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"The Co-evolution of ICT, Skills and Organization in Public Administrations: Evidence from new European country-level data"

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The Co-evolution of ICT, Skills and Organization in Public Administrations: Evidence from new European country-level data.

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Abstract: During the past two decades a big effort has been made in exploring the complementarities between information and communications technology (ICT) adoption, investment in human capital and organizational change, and how these affect economic performance. Such investigations, however, remain substantially circumscribed to private sectors, while the role of these factors in Public Sector performance has been largely disregarded.
In this paper we aim at filling this gap in empirical literature by combining different data-sources and constructing a panel of comparable data about output quality, input costs, ICT investments, skills and organizational changes in Public Administrations of 15 European countries. We propose an index-based approach to the measurement of PA performance relying on the adoption of public e-services as a proxy of revealed output quality, and provide an econometric analysis of how the co-evolution of ICT, skills and organizational factors affect Government effectiveness.

JEL codes: O14, O33, 038, L32
Keywords: Innovation in public services; ICTs; Organizational change; Skills

1. Introduction

During the past two decades a great deal of attention has been directed to the social and economic impact of the broad category of information and communication technology (ICT) innovations. Most of the systematic quantitative research by economists on this theme has focused on the issue of how the productivity and profitability of business organizations is affected by "ICT investments". In particular a big effort has been made in exploring the complementarities between ICT adoption, investment in human capital and organizational change, and how these affect economic performance. Such investigations, however, remain largely confined to private sectors. Both at the macro and micro levels extensive econometric analyses have been applied to the manufacturing sectors of different countries in the form of growth accounting analyses of ICT effects on economic performance (see e.g. Machin and Van Reenen, 1998; Acemoglu, 2002, Bartel et al. 2007) and detailed patterns of adoption within business firms (Brynjolfsson et alii, 1997; Caroli, 2001; Vivarelli, Piga and Piva, 2004; Cette and Lopez, 2010). A few works also explore the complementarity issue for market services in comparison with manufacturing industry (Zand et al 2010) and with specific reference to business firms involved in web based activities

(Zhu 2004, Koellinger 2008). While important insights can be drawn from this relatively wide range of-studies, to the best of our knowledge there is very limited systematic evidence on the complementarity story in the case of Public Administrations (PAs thereafter).

The lack of research on the links between ICT, organizational change, skill structure, and performance of the public sector is mainly due to the conceptual and analytical problems encountered when estimating output for non-market sectors. The absence of prices for non-marketed output of PAs is one of the key issues that make it difficult to measure productivity and other performance indicators in public sectors and their determinants. A wide literature about the measurement of public sectors' output is surveyed in the "Handbook of public administration" (Guy Peters and Pierre, 2003) which concludes that "only some quantitative performance measures will be indicators at best and not highly accurate or informative measures of a program's value or effectiveness". The result is that virtually no attention has been devoted to the investigation of the ICT effects on PA productivity, nor to the accompanying changes taking place among the organizational structures and skills composition of PA.

We submit that the complementarity between ICT investment, organizational change and human capital should be observed also in the case of PAs. However, human capital investment and organizational change play a key role as a drivers of performance in the case of public sector, over and above ICT. This has to do with the very nature of public services. These activities typically involve a variety of interdependent actors on both the supply and the demand sides, which are engaged in the co-production of output and pursue different and often conflicting sets of values and objectives (Djellal and Gallouj, 2008). From this perspective, ICT adoption alone can hardly enhance public sector performance. ICT investment needs be combined with a significant effort to improve skills and organizational structure and behavior. This might be even more the case when PAs are considered, due to the complexities of knowledge and information flows *within* individual PAs, *across* different PAs and *between* PAs and external actors (citizens, communities, firms and other institutions). It is the availability of more qualified workers and the introduction of substantial organizational innovations that makes it possible to deploy new public services. In fact the delivery of new services increases the need for public administrations to: adjust their internal information management and enable interoperability, organize communication with intermediate and final users, and design services with the support of ICT tools and digital networks. In other words, in the absence of appropriate combinations of human capital and organizational change one can expect that PAs will also experience the well known paradox pointed out by Solow in the 90s for private sectors, i.e. a throughout evidence of ICT investment except in output and productivity statistics.

In this paper we aim at filling this gap in empirical literature by combining different data-sources to analyze the co-evolution of ICTs, skills and organization in PAs and their effect on productivity. To this

aim we construct a panel of comparable data about output quality, input costs, ICT investments, skills and organizational changes in PAs of 15 European countries.

In the next section we review extant literature on ICT, skills, organizational change and productivity in private and public sectors. Section 3 considers the methodological problems underlying the lack of comprehensive empirical studies at the country level on this issue and section 4 presents the strategies adopted here to overcome the data shortage. In section 5 the data and the empirical exercises are described and commented. Section 6 concludes.

2. Background literature: the complementarity issue

There has been significant progress made since the mid 1990s in the analysis of IT and economic performance. The proliferation of databases covering thousands of firms and decades of data has enabled significant intellectual advance. Draca, Saduun and Van Reenen (2006) review an extensive literature on this topic and conclude that "There does seem to be some reasonable evidence of a strong firm level association between IT and firm performance (although causality has still to be convincingly demonstrated)". This evidence seems to be confirmed also by more recent empirical works both for Europe (Dahl, Kongsted and Sørensen, 2011) and the US (Mahony et alii, 2010). Nonetheless, a general claim of these studies concerns the need for a much greater understanding of the interactions between the technological and organizational dimensions of firm performance.

The interactions and complementarities existing between adoption of ICTs, organizational change and investments in human capital, and their mutual effects on firms' productivity have been recently analysed in both the management and economics literature. The general point is that the adoption of ICTs fosters new organizational practices and requires new labor skills. Only actions simultaneously involving all these three variables can effectively increase firm productivity and avoid the so-called Solow paradox, i.e. an insignificant, or even negative, impact of ICT diffusion on the firm or sector competitiveness and productivity (Brynjolfsson et alii, 1997; Caroli, 2001; Vivarelli, Piga e Piva, 2004).

However, there is still disagreement within the literature about the deployment of the complementarity hypothesis at different levels of aggregation and – more relevant to the aim of our analysis – according to the specificities of different sectors and non-market sectors in particular.

At the aggregate-national level, the hypothesis of complementarity follows the thesis, largely rooted in economic theory[1], that technological progress influences the composition of productive activity and its organizational assets, and as a result, affects demand for human resources. The growing pervasiveness of ICT today, has sparked new interest in this debate. It has been hypothesized that the digital revolution changes the quality of inputs used by economic agents, and hence implies changes in qualification and organization of labor forces. These themes have been the object of "skill-biased technical change" literature that has analyzed the impact of technological progress on the composition of the workforce of nations (see among others, Greiner, Rubart and Semmler, 2004). The central hypothesis in this literature is that technological progress implies a distortion or bias towards highly educated and qualified workers. Furthermore – as a reinforcing effect – the same progress reduces the possibilities for the employment of less educated and qualified people. Other authors, instead, support the opposite interpretation of these phenomena (Acemoglu, 1998, Acemoglu, 2002). According to these models, the increase in qualified work supply witnessed in the second half of the 20th century thanks to the wider diffusion of public education, would have induced technological progress favorable to the utilization of more abundant human resources, reversing in this sense the relation of causality between human resources and technology.

In the late '90s a greater attention has been given to organizational factors as co-determinants of economic performance. Aghion et alii (1999) propose a model where organizational change can be the result of technological progress, while Caroli and Van Reenen (2001) postulate a strong version of the skill-biased organizational change where organizational change can be the cause of technological progress. As opposed to mono-directional explanations, Vivarelli et alii (2004), emphasize the co-evolution of technical progress, organizational change and human capital accumulation, as theorized in the broad stream of evolutionary and neo-institutional economics (Cimoli and Correa, 2010).

Firm level analyses shed further light on this evolutionary process. Case studies at the micro level illustrate that firms introducing ICTs exhibit higher demand for skilled workers and workplace reorganization. With reference to Italian manufacturing firms, Giuri et al (2008) illustrate that ICT adoption is associated with vertical disintegration, with a reduction of the number of managerial levels, and with more decentralized decision and productive processes. For example, thanks to the cheaper monitoring over the entire production process made possible by the new technologies, single workers are more autonomous and more frequently called upon to make crucial decisions (Giuri et alii, 2008). According to Black and Lynch (2000) workplace practices accounted for approximately 90% of total factor productivity growth in US manufacturing in the 90s. These workplace innovations induce, in turn, a further increase in the demand for skilled labor, influencing also the pace of research activity and thereby the rate of growth. However more recent works do not find any clear-cut support to the

[1] A classic reference is here to the chapter devoted to the analysis of the effects of mechanizations on labour, in David Ricardo's "Principles of Economics".

hypothesis of full complementarity between ICT, human capital and organizational change. Giuri et alii (2008) show that the complementarity hypothesis holds only in the case of large sized enterprises in Italy. Based on a panel of 540 Italian manufacturing firms, they find that larger firms exhibit a greater demand for – and also a greater return from the usage of – all the complements compared with smaller firms. Bocquet et alii (2007) use a specially designed survey on French firms to provide empirical evidence on complementarities between ICT adoption and organizational change, but also in this case a full control for the size of the firm heavily influences the results. Arvanitis (2005) reviews an extensive empirical literature and shows that ICT, human capital and a new workplace organization alone produce distinctive positive and significant effects on labor productivity. However, the evidence on complementarity is less clear and widespread. Edgar and Ansgar (2009) carry out a systematic review of empirical studies in leading journals in management, economics and related disciplines and find mixed evidence on complementarities.

The complexity of the complementarity issue can hardly be reduced when the analysis is aggregated at the sectoral level. Mahony et alii (2010)hightlight that regularities across different sectors in terms of complementarities are hard to find.

As far as non-market sectors are concerned, ICT has been long considered as a trigger of modernisation in public administrations (Parijis, 1981). During the 1990s many studies draw on this hypothesis describing ICTs as an "attractor" of organizational changes within and between public administrations (Van de Donk and Snellen, 1998). From this perspective, information and comunication technologies should: i) facilitate adoption of modern techniques and methods in public management; ii) contribute to enhancing accountability, openness, and transparency; iii) promote interactive government–citizen processes. However, studies which, in the last ten years, have examined the informatization of PAs, only partially support this idea. Ebbers and Dijk (2007) illustrate a variety of patterns of e-government development, with cases of resistence to ICT adoption. Sorrentino (2004), examines 138 co-financing proposals put forward by numerous Italian public bodies within the context of a national e-government plan, and concludes that these types of initiatives are not really likely to improve organizational performance. Shaun Goldfinch (2007) in his paper on "Pessimism, Computer Failure, and Information Systems Development in the Public Sector" shows that the majority of information systems developments in public administrations are unsuccessful. This is especially the case of large ICT investment projects which have a higher complexity and are often harder to manage. He argues that, despite the persistence of this problem for decades and the expenditure of considerable amounts of money, computer failure has received surprisingly little attention in the public administration literature. The portrait of public officers that emerges from Goldfinch's analysis is that of a recalcitrant, suspicious, and skeptical adopter of information technologies who is most likely to act as a barrier to, rather than a promoter of, innovation in PAs.

A few papers carry out in-depth cross-country analyses on the diffusion of ICTs and web based services in the public sector (Lee et al. 2011), and on how the adoption of digital network technology affects performances of public organizations (Caldas, David and Ormanidhi 2005). The latter work provides perhaps the most extensive analysis capturing the interplay of technology adoption, organizational change and performances of PAs. Caldas, David and Ormanidhi exploit an extensive and very detailed dataset based on a survey of more than a thousand public sector organizations located in eight European countries, which was conducted during 2003. First, they find that while larger PAs have easier access to budgetary and technical resources, thus favoring digital network technology adoption, size per se may be not exercising independent effects upon the rates at which these organizations are able to improve their performance. They identify clusters of public organizations with different characteristics in terms of territorial distribution and hierarchical positions in the decision making processes which are associated to different technological profiles, largely independent of size. Second, they analyze a sub-sample of public organizations and compute a measure of performance that combines the relationship between their adoption and mode of utilization of e-network technologies, on the one hand, and, on the other hand, the rates of improvement that their managers perceived had occurred in the average number of cases resolved per employee. They obtain approximate estimates of the implied rate of growth in the sector-wide average number of "cases resolved per employee" during the period 2003-2008.
While Caldas, David and Ormanidhi develop an extremely rich and promising line of research, they can shed only a limited light on the complementarity issue in the case of PAs. In fact, they provide very detailed data and analyses on how technology adoption interacts with PAs' ability to "resolve cases". In order to do so, however, they are forced to focus on a subsample of organizations that do perceive a change of performances, thus reducing the possibility of generalizing their results.

The links between ICT, organizational change and productivity in the public administration still remain largely unexplored, due to both the lack of comparable data and to analytical problems encountered when estimating output for non-market sectors[2].

In the following sections we briefly discuss empirical strategies adopted to overcome methodological problems and data shortages in the analysis of PA performance and how this is affected by the interactions between organizational change, ICT investment and skill composition in PA. We then propose an index-based approach to the measurement of PA output adjusted for quality, and provide an econometric analysis of how the co-evolution of ICT, skills and organizational factors affects public sector performance.

[2] As illustrated below in section 3, the absence of reliable price indicators for non marketed services is perhaps the most difficult obstacle to be overcome in the estimation of output in public sector. Moreover, if one adopts a classic production function approach, further problems emerge in order to adapt classic Cobb Douglas or trans-logaritmic functions to public sectors.

3. Empirical strategies in extant literature

The analysis of performance in service sectors has traditionally posed a number of conceptual and methodological problems (Griliches 1984). In the case of public sector, this task is even harder to tackle. One may mention at least three specific sets of largely unresolved issues (Baxter 2000, Caplan 1998, Oecd 1999, Djellal and Gallouj 2008). First, public services are commonly provided free of charge or at modest prices that do not cover the costs of production. Hence, price and tariffs, when they exist, are not reliable measures of the unit value of output. Second, assessing public sector output in terms of quantities is a hard job as standard units of analysis and measures are seldom available. Indeed, one can hardly single out universally recognised tasks to be accomplished for each individual public function, associate volume measures to each individual task, and aggregate them into consistent sets of data to allow comparative analyses across countries. Third, even in the presence of comparable measures of output quantities (or values, when prices are available), evaluating quality is even harder. In fact the perceived quality of public sector output depends on social and economic objectives which differ across countries and depend on the actors being considered, whether they are providers or users of public services. Significant differences also exist across actors along the supply chain (e.g. the ministry of health vs. the director of a hospital vs. individual doctors) and across user categories (e.g. tax payers indirectly taking advantage from externalities created by a hospital, vs. patients directly using health services). The quality of output is thus undetermined unless one adopts the view-point of a specific set of actors.

A survey of extant literature (Worldbank, 2011; Jorgenson, 2010; Simpson 2009; Dean, 2009; Murray, 2010; Gallouj and Djellal 2008) makes it possible to distinguish between the following families of empirical strategies to tackle the above mentioned sets of problems:

Use of inputs as a proxy of output

One way of dealing with the difficulties of measuring output quantities and values is to rely on inputs, which can be more easily quantified and priced. In most international comparisons input data are used as a proxy for output of non market services. This procedure has long been used in many publications, including Dean (2009) and World Bank (2011). The success of this method reflects the commonly acknowledged difficulty at separating the output of most public services from the factors of production used to generate it (in other words the final output can hardly be disentangled from the production process). A theoretical justification can be found in the hypothesis advanced inter alia by Baumol (1967), that output coincides with the factors of production. A major limitation is that this method implicitly assumes that PAs are equally productive in utilizing inputs (Dean 2009, Jorgenson 2010). In principle, few economists or

statisticians would defend the equal productivity assumption and accept the simple use of inputs as a proxy of output without any adjustment. Some examples of questionable results are presented by Dean (2009), based on the cross-country comparisons of the 2005 ICP Global Report. He observed that while Portugal's GDP per capita was 34 percent below Germany's and 44 percent below Switzerland's, per capita education services in Portugal ended up being computed as 17 percent above Germany's and its per capita government collective consumption was 10 percent above Switzerland's.

Given these results, Dean (2009) maintains that "the use of input ratios to compute output ratios, with no adjustment for productivity differences and no other adjustment, is incorrect. It is surely time to end this procedure, for which no defensible rationale can be presented."

A more acceptable variant of this method would then be to consider input costs and correct them for some proxy of differences in efficiency of PAs. Some scholars propose to use labor productivity data as calculated for market sectors —where labor productivity is measured as output per employee— to estimate outputs in non market sectors. More specifically, in bilateral comparisons of Non Market Sector outputs, a ratio of the two countries' labor productivities should be computed on the basis of output and employment in the market sector, and it should be used to adjust a ratio of inputs in a nonmarket sector (see e.g. Dean, 2009 and Simpson 2006). More direct proxies of PA efficiency would be desirable but are often difficult to find. One procedure that has been followed (see e.g. Linna et alii, 2010) is to adjust input costs for some measure of quality of service activities, which would allow to better differentiate public sectors in terms of their actual performance. The empirical tests we shall carry out in this paper will follow the latter empirical strategy. See below for a description of quality based indexes.

Measuring output in terms of service activities

Indicators of public sector output have been introduced by several countries into their national accounting systems. However the shift to substitute input based measures with output indicators is a relatively recent one, with the partial exception of the UK which has started producing activity based statistics for public services in the mid 1980's. As mentioned earlier, the generalized introduction of output indicators and their use for comparative analyses across countries would require an effort to standardize units of analysis and measurement procedures (OECD 1999, Pritchard 2003, Handler et al. 2005). This effort is complicated by the heterogeneity of activities composing a given public service both within and across countries, and by the absence of reliable price indexes to assign a value to such activities. An agreement needs to be found on: which service activities should be covered (e.g. no universally accepted standards exist in terms of tasks to be performed by government servants); which volume-based measures should be used (e.g. number of hospital beds provided, number of pupils per school class, number of documents

processed); which weights should be adopted to aggregate different volume based activities (e.g. costs of individual cases treated). Most countries have produced indicators concerning a small number of public service activities, most often related to healthcare and education, while output indicators of government services (e.g. taxation, welfare, local and central administration) are seldom available. The two countries which have covered the widest variety of public services in terms of activity measures are Finland and the UK. The latter has stopped measuring public sector output in terms of inputs in 1998 in most government services (Ashaye 2001).

The fact that comparable data are not always available for a large set of public sector activities constitutes a serious hindrance to the use of this type of indicators. Even in case service activities can be considered relatively good proxies of public sector output as a whole, one may question whether and to what extent such indicators actually capture the performance of PAs. Indeed, the interpretation of changes in output levels measured in terms of service activities will depend on the context in which such changes occur. This is particularly the case of output variations in the presence of changing technological and organizational contexts. For instance, shorter hospital stays could be considered as a reduction of output, but this could be result of improved organization and hence reveal an improvement of performance. This would also be the case of the introduction of ICTs leading to a lower number of paper-documents processed by a public administration: this reduction of output should be interpreted as a sign of better performance as well. While measuring output and performances is *per se* a hard job to accomplish in the case of public services, the fact that indicators of increasing (decreasing) output may be interpreted as worsening (improving) performance adds further complexity to the analysis of public sector activities.

Capturing the quality of public sector activities

This is a hard exercise in general, and it is even harder in the absence of market prices as proxies of quality. Eurostat (2001) has identified three methods of taking quality into account in the case of non market services. The first such method is based on *ad hoc measures of the quality of output* produced by means of surveys on how effective services are perceived to be by either users, providers or inspecting/regulatory institutions. A major limitation is that data collected from these surveys often reflect a specific point of view (the one of the evaluator), and are more effective at assessing the quality of the production process than the quality of output (see e.g. the Atkinson Review 2011 of the UK Office for National Statistic).

A second method to approximate the quality of output consists in *measuring the quality of inputs*. From this perspective, workers' qualification and wages are taken as measures of output quality. Much like the first family of approaches recalled earlier (using inputs as a proxy of output), this

method is based on the heroic hypothesis that all changes in input quality will translate into output quality.

The third method addresses the issue of quality by *investigating outcomes*, i.e. by assessing the ultimate results of public sector activities. For instance, the quality of health services can be measured in terms of the number of healed patients or of mortality reduction rather than, or in addition to, the number of hospital beds available. Of course the closer indicators get to the outcome end, the more controls are necessary for additional factors, other than public sector characteristics or decisions, that may affect them. To illustrate, the number of students graduating from university in a given year might be considered as a good outcome indicator, but this will depend inter alia on the quality of students which is not only affected by teaching activities (e.g. the income level of their families will also play a role).

Rantanen et al (2007a) identified specific problems faced by Finnish public sector organizations in designing and implementing performance (quality) measurement systems. Three case studies are used to highlight two set of drawbacks of quality measures (Rantanen et al., 2007a, b): difficulties in target setting (i.e., the goal of the operations may not be clear); difficulties in solving the conflicts between the needs of different stakeholders (owners, employees, customers, suppliers and the community)which makes it difficult to identify what should be measured. In more general terms, Linna et alii (2010) alert on the fact that "Combining the pieces of information into aggregate level measures multiplies the errors." While the latter alert is certainly valid for all country-based comparison, the choice of a quality based index to adjust inputs should be considered with particular caregiven the complexity of analytical issues raised.

4. Assessing output and complementarity issues in PAs: variable definition and data-sources

Apart from a general criticism on the use of input based estimation in the absence of some control of PA efficiency, at present there is no clear agreement on the methodology one should follow to carry out cross-country economic analyses of output and productivity in the public sector.

For the purposes of this paper, we perform different tests to evaluate public sector output across countries and to assess how it is affected by some key characteristics of PAs in the observed countries, i.e. ICT expenditure, the skill composition of their labor force, and organizational change.

Our *dependent variable* will be a proxy of public sector performance obtained by adjusting input costs with an innovative measure of output quality. This implies correcting the traditional approach of measuring output in terms of inputs (first family of empirical strategies illustrated earlier) by taking into account differences of effectiveness of PAs (consistent with the third family of empirical strategies).

More precisely, our *quality adjusted index of output* combines two country level indicators: (a) per-capita PA expenditures net of Defense; (b) a measure of e-service adoption, which we consider a signal of quality of PA output as perceived by citizens and firms (adopters) to whom the services themselves are directed.

The former set of data (PA_SPENDING) refers to per capita production costs (labor costs, intermediate consumption and capital amortization) of Public Administrations at constant prices extracted from the EU KLEMS dataset[3], subtracting per capita Defense expenditures supplied SIPRI[4]. The second set of data (b), which we use to qualify non defense input costs, refers to the actual utilization (by citizens and enterprises) of public e-services, which we consider a proxy of quality of public services as perceived by user.

Our measure of public e-service adoption (eSERV_ADOPTION) is a weighted average of the following four indexes supplied by Eurostat[5]:

i. Individuals using the Internet for interaction with public authorities – the index denotes the percentage of individual citizens aged 16 to 74 who within the last 12 months before the survey used the internet for at least one of the following purposes: (a) obtaining information on services from public authorities websites, (b) downloading official forms, (c) for sending filled in forms.
ii. Enterprises using the Internet to obtain information from public authorities - the index considers the percentage of enterprises with at least 10 persons employed in two digit NACE sectors.
iii. Enterprises using the Internet for returning filled in forms to public authorities - the index considers the percentage of enterprises with at least 10 persons employed in the given NACE sectors.
iv. Enterprises using the Internet for submitting a proposal in a public electronic tender system to public authorities - the index considers the percentage of enterprises with at least 10 persons employed in the given NACE sectors.

We assume that e-service adoption by both citizens and business enterprises are indicators of the quality of public sector output. Hence, for the purpose of the present exercise, we assign the same weight to the first index, which refers to individual users, and to the sum of the other three indexes, which refer to enterprises[6].

We deem it particularly appropriate to use *public e-service adoption* as a quality indicator. On the one hand, it denotes the ability of PAs to introduce new services that are per se innovative. In fact, the

[3] http://www.euklems.net/
[4] http://www.sipri.org/databases
[5] http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database, See the folder "Computers and the Internet in households and enterprises" in "Information society statistics".
[6] More precisely, in this paper we used the following weights: 0,5 for the first index (individuals), 0,3 for the second index, 0,1 for the third and fourth index. Of course other weighting criteria are possible. Tests with alternative weights can be produced by the authors upon request.

deployment of public e-services requires: a non trivial effort to adapt existing services, and design new ones, in order to deliver them though the Web; an overall restructuring of both back-office and front-office activities; and a fundamental change in the approach to customers/users (Serrano Cinca et al. 2003, Arduini et al. 2010). On the other hand, adoption indicators reveal that the introduction of these relatively new services has survived a selection which is not only based on their cost-effectiveness but also on the satisfaction of user needs. In other words, the transformation of existing services into web based government activities will be associated with a sunk cost that users will have to bear in case of adoption[7]. We assume that, especially in a pre-paradigmatic phase of e-services development, users will only adopt "high quality" services, i.e. services that are really worth bearing this extra cost.

Our *quality adjusted output index* PA_ADJ_OUTPUT, obtained as PA_SPENDING * eSERV_ADOPTION, will then reflect the amount of input costs sustained by Public Administrations (in terms of capital services, labour services and intermediate inputs, either purchased from domestic industries or imported), but will turn out to be higher the greater the level of public e-service adoption. We shall use PA_ADJ_OUPUT as dependent variable in our econometric exercises.

Due to crossed missing values between the sources utilized to construct the two sets of measures - (a) PA expenditures net of defense and (b) public e-service adoption – we were compelled to restrict the analysis to 15 European countries (Austria, Belgium, Check Republic, Denmark, Finland, France, Germany, Hungary, Ireland, Italy, Netherland, Slovenia, Spain, Sweden, United Kingdom) for which a full panel of consistent data are available over the 2003-2007 period.

Table 1 illustrates the evolution of per capita input costs in non Defense public sectors in our sample countries.

Tab. 1. Per capita PA expenditure net of Defense

[7] One might argue that this is not the case when a radically new, non pre-existing service is delivered through the internet as users will bear a transaction cost – e.g. in terms of gathering information on the existence of the new service or of getting acquainted to the procedures to be followed – that are the same or even lower than in the case of traditional services (as the latter will also imply some costs in terms of displacement or paperwork). However the costs of getting acquainted to on-line services and using web based help desks are likely to be underestimated.

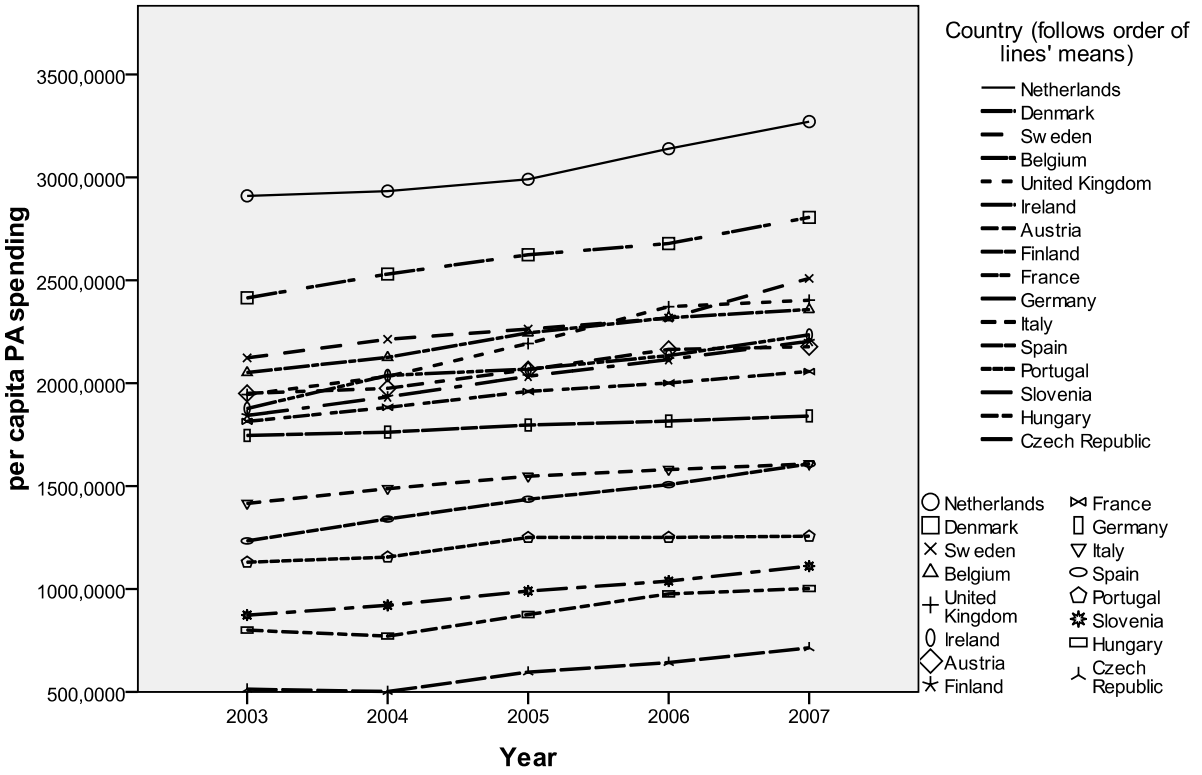
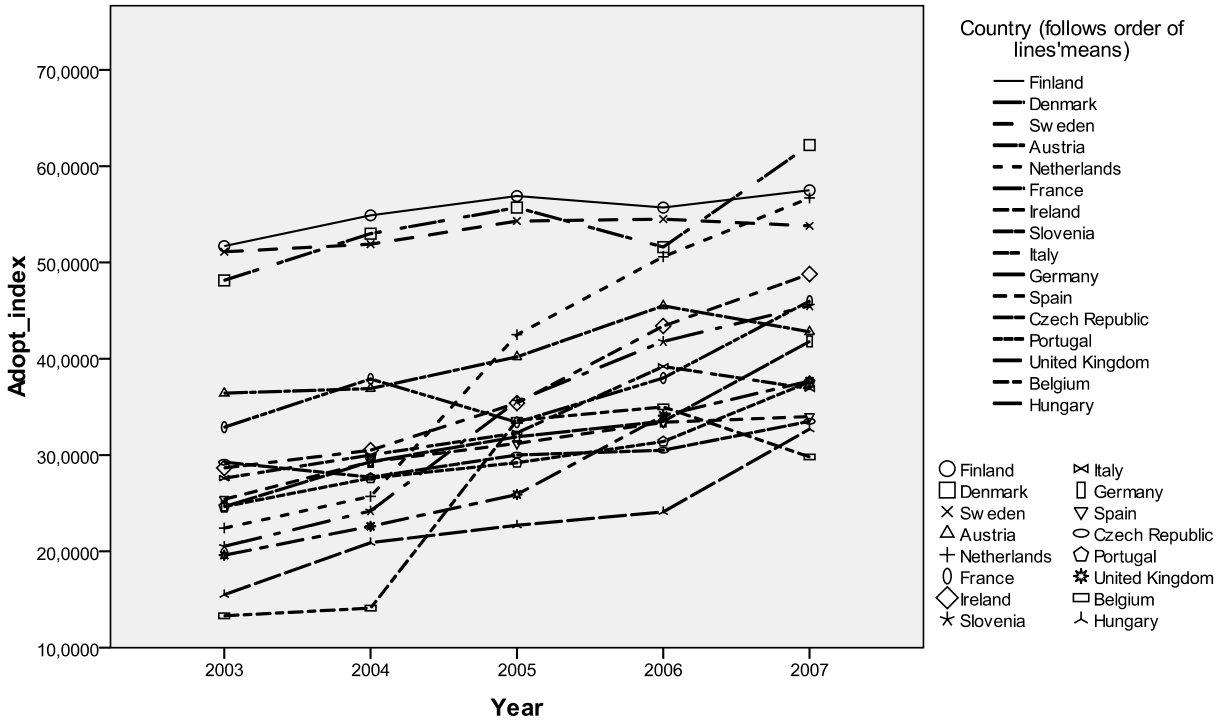


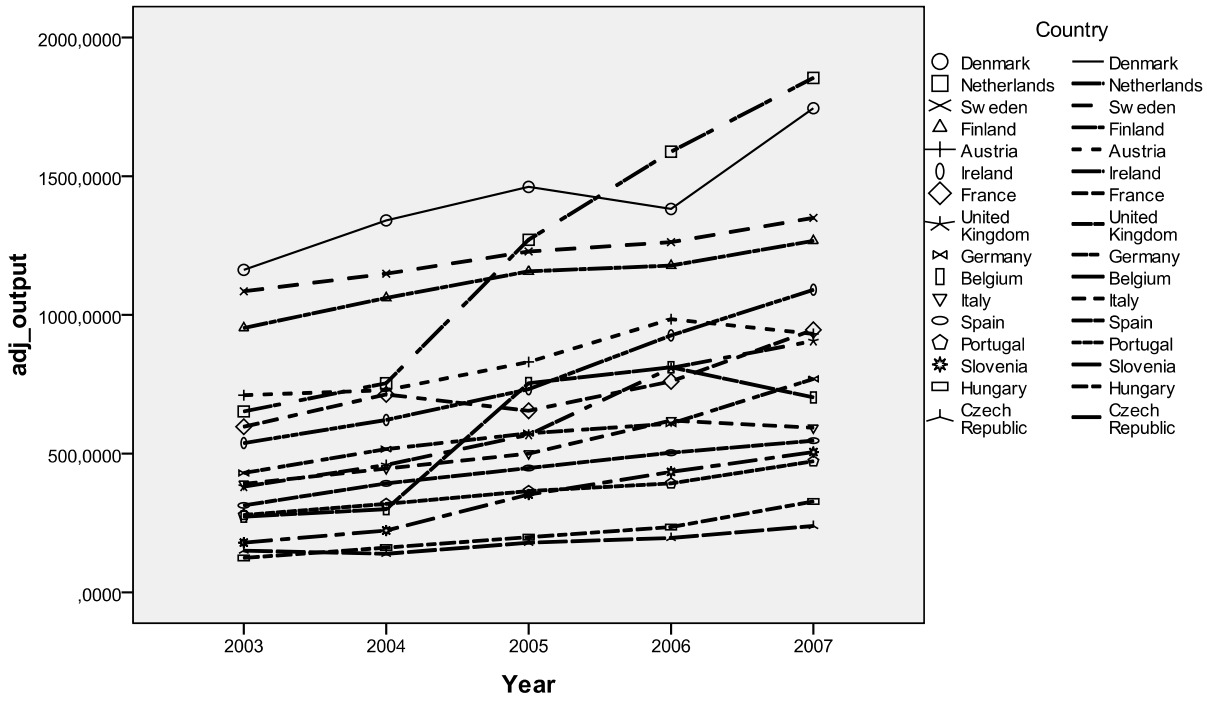
Table 2 shows our measure of public e-service adoption in the 15 sample countries in 2003-2007, obtained as a weighted average of the four Eurostat indexes we have illustrated earlier.

Tab. 2. Index of adoption – trend



Tab. 3 shows the evolution of our quality adjusted indicator of PA output in the 15 countries over the 2003-2007 period.

Tab. 3. PA quality adjusted output indicator (PA_ADJ_OUTPUT) - trend



Legend: ranking of countries' lines follows the order of period average values

In order to examine the complementarity issue in the case of public sector in Europe we also had to collect data on ICT investments, human capital and organizational change.

Data on skill levels of employees and ICT investment in PAs are drawn from the EU KLEMS dataset. The former is expressed as *PA investment in ICT on total population* (PA_ICT). The latter is EUKLEMS' *Human capital index* (PA_LAB_QUAL), measured as the difference in growth of labor services (here expressed in terms of costs) and hours worked in Public Administrations, taking 1995 as a reference. This difference is often identified as "labour quality" in the growth accounting literature (see e.g. Jorgenson, Ho and Stiroh 2005).[8] As much of extant literature on complementarity issue in the case of business activities has focused on the impact of (and interactions between) ICT expenditure and Human Capital, we shall first test how these variables affect our measure of PA output (PA_ADJ_OUTPUT) in the examined 15 countries over the 2003-2007 period.

[8] To the best of our knowledge available data do not permit to separate data on both ICT expenditure and skill levels in the labor force for Defense and Non-Defense Public Sectors. We are thus obliged to assume that the labour composition is the same in the defense and non-defense services. A further simplifying assumption we make is that the share of ICT spending in non Defense public expenditure be the same as the share in total public expenditure.

As shown earlier in section 2, the role of organizational change combined with human capital and ICT investment, has been increasingly emphasized in the literature. Measuring organizational change is by far the most complex task to accomplish. As mentioned in the introduction, public sector activities involve a variety of organizational levels – within individual PAs, across PAs and between PAs and users of services – all of which interact with human capital accumulation and ICT investments. Since direct (and homogeneus) measures of all of these organizational dimensions in non market sectors do not exist at the country level, we use an indirect measure based on the availability and sophistication of e-services. Our measure of organizational change (PA_ORG) is obtained as the weighted average of Public e-service Online Availability Index computed by Capgemini for the European Commission, where weights are represented by the degree of sophistication of services provided according to a 5-stage maturity model (see Capgemini et al. 2010). [9] See fig. 1 for the complete list of e-services monitored by Capgemini et al. (2010). The idea is that, much more than the provision of standard services, the introduction of web-based services imply an overall change in the organizational structure of PAs; and organizational change required will be even deeper the higher the level of "sophistication" (i.e. the degree of interactivity) of such e-services. As suggested in the recent UN "E-Government Ranking 2012" :

"Small-scale ICT activity – development of a website as an additional information channel – may not require complex supporting changes. Far reaching organizational change will be required when:
1) The website begins to offer deeper, more complex services.
2) Agencies are asked to work together to deliver services according to the needs of citizens and not their structure.
3) New work styles - tele-working, virtual teams - emerge.
4) With increased data-sharing and communication:
_ particular data holdings become redundant
_ more decisions are made at the lower organization levels
_ special units are established for government-wide projects" (UN 2012)[10]

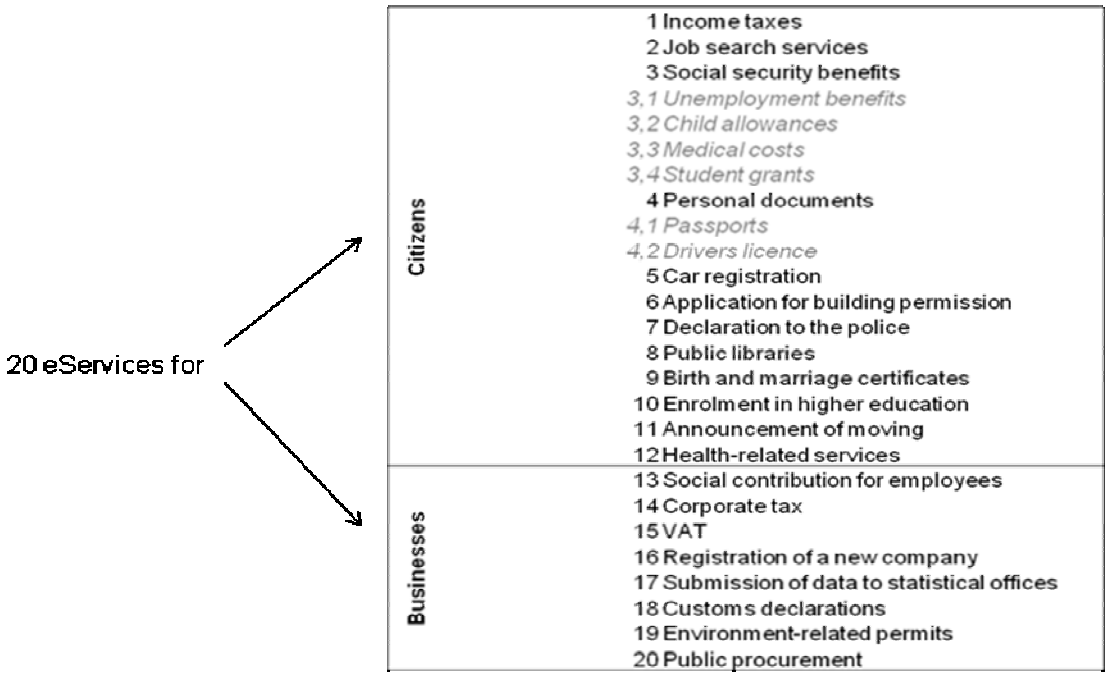
The introduction of e-services is generally associated to all four circumstances listed by the UN. By using PA_ORG as a proxy of organizational change, we thus assume that, once controlled for ICT

[9] An annual benchmarking survey carried out by Capgemini, IDC, Rand Europe, Sogeti and DTi for the European Commission has been monitoring the progress of e-Government delivery across European Countries over the past decade. These studies focus on the on-line availability of a set of 20 "basic public services", organised into 4 clusters: Income and fiscal services (taxes, social contributions, VAT, customs), Registration (car, company, natality & marriage, personal and business mobility, statistical data), Social services (health, libraries, procurement, job search, benefits) and Permits and Licenses (building, passports and other ID certification, education, environment management and protection). Full Online Availability (where on-line provision is combined with the highest level of sophistication according to a 5-stage maturity model), the EU27+ average reaches 82% in 2010, compared to 56% in 2007 (see Capgemini et al. 2010).

[10] http://unpan1.un.org/intradoc/groups/public/documents/un/unpan048065.pdf

investments and human capital composition, a higher provision of sophisticated e-services reveals that PAs will have undergone a profound change in its organizational structure and behavior.

Fig. 1. *List of e-services considered by the EU e-government benchmark*



(source: CapGemini et al 2010)

We are confident that the use of this proxy of organizational change should not cause major endogeneity problems in our analysis. Although we construct our dependent variable assuming that users' *adoption* decisions will signal the quality of e-services, the *introduction* a new e-service can be expected to be affected by a variety of factors (including cost efficiency and political pressures) which are largely independent on potential and actual demand conditions (See, inter alia, Arduini et al. 2010). We shall thus run regressions wherein PA_ORG is used as an additional explanatory variable both independently and in interaction with ICT expenditure and Human Capital, to further test the role of complementarities in Public Sector output dynamics.

In addition we shall introduce controls for per capita income (GDP_PC) as an indicator of economic development of observed countries, and for the level of infrastructural development in terms of share of population with broadband access (BROADBAND).

Tab. 4. Variable description and descriptive statistics

Variable name	**Description**	**Source**	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
PA_SPENDING	*Total PA spending net of Defense on total population*	EU KLEMS, SIPRI,	80	1804.8	651.3	501.9	3270.8

		Eurostat					
eSERV_ADOPTION	*Actual utilization of public e-services by citizens and enterprises*	Eurostat	80	36.4	11.6	13.3	62.2
PA_ADJ_OUTPUT	PA_SPENDING *eSERV_ADOPTION	EU KLEMS, SIPRI, Eurostat	80	696.9	408.8	123.9	1854.5
PA_LAB_QAL	*Labour quality, measured as the difference in growth of labour services and hours worked.*	EU KLEMS	80	16.0	6.9	2.0	25.7
PA_ICT	*PA investment in ICT on total population*	EU KLEMS	80	35.9	18.2	11.9	86.1
PA_ORG	*Proxy of organizational change in the PA, expressed as weighetd average availability of e-services with weights measuring "sophistication"*	Capgemini	80	53.3	19.3	10.5	100
GDP_PC	*GDP per capita*	Eurostat	80	25791.2	9336.0	7300	43500
BROADBAND	*Broadband penetration*	Eurostat	80	12.6	8.3	0	37.2

5. Empirical results

We test how ICT investments, skills and organizational change affect PA performance. As illustrated in section 4, we shall use a quality adjusted measure of PA output (PA_ADJ_OUTPUT) as a dependent variable, , and regress this indicator on our key explanatory variables (ICT investments, skill composition and our proxy of organizational change) and other controls. Table 4 shows the summary statistics for the variables used in the regression models.

Since our dependent variable is continuous over positive values and all variables are normally distributed with independent and homogeneous residuals throughout the whole period of observation (2003-2007), we can use OLS panel models. The presence of country-specific, time-invariant and unobservable factors which can influence the dependent variables suggests to use fixed (country) effects models for our econometric exercises. When used, this option has been also confirmed ex post confronting the results of the fixed vs. random models with the Hausman Test (Hahn et al. 2011). Since we may assume that investment in ICT, Human Capital and Organization will eventually produce any effect with a certain delay, we introduce a lag of one year for the dependent variables[11].

Tab. 5 shows the results of regressions. In column 1 we test how the two explanatory variables of our baseline model – investment in skilled personnel and ICT spending – singularly taken, influence our PA quality adjusted output measure. Controlling for GDP per capita does not add significance to the model, as fixed-effects largely capture country specificities with very limited variation in time (as it is the case of GDP per capita over a relatively short time period).

[11] Estimates with alternative time lags are available upon request

Table 5 – The impact of ICT, skills and organizational change on PAs' performance

	Model 1	**Model 2**	**Model 3**	**Model 4**
GDP_PC	.034 (.284)	-.046 (.027)	.045 (.028)	.047* (.025)
BROADBAND	12.701 (7.985)	8.700 (7.901)	9.604 (7.936)	5.992 (7.116)
PA_LAB_QAL	281.318*** (103.084)	337.010*** (102.584)	250.228** (101.585)	219.150** (90.569)
PA_ICT	-3.397 (4.074)	-6.522 (4.186)	-4.136 (3.981)	-2.350 (3.568)
PA_LAB_QUAL* PA_ICT		1.191** (.560)		
PA_ORG			2.369* (1.258)	.529 (1.231)
PA_LAB_QUAL* PA_ICT* PA_ORG				.042*** (.012)
Fixed effects	Yes	Yes	Yes	Yes

Note: Standard errors in parentheses; *** $p \leq .01$; ** $p \leq .05$; * $p \leq .10$;

Also the index of households having access to broadband shows only a low significance in this model (p-value = 0,119) principally because of its low dynamics in the short time period considered.

Using a pooled regression (without country fixed effects), rises of course the significance of estimated coefficients of both control variables (GDP and Broadband).

As far as our key explanatory variables are concerned, the first set of regression results in column 1 show that it is only the proxy for human capital that significantly affects our measure of output. ICT expenditure per se do not significantly impact on PA performance. This is consistent with what has long been observed in the case of business sector, i.e. the effect of investment in these technologies can hardly be seen in productivity statistics also in the case of public sector.

Similar to what has been found in extant literature focusing on business sectors, one may also assume that ICT expenditure will eventually translate into PA output changes only in the presence of key complementary factors, such as a qualified human capital. We test the latter hypothesis in column 2 of Table 5, where we add the interacted term PA_LAB_QUAL* PA_ICT, which allows us to capture the impact of joint investment in ICT and human capital sustained by PAs in the observed countries. In order to do that, according to Jaccard and Turrisi (2003), independent variables must be centered on the mean[12]. The interacted term turns out positive and significant as expected.

We interpret this result as a first partial confirmation of the complementarity thesis which has been proved for business sectors but has never been tested before in the case of PAs. One may venture saying that this result per se provides evidence on the fact that extensive ICT investments being undertaken in

[12] Centering a variable on its mean doesn't affect substance of results (e.g., R^2 is unaffected) while reducing multicollinearity (see also Crombach, 1987).

most European countries' PAs may be worthless (or even wasteful) in the absence of efforts to augment the quality of labor force using these new tools.

The next step will be to test the role of organizational change. As anticipated in section 4, we are conscious that our proxy of organizational change is quite rough. However, adding a control on the delivery of sophisticated e-services for any given level of ICT expenditure and labor qualification (and other contextual factors such as per capita GDP and broadband penetration) should capture PAs' ability to introduce significant changes in its organizational structure and behavior.

Columns 3 and 4 show that PA_ORG has a significant impact both when introduced as an additional variable in the baseline model, and when interacted with ICT and human capital investment. This result is consistent with our interpretation of organizational change as a critical variable affecting PA performance, and contributes to a positive role of ICT investments as well. In other words, it is not ICT investment alone, but its combination with qualified labor and far reaching organizational change, that affects PA performance.

What seems to be specific of PAs as shown in the data is the role of both labor qualification and organizational change, that remain significant also when considered in isolation from investments ICT. We may interpret the persistent significance of these variables as confirming that performance is heavily affected by the ability of Public Sector organizations to qualify their labor forces and effectively handle complex relationships within individual PAs, across PAs and between PAs and users.

5. Conclusion

This paper has explicitly addressed the issue of complementarities between ICT investments, skills and organizational change as factors that jointly affect performance of Public Sectors using comparable data for 15 European countries. This has raised multiple challenges such as the measurement of PAs output and the identification of a proxy of organizational change. We have proposed an empirical strategy that relies on the recent availability of data on public e-service adoption and provision. Similar to what has been observed for private sectors, we found that Solow's paradox applies also in the case of PAs investments in ICT alone – i.e. in the absence of appropriate organizational change and human capital – will not translate into better performance. Besides the observed complementarities, we have also shown that both human capital and organizational change play a key role as a driver of PAs performance. This result is likely to reflect the extreme complexity of information flows and decision making levels that characterize the provision and adoption of public services. This implies that the ability to improve the quality of labor force and handle organizational challenges is a distinctive factor affecting the performance of Public Administrations, over and above their investments in ICT.

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