Impact of regulation on digital automation in professional services

Franco, F[*]., Salmaso, E.[†], Sparacca, S.[†]

September 15, 2021

Abstract

This paper presents the results of the empirical analysis conducted in the report "The impact of regulatory environment on digital automation in professional services", prepared for the European Commission[1]. The study aims at investigating the interactions between the regulatory environment and the adoption of automated processes in four different professional categories: architects, lawyers, engineers, and accountants. Leveraging on information retrieved from a survey run in 12 European countries during August and September 2020, and on a new individual-level regulation index measuring the "subjective" perception of regulation, together with country indicators, we first test whether professional regulation, along with other relevant internal and external factors, affects the decision of each firm to start (or not) automation. Secondly, using a Heckman selection model, we investigate how the perception of higher regulatory environment impacts on the degree of digital automation adoption.

We find that regulation restrictiveness is negatively correlated to the adoption of technology. In particular, the higher the perception of regulation, the lower the probability that firms engage in digital automation. Specific forms of regulation (regulatory exclusiveness and qualification requirements in particular) exert a significant impact on the adoption (or not), while in terms of intensity, the results are less straightforward. Larger firms are more prone to adopt digital automation, while infrastructural barriers such as access to high speed internet and shortage of specific IT skills prevent firms to automate. Main policy aspects stemming from the empirical findings are finally discussed, related both to regulatory settings and environmental factors.

[*] Nova School of Business and Economics, Portugal

[†] Prometeia S.p.A., Italy

[1] European Commission (2021). "The impact of regulatory environment on digital automation in professional services". DOI: 10.2873/310173. Available at: https://op.europa.eu/en/publication-detail/-/publication/8457941c-974d-11eb-b85c-01aa75ed71a1/language-en. Prepared by Prometeia S.p.A., BIP Business Integration Partners – S.p.A., Economics for Policy a knowledge Center of Nova School of Business and Economics Lisboa. Hereafter referred to as the Report. The authors thank BIP, especially for its contribution in the conduction of the survey.

Table of contents

1. Introduction

The digital automation transformation that started in the last decades is changing business models by freeing humans from low value added repetitive tasks and influencing consumers' lives through cheaper online services delivery. Digital automation is also favoring the emergence of brand-new services and transforming the nature of many professional services. These rapid changes have prompted authorities to regulate and incentivise digital automation to guarantee that it improves consumers' welfare.

Leveraging on novel firm-level data on digital automation and regulation, this paper aims at investigating the interactions between the regulatory environment and the adoption of automated processes in four different professional categories: architects, lawyers, engineers, and accountants. These interactions are economically relevant and complex to identify. They are economically relevant because adopting automated processes implies investment in ICT and human capital, which are engines of productivity growth. They are complex because the regulatory environment impacts digital automation adoption through various channels such as competition, finance, skills, investment, costs, and size. Their complexity also lies in the identification challenge as both regulation and automation are not easily measurable.

Survey results on the perception of excessive regulation as a deterrent to technology adoption are used to assess whether general literature findings, summarized in the proposed theoretical framework, apply to European firms in professional services. Along with regulation, a number of other factors affecting the choice to engage in digital automation are tested. Some determinants pertain to the characteristics of the firm, such as size and revenue growth, or the technological infrastructure available at the firm, in terms of broadband connection, financial resources and economies of scale that might support digital transformation (retrieved from the survey). Other factors relate to the environment where the company resides, which are related to the degree of internet penetration, or the availability of relevant skills (country-level data). Hence, the analysis investigates not only the impact of regulation in shaping the decision to adopt digital automation, but the role of other relevant structural and environmental factors as well.

Two econometric models are specified to test the research question. The first model, a probit model, estimates how the perceived level of regulation influences the probability of a firm to adopt digital automation. Focusing on the adopters, the second model, a Heckman selection model, estimates how regulation affects the intensity of digital automation.

The main novelties of this study are (1) the use of primary data, collected through an online survey, on regulation perception and automation adoption, (2) the analysis of specific types of regulations and restrictions (e.g. reserve of activities, tariff restrictions, shareholding requirements, etc.), and (3) the use of “subjective regulation” as a measure of regulation. As for the latter, this work contributes to the debate on the measurement of regulatory barriers by using a regulation perception index, not built from the regulatory environment’s *de jure* situation.

The remainder of the paper is organized as follows. Section 2 provides the theoretical foundations of the study: it includes a review of the key literature providing a theoretical and empirical background for our analysis, and presents a theoretical framework for the interplay between digital automation and regulation. Section 3 presents the survey dataset and the main variables of interest. Section 4 describes

the empirical strategy employed to analyse the interplay between digital automation and regulation. Section 5 discusses the results of the econometric model. Section 6 concludes.

2. The interplay between digital automation and regulation

2.1. Literature review

Digital automation trends are deeply affecting the growth trajectories of economies. In the last two decades, research has focused, on the one hand, on the effects of this kind of innovation on economic performance (both at the micro and the macro level), and on the other hand, on the potential factors which can influence the technological diffusion process. With respect to the latter, regulatory factors have been identified from the economic literature as key variables for policy-makers to improve the framework conditions necessary to spur innovation.

How regulatory measures affect firms' incentives to innovate and competitiveness is a long-standing interest in the literature. The OECD (2002) and Van Gorp and Batura (2015) stress the importance of the swiftness of technological change and relatively low barriers to entry (if lock-in is absent) in promoting transitory market dominance. They all agree in recognizing that the major weakness of standard and antitrust policies stems from their focus on static models and static analyses, thus disregarding the speed of technological change and its acceleration over time. For example, Audretsch et al. (2000) refer to the term 'dominant position' itself as no longer adequate, given the growing importance of potential entry.

In defining the interplay between regulation and digital automation, most of the seminal works in the field (e.g. Carlin and Soskice, 2006; Blind, 2012) distinguish between compliance cost or negative incentive effect, and positive incentive effect. Thus, the regulatory environment can act as either a stimulus or a barrier to innovation, but also a specific norm can simultaneously promote or hinder innovation, depending on other factors. Blind (2012) explains how market entry regulation may entail both effects. On the one hand, it may hamper innovation by prohibiting market entry of potential innovative newcomers. On the other hand, limited competition may also be beneficial for incumbents by allowing them to engage and invest in frontier innovation activities, and to increase their R&D spending, enjoying temporary monopoly positions[2].

A significant number of empirical studies tends to confirm that restrictive regulation in professional services decreases competition, allows wage premiums and increases prices (e.g. Monteagudo, et al.,2012; Bouis and Duval, 2011). Particularly relevant for the present study is the strand of literature investigating the relationship between regulation and markup (e.g. Thum-Thysen and Canton, 2015; Thum-Thysen and Canton, 2017): evidence from both aggregate sectoral data, and firm-level data suggests a relationship between higher product market regulation and higher markups in professional service sectors in the European Union.

[2] The idea that capturing monopoly rents is the crucial reward for innovators has been the core argument of the Schumpeterian growth theory positing that a more competitive marketplace lowers incentives for firms to innovate by reducing their profit margins.

A number of other factors might contribute to the relationship between regulation and innovation. According to Pelkmans and Renda (2014) and Ravet (2017), sector-specific characteristics are among the most important ones. These studies stress that specific types of regulation have different impacts depending on the sector. Given the heterogeneity of regulations' stringency, timing, flexibility and uncertainty across sectors, a sectoral analysis is ultimately needed in order to better understand and address barriers and to study to what extent regulation affects innovation. Indeed, a sectoral perspective has been progressively adopted within the literature (Freel, 2006; Canton, et al. 2014) and has also been recently embraced by the European Commission in numerous reports (EC, 2016; EC, 2017; EC, 2018).

A large body of literature explores the structural factors and incentives that shape automation trends. Within this strand, several contributions focusing on the professional services have highlighted how differences across countries and heterogeneous institutional setting provide different stimulus to business dynamics (Canton et al., 2014; EC, 2017; van der Marel et al., 2016; World Bank 2016; Hook, 2016; Cette et al., 2014).

The most recent contributions (Andrews et al., 2018; Ferracane and van der Marel, 2020) stress the importance of sector and country-specific specifications, which enable exploration of the link between structural factors, such as human capital or business dynamism that help in speeding up the adoption of automation. Including these factors in the empirical analysis will help to obtain robust measurements of the contribution of the regulatory variables and address other important policy issues, pivotal to the successful implementation of new technologies.

2.2. A theoretical framework

Relying on the theoretical and empirical works just presented, it is possible to summarize the effects of different regulation restrictions on firms' digital automation adoption strategies. In order to assess the influence of the regulatory framework in a more schematic way, the specific restrictions will follow the classification of regulatory requirements illustrated in Table 1[3].

Table 1: Classification of regulatory requirements

Classification of regulatory requirements	
Categories of requirements	***Specific Restrictions[4]***
Regulatory approach	○ Exclusive or shared reserved activities ○ Protection of title
Qualification requirements	○ Years of education and training ○ Number of pathways to obtain qualifications ○ Existence of mandatory traineeship ○ Obligation to have professional experience to get full capacity ○ Existence of mandatory state exam ○ Continuous professional development obligations

[3] This framework draws on that used by the European Commission in the Communication on Reform recommendations for regulation in professional services (European Commission, 2017).

[4] These restrictions are explained in more detail in the Annex (Table I)

Other entry restrictions	○ Compulsory membership or registration in professional body ○ Limitation to the number of licences granted ○ Territorial validity of the professional qualification ○ Age restriction ○ Other authorisation requirements
Exercise requirements	○ Restriction on corporate form/ type of entity ○ Shareholding requirements ○ Voting rights control ○ Prohibitions on joint exercise of professions ○ Incompatibilities of activities for a professional ○ Professional indemnity insurance ○ Tariff restrictions ○ Restrictions on advertising

The effect of each specific restriction is analyzed with particular focus on the channels through which the regulation affects firms behavior on the adoption of digital automation. More specifically, five **general potential channels of impact on digital automation** have been identified:

- **Competition**: regulation modify the professional services market competition settings, thus limiting competitive pressure between incumbents and from new entrants, in turn affecting the firms' propensity to introduce digital automation technologies. "The entry of new firms, or the threat of it, induces existing firms to become more efficient through reallocation of resources inside the firm or cutting slack or by investing in innovation to escape competition (allocative, productive and dynamic efficiency gains)" (Canton et al. 2014).

- **Access to finance**: regulation can exert its effects on the possibility of companies to have access to external funding, thus conditioning future automation investments plans. The positive impact of financial dependence (i.e. the need for external funds) and faster value added growth is well documented in the literature (pioneered by the Rajan and Zingales' work in 1998). Barone and Cingano (2011) show lower regulation and higher financial development in the service sector has a significant impact on value added growth, in turn closely related to innovation.

- **Skills**: each regulation can influence the adoption and development of new skills and expertise complementary to digital automation adoption. The economic literature has stressed the role of capabilities and their evolution within professional services firms for innovation activities (e.g., Criscuolo et al., 2007; Bryson and Daniels, 2008).

- **Costs**: specific restrictions can imply additional costs for the professional services firms, draining resources and thus reducing funds for investment in digital automation.

- **Size**: specific regulations can influence the dimensional development of firms and therefore the scope and the resources for the introduction of new digital technologies (OECD, 1997; Ribes, 2018).

The existence of a well-functioning professional services market ultimately affects most economic activities and is fundamental to enable productivity growth[5]. The introduction of digital automation in

[5] This channel is further analyzed in its impact on productivity and markup in Chapter 4 of the Report

these sectors can boost their own productivity and guarantee a general increase in the efficiency of the EU economic system. In what follows it will be briefly described how specific regulation restrictions, through the channels above mentioned, can have an impact on the adoption and diffusion of digital automation technologies and thus distort growth potential.

With respect to the **regulatory approach**, **reserve of activities** is the specific restriction that can most represent a constraint on the road to digitalization of professional services. As a matter of fact, by reserving services to specific providers, reserve of activities automatically trigger the impacts of all the other restrictions that apply to these providers. As a result, all the channels of impact are directly or indirectly involved. Indeed, by giving a monopoly to exercise certain activities or professions to individuals with the required qualification (or title), reserve of activities limits competition between service providers and the potential entrance of online service providers (e.g. legal tech) can be limited, hence reducing the incentive to innovate and productivity improvements (CSES, 2012).

As far as the **qualification requirements** are concerned, **continuous professional development obligations** involve both the **skills** and the **cost** channels. Professional qualifications might not provide the skills required to implement digital automation tools, as well as imply additional financial costs and time investment. Therefore, it is possible that not only they do not guarantee a step forward to digital automation but they can even divert resources from it. On the other side, it might be argued that, whenever the required skills are relevant to digital automation, it could have a positive impact on digital automation as it allows to keep skills up-to date. The category of **qualification requirements** constitutes another specific restriction within this regulatory area: **skills** and **costs** channels operate in this case, as well. Indeed, qualifications required to practice the profession could not provide the digital skills necessary to implement the digital tools and innovative services. Moreover, this restriction may represent a skill mismatch between the qualification requirements and the actual skills and knowledge required to implement digital automation tools, and thus an obstacle to expand abilities, effort and skills into digital transformation. This means that specialization in specific activities and skills relevant for the regulated profession might divert resources and time that might be invested in digital automation training and development. The greater and greater complexity of technology demands higher absorption capacity in the form of prior accumulated knowledge and an adequate skills endowment, in order to be able to reap the benefits of technological change: an optimal mix of different skills must be adopted to exploit the productivity improvements linked to digital automation adoption. In addition, the cost channel is involved, as the lengthy and costly qualification process can divert resources from automation.

Among the **other entry restrictions** regulatory area, **compulsory membership or registration in professional body** and **limitation of the number of licences granted** are the main specific restrictions under scrutiny in the next paragraphs. The first can constitute an obstacle to the adoption of new automation tools mainly through the **competition** and **costs** channels. Indeed, where a professional association is delegated certain regulatory powers, such as the power to discipline its members, concerns have arisen that professional associations may use these powers as a tool to restrict entry, fix prices and enforce anti-competitive behaviours, thus distorting competition and, in turn, limiting innovation investment (OECD 2000). In the specific case of **compulsory membership or registration in professional body**, compulsory membership, including its annual renewal, can also create additional **costs** for professionals over and above formal regulatory requirements, due to the unwanted bundling of additional representative services.

Limitation of the number of licences granted constitute a barrier to entry that restricts foreign and domestic service providers from bringing competition to the market. If entry barriers are high, domestic incumbents will be sheltered from competition and less incentivized to better perform and to invest in digital automation (European Parliament, 2017). Moreover, this kind of market entry barriers can also limit new entrants like start-ups which are generally characterized by a higher level of products and processes innovation.

Under the **exercise requirements** regulatory area there is a set of other specific restrictions which can affect firms' choices about digital automation adoption through different channels. **Restriction on corporate form** can constitute an obstacle to **dimensional growth** and firms' **access to finance**, limiting the scope for collaboration with other professions. In addition, it can limit the development of start-ups. Restriction on corporate form can also limit the choice of financial and business models for companies and thereby can hamper service innovation, have adverse consequences on service prices, and a negative effect on the competitiveness of such services. Additionally, the competition channel is involved, as such restriction may prevent some firms to enter the market (e.g. foreign firms). Similarly, **shareholding requirements and/or voting rights control** can represent an obstacle to **dimensional growth** and firms' **access** to **finance**, thus limiting economies of scale and hampering the development of innovative services and cost-effective business models. This kind of restriction can eventually limit automation adoption through the **skills** channel as well, as it could condition investment partners in fund allocation on ICT training as well as digital technologies infrastructures. Moreover, it may constitute an obstacle to the freedom of cross-border establishment and can even result in making it impossible to set up subsidiaries (investments which often export best practices and innovation[6]) or create multi-disciplinary practices which can boost innovation through cooperation and knowledge spillovers. In sum, the **competition channel** is also triggered, as these restrictions by limiting business development and market entry, reduce the scope for competition.

Incompatibilities of activities and **restrictions on joint exercise of professions** can affect investment in digital automation through the **size, skills** and **competition** channels. This kind of restrictions can impact on firms' growth by limiting economies of scale and collaboration between professions, hence limiting the scope for investment in digital technologies. Moreover, they can limit knowledge spillover which are crucial for ICT tools absorption capacity, thus slowing down efficiency and innovation adoption. Lastly, these restrictions might distort competition by preventing market entry. **Obligatory professional indemnity insurance** is a clear example of expenses that drain resources that could be allocated to investment in automation (**costs** impact channel), although the impact might not be significant. In the cases of **tariff** and **advertisement restrictions**, regulation can impact automation adoption through the **competition** impact channel. **Minimum tariffs** mainly prevent service providers from competing on price and can protect less efficient competitors. In turn, this might reduce the incentive to improve quality through investment in digital automation innovation. **Maximum tariffs** can instead reduce profitability and future prospects of profits thus limiting investing capacity. Arguably, maximum tariffs can also limit competition by establishing *de facto* agreed prices (similar to cartel behaviour) that may result above competitive levels (Canton et al., 2014). As far as the **advertisement restrictions** are concerned, it can be stressed that advertising, and in particular comparative advertising, can be a crucial competitive tool for new firms entering the market and for existing firms to launch new products. Allowing advertising, and

[6] The work of Arnold et al. (2007) on service liberalization in Czech Republic highlighted the positive impact of the presence of foreign providers on productivity growth, especially with foreign firms being at the forefront of introducing innovative services.

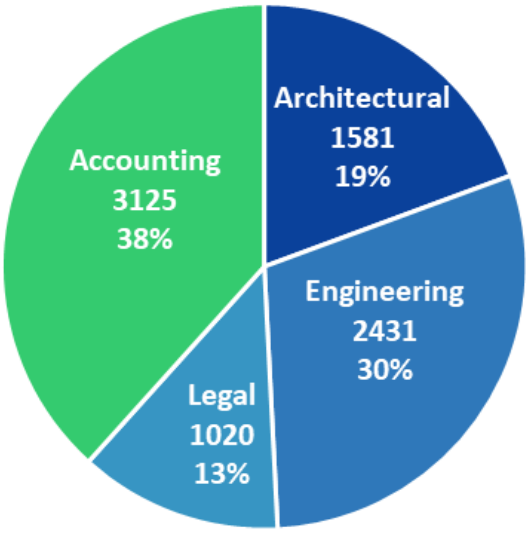
digital advertising above all, could thus provide an incentive to competition and thus stimulate digital automation. Therefore, restrictions on advertising can reduce stimulus to innovate by curbing competition and firms' investment plans.

3. Data

3.1. Survey

The systematic analysis at the professional level of automation and its interaction with the regulatory environment required novel, firm-specific data. These data were collected through an online survey that ran during August and part of September 2020. The survey produced a working sample of 8157 responses across the four professions (architectures, engineers, lawyers and accountants) and 12 EU Member States. The survey collected more than one hundred variables for each respondent[7]. It produced a substantial body of information on the adopted technologies, the perceived costs, and benefits of digital automation, the perceptions on the impacts of specific regulations, and the views on the professional services market conditions.

Figure 1: Total Respondents by professional service

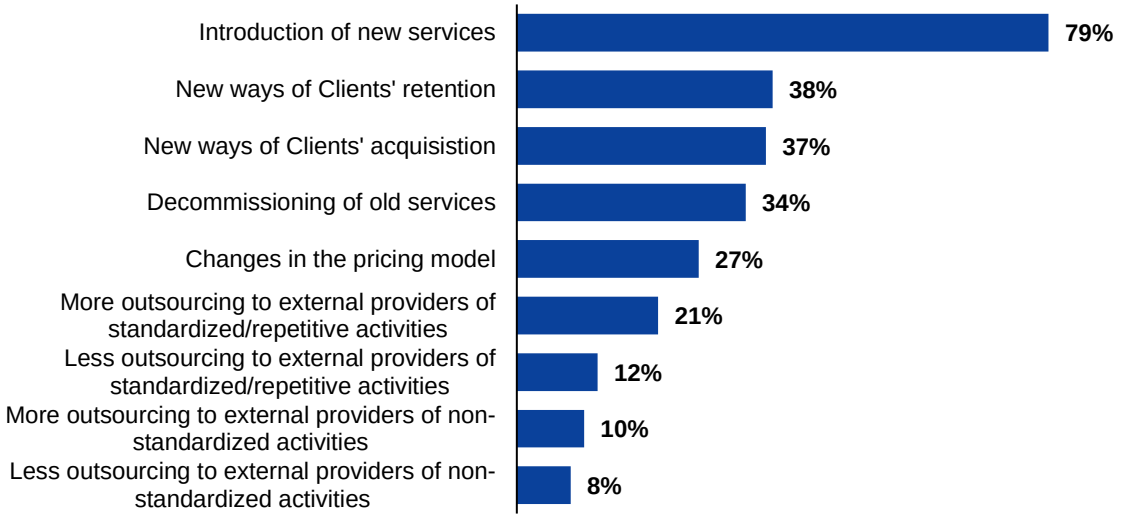


The resulting survey database permitted to build the main variables of interest of our model: the digital automation adoption and intensity and the perception of regulation, along with other firms' characteristics.

A preliminary analysis of the survey results allows to outline the state of play in digital automation of the four professional services. One relevant observation is that 43% of the respondents declared that digital automation led to a change in their business model, and 79% of those said that it led to the introduction of new services (Figure 2).

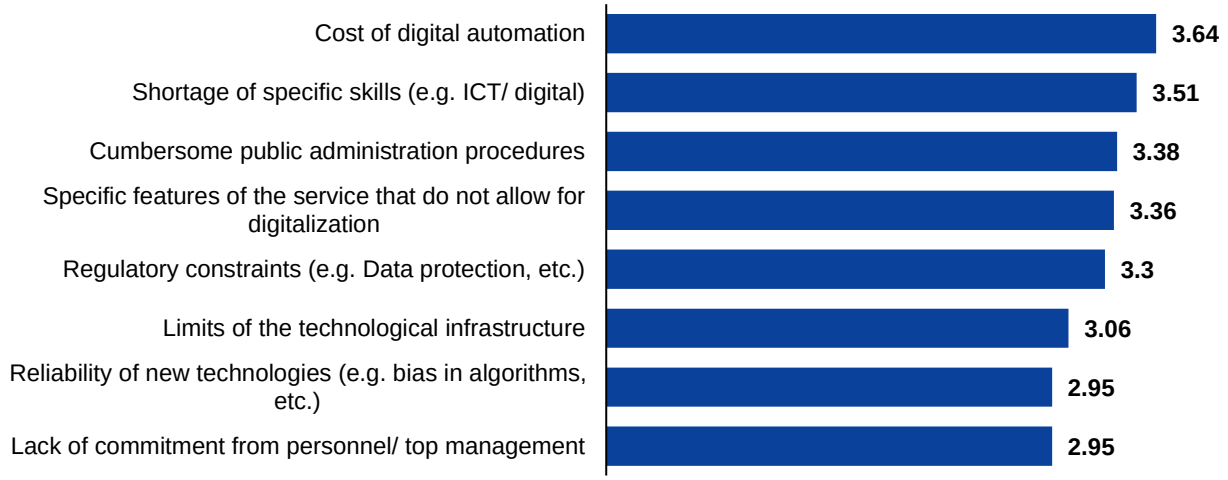
[7]For further details see Table II in the Annex and Chapter 2 of the Report.

Figure 2: Has the adoption of digital automation led to changes in your business model? If yes, which one? - For each business model change, share of respondents who adopted that change



Turning to the obstacles to the adoption of digital automation, the two main obstacles to automation that result from the survey are the cost of investing in digital automation and the shortage of digital skills.

Figure 3: How do you assess the relevance of the following obstacles that could arise when introducing digital automation solutions? - Average relevance (out of 5) of each obstacle stemming from digital automation according to respondents

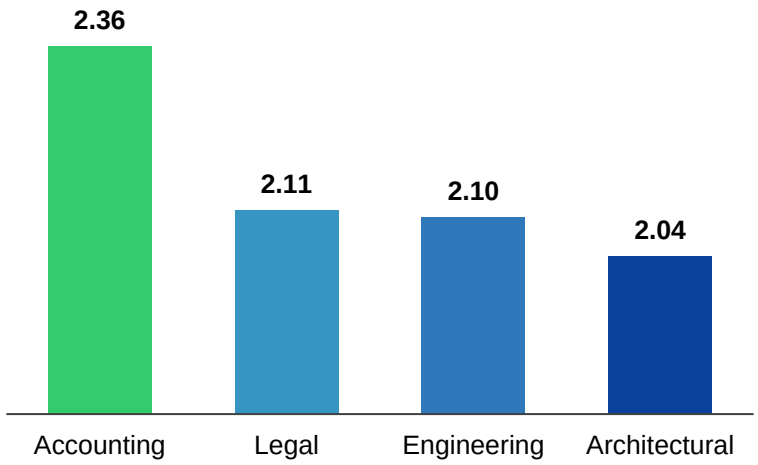


Leveraging on six questions concerning the digital automation level, a synthetic digital automation index was built. The index provides a comparable measure to evaluate the degree of digital automation for each respondent and provides a quantitative measure of automation intensity for the econometric analysis. It was constructed by combining professionals' self-assessment of the number and type of automated activities adopted, the number and type of technologies adopted, and the level of ICT expenditure. The

value of the index ranges from 1 to 5 where 1 stands for “no digital automation at all” and 5 “the highest level of automation given the available technologies”.

The resulting index shows that larger firms have a higher index of automation adoption. The index also shows that the accounting profession is the most automated, while architectural services the least (Figure 4).

Figure 4: Synthetic index by professional service



As regards regulation, the survey showed that respondents perceive that regulation can be an obstacle to adopting digital automation solutions. While several restrictions are mentioned to have an impact, each professional category identifies different aspects of the regulatory environment specific to its activity. As for digital automation, the question on regulation was exploited to produce a measure of perceived regulatory environment to be used in the subsequent econometric analysis. The perceived regulation index was constructed by combining the respondents' assessment of specific regulatory restrictions.

Figure 5: Average perceived negative impact (out of 5) of regulation on digital automation, by sector

3.2. Other control variables

Other variables complement the analysis to control for external factors impacting on the choice to adopt digital automation. External factors include country-level infrastructural variables concerning the availability of fast broadband internet and capabilities factors, such as the availability of high-skill human capital. This country-level information was retrieved from The Community survey on ICT usage in households and by individuals and the Community survey on ICT usage in enterprises (EUROSTAT). The two surveys collect data on the use of information and communication technology, the internet, e-government, e-business and e-commerce and can be used to evaluate both consumers and enterprises' level of digitalization. In addition, the surveys provide useful information on the availability of digital skills among individuals and enterprises.

4. Methodology

According to the main findings and approaches stressed by the economic literature, we implement two different and complementary approaches to assess the relevance of the regulatory framework on the digital automation adoption in the selected professional services. The first research objective is to investigate which factors affect the choice to adopt digital automation and to what extent. In other words, the model tests whether professional regulation, along with other relevant internal and external factors, affects the decision of each firm to start (or not) automation.

The second research question concerns the impact of relevant factors on the intensity of automation. According to the methodological findings highlighted in the literature review, a selection model was implemented to investigate the links between a set of exogenous variables and the intensity of adoption of the automation technologies (for the firms which have introduced them).

Relying on the combination of the different sources (survey and environmental variables), the econometric analysis was carried out at the respondent/firm-level and explored two different relationships and measures of digital automation exploiting two complementary methodologies. First, a probit model was implemented with the aim of exploring the relationship between the choice of adopting digital automation and regulation. The estimating equation is the following:

$$Automation\ choice_i = \beta_0 + \beta_1 * Regulation_i + Z_i + X_c + \eta_c + \varepsilon_i$$

where $Automation\ choice_i$ is the binary dependent variable which is equal to one if firm engages in digital automation, and equal to zero if the firm does not adopt digital automation.

Conventionally, information on automation choice is retrieved from Question Q16 of the survey asking "If digital automation were a journey, where would your practice be on that journey as of today?". Answers to this question where coded as following:

$$Automation\ choice = 0\ if \begin{cases} Q16 = «We\ Have\ not\ started\ yet» \\ Q16 = «We\ have\ started\ but\ we\ are\ at\ the\ beginning/early\ stages\ » \\ Q16 = «\ Not\ sure\ » \end{cases}$$

$$Automation\ choice = 1\ if \begin{cases} Q16 = «We\ have\ been\ on\ the\ journey\ for\ some\ time, but\ it\ is\ not\ over\ yet» \\ Q16 = «We\ have\ almost\ reached\ our\ destination» \end{cases}$$

The main explanatory variable of interest is $Regulation_i$, which captures the regulatory perception level of each respondent *i* . The variable is constructed from the information retrieved from the survey as it has been elaborated reporting the average perceived negative impact of regulations on digital automation. In particular, question 32 asking "To what extent the following rules of access and conduct might constitute an obstacle to digital automation?" has been selected as source of information concerning the perceived level of regulation. For the calculation of the index, each answer to each of the 12 rules of access and conduct listed has been associated with a parametric value from a minimum of 1 to a maximum of 5. For each respondent, an index value is computed. Thus, the regulation index ranges from 1 to 5, where 1 represents "no perceived impact of regulation" and 5 "the highest impact of regulation to digital automation".

The vectors Z_i and X_c contain respondent-specific control variables (retrieved from the survey) and country-specific control variables (retrieved from Eurostat), respectively. These variables include:

- **Structural variables**: respondent-level data retrieved from the survey about:
  - Size (revenues range and growth)
  - Broadband available at the firm
  - Other information from the survey (e.g. financial constraints binding automation decisions, …)
- **Infrastructural variables:** Information for each country about broadband speed;
- **Capabilities factors:** variables that should help to take into account other intangible elements which can have a role in the digital automation adoption process (e.g. level of digital skills at country level).

We include country-specific fixed effects, η_c, in order to control for unobserved country characteristics. Finally, ε_i is the observation specific error term.

The probit model is run in three different specifications:

1. Aggregate data pooling professions: one single regression controlling for country-specific and profession-specific effects.
2. Professional service-specific: four regressions, one for each professional service under scrutiny, controlling for country-specific effects.
3. Professional service- and regulation-specific: 48 regressions: one for each professional service, testing separately each of the 12 regulation items (reserve of activities, qualification requirements, …) instead of regulation index.

In the second step, the scope of the analysis shifts from the choice to adopt to the degree of digital automation, aiming at assessing the factors that have an impact on the automation level of the adopters.

With particular regard to the technical aspects of the empirical analysis, the econometric literature on the regulation-innovation relationship (e.g. Blind et al., 2017), places a special emphasis on the Heckman selection model (1979) when the aim of the analysis is to investigate the intensity of technology adoption with respect to changes in the regulatory context. It is indeed stressed that companies that introduce innovation are not a random subset of the entire sample, so a two steps procedure is necessary to first isolate the adopters from the non-adopters and then, on a second stage, measure the intensity of the formers over a more balanced set of observations. Failure to take into account this self-selection element would lead to results that suffer from a selection bias. It should be noted that this argument does not hold when innovation is measured by a binary variable (adopting or not). The selection bias in Heckman sense would, in that case, only suggest that an OLS model linking the intensity of digital automation to the regulation would be biased, but would not signal any bias in the relationship between the choice of adopting (or not) digital automation and regulation.

Therefore, a sample-selection[8] approach is implemented, following the empirical literature on automation/innovation. The procedure basically consists of two steps: a selection model, which in its specification follows closely the probit model presented in the previous paragraph, and an output model, which links the intensity of adoption of the automation technologies (measured with the synthetic index elaborated from the survey and described in paragraph 3.1), for the firms that have introduced them, to a set of explanatory variables.

Given the regression equation:

$$Automation^* = \beta_0 + \beta_1 * Regulation + \beta_i * Control\,Variables$$

The selection equation is a probit model where:

$$Automation\ choice = \begin{cases} \gamma_0 + \gamma_i * Z \ \ if\, Automation^* > 0 \\ 0\ if\, Automation^* \ \leq 0 \end{cases}$$

And is modeled as the probit tested above, which gives consistent and robust estimates.

[8] The model we estimate is a model where the dependent variable is distributed over a range of values, but take on focal point. We have in our case an index of automation that has a continuous distribution over strictly positive values whereby there is a possibility that the variable takes the value of 0 (not adopting and therefore no intensity). In this case, Heckman 2-step procedure for a corner solution model can be used.

From the estimates of the selection model, the nonselection hazard—what Heckman (1979) referred to as the inverse of the Mills' ratio, m_j—for each observation j is computed as

$$m_j = \frac{\varphi(Z\hat{\gamma})}{\phi(Z\hat{\gamma})}$$

Where φ is the standard normal probability density function and ϕ the standard normal cumulative distribution function.

In the second step, the output model, which links the intensity of adoption of the automation technologies, for the firms which have introduced it, to a set of exogenous variables, corrected for the selection bias (the inverse Mills' ratio), is estimated following:

$$Automation\ intensity_j = \beta_0 + \beta_1 * Regulation_j + \beta_i * Control\ Variables_j + \ \delta * m_j$$

Where automation intensity is measured as the synthetic index elaborated in par. 3.1.[9] and control variables are once again retrieved from the above-mentioned exogenous variables. The econometric work involves the entire wide spectrum of variables obtained by the combination of the different data sources and guarantees for the selection model and the output model the choice of the most reliable specification both from the econometric and the economic point of view.

While the selection model replicates the probit model tested above with some minor changes[10], the second step, the output model, tests some different control variables[11], that might have a more significant impact on automation intensity rather than choice.

Likewise the probit model, three specifications are tested: a pooled model, a professional service-specific and the last one testing professional service- and regulation-specific regressions. In the specifications tested, we generally find a significant selection bias suggesting that an OLS model linking the intensity of digital automation to regulation would be biased. On the other hand, the selection equation remains strongly negative, thus the relationship between the choice of adopting (or not) digital automation and regulation is confirmed negative.

5. Results

5.1. Automation adoption - Probit model

Table 2 summarizes the regression outcomes, including coefficient estimates for the regulatory index, as well as the relevant infrastructural and environmental factors, for the whole survey sample. Overall, an increase in the perception of the strength of regulatory obstacles is shown to be significantly negatively related to the decision to engage in digital automation. In other words, the model finds that when firms perceive regulation as a greater obstacle, they are less prone to engage in digital automation activities (choosing not to start the digitalization process at all).

[9] Aiming at keeping a consistent measure of automation intensity, we employed the index elaborated in par. 3.1. To check robustness, we also tested regulation against each single component and their different aggregations (e.g. only Q17 and Q18). Different specifications confirm results are robust and consistent.

[10] Digital skills were removed from the list of control variables and tested only in the output model.

[11] Heckman procedure requires that variables should differ in the two steps. Generally, an exclusion restriction is required to generate credible estimates.

Table 2: Probit results, pooled model

	Automation choice
Regulation	-0.0847**
	(0.005)
Revenues	0.137***
	(0.000)
Trends of revenues over the last 3 years	0.0283
	(0.414)
Access to high speed internet	0.305***
	(0.000)
Cost of digital automation (e.g. financial costs, time investment etc.)	-0.144***
	(0.000)
Shortage of specific skills (e.g. ICT / Digital)	-0.0828**
	(0.006)
Limits of the technological infrastructure (e.g. limited access to high speed internet connection)	-0.0268
	(0.250)
Broadband Speed	0.175
	(0.276)
Digital skills	-0.121
	(0.070)
Constant	-2.384
	(0.745)
Observations	2930
Professional service fixed effects	Yes
Country fixed effects	Yes

p-values in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Other variables appear to be significantly related to the digital automation choice: structural variables such as size and growth are positively related, thus larger and growing firms are more likely to be adopters; while infrastructural barriers such as lack of access to high speed internet and shortage of specific IT skills prevent firms to adopt. Country specific characteristics such as Broadband speed and Digital skills available seem to be less related[12] to the choice to adopt digital automation although the direction of the impact suggest there is a weak relationship (respectively positive and negative).

As put forward in the theoretical framework (par. 2.2), larger firms are more inclined to adopt digital automation, thanks to greater financial and human resources. As expected, in fact, firms with higher revenues have higher chances to adopt digital automation. In terms of infrastructural barriers, access to high-speed internet on premises represents a natural enabler of digital automation. Conversely, a perceived high cost of digital automation (e.g. financial costs, time of the investment etc.) is a self-

[12] Although much of country-specific characteristics is captured by η_c, country-specific effects

explanatory obstacle. On the obstacles side, a shortage of specific ICT and digital skills also appears as a factor preventing the firms from adopting digital automation. Country-specific characteristics such as broadband speed and digital skills availability seem to be less strongly related to the choice to adopt digital automation, although the direction of the impact suggests that there is a weaker relationship (respectively positive and negative).

The aggregate data gives an overview of the main relationships in place between the perception of the regulatory framework and the digital automation choice. To obtain a better understanding of the role of regulation, the analysis digs into each professional service separately and provides a breakdown into twelve specific entry and exercise restrictions (reserve of activities, qualification requirements, …) instead of a composite regulation index, providing further information on the relationship under scrutiny.

Table 3: Probit results, by profession

	Architects	Engineers	Accountants	Lawyers
Regulation	-0.333***	-0.0493	-0.0466	-0.122
	(0.001)	(0.292)	(0.322)	(0.369)
Revenues	0.349**	0.120***	0.154***	0.0179
	(0.003)	(0.000)	(0.000)	(0.830)
Trends of revenues over the last 3 years	0.258*	-0.0613	0.0649	0.251
	(0.016)	(0.215)	(0.283)	(0.102)
Access to high speed internet	0.210	0.310***	0.291*	0.499
	(0.296)	(0.000)	(0.028)	(0.071)
Cost of digital automation (e.g. financial costs, time investment etc.)	-0.148	-0.148**	-0.116*	-0.179
	(0.135)	(0.001)	(0.036)	(0.187)
Shortage of specific skills (e.g. ICT / Digital)	-0.0456	-0.0707	-0.137**	0.0232
	(0.641)	(0.103)	(0.007)	(0.851)
Limits of the technological infrastructure (e.g. limited access to high speed in	0.0826	-0.0477	-0.0122	-0.175
	(0.246)	(0.171)	(0.750)	(0.096)
Broadband Speed	0.0359	0.00228	-0.0138	0.00510
	(0.079)	(0.833)	(0.230)	(0.910)
Digital skills	0.0292	0.00959	-0.0143	-0.0482
	(0.091)	(0.640)	(0.672)	(0.576)
Constant	-2.621	0.484	2.007	2.864
	(0.111)	(0.604)	(0.053)	(0.218)
Observations	293	1281	1155	170
Country fixed effects	Yes	Yes	Yes	Yes

p-values in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Professional service-specific investigation (Table 3) allows to confirm the direction of the relationship, which is significantly strong especially for the architects. The drilldown of the specific regulations (Table 4) provides further information on the relationship under scrutiny with few regulations being more strongly related to digital automation than others (e.g. Reserve of activities appears to be the most discouraging regulation), while some appear significant only to certain professions (the architects surveyed seem to be more sensitive to regulation barriers).

Table 4: Probit results, by profession and type of regulation

Automation choice	**Architects**	**Engineers**	**Accountants**	**Lawyers**
Reserve of activities	-0.140	-0.056	-0.067	-0.246*
	(0.059)	*(0.125)*	*(0.076)*	*(0.021)*
Qualification requirements	-0.135	-0.047	-0.0848*	-0.096
	(0.057)	*(0.183)*	*(0.016)*	*(0.350)*
Continuous professional devlopment obligations	-0.086	-0.029	-0.035	-0.132
	(0.185)	*(0.380)*	*(0.341)*	*(0.194)*
Compulsory membership or registration in professional body	-0.195**	-0.017	0.007	-0.057
	(0.003)	*(-0.5)76*	*(0.843)*	*(0.580)*
Limitation of the number of licenses granted	-0.043	-0.044	-0.004	-0.142
	(0.516)	*(0.181)*	*(0.900)*	*(0.170)*
Restriction on corporate form	-0.165*	0.000	-0.045	0.004
	(0.018)	*(0.998)*	*(0.226)*	*(0.967)*
Shareholding requirements and/or voting rights control	-0.149	-0.005	-0.047	-0.016
	(0.053)	*(0.885)*	*(0.216)*	*(0.874)*
Restrictions on joint exercise of professions	-0.104	-0.032	-0.009	-0.095
	(0.142)	*(0.357)*	*(0.803)*	*(0.344)*
Incompatibilities of activities	-0.139*	-0.050	-0.011	-0.087
	(0.047)	*(0.161)*	*(0.765)*	*(0.428)*
Obligatory professional indemnity insurance	-0.260***	-0.038	-0.019	-0.059
	(0.000)	*(0.232)*	*(0.593)*	*(0.542)*
Tariff restrictions	-0.199**	-0.027	0.019	0.023
	(0.004)	*(0.408)*	*(0.599)*	*(0.814)*
Advertising restrictions	-0.145*	0.054	0.026	0.055
	(0.034)	*(0.125)*	*(0.481)*	*(0.554)*

p-values in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Note that only coefficients and p-values of automation dummy are reported, although the specification employed for each regulation and each sector controls for the same variables as the previous two outlined models

Architects

A higher coefficient (in absolute value) on regulation with respect to the pooled regression findings suggests that among surveyed professional categories, architects are more sensitive to regulation barriers than others (Table 3). Indeed, the descriptive analysis presented in par. 3.1 anticipated that architects were the professionals who feel most hampered by the rules of access and conduct. Moreover, regulation appears to have a much more significant impact on digital automation choices, as opposed to other structural variables that have limited statistical significance: access to high speed internet, cost of digital automation and shortage of specific skills seem to be less related to the decision to adopt with respect to the aggregate results. This might imply that architects, among other professionals, are much less constrained by the infrastructure, as the adoption of key specific technologies is paramount for competition in the sector. Moreover, most of the digital instruments used for design do not strictly require broadband connection or a sophisticated technological infrastructure. Alternatively, a different perspective could involve the nature of digital automation in this professional service. Differently from accountants and lawyers, architects often employ digital automation technologies during their day-to-day activities, and acquire the related skills throughout their educational path.

Concerning specific regulations (Table 4), architects surveyed signal almost all of the regulation items represent an obstacle to entering the digital automation journey. The highest coefficients are found on "obligatory professional indemnity insurance", "tariff restrictions" and "compulsory memberships or registration in professional body". According to the Commission document on Reform recommendations for regulation in professional services (European Commission, 2017), insurance requirements are some of the most widespread elements in the regulation for this profession in the EU, since public security and safety, protection of service recipients and the environment are the most commonly quoted justifications for regulating this profession. As described in the theoretical framework, although "obligatory professional indemnity insurance" and "compulsory memberships or registration in professional body" might not be strictly connected to digital automation capacity, they might be perceived as burdensome expenses that drain resources that could be allocated to investment in automation. More than the other professional services, architects perceive tariff restrictions as an important obstacle to automation. Indeed, as put forward in theoretical framework proposed at par. 2.2., suggested or minimum tariffs might allow prices to remain above the competitive levels thus limiting price competition and thus incentives to innovate. A further obstacle to competition might derive from advertisement restrictions that could prevent architects to invest. This would impact on them directly, since advertisement, and online advertisement such as the development of a website and other digital channels and media, would increase competition and hence stimulate digital automation adoption. Other two exercise requirements appear to be negatively related to the incentive to innovate: incompatibilities of activities and restrictions on corporate forms. Both these restrictions might represent an obstacle to dimensional growth and thus access to finance, limiting the scope for investment on digital automation.

Engineers

Overall, regulation does not appear to be an obstacle (the overall coefficient in Table 3 is not statistically significant) to digital automation adoption. Main drivers of the choice to engage in digital automation activities seem to be infrastructural factors. Other than revenues, access to high-speed band emerges as the main enabler. On the contrary, the cost of digital automation appears to be the highest barrier to automation, relatively more than in the other regulated professions. Costs associated to digital automation seem thus to weigh more on the decision to go digital, and this might relate to the high costs of the technologies for this profession or to a different awareness of their costs. As is the case with

architects, the shortage of specific skills does not appear to be an obstacle, as education programmes already integrate a large amount of technical and technological training.

In line with the findings of the aggregate regulation index analysis, the analysis of its components does not reveal any of the specific regulation having a strong impact on the automation adoption. With weakly significant coefficients, reserve of activities, qualification requirements, limitation of the licences granted, incompatibilities of activities and advertising restrictions are the regulations that appear as the most salient obstacles to engineers. These results, adding up to the general finding on firm size being an important driver of adoption, suggest regulations that place an obstacle to dimensional growth and firms' access to finance (such as restrictions on corporate form or shareholding requirements) represent a relevant hurdle in the decision to start adopting new automation tools or digitalize activities.

Accountants

The overall regulation index is not significantly related to the choice to adopt digital automation. As for the other variables, infrastructural obstacles such as size and access to high speed internet are significant hurdles to automation. However, the most striking outcome of the model is that shortage of ICT and digital skills emerges as a significant barrier to automation, relatively more than in other professions. One possible explanation could stem from the nature of digital automation in this profession, which demands specific ICT skills that are not embedded into the conventional educational path of an accountant, and would thus require investment in dedicated staff or additional training.

As regards specific regulations, qualification requirements appear to be the most strongly related to the choice to opt for digital automation and therefore represent the largest obstacle. If matched with the finding on specific skills, one might hypothesize that the qualification required to practice the profession does not provide significant digital skills required to implement digital automation tools. A weak significance on reserve of activities points in the same direction, as specialization in the activities reserved to accountants might represent a skill mismatch and thus an obstacle to expand abilities, effort and skills into digital transformation.

Lawyers

Similarly to engineers and accountants, regulation overall does not appear to be a significant obstacle to digital automation adoption. In addition to this, despite displaying the same direction, in terms of sign, to the results for other professions, most of the variables under scrutiny do not seem to significantly affect the digital automation choice (Table 4).

However, the analysis of the regulation components reveals that reserves of activities is a factor that significantly inhibits the adoption of digital automation. Similar to accountants, a possible explanation may lie in the skill mismatch, when specialization in specific activities and skills relevant for legal services diverts resources and time that might be invested in digital automation training and development. Indeed, as resulted from interviews with legal experts conducted in the Report (see p. 118), implementing and developing automation implies the need of having a team of resources with specific transversal skills that need some time and effort to build. Most importantly, as stressed in par. 2.2, reserve of activities act together with the other entry and conduct restrictions automatically triggering the impacts of all the other restrictions that apply to these providers and can directly prevent the provision of certain services online. For instance, reserve of activities may lead to difficulties in areas such as the provision of online legal consultations and digital automation of legal documents by non-lawyers.

5.2. Automation intensity - Heckman model

Overall, the Heckman model finds that when firms adopt digital automation, their perception of intensity of regulation increases along with their automation intensity. Keeping in mind that regulation in this analysis is not an exogenous variable (see par. 5.3), this might be explained by a stronger and more conscious perception of the regulatory environment by the firms that are advanced in their automation journey. Nevertheless, once the relationship is broken down to specific restrictions, it appears that the positive relationship between automation intensity and perceived regulation is significant mostly because of tariffs across professions and corporate form restrictions for lawyers, thus signaling restrictions on tariffs might drive the positive relationship. Along with some of the infrastructural variables tested in the probit model, the output model was enriched with other information from the survey, including "competition from online professional services providers" and "benefits from the implementation of digital automation". The first measure is the answer to the question "In your opinion, how much competition is your business / company facing from online professional services providers?"; our estimates find that professionals who feel competition from online competitors report higher levels of digital automation; online providers therefore appear to be a stimulus to invest in digital automation. Conversely, it might indicate that professionals who invest the most in digital automation are also more aware of the competition they are facing from online providers. Furthermore, benefits from the implementation of digital solutions are also felt as higher for those who display a higher level of digital automation, a sign of higher awareness by those who are at the frontier of technological and digital innovation. Differently from the probit model, shortage of specific skills (e.g. ICT/ Digital) in the firm is positively related with automation intensity, as for regulation, the interpretation might lie in the strongest perception of the importance of digital skills by adopters of digital automation. In other words, the more advanced in their automation journey, the more firms acknowledge shortage of skills as a salient obstacle to automation.

The results are reported in the following tables.

Table 5: Heckman results, pooled model

	Automation intensity
Regulation	0.0676***
	(0.000)
Competition from online professional services providers	0.0380***
	(0.000)
Trends of revenues over the last 3 years	0.0709**
	(0.001)
Benefits from the implementation of digital automation solutions (Yes/ No)	0.400***
	(0.000)
Shortage of specific skills (e.g. ICT / Digital)	0.0378*
	(0.035)
Digital skills	0.0399
	(0.206)
Constant	-0.0365
	(0.987)
Automation choice	
Regulation	-0.0757*
	(0.012)
Revenues	0.142***
	(0.000)
Trends of revenues over the last 3 years	0.0270
	(0.439)
Access to high speed internet	0.295***
	(0.000)
Cost of digital automation (e.g. financial costs, time investment etc.)	-0.142***
	(0.000)
Shortage of specific skills (e.g. ICT / Digital)	-0.0864**
	(0.004)
Limits of the technological infrastructure (e.g. limited access to high speed in	-0.0284
	(0.225)
Broadband Speed	-0.0266
	(0.765)
Constant	2.423
	(0.687)
mills	
lambda	-0.547***
	(0.000)
Observations	2890
Professional service fixed effects	Yes
Country fixed effects	Yes

p-values in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 6: Heckman results, by profession

	Architects	Engineers	Accountants	Lawyers
Automation intensity				
Regulation	0.0116	0.126***	0.0138	0.106
	(0.859)	(0.001)	(0.545)	(0.101)
Competition from online professional services providers	0.0493*	0.0432***	0.0289**	0.0118
	(0.021)	(0.000)	(0.009)	(0.669)
Trends of revenues over the last 3 years	0.0696	0.0601	0.101***	0.151
	(0.320)	(0.118)	(0.001)	(0.060)
Benefits from the implementation of digital automation solutions (Yes/ No)	0.412***	0.443***	0.392***	0.360**
	(0.000)	(0.000)	(0.000)	(0.003)
Shortage of specific skills (e.g. ICT / Digital)	0.0143	0.0539	-0.00685	0.0462
	(0.797)	(0.098)	(0.770)	(0.408)
Digital skills	-0.00861	-0.0119	0.00874	-0.0122
	(0.234)	(0.187)	(0.433)	(0.518)
Constant	2.632***	2.439***	1.489*	2.459
	(0.000)	(0.000)	(0.024)	(0.060)
Automation choice				
Regulation	-0.302**	-0.0384	-0.0462	-0.103
	(0.002)	(0.418)	(0.327)	(0.455)
Revenues	0.377**	0.127***	0.155***	0.0192
	(0.002)	(0.000)	(0.000)	(0.822)
Trends of revenues over the last 3 years	0.242*	-0.0582	0.0655	0.252
	(0.026)	(0.243)	(0.280)	(0.103)
Access to high speed internet	0.211	0.293***	0.288*	0.531
	(0.300)	(0.001)	(0.031)	(0.058)
Cost of digital automation (e.g. financial costs, time investment etc.)	-0.153	-0.147**	-0.114*	-0.180
	(0.126)	(0.002)	(0.039)	(0.184)
Shortage of specific skills (e.g. ICT / Digital)	-0.0655	-0.0727	-0.135**	0.0197
	(0.509)	(0.096)	(0.008)	(0.874)
Limits of the technological infrastructure (e.g. limited access to high speed in	0.0869	-0.0497	-0.0143	-0.179
	(0.226)	(0.157)	(0.709)	(0.089)
Broadband Speed	-0.126***	0.274	-0.440***	-0.379***
	(0.000)	(0.975)	(0.000)	(0.000)
Constant	4.420	-13.98	31.31	23.13
	(.)	(.)	(.)	(.)
mills				
lambda	-0.456*	-0.880***	0.131	-0.233
	(0.040)	(0.000)	(0.299)	(0.445)
Observations	289	1274	1157	170
Country fixed effects	No	No	No	No
Dummy Italy	Yes	Yes	Yes	Yes

p-values in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 7: Heckman results, by profession and type of regulation

		Architects	Engineers	Accountants	Lawyers
Reserve of activities	***Automation intensity***	**-0.0864***	**0.012**	**-0.007**	**0.060**
		(0.026)	***(0.590)***	***(0.689)***	***(0.209)***
Regulation index	*Automation choice*	-0.276**	-0.016	-0.036	-0.103
		(0.007)	*(0.733)*	*(0.449)*	*(0.455)*
Qualification requirements	***Automation intensity***	**-0.0803***	**0.016**	**0.006**	**-0.005**
		(0.038)	***(0.480)***	***(0.734)***	***(0.923)***
Regulation index	*Automation choice*	-0.280**	-0.019	-0.036	-0.085
		(0.006)	*(0.686)*	*(0.453)*	*(0.547)*
Continuous professional devlopment obligations	***Automation intensity***	**-0.049**	**0.013**	**0.000**	**-0.044**
		(0.177)	***(0.527)***	***(0.998)***	***(0.361)***
Regulation index	*Automation choice*	-0.302**	-0.029	-0.042	-0.085
		(0.002)	*(0.539)*	*(0.382)*	*(0.547)*
Compulsory membership or registration in professional body	***Automation intensity***	**-0.039**	**0.017**	**0.014**	**-0.001**
		(0.289)	***(0.406)***	***(0.404)***	***(0.990)***
Regulation index	*Automation choice*	-0.286**	-0.020	-0.033	-0.085
		(0.005)	*(0.675)*	*(0.488)*	*(0.547)*
Limitation of the number of licenses granted	***Automation intensity***	**-0.034**	**0.027**	**0.014**	**0.002**
		(0.324)	***(0.186)***	***(0.390)***	***(0.962)***
Regulation index	*Automation choice*	-0.281**	-0.006	-0.023	-0.080
		(0.006)	*(0.903)*	*(0.627)*	*(0.572)*
Restriction on corporate form	***Automation intensity***	**0.011**	**0.022**	**0.003**	**0.103***
		(0.777)	***(0.328)***	***(0.874)***	***(0.015)***
Regulation index	*Automation choice*	-0.262*	0.073	-0.012	-0.072
		(0.011)	*(0.151)*	*(0.810)*	*(0.611)*
Shareholding requirements and/or voting rights control	***Automation intensity***	**0.008**	**0.010**	**0.013**	**0.084**
		(0.859)	***(0.683)***	***(0.478)***	***(0.066)***
Regulation index	*Automation choice*	-0.229*	0.103*	-0.007	-0.012
		(0.028)	*(0.047)*	*(0.888)*	*(0.934)*
Restrictions on joint exercise of professions	***Automation intensity***	**0.001**	**0.024**	**0.015**	**0.076**
		(0.974)	***(0.290)***	***(0.365)***	***(0.081)***
Regulation index	*Automation choice*	-0.244*	0.065	0.000	0.002
		(0.018)	*(0.195)*	*(0.993)*	*(0.989)*
Incompatibilities of activities	***Automation intensity***	**0.030**	**-0.002**	**0.012**	**0.096**
		(0.467)	***(0.926)***	***(0.469)***	***(0.068)***
Regulation index	*Automation choice*	-0.222*	0.086	-0.011	-0.020
		(0.034)	*(0.091)*	*(0.820)*	*(0.891)*
Obligatory professional indemnity insurance	***Automation intensity***	**-0.002**	**0.007**	**0.005**	**0.026**
		(0.959)	***(0.718)***	***(0.771)***	***(0.543)***
Regulation index	*Automation choice*	-0.257*	0.013	-0.022	-0.026
		(0.013)	*(0.794)*	*(0.647)*	*(0.859)*
Tariff restrictions	***Automation intensity***	**0.0452***	**0.0507*****	**0.0301****	**0.011**
		(0.040)	***(0.000)***	***(0.007)***	***(0.708)***
Regulation index	*Automation choice*	-0.273**	0.029	0.003	-0.064
		(0.008)	*(0.564)*	*(0.943)*	*(0.657)*
Advertising restrictions	***Automation intensity***	**-0.011**	**0.021**	**0.004**	**0.051**
		(0.749)	***(0.370)***	***(0.813)***	***(0.206)***
Regulation index	*Automation choice*	-0.250*	0.063	-0.008	-0.051
		(0.016)	*(0.208)*	*(0.875)*	*(0.717)*

p-values in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Note that only coefficients and p-values of automation dummy are reported, although the specification employed for each regulation and each sector controls for the same variables as the previous two outlined models.

Architects

Table 6 suggests the positive relationship between automation intensity and regulation perception is not significant for the architects surveyed. Hence, although the regulation appeared to be an obstacle in the choice of whether to adopt automation or not, adopters do not seem to be affected by their perception of regulation in their level of digital automation. Interestingly, the only variables that seem to be significant for the intensity of automation are "competition from online professional service providers" and "Benefits from the implementation of digital automation". On the other hand, when looking at specific regulations, the estimates provide evidence of a negative relationship of reserves of activities and qualification requirements with automation intensity. These two restrictions did not appear to be significant obstacles to adopt digital automation, according to the probit regression. It thus seems that, instead, architects perceive reserve of activities and qualification requirements as less salient obstacle when they advance in their automation journey. Evidence is mixed though, as the "tariff restrictions" coefficient is estimated to be positive.

Engineers

Engineers seem to be the professionals who display the most significant and positive relationship between their regulation perception and automation intensity. In other words, the more intense the adoption of digital automation is, the more regulation is perceived as an obstacle to it. Moreover, competition from online professional service providers is found to be an important driver of digital automation intensity. As regards specific regulations (Table 7), the estimates suggest that, as for architects, only tariff restriction is positively associated with higher levels of digital automation.

Accountants

Overall, for accountants, it does not appear that a significant relationship between regulation and automation intensity exists. Main drivers of automation intensity seem to be competition from online providers, trends of revenues over the last three years and benefits from the implementation of digital automation. Among the professionals, accountants are the only ones who display a positive relationship between trend of revenues and automation intensity, thus confirming the hypothesis of a peculiar and specific nature of automation solutions, which probably require highly skilled staff and considerable investments. The analysis of specific regulations highlights a pattern comparable to that observed for architects and engineers, with tariff restrictions being the only regulation significantly and positively related to automation intensity. For these three professions the overall positive relationship seems to be driven by the result on tariffs. As put forward in the theoretical framework, minimum tariffs would prevent professional service providers from competing on price, while simultaneously protect less efficient competitors and limiting the incentive to improve quality and innovate. Conversely, maximum tariffs could discourage investment in automation by reducing profitability and future prospects of profits. Both interpretations could fit the hypothesis that higher tariff restrictions, by imposing restrictions on investment capacity and price competition could be perceived as obstacles to digital automation.

Lawyers

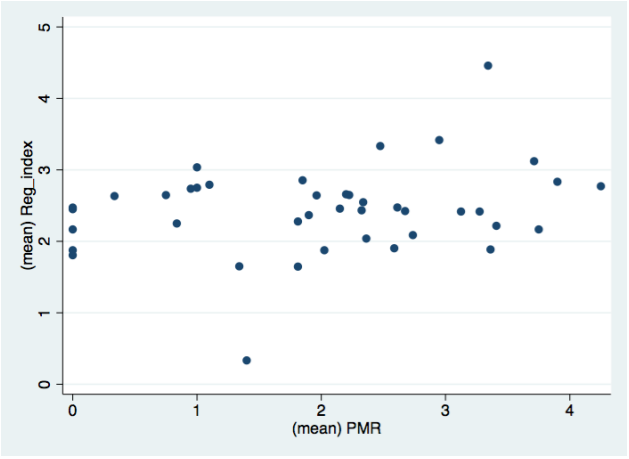
As for automation adoption, estimates on automation intensity for lawyers do not spotlight any significant driver or obstacle, as none of the variable coefficients are significant, with benefits from the implementation of digital automation solutions representing the only exception. Concerning specific regulations, restrictions on corporate forms appear to be significantly and positively related to automation intensity, along with the weakly significant shareholding requirements and/or the control of voting rights, restrictions on joint exercise of professions, and incompatibilities of activities. All in all, it appears that in case of lawyers, corporate requirements are positively related with automation intensity and that lawyers perceive these restrictions relatively more acutely.

5.3. Subjective and Objective Regulation

In this paper we adopt a "subjective" perspective on regulation, as opposed to an "objective" measure provided by *de jure* indicators of regulatory restrictiveness, such as the OECD Product Market Regulation (PMR) index. The "subjective" regulation index has been elaborated reporting the average perceived negative impact of regulations on digital automation. Therefore, this indicator aims at capturing the level of perception of regulation for each respondent. Used as the main explanatory variable in the assessment of the impact of the regulatory framework on digital automation, this "subjective regulation" index measures how much each respondent perceives regulation as an obstacle.

The relationship between "subjective" and "objective" regulation is depicted in Figure 6.

Figure 6: Scatter plot between "objective" (horizontal axis) and "subjective" regulation (vertical axis)



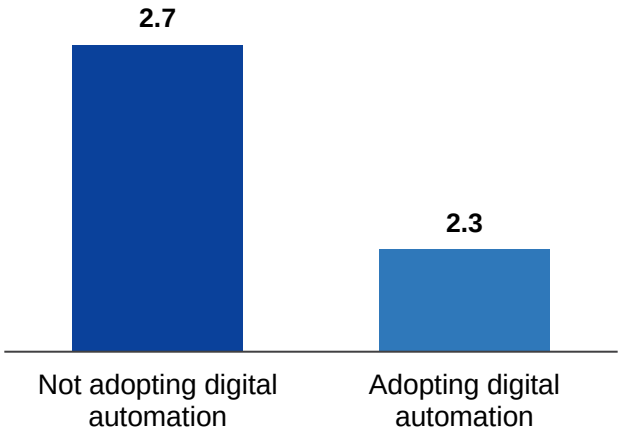
The scatter plot of the OECD PMR index vs the constructed Regulation index shows that the "subjective" perception of regulation by firms and the "objective level" of regulation are not correlated. One would expect that higher levels of PMR correspond to higher levels of regulation index, instead the cloud does not follow any trajectory that would indicate a relationship is in place. Graphical evidence is supported by correlation estimates (far from 1) and regression results (when regressing Regulation Index on PMR, the resulting coefficient is very close to 0). Looking at sector levels, no correlation is found, not even in the ranking of sectors.

There might be a number of possible explanations for the departure between "subjective" regulation intensity from the "objective" one. One explanation is that the survey does not ask about the level of regulation (which would mirror PMR construction questionnaire), rather, respondents are asked whether the regulation constitutes an obstacle to automation. Thus, the answers would provide a measure of perception rather than a degree of regulation. Another possible interpretation is that perception does not reflect the status quo and because of a knowledge bias, respondents might not be fully aware of the

regulatory framework, either due to scarce information received or researched, or because of poor transparency of the regulatory framework.

Since subjective and objective regulation are not providing correlated information, results from previous models should be read and interpreted carefully. The first model, for instance, assessing the choice to adopt automation or not, finds that when firms perceive regulation as a greater obstacle, they are less prone to engage in digital automation activities (choose not to start the digitalization process). Moreover, the Heckman model tells us that adopters have a stronger and more conscious perception of the regulatory environment the more their firm is ahead in its automation journey. Figure 7 compares median regulation index by state of adoption, and it can be seen that non-adopters score higher. While divergence between the practical understanding of the relevant regulation by professionals and the *de jure* situation as measured by standard indicators suggests caution in the interpretation of the results, this subjective perception of the regulatory restrictiveness appears to be relevant to the firms' innovation strategies, indicating an important role of regulation in their decision-making.

Figure 7: Median Regulation index by state of adoption of digital automation



6. Conclusions and policy implications

This paper presents new evidence on the relationship between the regulatory environment and the adoption of automated processes in professional services. Survey results on the perception of excessive regulation as a deterrent to technology adoption are used to assess whether general literature findings, apply to European firms in professional services. Two econometric models are specified to test the research question. The first model, a probit model, estimates how the perceived level of regulation influences the probability of a firm to adopt digital automation. Focusing on the adopters, the second model, a Heckman selection model, estimates how regulation affects the intensity of digital automation.

We find that regulation restrictiveness is negatively correlated to the adoption of technology. In particular, the higher the perception of regulation, the lower the probability that firms engage in digital automation. Furthermore, specific forms of regulation (regulatory exclusiveness and qualification requirements in particular) exert a significant impact on the adoption (or not). However, in terms of automation intensity, the results are less straightforward. In other words, regulation is perceived more as an entry barrier rather than a determinant of the scale of the investment.

This evidence calls other results on how specific forms of regulation might affect digital strategies and specifically how to improve them. The results of the regulation-specific regression (Table 4) call in

particular for a thorough review of the scope of reserved activities, especially when it seems too wide or rather inconsistent. Moreover, we find that larger firms are more prone to adopt digital automation. In terms of policy implications, the finding points out how economies of scale work as an enabler of digital automation. Regulations that end up, even indirectly, limiting businesses in terms of size (by prohibiting for instance access to new markets or certain corporate forms) should be then seen as discouraging digital automation.

Other factors, beyond regulation and more related to the business environment, as, for instance, broadband and IT skills availability, prove to influence firms' digital strategies. Policy implication for these environmental variables do not strictly entail regulation for professional services, but still call for action in order to favour within the EU those conditions enabling digital automation. In other words, the estimates suggest that policy interventions should combine initiatives to address some overlapping innovation triggers (5G infrastructure, STEM education, …) and industry-specific types of reform to work as an incentive for digital automation in professional services.

7. References

Andrews, D., G. Nicoletti and C. Timiliotitis, 'Digital technology diffusion: a matter of capabilities, incentives or both?', *OECD Economics Department Working Paper* n.476, 2018.

Arnold, J., Javorcik, S. and Matoo. A., 'Does Services Liberalization Benefit Manufacturing Firms? Evidence from Czech Republic', *World Bank Policy Research Working Paper*, N. 4109, 2007.

Audretsch, D, B., Baumol, W. J., Burke, A. E., 'Competition policy in Dynamic markets', 19, *International Journal of Industrial organization*. 19, pp.613-634, 2001.

Barone, G. and Cingano, F. 'Service regulation and growth: evidence from OECD countries', *Economic Journal*, 121, 931-957, 2011.

Baumol, W., Ordover, J., 'Antitrust Policy and High-technology Industries', *Oxford Review of Economic Policy*, Oxford University Press, Oxford, 4(4), pp. 13-34, 1988.

Blind, K., 'The Impact of Regulation on Innovation', *Nesta Working Paper* No. 12/02, London, 2012.

Blind, K., Petersen, S.S and Riillo, C.A.F., 'The impact of standards and regulation on innovation in uncertain markets', *Research Policy*, 46(1), 2017.

Bouis, R. and Duval, R., 'Raising potential growth after the crisis: a quantitative assessment of the potential gains from various structural reforms in the OECD area and beyond', *OECD Economics Department Working Papers*, No. 835, 2011.

Bryson, J.R., and P.W. Daniels, 'Skills, expertise and innovation in the developing knowledge economy: the case of business and professional services', International Journal od Services Technology and Management, 9, 3-4, 2008.

Canton, E., Ciriaci, D. and Solera, I., 'The Economic Impact of Professional Services Liberalisation', *Economic Papers* 533, September, European Commission, Brussels, 2014.

Carlin, W. and D. Soskice, *Macroeconomics: Imperfections, Institutions and Policies*, Oxford University Press, Oxford, 2006.

Cette G., Lopez, J. and Mairesse, J., 'Product and Labor Market Regulations, Production Prices, Wages and Productivity', *NBER Working Paper* 20563, 2014.

Criscuolo, P, A. Salter and T. Sheehan, 'Making Knowledge Visible: Using Expert Yellow Pages to Map Capabilities in Professional Services', Research Policy, 36 (10), 2007.

CSES, Centre for Strategy & Evaluation Services, 'Study to Provide an Inventory of Reserves of Activities linked to Professional Qualification Requirements in 13 EU Member States and assessing their economic impact', Final Report, study carried out for European Commission's DG Internal Market and Services, 2012.

European Commission, 'Better regulations for innovation-driven investment at EU level', *Staff Working Document*, 2016.

European Commission, 'Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on reform recommendations for regulation in professional services', *Commission Staff Working Document,* 2017.

European Commission, 'Regulatory barriers and firm innovation performance', *Business Innovation Observato*ry, 2018.

European Parliament, 'Economic effects of reform in professional services', Briefing PE 607.337, 2017.

Ferracane, M.F., Van Der Marel, E. L., 'Digital Innovation in East Asia: Do Restrictive Data Policies Matter'. *Policy Research working paper*, no. WPS 9124, World Bank Group, Washington, D.C., 2020.

Freel, M., 'Patterns of Technological Innovation in Knowledge-Intensive Business Services', *Industry and Innovation*, 13:3, pp. 335-358, 2006.

Heckman, J., 'Sample selection bias as a specification error'. *Econometrica* 47, pp. 153–161, 1979.

Hook, A., 'Regulation and Productivity in the Europe's Professional Services Market', Hook Tangaza Report, 2016.

Monteagudo, J., Rutkowski, A. and Lorenzati, D., 'The economic impact of the services Directive: a first assessment following implementation, *European Commission Economic papers* 456, 2012.

OECD, 'Small business, job creation and growth: facts, obstacles and best practices', 1997.

OECD, 'Competition in professional services', DAFFE/CLP(2000)2, 2000.

OECD, 'Merger Review in Emerging High Innovation Markets', DAFFE/COMP(2002)20, 2002.

Pelkmans, J. & Renda, A., 'Does EU regulation hinder or stimulate innovation?', *CEPS Special Report* No. 96, November, 2014.

Philippon, T., *The Great Reversal: How America Gave Up on Free Markets.* Harvard University Press, Cambridge, Massachusetts, 2019.

Rajan, G. R. and Zingales, L., 'Financial Dependence and Growth', *American Economic Review*, vol. 88, pp. 559-586, 1998.

Ravet, J., *Assessing the Impacts of EU Regulatory Barriers on Innovation: Task 1 Development of the Economic Analysis*, European Commission, Brussels, 2017.

Ribes, E., 'Growth patterns of US professional services firms', Working Papers hal-01762381, 2018.

Thum-Thysen, A. and Canton, E., 'Estimation of service sector mark-ups determined by structural reform indicators', *European Commission Economic Papers*, No. 547, 2015.

Thum-Thysen, A. and Canton, E., 'Estimating mark-ups and the effect of product market regulations in selected professional services sectors: a firm-level analysis', *European Economy, Discussion paper* 046/May 2017, European Commission, 2017.

van der Marel, E., J. Kren and M. Iootty. 'Services in the European Union: What Kinds of Regulatory Policies Enhance Productivity?'. World Bank Policy Research Paper Series, No. 7919: http://bit.ly/2dtb45p, 2016.

World Bank, Regular Economic Report: Growth, Jobs and Integration: Services to the Rescue. Washington DC: The World Bank, 2016.

Annex

Table I: Regulatory restriction definitions

Specific Restrictions	Definition
Exclusive or shared reserved activities	It refers to those activities that either are reserved to the holders of a specific professional qualification or are shared with other regulated professions. In other words, they are activities for which these professionals enjoy a sectoral monopoly.
Protection of title	It refers to legislation conferring the right to carry a particular professional title (such as attorney-at-law, architect) for those who meet particular requirements, most often holders of a particular qualification.
Years of education and training	It refers to the number of years necessary to obtain the academic qualification. This includes the period of mandatory training included in the curriculum to obtain the qualification.
Number of pathways to obtain qualifications	It measures how flexible the system is to obtain the required qualifications. The more possibilities (pathways) there are, the less restrictive the system is considered.
Existence of mandatory traineeship	This restriction concerns situation where future professionals, after having graduated have to undergo a specific mandatory traineeship prior to be granted access to the profession.
Obligation to have professional experience to get full capacity	It refers to the obligation to possess a professional experience of a minimum duration in order to be authorised to access a profession and exercise the related activity.
Existence of mandatory state exam	It refers to the obligation to pass a state/public exam to access a profession after having completed mandatory education.
Continuous professional development obligations	Specific obligations imposed on professionals to follow a specific number of hours of training over a given period associated with costs supported by the professional.
Compulsory membership or registration in professional body	It refers to the requirement for professionals to be certified by and registered with specific professional organizations (e.g. Bar Associations, Chambers of Architects, Chambers of Engineers, Medical Associations, etc.) prior to being allowed to work in the profession.
Limitation to the number of licences granted	It refers to the regulation that limits the number of professionals having access to a profession or the use of quotas of licenses granted.
Territorial validity of the professional qualification	This concerns situations in which the law relates the authorisation to practice only to a given geographical territory within the same country (e.g. in one region but not in others).

Age restriction	This applies when the law explicitly requires the professional to be older (or younger) than a minimum age in order to access and exercise the profession.
Other authorisation requirements	The authorisation could be at the level of access (before you can practice or use the title as individual professional) or could be at the level of exercise, when, for specific activities within the profession you might need to get an authorisation (for example you can practice as an engineer but in order to work on certain type of electrical infrastructures part of the national grid you need a specific authorisation).
Restriction on corporate form/ type of entity	It refers to the existence or not of restrictions to the legal form a company may take. Distinction is made between the following cases: no restriction on the company form exists; it is possible to exercise the profession in a corporate structure with limited liability; it is not possible to exercise the profession in a corporate structure with limited liability; and under the most restrictive form whether the profession can only be exercised as a sole practitioner.
Shareholding requirements	It refers to the case where the law imposes a minimum percentage of the shares to be held by professionals with the required qualifications.
Voting rights control	This restriction looks at whether the law imposes a minimum percentage of voters to be qualified professionals.
Prohibitions on joint exercise of professions	It refers to the case where national laws may include a provision which prohibits the joint exercise of the profession concerned to avoid conflicts of interests. This may include straightforward prohibitions of joint activities either across the board or with particular activities or professions or the existence of a general provision that aims to exclude the joint exercise of professions that would be contrary to the independence or impartiality of the professionals.
Incompatibilities of activities for a professional	This concerns situations where the professional himself may not exercise certain activities together with his profession. This may range from a total prohibition to exercise any additional activities, over specific prohibitions regarding the nature of the other activities to a general provision, stating that a professional should avoid conflict of interest, without prohibiting specific activities.
Professional indemnity insurance	It concerns the case where professional indemnity insurance is required by law for professionals wishing to exercise the regulated activities. This concerns only cases of establishment.
Tariff restrictions	This concerns situations where specific regulation by the government or self-regulation by the profession (e.g. via the code of conduct) defines rules on the level of the fees or prices charged by the professional to the services recipient.
Restrictions on advertising	It refers to the existence of restrictions for professionals on advertising in one or more given media, or as regards the content and methods of commercial communication.

Table II: Total Respondents by country and sector

Respondents by country and sector					
Country	**Architectural**	**Engineering**	**Legal**	**Accounting**	**Total**
Belgium	9	6	27	14	55
Croatia	1	3	5	15	25
France	667	20	12	1 145	1 844
Germany	17	41	308	27	393
Ireland	5	15	30	7	57
Italy	659	2 086	535	1 339	4 619
Netherlands	3	11	19	4	38
Poland	16	9	30	16	71
Portugal	57	41	37	546	681
Romania	105	173	4	7	288
Spain	32	26	9	3	70
Sweden	10	0	4	2	16
TOTAL	1 581	2 431	1 020	3 125	**8 157**