in the nature of ICT adoption where firms are purchasing digital services (e.g. "cloud" computing) rather than making such investments themselves (OECD, 2015). In addition, as long as a business has reliable high-speed broadband, they can access a range of services including data storage and processing, virtual desktops, software platforms and applications (See Figure 2).

Cloud computing is a service delivered by third party providers which "enables ubiquitous, convenient on-demand network access to a shared pool of configurable computing resources (e.g. networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction" (Mell & Grance, 2011). The largest global cloud providers include Amazon Web Services, Microsoft Azure and Google Cloud Platform. Together these firms are expected to represent 83% of the global market of cloud services in 2020 (Columbus, 2018). The most commonly referred definition of cloud computing comes from the US National Institute of Standards and Technology (NIST). This definition lists five essential characteristics, three service models, and a total of four deployment models which are condensed below.

The five main characteristics of cloud computing are:

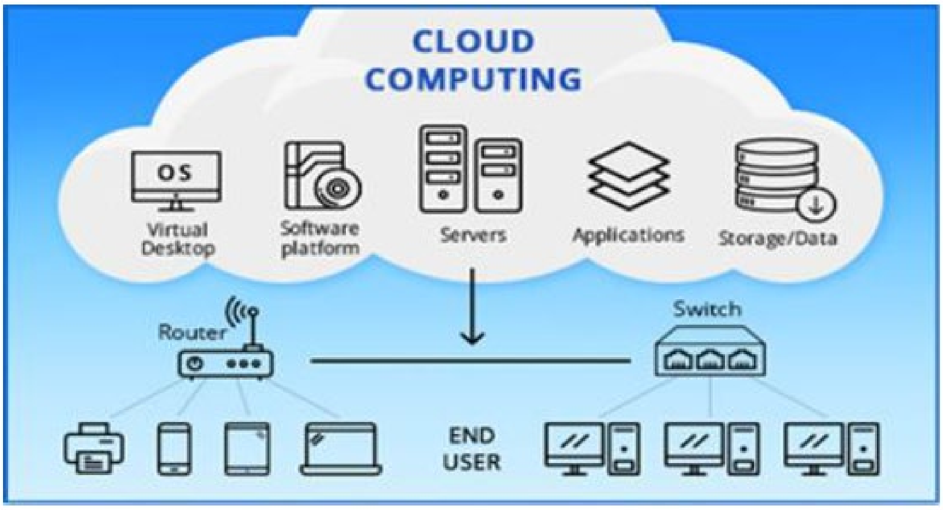
- On-demand self-service means that a consumer of cloud services can unilaterally provision computing capabilities
- Broad network access means that the capabilities are available over the network
- Resource pooling means that the available computing resources can be pooled to serve multiple consumers
- Rapid elasticity or expansion means that capabilities can be elastically provisioned and released
- Measured service means that resource usage can be transparently monitored, controlled, and reported

There are also three different deployment models for cloud computing services:

- Private Cloud means that the cloud infrastructure is provisioned for exclusive use by a single organisation but may be owned, managed, and operated by the organisation, and/or a third party, and it may exist on or off premises. This research focuses solely on private cloud services.
- Public Cloud means that the cloud infrastructure is provisioned for open use by the general public and may be owned, managed, and operated by a business, academic, or government organisation and exclusively exists on the premises of the cloud provider
- Hybrid cloud means that a combination of private and public cloud services is used and that data and applications are portable between these two deployment models.

The measure of cloud computing used in this paper refers to whether a firm has adopted private cloud computing. In addition, the data also contain information on the specific type of cloud service the firm uses, such as data storage and processing, a software platform, and/or software applications. Unfortunately, within our data we cannot distinguish different deployment modes (such as public and hybrid cloud). However, these are not the major method of cloud use by businesses.

Figure 2. What is the cloud?



Source: thinkIT solutions.[7]

2.2. Expected benefits from cloud

Cloud computing is perceived to lower entry barriers, allowing the entry of new firms, creating new employment opportunities and enhanced competition, particularly for firms that previously used fixed ICTs intensively (OECD, 2015; Etro, 2009). Some optimistic estimates suggest that between 2008 and 2020, cloud could positively impact employment by creating 1.6 million jobs and enabling the start-up of 303,000 new businesses between 2015 and 2020 in the EU (European Commission, 2017). The report concludes that in the next five years cloud computing may contribute an additional EUR 449 billion of revenue to GDP in the EU alone.

Increased reliance on the cloud may also increase the impact of early-stage investment. In the past, a considerable amount of equity investment were used to acquire IT equipment, however greater use of the cloud may incentivise investors to spread smaller amounts of equity to more firms (Ewens, Nanda, & Rhodes-Kropf, 2018). Renting hardware and software is also expected to allow businesses to allocate more resources to essential areas of firm competitiveness including product and processes innovation, distribution networks, marketing and so on (OECD, 2015; Columbus, 2013).

Cloud is believed to allow firms to scale their operations very quickly without the need for upfront investments and facilitate new business models, “Scale without mass”. Negating the need for quasi-irreversible investments in hardware, cloud can allow for greater flexibility and experimentation in the face of uncertainty (Jin & McElheran, 2017). Cloud not only makes the firm itself more flexible, it also allows for potential employment reallocation throughout the firm by eliminating the need for fixed PCs to be connected to the internal hardware and software infrastructure of the firm. Furthermore, since a substantial percentage of server and storage space are typically underutilised by businesses, increased usage of the cloud is also anticipated to enhance energy efficiency and reduce firm utility costs (Masanet, et al., 2013).

To date there is limited empirical studies on the economic implications of cloud. One exception is DeStefano, Kneller and Timmis (2019) which finds that cloud leads to the growth of young firms in terms of employment (with some evidence of productivity gains), but these firms become more concentrated in fewer plants. For older firms, cloud does not result in scale or productivity growth, but instead in more geographically disperse activities by closing plants and moving employment further from the headquarters.

2.3. Determinants of cloud adoption

2.3.1. Firm characteristics

While there are only a few studies assessing the effects of firm characteristics on cloud use, much of the empirical evidence is consistent with what is found for ICT investment. For example the propensity for firm-level cloud adoption is negatively linked with firm age and positively linked with firm size (DeStefano, Kneller, & Timmis, 2019; Ohnemus & Niebel, 2016; Oliveira, Thomas, & Espadanal, 2014)[89]. The availability of highly skilled workers tend to increase the likelihood of adapting cloud technologies (Bloom & Pierri, 2017) while advanced management practices is positively related to cloud adoption (Andrews, Nicoletti, & Timiliotis, 2018).[10]

2.3.2. Market characteristics

To date there are limited studies on the effects of various market environments on cloud adoption and none which assess capital incentive policies. One exception is Andrews, Nicoletti and Timiliotis (2018), which examines the impact of traditional policies indictors (long been used in the literature to assess of ICT investments) on cloud adoption at the industry level. The policies include barriers to entry and exit, insolvency regimes, digital trade restrictiveness, labour market rigidities, venture capital, and tax incentive for R&D. Consistent with that is found for ICT adoption more generally, rigidities to entry, exit, employment production legislation and insolvency regimes are linked with a lower likelihood of cloud adoption. Their analysis also finds that broad indicators on R&D tax incentives are linked to a positive likelihood of cloud adoption.

2.3.3. Other factors

Another factor, which may influence the adoption of cloud is the availability of fibre broadband. The growth of cloud services is a phenomenon that has gone hand-in-hand with the rollout of high-speed fibre broadband. A stable, high-speed broadband connection is required to allow the large flows of data between the cloud service providers and users, and is therefore a technological prerequisite for cloud adoption (ITU, 2017). Recent empirical evidence demonstrates that fibre broadband and its speed are important determinants for cloud adoption (DeStefano, Kneller, & Timmis, 2019). The extent to which this results holds for other countries will be tested in Germany within the paper.

Chapter 3. Policy implications in the UK and Germany

The following section introduces the policies, empirical strategies, data used and results in the United Kingdom and Germany respectively. For the United Kingdom, the policy assessed is a capital incentive programme known as the *Annual Investment Allowance* (AIA), which provided tax incentives to eligible firms towards investments in physical capital. In Germany, the investment policy analysed is the *Joint Task for the Improvement of the Regional Economic Structure* (GRW) programme. This framework provides investment grants to firms located in particular regions and funds are differed by firm size. Traditionally, one would pool data and use consistent econometric frameworks for the two countries and assess the effect and the heterogeneity of the policies. Pooling the datasets, is not possible in this case because the data cannot be taken out of their respective Offices of National Statistics and combine elsewhere. Moreover, given that the policies in Germany and the United Kingdom are distinctly different (qualification into the AIA is based on total investments while qualification in Germany is based on regions and firm size), consistent empirical approaches would not be appropriate. As such, the paper uses slightly different empirical frameworks that will be explained below. The benefit of the study however is that it allows one to assess whether similar policies (capital incentive programmes) located in different jurisdictions thus helping to establish external validity regarding the effects of these programmes on cloud adoption.

3.1. The Annual Investment Allowance in the UK

The AIA was introduced in the United Kingdom for the financial year 2008-2009, with the objective of stimulating business invest in new forms of (physical) capital and induce economic growth (HMRC, 2018). The programme allowed firms to deduct capital investment during the year, up to the AIA ceiling, from their (pre-tax) profits. As we discuss further below, this ceiling has shifted upwards and downwards a number of times over the course of its implementation (see Table 1). It is important to note that the allowance is not specific to digital capital investment, but covered all long-term equipment used to produce or sell products – termed "plant and machinery" – which also includes ICT capital.[11] At the onset, this was seen as a move away from a policy based on size and/or legal form eligibility linked incentive for investment, towards one targeting the activity to be encouraged, in this case capital investment (Freedman & Crawford, 2008).

It is reasonable to assume that physical ICT capital investment and cloud adoption to react very differently to capital incentives. Firms make capital investments so as to modify to an optimal level of capital, contingent upon optimal output and cost of capital. An increase in the AIA investment ceiling lowers the user cost of capital for some businesses, incentivizing new investment. Estimates suggest that the 2010 increase in the AIA threshold from £50,000 to £100,000 decreased user cost of capital for an additional £1 investment between these two figures by 28% (if financed by earnings and equity) and 31% (if financed with debt) (Harper & Liu, 2013). As such, rises in the allowance threshold over the period should further increase the incentive to invest in physical ICT capital as opposed to cloud services.

These policy changes provide an ideal setting for the assessment of its impact on firms' decision to invest in ICT capital or adoption cloud computing. The empirical framework of this paper uses the four periods when AIA increased considerably, the years ending in 2009, 2011, 2014 and 2015. Changes in the threshold do not appear to occur in a predicative manner lowering concerns about potential anticipation effects by firms.

Table 1. Annual Investment Allowance ceiling, 2008 to 2015

Financial year (ending 31 March)	Annual Allowance threshold
2008 and earlier	-
2009 – 2010	£50,000
2011 – 2012	£100,000
2013	£81,250*
2014	£250,000
2015	£425,000*

Note: *Pro rata as changed mid-year. The financial year April 2011-March 2012 had nine months of an allowance of £25,000 and three months of £250,000, equal to £81,250 pro-rata for the year. The financial year April 2014 – March 2015 had nine months of £500,000 allowance and three months of £200,000, which equals £425,000 for the year. All other allowances coincide with complete financial years.
Source: (HMRC, 2018).

It is important to mention the existence of other policies during our sample period, which may bias the results. The United Kingdom did have an ICT capital specific incentive for small firms, but this was only in place from 1 April 2000 to 31 March 2004 (Gaggl & Wright, 2017). Another policy is the First Year Allowance, which existed before our sample period and ended in 2008, re-emerging for one year in 2010. The policy provided tax allowances for capital investment to firms with revenue less than £22.8 million. As a robustness test, we exclude firms in our sample with revenue below this threshold.

3.1.1. Empirical strategy

The empirical strategy exploits changes in the thresholds of the AIA to identify treated firms for whom the marginal incentives to invest (in capital) decreased. We compare these firms against those whose lagged investment that would remain either above or below the AIA threshold in both periods, and thus for whom there would be no change in their marginal incentives. E.g., a firm with investment of £25,000 in 2010 would be beneath the AIA ceiling in both 2010 (£50,000) and 2011 (£100,000). Similarly, a firm with investment of £200,000 in 2010 would be above the AIA ceiling in both 2010 and 2011. For these firms that remain above or below the AIA ceiling in both years, there is no change in their marginal investment incentives. We examine how cloud and ICT capital investment decisions differ for the set of firms whose marginal investment incentives have changed, compared to those that remain above or below the AIA allowance. In particular, we look at the use of cloud along with total investment, IT acquisition and hardware acquisition. In our data, cloud adoption is binary while investments are represented as continuous variables.

Out of a concern for anticipation effects into the policy we use their total investment in machinery and equipment two and three years earlier for this assessment. In particular, the baseline results use averages across lagged investment in periods t-2 and t-3 to identify treated firms. As a robustness test the paper also uses lags rather than averages.

The paper uses a difference-in-differences regression to estimate the effect of the changes in AIA allowances on physical ICT capital investment and purchase of cloud technologies (see Equation 1).

$$y_{it} = \alpha + \beta Z_{it} + FE_i + FE_t + \chi_{it} + \varepsilon_{it} \qquad 1. \qquad (1)$$

y_{it} represents either ICT investment or cloud adoption of firm i in period t. Z_{it} identifies the treatment group and thus is equal to one for the periods post-AIA reform, for the firms whose average lagged investment is lower than the post-reform AIA threshold, but greater than the pre-reform threshold. The parameter of interest β measures the intention to treat effect.

The regressions include firm and year fixed effects, thus the regressions are capturing within firm effects. This also enables the econometrician to control for unobserved firm characteristics and trends, signified by FE_i and FE_t, respectively. The regressions also contain a number of control variables, including lagged investments, age, multi-plant, foreign ownership represented by χ_{it}. The constant is α and ε_{it} is an error term.

It is important to note that firms' adoption of cloud technologies are only observed in three years, 2008, 2013 and 2015. As a result, that the period over which treatment occurs differs according to the AIA reform under consideration. Thus, for the introduction of the AIA policy we observe cloud adoption by treated and control firms between five and seven years later, whereas for the 2011 reform we observe outcomes two and four years later. Therefore, when pooling the AIA reforms into a single regression we capture a mix of short- and medium-run outcomes.

3.1.2. UK data

The data for the United Kingdom come from three sources and is held by the Office for National Statistics (ONS). Information on cloud adoption and the use of big-data analytics is collected by the E-commerce Survey. Importantly the survey is administered by Eurostat, thus resulting in consistency in survey questions regarding technology adoption between EU countries overtime. The E-commerce Survey contains seven different types of cloud services including, data, storage, processing, email, office software, finance software, customer relationship management software (CRM). "Cloud data" refers to the hosting the business' databases on the cloud, "cloud storage" reflects the storage of files on the cloud and "cloud processing" refers to the using cloud computing capacity to run the business' own software. From these various measures, we construct a single overall measure of cloud adoption (of any type) by the firm.[12]

The big data variable is a binary measure equal to one if the enterprise is analysing big data either via the enterprise's own data collected with smart devices or sensors, data gathered from geolocation data from the use of portable devices, generated from social media, and/or data is collected from other external sources.

Information on the AIA programme including details regarding the introduced and changes in the thresholds comes from the UK Tax Authority (HMRC). Data on lagged total investment in plant and machinery – which is employed to identify treated and control firms come from the Annual Business Survey. This dataset also includes details on ICT capital investment as well as information for the firm control variables including age, multi-plant status and foreign ownership.[13]

3.1.3. Descriptive statistics

Table 16 in the annex contains the summary statistics for the main variables of the UK study. In the UK sample, on average 38% of firms use cloud, however this varies considerably across types of cloud technology. 8% of firms use cloud for finance software, but 23% use cloud for storage. In terms of big data analytics, over the sample period on average 21% have used this. In terms of how big data is employed, 12% of firms conduct big data analytics only in-house, only 2% of firms wholly outsource big data analytics to external providers, and 8% conduct a mixture of in-house analytics and through external providers.[14]

3.1.4. Empirical results

This section econometrically estimates the effects of changes in the AIA allowance, i.e. the treatment effect on firm investment in IT capital and cloud adoption. It first presents the baseline results, which assess the effects of changes in the AIA threshold on firm investment and cloud adoption decisions.[15] Next, the analysis considers the effects of the individual changes in the AIA policy on firm investment and cloud adoption decisions. Afterwards, this section explores the extent to which the policy influences the adoption of different types of cloud services as well as alternative investment decisions such as capital investment in land and buildings, IT intensity, IT employees and so on. Finally, in order to assess the extent to which cloud diffusion is relevant for emerging business models, the paper econometrically estimate the effects of cloud on big data analytics.

The effects of the AIA on IT investment decisions

Table 2 illustrates the results on the effects of the AIA policy on firm IT investment and cloud adoption. In line with Criscuolo et al. (2019), the results show that increases in the AIA allowance result in increases of total investment, IT capital acquisition and hardware capital acquisition for the treated firms. The magnitude of the effect of the policy on investment is sizable. For example the impact of the policy on treated firms (with 2 year average lags) leads to an increase in total investment, IT acquisition and hardware acquisition by is 64%, 34% and 31% respectively.[16] Secondly, these effects are average over the post-treatment period and therefore are not necessarily realised in a single year. Thus while substantial; these results are plausible.

Conversely, AIA resulted in a reduction in the propensity to adopt cloud (again see Table 2). In particular, increases in the AIA for affected firms results in a reduction in the propensity to adopt cloud by 12% (with 2-year lags) and 7% (with 3-year lags). The size of the estimated coefficients here are also somewhat large, given that average cloud adoption in the sample is 38%. Thus for treated by the AIA (those that are relatively small), diffusion of cloud is considerably reduced. Give the consistency in the results when using different lagged averaged and lagged firm investments to define the treatment, the remained of the paper will use 2-year average lagged investments for brevity. Addition results are available upon request.

There are two different important take aways from these results. One, firms appear to view ICT capital investment and cloud ICT services as substitutes – a reduction in the relative price of ICT capital leads to a substitution away from cloud and towards ICT capital. Common capital incentive programmes (employed across many OECD member countries) that are used to induce digital investments appear to be relevant only to traditional physical ICT capital investment. These policies may inadvertently create disincentives to adopt digital services, such as cloud. This is relevant as they may be particularly harmful young small firms, given that cloud is well suited for their digital needs and is found to increase their scale (DeStefano, Kneller, & Timmis, 2019).

Table 2. Capital allowances and investment in ICT capital vs. cloud adoption

	2 year lagged averages				3 year lagged averages			
Variables	Investment	IT acq	Hardware acq	Cloud	Investment	IT acq	Hardware acq	Cloud
AIA treatment	0.492***	0.292***	0.273***	-0.118***	0.230***	0.179***	0.164***	-0.069**
	(0.070)	(0.052)	(0.048)	(0.028)	(0.065)	(0.049)	(0.045)	(0.029)
Total investment (2 or 3 years)	-0.065***	-0.038***	-0.036***	0.002	-0.115***	-0.076***	-0.069***	0.006
	(0.011)	(0.008)	(0.007)	(0.004)	(0.010)	(0.007)	(0.007)	(0.005)
Foreign ownership	-0.042	-0.032	-0.034	0.006	-0.061	-0.012	-0.018	-0.006
	(0.066)	(0.052)	(0.048)	(0.030)	(0.066)	(0.052)	(0.048)	(0.031)
Multi-plant	0.200**	0.211***	0.194***	-0.040	0.308***	0.234***	0.210***	-0.037
	(0.088)	(0.072)	(0.068)	(0.040)	(0.090)	(0.075)	(0.070)	(0.040)
Age	0.190*	0.142	0.124	0.013	0.172	0.064	0.048	-0.051
	(0.112)	(0.098)	(0.093)	(0.049)	(0.107)	(0.095)	(0.089)	(0.056)
Observations	30,337	31,554	31,554	12,293	29,021	30,306	30,306	12,106
R^2	0.02	0.02	0.02	0.53	0.03	0.02	0.02	0.54

Note: All regressions include year and firm fixed effects, as well as firm controls of lagged investment, a multi-plant dummy, foreign owned dummy and log age. Columns 1 to 4 use average firm investment (over t-1 and t-2) and Columns 5 to 8 use average firm investment (over t-1, t-2 and t-3) to determine the treatment group. Total investment, IT Acquisitions and Hardware Acquisitions are log values, cloud reflects a binary variable. Robust standard errors clustered at the firm-level are in parentheses. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table 3 examines separately the changes in the AIA threshold in 2009, 2011 and 2014 on firm investment and adoption decisions.[17] To estimate the regressions, we separate observations according to the treatment year (2009, 2011 or 2014) and thus each cell in the table represents a unique regression. The results in Table 3, demonstrate strong positive effects from the 2009 and 2011 AIA changes on investment in ICT capital, but no significant impact of the 2014 reform. This is likely because we have only 1-year post-treatment to observe an effect for the 2014 reform.[18] In general, the smaller coefficients in later waves of the AIA, reflect the fact that larger firms are treated in later waves.

On the other hand, the results continue to suggest that changes in the tax allowance reduced propensity that the firm adopts cloud computing, where this negative effect is apparent from the 2009, 2011 and 2014 AIA reforms, although only statistically significant for the latter two reforms. For the 2009 reform the effect is negative but weaker, which may be driven by the fact that the adoption of cloud is observed in 2013 and 2015, which is a long time after the reform. Consistent with the results found above, they suggest that physical ICT investment is substituting for ICT as a service due to this capital tax allowance.

Table 3. Individual changes of capital allowances and investment in ICT capital vs. cloud adoption

	2 year lagged averages			
Variables	Total investment	IT acquisition	Hardware acquisition	Cloud
AIA treatment 09	1.690***	0.845***	0.765***	-0.058
	(0.152)	(0.089)	(0.080)	(0.039)
AIA treatment 11	0.194	0.252**	0.251***	-0.235***
	(0.131)	(0.101)	(0.091)	(0.085)
AIA treatment 14	-0.017	-0.140	-0.131	-0.166***
	(0.111)	(0.086)	(0.080)	(0.055)
Observations	30,337	31,554	31,554	12,293
R^2	0.81	0.83	0.83	0.84

Note: All regressions include year and firm fixed effects, as well as firm controls of lagged investment, a multi-plant dummy, foreign owned dummy and log age, not reported for brevity. Regressions use two year average lagged firm investment to determine the treatment group. The estimated treatment effects for each treatment group are shown individually, for the introduction of the AIA in 2009 and increases in 2011 and 2014. Total investment, IT Acquisitions and Hardware Acquisitions are log values, cloud reflects a binary variable. Robust standard errors clustered at the firm-level are in parentheses. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Types of cloud

As a next step, we take advantage of additional detail on the various different types of cloud that firms adopt, which includes software cloud services and hardware cloud services.[19] Additionally, we aggregate the detailed cloud measures according to the two broader cloud measures as defined by Eurostat which clusters these measures based on their level of complexity (Eurostat, 2018a)[20] According to this definition, as shown in Table 4, a firm is flagged as a user of basic cloud technologies if it uses at least one of email, office software, or file storage via cloud and none of the more advanced cloud services. On the contrary, a firm is flagged as user of complex cloud technologies, if it uses at least one of the basic cloud services as well as at least one of the more advanced cloud services.

Table 4. Cloud by degree of complexity

Use of cloud computing service	Basic cloud	Complex cloud
Email	At least one	At least one
Office software		
Storage of Files		
Hosting the Enterprise's database(s)	None	At least one
Finance Software		
CRM		
Processing		

Source: (Eurostat, 2018a)

The results in Table 5 and Table 6 assess the extent to which cloud technologies respond differently to the AIA allowances, and explore this heterogeneity between hardware and software services. A priori, one would expect the policy to be negatively linked to cloud services which represent hardware functions as opposed to software functions, since the programme targets physical capital investments. Indeed, the policy is negatively correlated with the adoption of cloud hardware services. The negative effects for example, cloud processing and storage are perhaps unsurprising, since they likely reflect access to cloud-infrastructure that is likely to at least partially substitute for servers and other in-house hardware investment. As expected the relationship between the policy and cloud service software is negative (with the exception of cloud finance), but considerably weaker and not statistically significant.

Table 7 contains the results, which classify cloud services by their level of complexity. Overall, we find that the capital incentive allowance is negatively linked to the adoption of the low cloud technologies (albiet significant at the 10% level) but not with the more advanced forms of cloud. One explanation for this may be due to the fact that the policy is more applicable to smaller firms (given the initial size of the thresholds). The results however may be worrisome as well if the less complex cloud services represent an important stepping stone for the adoption of more complex services as firms improve performance overtime.

Table 5. Capital allowances and different types of cloud hardware technologies

Variables	Cloud hardware	Cloud data/storage	Cloud storage	Cloud data	Cloud processing
AIA treatment	-0.073**	-0.082***	-0.086***	-0.042	-0.037*
	(0.030)	(0.029)	(0.028)	(0.027)	(0.021)
Observations	12,642	12,642	12,642	12,642	12,642
R^2	0.80	0.79	0.77	0.74	0.70

Note: All regressions include year and firm fixed effects, and firm controls including lagged investment, a multi-plant dummy, foreign owned dummy and log age, not reported for brevity. All regressions use two year average lagged firm investment to determine the treatment group. Each cloud measure reflects a binary variable. Robust standard errors clustered at the firm-level are in parentheses. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table 6. Capital allowances and different types of cloud software technologies

Variables	Cloud software	Cloud CRM	Cloud finance	Cloud office software	Cloud Email
AIA treatment	-0.043	-0.014	0.004	-0.021	-0.033
	(0.031)	(0.024)	(0.021)	(0.025)	(0.029)
Observations	12,642	12,642	12,642	12,642	12,642
R^2	0.80	0.73	0.68	0.74	0.77

Note: All regressions include year and firm fixed effects, and firm controls including lagged investment, a multi-plant dummy, foreign owned dummy and log age, not reported for brevity. All regressions use two year average lagged firm investment to determine the treatment group. Each cloud measure reflects a binary variable. Robust standard errors clustered at the firm-level are in parentheses. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table 7. Capital allowances and investment in low, medium and high technology cloud

Variables	Cloud	Cloud low-tech	Cloud high-tech
AIA treatment	-0.111***	-0.035*	-0.031
	(0.03)	(0.02)	(0.03)
Observations	12,642	12,642	12,642
R^2	0.85	0.72	0.76

Note: All regressions include year and firm fixed effects, and firm controls including lagged investment, a multi-plant dummy, foreign owned dummy and log age, not reported for brevity. All regressions use two year average lagged firm investment to determine the treatment group. Each cloud measure reflects a binary variable. Robust standard errors clustered at the firm-level are in parentheses. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Alternative ICT decisions

Table 8 examines the link between the AIA and a host of outcomes for the firm that may also be linked to the policy including IT Intensity (IT investment per worker), PCs per employee, hardware disposals, IT employees, IT services and land and building acquisition. The results demonstrate that IT intensity of the firm rises as a result of the increase in the AIA, consistent with the rise of IT investment made by firms. At the same time, there is no evidence that the number of PCs per employee rises, similar to the disposals of IT equipment or the number of IT workers (used in the past as a proxy for IT intensity). There is however evidence that land and building investment rises, consistent with the fact that such forms of capital investment are eligible under the AIA. There is no statistically significant effect of IT services. Moreover, the estimated coefficients and the standard errors are small suggesting that this is a well identified zero effect.

Table 8. Alternative investment and adoption outcomes

Variables	IT intensity	Land&Build acq	PCs per emp	Hardware disposal	IT employees	IT services
AIA treatment	0.160***	0.229***	0.596	-0.058	-0.002	-0.049
	(0.06)	(0.06)	(1.58)	(0.04)	(0.02)	(0.03)
Observations	30,545	33,357	17,273	32,356	9,130	33,442
R^2	0.80	0.77	0.65	0.66	0.55	0.55

Note: All regressions include year and firm fixed effects, and firm controls including lagged investment, a multi-plant dummy, foreign owned dummy and log age, not reported for brevity. All regressions use two year average lagged firm investment to determine the treatment group. IT intensity if IT acquisitions per employee. PC per employee reflects the share of computers per employee. Robust standard errors clustered at the firm-level are in parentheses. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Cloud diffusion and big data analytics

The results of the prior section suggest that AIA capital incentives are discouraging the adoption of cloud computing. Barriers to cloud adoption may also impact the diffusion of new business models, including the use of big data analytics. Cloud is expected to promote the use of big data given that it provides less expensive and more flexible methods for storage and processing information (McKinsey, 2011; Niebel, Rasel, & Viete, 2019). As a result, this section examines whether this impacts the diffusion of big data analytics.

We estimate the impact on big data in a simple ordinary least square (OLS) framework including firm and year fixed effects along with the sample control variables used throughout. The results in Table 9 demonstrate a positive and significant link between cloud use and the adoption of big data analytics. In addition, the results find that cloud use increases the propensity to adopt internal, external and internal and external big data techniques simultaneously. While it is important to interpret the naïve OLS results with caution due to the potential presence of endogeneity bias, the results do suggest these two factors go hand in hand.

Table 9. The effects of cloud adoption on big data analytics

		2 year lags		
	Big data analytics	Internal-only big data analytics	External-only big data analytics	External and internal big data analytics
Cloud	0.183***	0.069***	0.025**	0.089***
	(0.029)	(0.025)	(0.010)	(0.020)
Observations	10,521	10,521	10,521	10,521
R^2	0.47	0.29	0.05	0.20

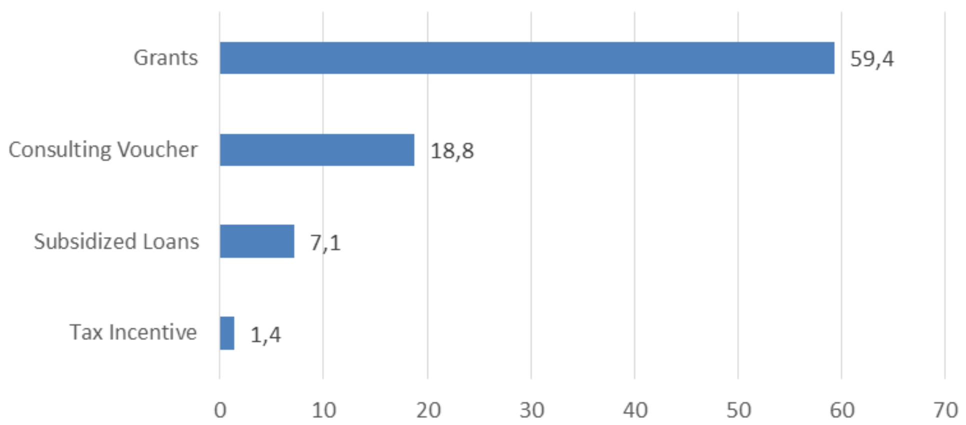
Note: All regressions include year and firm fixed effects, and firm controls including lagged investment, a multi-plant dummy, foreign owned dummy and log age, not reported for brevity. Cloud and big data measures reflect a binary variable. Robust standard errors clustered at the firm-level are in parentheses. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

3.2. Joint task for the improvement of the regional economic structure in Germany

We now move on to the second empirical case study, which assesses the relation between public investment incentives and cloud adoption, exploiting variation in access to regionally targeted investment grants in Germany. As mentioned previously, the analysis here uses consistent information on cloud adoption for a different policy context in Germany. The benefits of conducting econometric analysis with firm-level micro data for multiple countries in different settings allows one to assess the external validity of our findings and underlines the relevance of the phenomenon under study.

Traditionally, public financial support in Germany is directed towards rewarding investments. As shown in Figure 3, grants are the most important policy incentive for digitisation projects in the German information sector: If firms applied for investment support, 60% of the firms indicated that they applied for receiving an investment grant. Other policy incentives, such as consulting vouchers, subsidized loans or tax incentives, are by far less prevalent.

Figure 3. Relevance of different policy incentives for digitisation projects in the German information sector

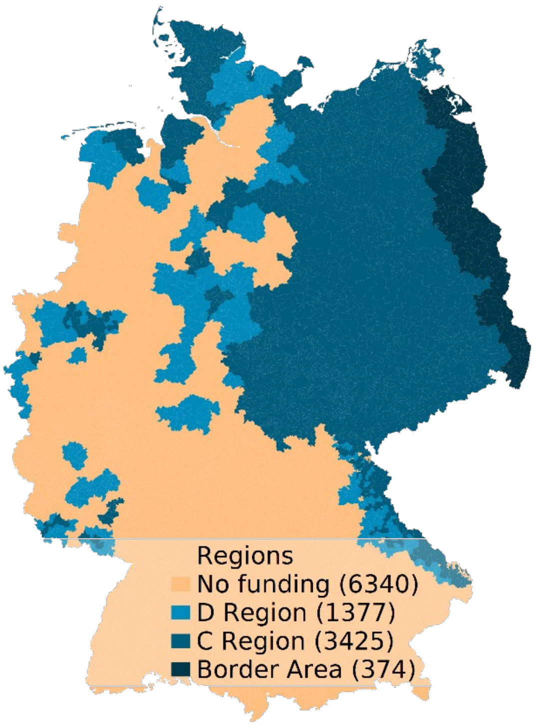


Note: Share of firms among those which applied for support for digitisation projects.
Source: ZEW Economic survey of the information sector (2019).

Given the relative importance of investment grants compared to other investment incentives in Germany, our study focuses on the impact of the primary national programme for non-repayable investment grants - the GRW. One of the project's deliberate goals is to support private businesses in economically lagging regions through funds for physical capital investment projects for expansion and diversification of production or for fundamental changes to the production process.[21] A second objective of GRW is the support of public infrastructure, which made up 30% of all grants between 1995 and 2014 (GRW, 2016).[22] Targeted regions eligible for funding and the maximum shares of the investment costs which can be funded were newly defined in 2014. Eligible regions are chosen based on an evaluation of various indicators (unemployment, gross salaries, expected employment, infrastructure). The German Federal States are responsible for implementing GRW, i.e. they decide about the allocation of funds to eligible projects (Deutscher Bundestag, 2014). Funding is available for specific investment projects and eligible costs are capital expenditures or personnel costs.[23] Maximum funding rates of the investment costs vary regionally and by firm size.

Funds are available in the whole of Eastern Germany and with lower funding rates in various regions in West Germany. Maximum funding intensities, i.e. the shares of the total investment costs, which can get funded, were assigned based on the region's previous economic output (Figure 4). The regional variation in eligibility for public funding within the scope of the GRW at the municipal level will be used in this paper to investigate the relation between public investment incentives and firms' use of cloud computing and other IT-assets.

Figure 4. GRW 2014 regions



Source: Authors illustration based on BAFA (Federal Office of Economic Affairs and Export Control, 2019).

Figure 4 plots the GRW regional aid map, which came into effect in mid-2014. The former GRW regions were in place between 2007 and 2013 (see Figure A.2 and Figure A.3 in the Annex). While location determines whether a firm has access to GRW funding, the map additionally illustrates variation in the maximum funding rates across regions and by firm's SME status. Whereas the whole of Eastern Germany has access to GRW funding, in Western Germany only selected regions are addressed by GRW. The highest funding rates apply to regions at the border to Poland. Since GRW funding is targeted towards economically weaker regions and is implemented by the federal states, we need to take account for confounding regional characteristics in our empirical analysis. We will therefore control for regional states, as well as the municipalities' population density and broadband quality at the firm level, which both proxy for regional economic performance at the most granular level. In addition, in a robustness check in the Annex we show that the main results hold in a fixed-effects model, where we control for time constant unobserved heterogeneity between firms, such as location (see Table A.5).

Table 10 displays the maximum funding rates for the funding period 2014-2020 as determined by the GRW region and SME status.[24] For instance, a small firm located in a "D region" can apply for a grant that amounts to 20% of the investment costs of the respective project. Funding rates are higher for small enterprises in each region. Maximum funding rates range up to 40% of the eligible investment costs.

Table 10. Maximum incentive rates in the GRW Programme, in percentage of eligible investment costs

Region	Small enterprise	Medium enterprise	Large enterprise
Border area	40%	30%	20%
C region	30%	20%	10%
D region	20%	10%	200.000 €

Note: The lowest maximum available funding rates in D regions are 20% for small- and 10% for medium sized enterprises. For large enterprises this limit is set in an absolute value, 200.000 €.
Source: Deutscher Bundestag (Unterrichtung durch die Bundesregierung - Koordinierungsrahmen der Gemeinschaftsaufgabe "Verbesserung der regionalen Wirtschaftsstruktur" ab 1. Juli 2014, 2014).

In addition, the GRW also serves as a coordination framework for other policies in Germany, which aim at supporting regional development. Thus, the same regions are addressed by the European Regional Development Fund (ERDF), as well as the European Recovery Programme (ERP)- Regional Promotion Programme by the German government-owned development bank (KfW). We note that these two policies also target investments, either through grants (ERDF) or through loans (ERP). Therefore, when we simply explore regional variation in access to investment incentives, we capture these policies along with GRW. In contrast, exploiting variation in the maximum funding rates is specific to the GRW programme. We also note that other incentives for digitization projects, such as consulting vouchers, typically do not overlap with the regions defined by GRW.

3.2.1. Empirical strategy

We use the regional variation in access to GRW funding to assess the relation between incentives to invest and the adoption of cloud computing in firms. For each firm we determine whether it had access to GRW funding based on its location and its SME status. Our main variable of interest is a treatment dummy, which is equal to one if the firm had access to GRW funding and zero otherwise, based on their location. Later on, we additionally exploit the variation in maximum funding rates to analyse the relation not only at the extensive, but also at the intensive margin.

As information on cloud computing is only available in two waves of the survey, the data has very limited time-series coverage for our analysis. Since, in addition, the administrative ICT survey in Germany is a rotating panel, we have only few firms, which we observe in the two years in which the survey contains information on cloud use, 2014 and 2016. Therefore, for the main analysis we resort to estimations based on a pooled cross section of all firms in the data. Due to the cross-sectional nature of our main analysis, our results should be interpreted with caution. We are only able to assess our research hypothesis by means of controlled correlations, even though we are able to control for the most important confounders. In the Annex, we additionally show that our main results hold in a simple two period fixed effects regression, controlling for any time-constant unobserved heterogeneity between firms. Nevertheless, the strength of our analysis stems from the fact that we are able to assess our research question based on micro-level firm data in two countries and under different policy settings. This enables us to assess the external validity of each case study and shows whether or not the results substantiate each other.

We assess the relation of treatment and the adoption of cloud in the following regression model:

$$CC_i = \beta_0 + \beta_1 Treat_i + \beta_2 X_i' + \varepsilon_i \quad (2)$$

Where CC_i is an indicator, which equals one if firm i uses cloud computing and zero otherwise. The vector X_i' represents a number of firm characteristics which may also predict cloud use. In order to control for the general ICT-intensity of the firm, we include the share of employees with access to the internet and with access to the mobile internet. Consistent with the literature of technology adoption, the model controls for firm age and size (measured by employment and sales). As the implementation of GRW is determined by the firm's location and firm size, we additionally control for a full set of federal state dummies, a set of indicator variables which denote the bandwidth of the firm's internet access, as well as the population density in the respective region. Since we estimate our model with a pooled cross-sectional sample for the years 2014 and 2016, we additionally include year effects. Finally, ε_i captures unobservables related to the firm's cloud adoption. As the dependent variable in our model is binary, we estimate Equation (2) using logit models.

In addition to mere access to regional investment incentives, we also assess the extent to which differences in the maximum share of investment costs funded by the GRW are associated with cloud use. Therefore, in a second specification, we additionally exploit variation in these maximum funding rates the firm has access to, thereby looking into investment incentives at the intensive margin. The maximum funding rate is determined by the region as well as the firm's SME status according to Table 10. Consequently, maximum funding rates range from 0% to 40% and instead of a binary treatment indicator, we construct a variable $grant_i$ to take the value of the maximum share of investment costs which the firm can apply for. The distribution of maximum intensities over the firms in our sample is shown in Figure A.1 in the Annex. We also include the funding rates in squared terms in order to allow for a more flexible relationship between GRW funding rates and cloud adoption, such that funding rates can have a decreasing marginal effect on the propensity to use cloud. Consequently, our model then changes to the following:

$$CC_i = \beta_0 + \beta_1 grant_i + \beta_2 grant_i^2 + \beta_3 X_i' + \varepsilon_i \qquad (3)$$

As the GRW also works as a framework for other policy instruments, the binary treatment indicator in Equation (2) captures access to further policy programmes, such as the ERP Regional Promotion Programme, while the maximum funding rates are specific to the GRW programme. This means that both specifications are not directly comparable: In the specification including the treatment indicator, we assess the relation of cloud adoption with broader access to public investment incentives, while the specification including the maximum funding rates is specific to one single programme only.

3.2.2. German data

The econometric analysis here relies on a data set, which combines information from various administrative sources. This includes administrative data for cloud adoption, which stem from the E-commerce Survey administered by Eurostat. These data are therefore directly comparable to the UK data, as both are collected within the same framework by the respective national statistical offices. In addition, we use the German administrative business registry that contains additional information on firm characteristics. Finally, we rely on policy data, which provides specifics about the context and eligibility of the GRW grant scheme.

The primary data source is administrative data on the use of cloud computing by firms. Under the administration of Eurostat, information on cloud computing and other ICT variables is collected by means of a business survey by each country annually by their office of national statistics, thus resulting in reasonable consistency in terms of questions asked and technologies covered across countries overtime. The German data set provided by the German Federal Statistical Office (destatis) is called "*Erhebung zur Nutzung von*

Informations- und Kommunikationstechnologien in Unternehmen" (henceforth ICT survey). Asides for Schivardi and Schmitz (2018), this paper is among the first to exploit this data set for firm-level analyses. Information on cloud adoption pertains to the years 2014 and 2016.

In order to locate firms in municipalities, we match the administrative ICT survey with the German business registry (Unternehmensregister), which, in addition to regional identifiers, contains information on the firms' industry affiliation, sales, number of employees and firm age.

Data on the GRW programme has been acquired through the German Federal Office of Economic Affairs and Export Control (BAFA) as well as the German Federal Ministry for Economic Affairs and Energy (BMWi). The data contain information at the municipal level on whether or not a municipality is eligible to GRW grants, maximum funding rates, and approved funding for the years 2000 until present.

3.2.3. Descriptive statistics

Table A.1 in the Annex shows descriptive statistics of the pooled cross section that we will rely on for the main analysis. Our sample comprises 9,885 observations on cloud computing usage throughout Germany, out of which 5,391 firms are observed in 2014 and 4,494 firms are observed in 2016. Cloud computing is used by 20% of the firms in the sample. Within the average observation, 54.4% of the employees have access to the internet and 18.2% of the employees are equipped with a mobile internet connection. Own IT staff are employed by 49% of the firms. We also note that no firm entered the market after 2014, which is the year of the last policy change of the GRW. We point out that the average firm in our sample has 433 employees, which is driven by a skewed distribution in terms of firm size. The respective median value is 79 employees

3.2.4. Empirical results

The following section presents the results of the econometric analysis of the relation between access to the regionally targeted investment grants as determined by the GRW at the extensive and intensive margin. The analysis first assesses the relation between cloud use and eligibility for investment grants as well as the maximum funding rates the firm is able to apply for. Next, the relation with the propensity to employ IT-staff is being analysed, in order to examine whether investment incentives differentially affect cloud adoption and the general ICT intensity in the firm. Afterwards, the analysis explores which specific cloud technologies are related to the firms' access to investment incentives. Finally, the section looks into the relation between the use of cloud computing and the firms' use of big data analytics to substantiate the respective findings for the United Kingdom. Additionally, in the Annex we present robustness checks of our main findings by means of two period fixed effects regressions.

We now move to the results of our econometric analysis. Table 11 shows the estimates of the average marginal effects computed from our model according to Equation (1). In Column (1) we estimate a parsimonious model in which we only include a full set of dummy variables for federal states, industry and year. In Columns (2) and (3) we additionally include into our model the log number of employees, as a control for firm size, as well as the log of sales. This considerably reduces the measured relation between treatment status and cloud adoption. In addition, in Column (4) we control for the firm's use of internet based ICT by including the share of employees with access to the internet in general and with access to the mobile internet. Furthermore, we include the firm's fixed-line internet quality by adding a set of dummy variables denoting internet speed and account for the firm's age in logarithmic terms as well as the population density in the municipality. The last column additionally includes dummies for being a medium or large enterprise, since GRW funding rates depend on the firm's SME status..

In all specifications, we find a negative and statistically significant relation between access to public investment incentives and the propensity to use cloud computing. Looking at Column (4) as our preferred specification, we find that having access to investment incentives decreases the propensity to use cloud computing by 2.1 percentage points. This effect is statistically significant at the 10% level.

Looking at other variables in the model, we find that firm size is an important determinant of cloud adoption. According to the estimates in Column (4), a 1% increase in the number of employees is associated with a 4.7 percentage point increase in the propensity to adopt cloud. Moreover, internet access is an important determinant for the use of cloud technologies. Looking at Column (4) again, a 1% increase in the share of employees with access to the internet relates to a 0.2 percentage point increase in the propensity to adopt cloud. Beyond the general use of internet in the firm, a respective increase in the share of employees with access to mobile internet technologies increases the likelihood to adopt cloud by 0.1 percentage points. Furthermore, our estimation results underline the importance of internet quality for the use of cloud technologies. We find statistically significant and positive effects for the indicators denoting internet access with 2 Mbit/s and beyond. Interestingly, the effects get larger for higher bandwidth up to 30 Mbit/s while there is no increase in the effect when moving further to 100 Mbit/s. Overall, these results suggest that there is a decreasing return to internet speed in terms of firms' cloud adoption. In interpreting these results one has to keep in mind that the data refer to the years 2014 and 2016. Finally, cloud adoption is more likely in younger firms as denoted by the negative marginal effect of firm age on cloud adoption.

Table 11. Cloud computing and access to regional incentives - Logit regression - Average marginal effects

	(1)	(2)	(3)	(4)	(5)
treated	-0.042***	-0.032***	-0.029**	-0.021*	-0.021*
	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)
Log(employees)		0.058***	0.033***	0.047***	0.048***
		(0.003)	(0.005)	(0.005)	(0.006)
Log(sales)			0.025***	0.006	0.006
			(0.004)	(0.004)	(0.004)
% of employees with internet connection				0.002***	0.002***
				(0.000)	(0.000)
% of employees with mobile internet connection				0.001***	0.001***
				(0.000)	(0.000)
Broadband speed					
below 2Mbit/s				0.038	0.037
				(0.031)	(0.031)
between 2 Mbit/s and 10 Mbit/s				0.086***	0.087***
				(0.023)	(0.023)
between 10 Mbit/s and 30 Mbit/s				0.109***	0.109***
				(0.023)	(0.023)
between 30 Mbit/s and 100 Mbit/s				0.135***	0.135***
				(0.023)	(0.023)
more than 100 Mbit/s				0.108***	0.108***
				(0.024)	(0.024)
Log(age)				-0.015***	-0.014***
				(0.005)	(0.005)
Population density				0.011**	0.011**
				(0.005)	(0.005)
SME Indicators					
medium					-0.015
					(0.013)
large					-0.008
					(0.020)
Industry Effects	Yes	Yes	Yes	Yes	Yes
Fed. State Effects	Yes	Yes	Yes	YesF	Yes
Year Effects	Yes	Yes	Yes	Yes	Yes
Pseudo R^2	0.033	0.077	0.082	0.116	0.116
Observations	9885	9885	9885	9885	9885
Log likelihood	-4846.332	-4621.840	-4600.057	-4427.349	-4426.384

Note: Robust standard errors in parentheses, * p<0.10, ** p<0.05, *** p<0.01. All models include an intercept.

2. In Table 12, we move on and exploit variation in the maximum GRW funding rates available to the firm. Again, note that the treatment dummy from our first set of results captures access to a multitude of regionally targeted public investment incentives besides the GRW, such as the ERDF. In contrast, the maximum funding rates only refer to the GRW programme. The columns in Table 12 replicate the specifications of our main results in Table 11, but instead of a binary treatment indicator we include a continuous measure of the GRW funding rates available to the firms as well as its squared term according to Equation 2.

Table 12. Cloud computing and incentive rates - Logit regression - Average marginal effects

	(1)	(2)
Grant	-0.262**	-0.184*
	(0.110)	(0.110)
Log(employees)	0.034***	0.048***
	(0.005)	(0.006)
Log(sales)	0.025***	0.006
	(0.004)	(0.004)
Controls	No	Yes
Industry Effects	Yes	Yes
Fed. State Effects	Yes	Yes
Year Effects	Yes	Yes
Pseudo R^2	0.082	0.116
Observations	9885	9885
Log likelihood	-4599.836	-4426.299

Note: Robust standard errors in parentheses, * p<0.10, ** p<0.05, *** p<0.01. All models include an intercept. Controls include the share of employees working predominantly at PCs, the share of employees with internet access, four indicators for broadband speed, firm age, regional population density and indicators for SME status.

In addition to the firms' location, maximum GRW funding rates are also determined by the firms' SME status. Therefore, in Column (5) we include indicators for the firms' SME status in addition to firm size as measured by the number of employees. Looking at the average marginal effects, we again find a negative and statistically significant relationship between GRW funding rates accessible to the firm and cloud adoption.

3.2.5. Relation of investment incentives and alternative ICT measures

Overall, our estimation results suggest a negative relationship between regional investment incentives and the propensity to adopt cloud services. This holds at the extensive margin of the investment incentive, i.e. having access to funding, and at the intensive margin, i.e. the maximum funding rates available to the firm. We now want to assess the relation of regional investment incentives with other ICT technologies. Ideally, we would assess the relation with investments in physical (ICT) capital, as compared to cloud services. Unfortunately, our data do not include investment information in general. Moreover, the data only contain very few items which were asked in both years, 2014 and 2016, and which we can thus use for our analysis. Among the very few items available in both waves, we investigate the relationship with a binary variable whether or not the firm employs IT staff. We regard the employment of IT staff as a proxy for the firms' investment in IT assets and on-premise technologies (Xue, Ray, & Sambamurthy, 2012; Hitt & Brynjolfsson, 1996). Table 13 replicates our main results, but assesses the relation between access to regional investment incentives and the propensity to employ IT staff. Once we control for the firms' sales in logarithm and ICT intensity by means of internet use, the estimated marginal effects are very small and insignificant. Consequently, in contrast to the relation with cloud use, we do not find a significant relationship between access to regional investment incentives and the propensity to employ IT-staff.

To sum up, exploiting variation in access to regionally targeted investment incentives in Germany yields results in line with the findings from the UK case, which exploits investment incentives through tax schemes. Having access to regionally targeted investment incentives is associated with a decreased propensity to use cloud computing. In contrast, there is no significant relation with the propensity to employ IT-staff, which serves as a proxy for investment in IT assets and on-premise technologies.[25]

Table 13. Alternative ICT measure - Logit regression - Average marginal effects

	IT staff			
	(1)	(2)	(3)	(4)
treated	-0.015	-0.007		
	(0.012)	(0.012)		
grant			-0.046	0.011
			(0.093)	(0.090)
Log(employees)	0.106***	0.142***	0.105***	0.142***
	(0.007)	(0.007)	(0.007)	(0.007)
Log(sales)	0.072***	0.035***	0.072***	0.035***
	(0.005)	(0.005)	(0.005)	(0.005)
Controls	No	Yes	No	Yes
Industry Effects	Yes	Yes	Yes	Yes
Fed. State Effects	Yes	Yes	Yes	Yes
Year Effects	Yes	Yes	Yes	Yes
Pseudo R^2	0.297	0.365	0.297	0.365
Observations	9885	9885	9885	9885
Log likelihood	-4818.309	-4352.555	-4818.743	-4351.973

Note: Robust standard errors in parentheses, * p<0.10, ** p<0.05, *** p<0.01. All models include an intercept. Controls include the share of employees working predominantly at PCs, the share of employees with internet access, four indicators for broadband speed, firm age, regional population density and indicators for SME status.

3.2.6. Effect by different cloud technologies

In a next step, we exploit the fact that the data allow to look into different types of cloud technologies which were already investigated above for the United Kingdom. In Table A.2 and Table A.3 in the Annex, we analyse the relation between these detailed cloud items and the firms' treatment status. However, we do not seem to have sufficient statistical power to obtain any statistically significant coefficients. Therefore, in a next step we aggregate the detailed cloud measures according to the two broader cloud measures as defined by Eurostat (see Table 4). Aggregating the individual cloud technologies in this manner, we find that 7.7% of the firms in our sample are users of basic cloud technologies in 2016, whereas 12% of the firms have adopted complex cloud services by that time.

Replicating our analyses with these two aggregate cloud measures, we find that the negative and statistically significant relation between treatment and cloud adoption only holds for basic cloud technologies. As shown in Table 14, the regression results suggest that having access to financial support is associated with a 1.3 percentage point decrease in the propensity to have such technologies in place. The respective association with complex cloud technologies is considerably smaller and thus statistically insignificant. These results also hold qualitatively for the maximum funding rates (Columns 3-4). Investment incentives, especially within the scope of the GRW, are primarily targeted towards new activities, in contrast to other programmes targeted towards innovation and R&D. Therefore, they seem to affect only the use of those cloud technologies which are the first to adopt when moving towards cloud. In contrast, they do not seem to affect firms moving further to more complex cloud services.

Table A.3 in the Annex displays the full estimation results, since other variables in the model also yield interesting patterns: Firm age is only significantly related with complex cloud technologies, i.e. older firms are less likely to use these advanced technologies whereas for basic cloud services, firm age is not a significant determining factor. Looking at bandwidth, the smallest bandwidth (below two Mbit/s) already increases the propensity to use basic cloud technologies, whereas for complex cloud technologies, only bandwidth beyond 2 Mbit/s starts to significantly increase the propensity of using cloud. Sales are only significantly related to advanced cloud technologies.

Table 14. Access to regional incentives and basic- vs. complex cloud services – Average marginal effects

	Basic cloud	Complex cloud	Basic cloud	Complex cloud
	(1)	(2)	(3)	(4)
treated	-0.013*	-0.005		
	(0.008)	(0.010)		
grant			-0.147**	-0.004
			(0.070)	(0.087)
Controls	Yes	Yes	Yes	Yes
Industry Effects	Yes	Yes	Yes	Yes
Fed. State Effects	Yes	Yes	Yes	Yes
Year Effects	Yes	Yes	Yes	Yes
Pseudo R^2	0.043	0.113	0.044	0.113
Observations	9885	9885	9885	9885
Log likelihood	-2237.561	-2846.910	-2236.714	-2846.999

Note: Robust standard errors in parentheses, * p<0.10, ** p<0.05, *** p<0.01. All models include an intercept. Controls include the number of employees and total sales in logarithmic terms, share of employees working predominantly at PCs, the share of employees with internet access, four indicators for broadband speed, firm age in logarithmic terms, regional population density and indicators for SME status.

3.2.7. Cloud diffusion and big data analytics

Finally, we move on to assess the relation between the use of cloud computing and big data analytics. Among the firms in our sample, around 11% rely on big data and related analytics to support their business operations. In line with the previous analyses, we estimate the relation between cloud and big data by means of simple logit regressions. The results in Table 15 indicate a positive and statistically significant relation between the use of these two technologies. Controlling for other firm characteristics, the use of cloud computing is associated with a 7.5 percentage point increase in the likelihood to adopt big data (Column 2). Therefore, the results are qualitatively in line with the analysis of UK firms, and support the notion that cloud computing is a prerequisite of big data analytics practices. We note that, in comparison, the relation with other measures for the firms ICT intensity, including the share of employees working with PCs and with access to the internet, as well as broadband quality (excluded for brevity) is rather weak.

Table 15. Cloud computing and big data analytics - Average marginal effects

	Big data analytics	Internal-only big data analytics	External-only big data analytics	External and internal big data analytics
	(1)	(3)	(2)	(4)
cloud computing	0.075***	0.055***	0.036***	0.074***
	(0.010)	(0.009)	(0.007)	(0.010)
Log(employees)	0.027***	0.024***	0.006	0.027***
	(0.006)	(0.005)	(0.004)	(0.006)
Log(sales)	0.005	0.005	0.004	0.006
	(0.005)	(0.004)	(0.003)	(0.005)
% of employees with internet connection	0.000*	0.000***	0.000	0.000**
	(0.000)	(0.000)	(0.000)	(0.000)
% of employees with mobile internet connection	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Industry Effects	Yes	Yes	Yes	Yes
Fed. State Effects	Yes	Yes	Yes	Yes
Year Effects	Yes	Yes	Yes	Yes
Pseudo R^2	0.113	0.141	0.115	0.127
Observations	4474	4474	4474	4474
Log likelihood	-1338.602	-1090.346	-679.018	-1257.288

Note: Robust standard errors in parentheses, * p<0.10, ** p<0.05, *** p<0.01. All models include an intercept. Controls include four indicators for broadband speed, firm age in logarithmic terms, regional population density and indicators for SME status.

Chapter 4. Summary of results in the UK and Germany

The substitution of traditional ICT with cloud is taking place quite rapidly, which is expected to be important for firm competitiveness and productivity growth. However, the rates of cloud adoption across countries is considerably different raising several issues regarding the appropriate policy to enable cloud use. In fact, across many OECD countries, current and future proposed policies target ICT investments and tangible investments in capital more generally rather than digital services (OECD, 2019). Such policies may discourage firms from using cloud services, which are typically regarded as important, particularly for young entrants given that many non-cloud technologies are biased towards large incumbents. Cloud services on the other hand can increase firm growth and productivity for young firms, which is relevant in light of the recent slowdown of business dynamism.

This paper assesses the effects of two distinct capital incentive policies in the United Kingdom and Germany on firm-level cloud adoption. For the United Kingdom, we find that the capital incentive policy led to an increase in total capital and hardware capital investment. However, the results for both empirical studies suggest that capital incentive policies are discouraging cloud adoption in the United Kingdom and in Germany. These results suggest that various methods of capital incentive policies (in this case tax allowances in the United Kingdom and grants for investments in Germany) consistently negatively predict the use of cloud services. This indicates that firms view ICT capital investment and cloud adoption as substitutes. Therefore, a reduction in the price of ICT investment leads to a substitution away from cloud and towards traditional ICT.

One of the motivations for conducting an empirical study on the determinants of cloud adoption is that cloud computing is perceived to enable the adoption of new big data driven business models. The results in this paper are consistent with this view as they find for firms in both the United Kingdom and Germany, that cloud adoption is linked to a greater propensity in the use of big data analytics. While these results are not causal and further research is needed in this area, it does suggest that the adoption of cloud and the collection and use of data by firms goes hand in hand. Therefore, by incentivising traditional forms of ICT, government policy may inadvertently be slowing the diffusion of cloud with potential knock-on effects to further slow the diffusion of other data-driven technologies that are leveraged by the cloud.

Our results present interesting insights that should be considered when designing policies for the digital transformation. Most OECD countries currently have some form of a capital incentive policy in place (many include or even explicitly target IT capital investments) and are therefore similar in nature to the policies assessed in this paper (Tax Foundation, 2018).More generally, the results suggest that policies designed for firms comprised of PCs, servers, bricks and mortar may need reconsideration for business models that are increasingly comprise of intangibles.

Policy makers may therefore want to consider broadening these incentive schemes to include digital services. At the same time, when unbundling the aggregate sum of ICT capital and services within the firm, the rapid and continuous churning across technologies and services becomes apparent (DeStefano, De Backer, & Moussiegt, 2017). This highlights the difficult job policy makers face when choosing particular technologies to encourage and demonstrates the need for constant adjustment of these programmes.

Finally, the analysis suggests that the availability of fast broadband is an important determinant for cloud use. These results are consistent with evidence on the importance of broadband for cloud but also for digital technologies in general (DeStefano, Kneller, & Timmis, 2019; DeStefano, Kneller, & Timmis, 2018). Most OECD countries are providing considerable policy attention towards rolling out more high quality broadband (OECD, 2015). At the same time, important disparities exist in fibre broadband available across and within countries and this presents a likely barrier to cloud adoption for firms that reside on the wrong side of the digital divide.

Endnotes

[1] From the perspective of SMEs please see (OECD, 2019) which assesses cloud opportunities to these types of firms and illustrates a nature of adoption across countries.

[2] Additional examples of policies tagetting cloud services for Hungary and Turkey can be found in (OECD, 2019).

[3] "Joint task for the improvement of the regional economic structure" in English.

[4] There are a few paper which assess the determinants and performance effects of cloud adoption at the industry level (Gal, Nicoletti, Renault, Sorbe, & Timiliotis, 2019) (Andrews, Nicoletti, & Timiliotis, 2018).

[5] Firm-level analysis has been undertake for individual countries including (Ohnemus & Niebel, 2016) and (DeStefano, Kneller, & Timmis, 2019).

[6] Note, the purpose of this paper is not to assess reasons for the differences in adoption between these two countries but to understand whether policies in place influence cloud use for firms in each country respectively.

[7]https://thinkitsolutions.com/what-i-think-i-need/increased-productivity-and-efficiency/cloud-computing-solutions/66/

[8] Both results are in line with previous studies on ICT adoption, see Haller and Siedschlag (2011).

[9] However adoption of cloud is occurring relatively earlier and more comprehensively by small firms than for previous ICT investments such as E-commerce applications, PCs and so on (Bloom & Pierri, 2017).

[10] This is again in line with the literature on general ICT adoption for skilled workers (Bresnahan, Brynjolfsson, & Hitt, 2002) (Haller & Siedschlag, 2011) and management (Bloom, Sadun, & Reenen, 2012).

[11] The policy however does not cover intangible capital such as software.

[12] The paper also explores heterogeneity in the policies on the various types of cloud services listed above.

[13] Differences in data used between the United Kingdom and Germany mean that the control variables used in the respective approaches are slightly different.

[14] As discussed previously, there are observations for cloud use and big data (in comparison to investments) since information on cloud is only available for the years 2013 and 2015, and big data for 2015. In addition the cloud and big data variables come from the E-commerce survey which surveys fewer firms than the Annual Business Survey, where investment and other firm characteristics come from.

[15] As a robustness test we use separately average lagged two-year and three-year of the firm's investment to determine the treatment.

[16] Since the investment outcomes are in logs, the percentage increase in total investment, IT acquisition and hardware acquisition are calculated as 64% = exp(0.492) – 1, 34% = exp(0.292) – 1 and 31% = exp(0.273) – 1 respectively. Again, our data are not well suited to drawing inferences about implied elasticities.

[17] Note that in 2009 the AIA threshold was $50,000, in 2011 the ceiling was £100,000, this was then reduced to £81,250 in 2013 and increases to £250,000 in 2014 (See Table 3-1).

[18] Data on investments is not available after 2014 in the UK business registry.

[19] Cloud hardware classification includes Cloud used for storage, hosting databases and processing. Cloud services refer to CRM, office software, finance software and email.

[20] See also Gal et al. (2019), or Andrews et al. (2018), who use the same aggregate cloud measure.

[21] Unfortunately, the authorities do not collect data on the purpose/intended use of the funding.

[22] We note that infrastructure funds in the GRW framework should either be neutral towards the firms' decision between investment in ICT assets versus acquisition of ICT services, or, in case they are used for broadband infrastructure, they should indirectly incentivise cloud adoption. This would downward bias potential negative effects of investment incentives on cloud adoption.

[23] Figure A.1 in the Annex provides information on the development of GRW cases and funding over time.

[24] See the EU recommendation 2003/361 (http://data.europa.eu/eli/reco/2003/361/oj): In particular, we will treat firms with less than 50 employees and annual sales up to 10.000 € as small, firms with less than 250 employees and sales up to 50.000 € as medium, and firms beyond as large firms.

[25] Furthermore, we find no statistically significant effect of the investment scheme on firm size. This indicates that we are not solely capturing laggard firms being less likely to purchase cloud services and further reassures our findings.

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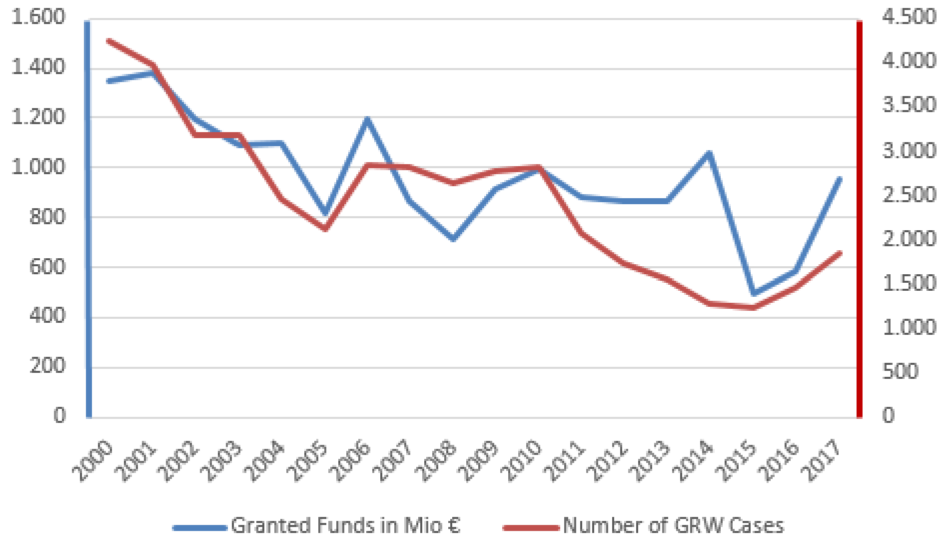
Annex A. Appendix

Table 16. Summary statistics of the estimation sample for the UK

Variable	Mean	Standard deviation	Observations
Cloud	0.381	0.486	4,678
Cloud Hardware	0.293	0.455	4,678
Cloud Processing	0.110	0.313	4,678
Cloud Storage	0.231	0.421	4,678
Cloud Data	0.173	0.379	4,678
Cloud Data/Storage	0.276	0.447	4,678
Cloud Software	0.273	0.446	4,678
Cloud CRM	0.126	0.332	4,678
Cloud finance software	0.078	0.268	4,678
Cloud Office Software	0.128	0.334	4,678
Cloud Email	0.183	0.387	4,678
Cloud Low-Tech	0.092	0.289	4,678
Cloud Med-Tech	0.173	0.379	4,678
Cloud High-Tech	0.211	0.408	4,678
Big data analytics	0.211	0.408	2,348
Big data analytics – internal only	0.119	0.324	2,348
Big data analytics – external only	0.016	0.126	2,348
Big data analytics – external and internal	0.076	0.265	2,348
(log) Log(Total investment)	6.561	2.608	28,030
(log) Log(IT acquisitions)	4.383	2.253	29,244
(log) Log(Hardware acquisitions)	3.812	2.122	29,244
% PCs per employees	59.878	34.393	13,170
(log) Log(Employees)	5.650	1.620	56,649
(log) Log(Sales)	10.525	1.962	56,614
(log) Log(Sales per worker)	4.863	1.620	56,614
Multi-plant	0.679	0.467	56,676
Number of plants	39.383	266.990	56,676
Foreign owned	0.284	0.451	56,676
(log)Log(age) Age	3.270	0.469	56,676
Urban	0.785	0.410	56,867
Young (<= 5 years)	0.017	0.130	56,676

Figure 5 plots the number of GRW cases as well as the total sum of GRW grants awarded by year. There has been a steady decline in total grants and the number of GRW cases from 2000 to 2015. However, both figures recovered from 2015 on.

Figure 5. Development of GRW grants

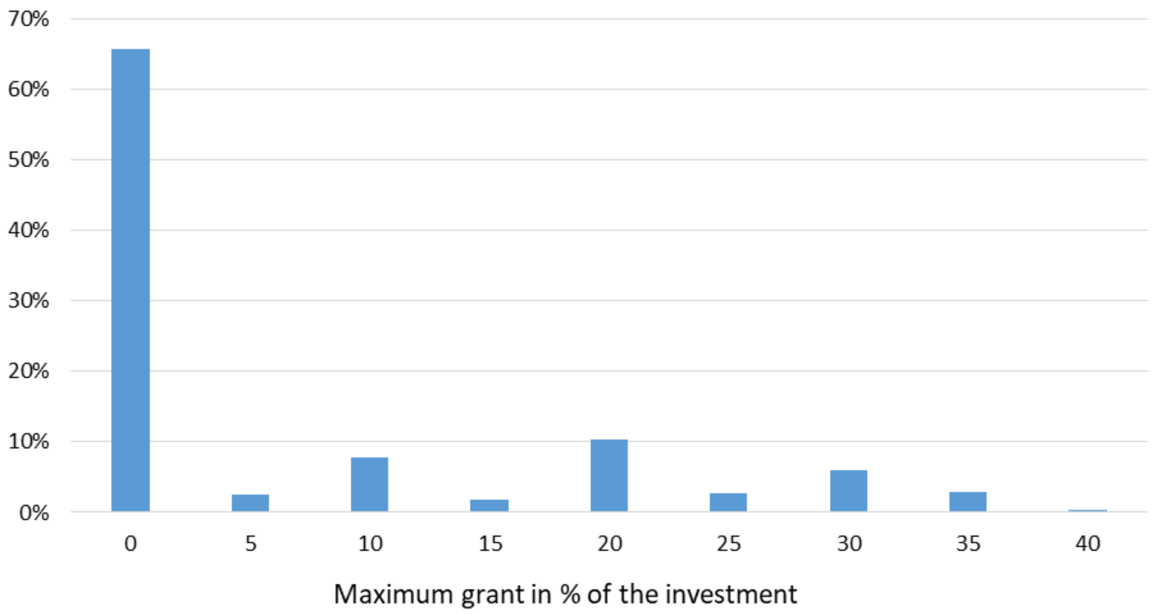


Note: Left scale: Granted funds in Mio € (blue). Right scale: Number of GRW cases (red).
Source: Source: Authors calculations based on BAFA (2019).

Table A.1. Summary statistics of the estimation sample for Germany

Variable	Mean	Standard deviation	Observations
Number of employees	433	4220.20	9,885
Sales in Mio €	140.5	2175.70	9,885
Firm age	28.4	22.70	9,885
% of employees with internet connection	54.4	33.50	9,885
% of employees with mobile internet connection	18.2	22.70	9,885
Cloud	0.20	0.40	9,885
Employment of own IT-staff	0.49	0.50	9,885
Population density	1.13	1.08	9,885
Eligibility for GRW funding	0.35	0.48	9,885
Broadband speed			
below 2Mbit/s	0.042	0.20	9,885
between 2 Mbit/s and 10 Mbit/s	0.26	0.44	9,885
between 10 Mbit/s and 30 Mbit/s	0.27	0.44	9,885
between 30 Mbit/s and 100 Mbit/s	0.21	0.41	9,885
more than 100 Mbit/s	0.18	0.39	9,885

Figure A.1. Percentage of firms by eligibility of maximum grant



Note: This figure shows the distribution of the maximum funding rates of the GRW as determined by location and firm size over the firms in the sample. For the empirical analysis, the maximum funding of 200.000 € for large enterprises (compare to Table 10) is coded as an incentive rate of 5%.
Source: Own illustration by authors based on ICT survey and BAFA (2019).

Table A.2. Access to regional incentives and different types of cloud adoption – Average marginal effects

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Cloud email	Cloud finance software	Cloud processing	Cloud CRM	Cloud office software	Cloud storage of files	Cloud hosting the enterprise's database(s)
treated	**-0.173**	**-0.079**	**-0.241**	**0.230**	**-0.009**	**-0.103**	**0.073**
	(0.125)	(0.169)	(0.158)	(0.174)	(0.158)	(0.113)	(0.143)
Log(employees)	0.159***	0.027	0.203***	0.214***	0.317***	0.198***	0.233***
	(0.055)	(0.068)	(0.066)	(0.070)	(0.067)	(0.048)	(0.060)
Log(sales)	0.019	0.107**	0.005	-0.007	0.036	0.035	0.014
	(0.038)	(0.051)	(0.045)	(0.050)	(0.051)	(0.034)	(0.043)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fed. State Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pseudo R^2	0.052	0.054	0.094	0.132	0.132	0.102	0.084
Observations	9858	9855	9857	9796	9843	9855	9810
Log likelihood	-2599.875	-1842.682	-1798.119	-1610.928	-1704.195	-3069.054	-2078.559

Note: Robust standard errors in parentheses, * p<0.10, ** p<0.05, *** p<0.01. All models include an intercept. Controls include the share of employees working predominantly at PCs, the share of employees with internet access, four indicators for broadband speed, firm age, regional population density and indicators for SME status.

Table A.3. Access to regional incentives and basic- vs. complex cloud services – Average marginal effects – Full estimation results

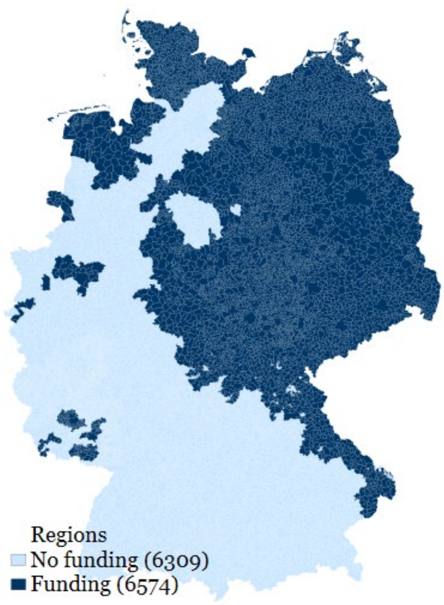
	Basic cloud	Complex cloud	Basic cloud	Complex cloud
	(1)	(2)	(3)	(4)
treated	-0.013*	-0.005		
	(0.008)	(0.010)		
grant			-0.147**	-0.004
			(0.070)	(0.087)
Log(employees)	0.008**	0.019***	0.003	0.005*
	(0.003)	(0.004)	(0.002)	(0.003)
Log(sales)	0.003	0.005*	0.008**	0.019***
	(0.002)	(0.003)	(0.003)	(0.004)
% of employees with internet connection	0.000***	0.001***	0.000***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)
% of employees with mobile internet connection	0.000**	0.000***	0.000**	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)
Broadband speed				
below 2Mbit/s	0.033*	0.006	0.033*	0.006
	(0.017)	(0.020)	(0.017)	(0.020)
between 2 Mbit/s and 10 Mbit/s	0.038***	0.051***	0.038***	0.051***
	(0.011)	(0.015)	(0.011)	(0.015)
between 10 Mbit/s and 30 Mbit/s	0.045***	0.060***	0.045***	0.060***
	(0.011)	(0.015)	(0.011)	(0.015)
between 30 Mbit/s and 100 Mbit/s	0.052***	0.079***	0.052***	0.079***
	(0.011)	(0.015)	(0.011)	(0.015)
more than 100 Mbit/s	0.036***	0.074***	0.036***	0.073***
	(0.011)	(0.016)	(0.011)	(0.016)
Log(age)	0.000	-0.017***	0.000	-0.017***
	(0.004)	(0.004)	(0.004)	(0.004)
population density	0.000	0.009**	0.000	0.009**
	(0.004)	(0.004)	(0.004)	(0.004)
SME Status				
medium	-0.006	0.003	-0.005	0.002
	(0.008)	(0.009)	(0.008)	(0.010)
large	0.004	-0.002	0.005	-0.003
	(0.012)	(0.014)	(0.013)	(0.015)
Industry Effects	Yes	Yes	Yes	Yes
Fed. State Effects	Yes	Yes	Yes	Yes
Year Effects	Yes	Yes	Yes	Yes
Pseudo R^2	0.043	0.113	0.044	0.113
Observations	9885	9885	9885	9885
Log likelihood	-2237.561	-2846.910	-2236.714	-2846.999

Note: Robust standard errors in parentheses, * p<0.10, ** p<0.05, *** p<0.01. All models include an intercept.

4.1.2. Panel data analysis

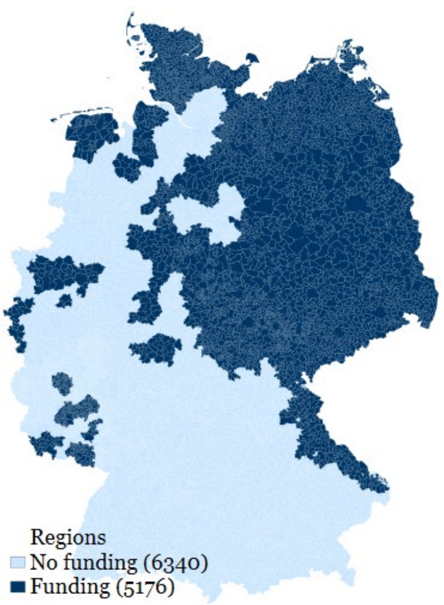
As the German administrative ICT survey is a rotating panel, we only observe a small fraction of the firms in both waves. In addition, most of the variables in our model exhibit very little within-variation, which additionally mitigates the scope to identify parameters of interest within a fixed effects estimation. Nevertheless, as a robustness check we perform a fixed effects regressions with the sample of firms which we observe in both waves. For these firms there is no change in the treatment status between 2014 and 2016. However, we exploit the fact that GRW regions were newly assigned in 2014 and therefore treatment status changed for some firms between 2013 and 2014. Figure A.2 and Figure A.3 show the regions eligible for GRW funding under the scheme which was in place form 2007 until 2013 (left hand side) and the current one, which came into place in 2014 (right hand side).

Figure A.2. GRW eligible regions 2007-2013



Source: Authors illustration based on BAFA (Federal Office of Economic Affairs and Export Control, 2019).

Figure A.3. GRW eligible regions since 2014



Source: Authors illustration based on BAFA (Federal Office of Economic Affairs and Export Control, 2019).

Table A.4 displays that out of 1,276 firms we retain in the balanced panel, 24% lost access to GRW investment incentives and 6% gained access.

Table A.4. Change in treatment status

Change in treatment status	Observations	Freq.
-1	300	23.5%
0	903	70.8%
1	73	5.7%
Total	1,276	100%

Source: Authors calculation based on BAFA (Federal Office of Economic Affairs and Export Control, 2019).

In order to exploit this variation in treatment status we estimate the following fixed effects linear probability model (see Equation 4).

$$CC_{it} = \beta_0 + \beta_1 Treat_{i,t-1} + \beta_2 X'_{it} + \mu_i + \varepsilon_{it} \quad (4)$$

We now consider lagged treatment status, which is necessary to gain variation in treatment status within firms over time for the survey years 2014 and 2016, as the status in t-1 for 2014 refers to the previous GRW funding period (see Figure A.2 and Figure A.3). Note that in the estimation we consider all firms, those who gained access to funding, those who lost access to funding, and those for whom treatment status did not change. In addition, X_{it}' is a vector of time-varying firm characteristics and μ_i denotes the firm fixed effect, which captures any time-constant, unobserved heterogeneity between firms, such as any region specific characteristics. Table A.5 Columns 1-3 show that the negative relation between treatment status and the propensity to adopt cloud computing remains robust to the inclusion of firm fixed effects. However, any other estimates become insignificant, reflecting the little variation in variables within firms over time. Therefore, our panel estimations need to be taken with a grain of salt. Still, the results increase the confidence in the results we obtain from the pooled cross section.

3. In Columns 4-6 of Table A.5 we also look into the relation between the treatment status and the propensity to employ own IT-staff within a fixed effects panel regression. Analogous to the results in the cross section, we find that, in contrast to the propensity to use cloud, treatment is positive yet statistically insignificantly related to employing IT-staff. The findings of a differential effect of investment incentives on cloud adoption versus employment of IT-staff, as a proxy for general ICT investments, also hold when we rely on the continuous maximum funding rates in the panel estimations (results excluded for brevity). The regression results furthermore suggest that firm size and the share of employees with access to the internet is positively related to the propensity to employ own IT-staff.

Table A.5. Access to regional incentives - Panel fixed effects estimation

	Cloud computing			IT staff		
	(1)	(2)	(3)	(4)	(5)	(6)
treatedt-1	-0.049**	-0.049**	-0.046**	0.017	0.018	0.025
	(0.023)	(0.023)	(0.023)	(0.017)	(0.017)	(0.017)
Log(employees)		0.036	0.038		0.037*	0.039**
		(0.034)	(0.036)		(0.020)	(0.020)
Log(sales)		-0.002	-0.004		-0.005	-0.004
		(0.011)	(0.011)		(0.009)	(0.009)
% of employees with internet connection			0.000			0.001**
			(0.001)			(0.001)
% of employees with mobile internet connection			0.001			-0.000
			(0.001)			(0.001)
Broadband speed						
below 2Mbit/s			-0.009			0.070
			(0.073)			(0.072)
between 2 Mbit/s and 10 Mbit/s			0.019			0.018
			(0.062)			(0.051)
between 10 Mbit/s and 30 Mbit/s			0.002			0.056
			(0.063)			(0.053)
between 30 Mbit/s and 100 Mbit/s			0.024			0.082
			(0.063)			(0.055)
more than 100 Mbit/s			0.050			0.054
			(0.067)			(0.057)
Constant	0.248***	0.085	0.053	0.663***	0.517***	0.403***
	(0.005)	(0.181)	(0.205)	(0.004)	(0.128)	(0.154)
Observations	2452	2452	2452	2452	2452	2452

Note: Robust standard errors in parentheses, * p<0.10, ** p<0.05, *** p<0.01. All columns show the estimation results of a panel fixed effects linear probability model.