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Information Economics and Policy xxx (2005) xxx–xxx
INFORMATION ECONOMICS AND POLICY
www.elsevier.com/locate/iep

The quantitative evaluation of the economic impact of e-government: A structural modelling approach

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Received 3 September 2004; received in revised form 25 August 2005; accepted 30 August 2005

Abstract

I propose a quantitative methodology to analyze the economic impact of e-government based on structural modeling, allowing for a careful description of the underlying theoretical assumptions and for an assessment of different policy scenarios.

The transparent relation between the theory and the results obtained is an advantage with respect to purely narrative methods. The methodology departs significantly both from studies in the cost-benefit analysis tradition and from the analysis of "e-readiness" indexes, whose purpose is a quantification of preconditions for successful policies.

An illustration of the method is provided, using data from the Italian region of Tuscany.

JEL classification: C300; H110; H430; H700

Keywords: E-government; Evaluation of public policies; Econometric structural modeling; Multi-level governance

1. Introduction

Most people would agree that the new information technologies hold vast potentials for improving public administrations, and that better administrations in turn would have a positive influence on the economy and on society. Positive expectations on e-government are certainly based on good reasons, but do not rest on any serious quantitative appraisal.

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0167-6245/$ - see front matter
doi:10.1016/j.infoecopol.2005.08.001

Nomenclature

Variables

A_t technology (12), (13), (19)
$\bar{A}$ "core" technology (19)
Capitalstock stock of capital (9)
EGOV aggregate e-government, before lags are considered (16)–(18)
$\text{EGOV}^{\max}$ maximum level of aggregate e-government (7)
EGOV* aggregate e-government, after considering lags (2), (7), (18), (19)
EGOV_A e-government by the regional administration (15), (16)
EGOV_C e-government by the central administration (14), (16)
G_A total resources available to regional administration (4), (5), (11)
IK_A investments contributing to regional administration's fixed capital stock (5), (9)
IKP_A public works investment by the regional administration (5), (9)
IKICT_A ICT related investment by public administration (5), (9)
Investment investments (9)
K private capital stock (10), (12), (13)
KICT_A regional administration's ICT capital stock (14), (17)
KICT_C central administration's ICT capital stock (15), (17)
KP public capital stock (12), (13)
N inhabitants in the region (1)
N_A total (regional) public administration workers in region (1), (2), (3), (5), (13)
N_I total employed in the private sector in region (1), (2), (12), (13)
$\bar{N}_\text{I}$ fixed quota of employment in the private sector (2), (5)
NAG_A regional administration's employees working on other services (3)
NFL persons outside the labor force in region (1)
NSC_A regional administration's employees working on services to citizens (3)
NSI_A regional administration's employees working on services to firms (3)
SC_A the services dedicated to persons (2), (6)
SI_A services dedicated to firms (2), (6), (19)
SPAAG_A regional administration's expenditure on other activities (8)
SPAG_A regional administration's expenditure on general activity (5), (8), (15)
SPEGOVAG_A regional admin.'s expenditure on e-gov. activities (8), (15), (17)
SPEGOVAG_C central administration's expenditure on e-gov. activities (14), (17)
SPSC_A regional admin.'s expenditure on services dedicated to persons (5), (6)
SPSI_A regional admin.'s expenditure on services dedicated to firms (5), (6), (19)
TR_A transfers from central administration to regional administration (4)
U total unemployed in region (1)
Y regional output (11)
Y_I regional private output (10)–(13)

Parameters

δ persistence of effect of public employment on private employment, $0 < \delta < 1$ (2)
ϕ lag parameter for services to firms (2)
ξ lag parameter for services to citizens (2)

π	effect of e-government on private employment (2)
w	average public administration wage (5)
σ	e-learning induced savings on services, $1 \leqslant \sigma$ (6), (7)
cof	central admin. e-learning co-financing of regional e-gov. ($0.1 \leqslant \text{cof} \leqslant 0.5$) (8)
ϑ	parameter in services' saving relation (7)
AS	is the service life of the type of capital good (9)
τ	capital to output ratio (10)
α, β, v	elasticities of the production inputs, $\alpha + \beta + v = 1$ (13)
ρ	substitutability between ICT and other e-gov. expenditures (14), (15), (17)
θ	substitutability between central and regional e-government expenditures (16), (17)
λ_j	lagged effect of e-government policies, $\sum_{j=0}^{K}\lambda_j = 1$ (18)
γ	elasticity of technology with respect to e-government (19)
ψ	elasticity of technology with respect to services to firms (19)

For sure, within official governmental documents there can be found quantitative evaluations of e-government policies, but they ought to be read cautiously. Not only are they based on the assumption that the projects succeed, whereas past experience suggests that good intentions are not enough to obtain good results (OECD, 2001a), but also they are almost inevitably impressionistic in nature and most often are carried out by the same administrations – or by their consulting firms – who are called to "sell" a given project to the political decision maker even before than to the public opinion.

Cost-benefit analysis is a well established technique within the domain of project evaluation (Gramlich, 1997) and often a prerequisite to access a vast array of public financing opportunities. However, it suffers from difficulties in quantifying the relevant magnitudes, particularly within the public sector, where policy makers are called to satisfy goals that are expressed in generic terms – consider "social cohesion" or "environmental sustainability" as examples. Further difficulties arise due to the specificities of the ICTs, because the quantification of many magnitudes related to the information society is particularly difficult.[1] Last, and even discounting for these problems, the lack of a historical record of e-government application precludes the adoption of quantitative techniques based on statistical inference: quite simply, there are no data on which to estimate a statistical model.[2]

To improve such a discomforting situation I here propose a structural modeling strategy for the assessment of the economic consequences of e-government policies. A formal model is constructed to describe the working of a public administration, its relations with the outside environment, and the policies that are based on the use of information technologies. An application is proposed for the analysis of e-government in the Italian region of Tuscany.

In what follows I first provide a general description of the methodology, then I describe the case study. Section 4 discusses the results of several simulations of the model. The conclusions follow.

[1] I have considered such an issue at length in Giacomello and Picci (2003), a paper that in part motivates and complements the present effort.

[2] In contrast, there exist many econometric assessments of the impact of the use of information technologies on the private sector. See Giacomello and Picci (2003).

2. A modeling strategy

The modeling strategy rests on a system of equations, each one quantifying a relevant aspect of the relationships between the e-government policy, the public administration and its outside environment. It is then a theory-based approach where each relevant aspect of the underlying theory (of the effects of e-government) is embodied in one or more equations. The general merit of the methodology lies in its ability to offer an evaluation of the effects of e-government that, while suffering from the current lack of much needed quantitative information, are rigorous in spelling out the hypotheses and the theoretical framework.

As an illustration consider an expression for the labor force participation rate that positively depends on e-government – for example, because on-line services free personal time and induce more people to enter the labor market. A higher participation rate boosts employment and production, a relation that also we could represent by one or more equations. A higher production would in turn increase tax returns, eventually allowing for a more courageous e-government strategy, setting in motion what would resemble a multiplier rate. Similar mathematical relations, reciprocally connected, would form an internally consistent structural model.

The representation could be highly stylized and focus on particular aspects of e-government (as in the application to be presented), or it could include a considerable number of equations, in an attempt to describe a broader spectrum of issues that are deemed to be relevant for the assessment of e-government policies. These alternatives are also present in structural econometric modeling, where there are both parsimonious models, aiming at synthesis, and comprehensive models, aiming at completeness.

The proposed methodology offers two main contributions. First, it represents an initial step towards a theory-based quantitative analysis of public policies to obtain quantitative assessments that are based on an explicit model, with respect to the old saying among econometricians that there cannot be "measurement without theory" (with reference to Koopmans, 1947). The methodology clarifies all the elements of the theory, so that with respect to a narrative description it is easier to isolate and modify them and to track their impact on the variables of interest.

The application of such structural modeling approach permits the computation of simulations conditional on a set of hypothesis, but not of forecasts in the usual econometric meaning of the word. While such simulations provide interesting insights on the likely effects of e-governments, unfortunately, and regardless of the methodology that we may choose, we still lack many of the necessary information to statistically estimate the effects of policies.

The second main contribution of structural modeling refers to its usefulness in setting the research agenda that will eventually allow for statistical inference and forecasts. The present methodology helps clarifying both the quantitative information that we currently miss and the theoretical issues that are either more controversial, or that carry a higher potential impact on the relevant outcomes. As such, it orientates future research and data-building efforts.

Structural modeling differs importantly from all methods that have been used so far in the literature, including so called "e-readiness indexes" (such as in Grigorivici et al., 2004). E-readiness indexes have been proposed to represent rankings of countries (or regions) in terms of their production or use of technologies. Their advantage rests on their ability to succinctly summarize broad characteristics of a given country or region. However, they do not provide an alternative solution to the set of problems addressed here. The link between an e-readiness index and its effects on the variable of interest is simply an implicit theoretical (or, sometimes, ideological) assumption that can be summarized as follows: (1) the new information technologies may have a very important positive impact on society at large, (2) a set of enabling conditions ("e-readiness") have to be met in order for that to happen. The e-readiness indexes literature addresses the issue of quantifying such enabling conditions, but does not assess the effects of policies.[3]

3. The model

We adopt a selective modeling strategy in order to focus on two main aspects of a theory of e-government. The first one regards the relationships between concomitant e-government policies carried out at different levels of governance. Multi-level governance, increasingly the dominant model of governance of democratic societies, carries with it complex problems of coordination of efforts. A proactive administration could in principle make up for the inaction of another administration, but such a choice would be effective only if policies at different levels of governance were somehow substitutable. The model allows for a careful description of the degree of substitutability between policies carried out by different administrations.

Second, the model explicitly includes a time lag between the enactment of a given set of policies and the manifestation of their effects. Much evidence suggests that such lags may be substantial (see David, 1990, on the adoption of general purpose technologies), so that the effects of a given policy may occur well after the end of the legislature during which it is enacted, leading to a problem of political appropriability.

I first provide a summary of the model, using a graphical representation, then I illustrate it in detail.

3.1. Summary of the model

The model, whose final outcome and main variable of interest is regional private output, includes a central and a regional public administration. The regional administration supplies services to citizens and to firms that increase employment in the private sector, by influencing the decision to participate in the labor market and by facilitating the creation of firms. Also, services to firms improve the prevailing technology, that is part of the production function.

The regional administration's e-government policy is the result of investments in technologies and of those interventions – training, project management activities, etc. – that are needed to manage e-government projects. These two types of interventions, together, define "regional e-government". The central administration also invests in e-government and may co-finance the regional administration's own e-government policy.

[3] This is also true of Grigorivici et al. (2004), the only case in the literature where, to the best of my knowledge, some type of "structural modeling" is proposed – again, with the purpose of quantifying e-readiness, and not the effects of public policies on the variables of interest.

Regional and central e-government policies do not have a direct effect on the relevant economic variables of the model, but they shape an aggregate concept of overall e-government policy. Such a two-tiered framework permits to describe the relation between policies at different level of governance. In particular, it allows for a description of their degree of substitutability.

The aggregate e-government intervention has three effects. First, it produces savings in the provision of regional services to citizens and to firms. Second, by facilitating economic activities, and by favoring participation in the labor market, it increases private sector employment. Last, by providing a "connected environment", it improves the prevailing technology, that influences the production process (see the bottom part of Fig. 1). The aggregate e-government effect, moreover, takes time to be effective, reflecting not only the time to completion of projects, but also the presence of various types of learning phenomena.

The regional administration carries out public investments in traditional infrastructure that contribute to regional private output via a production function. The production inputs include private capital and labor. Output positively influences private investments as in an accelerator mechanism. Overall, the model presents a reduced level of simultaneity: only private capital and output are endogeneously determined, through the accumulation of the investment flow.

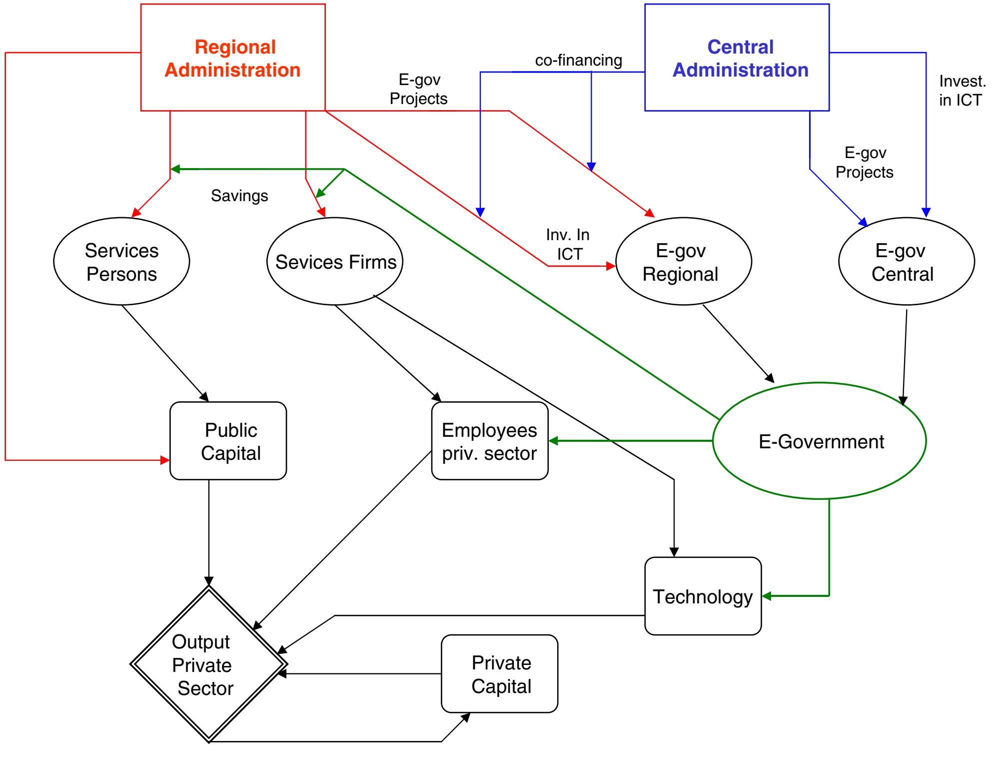

Fig. 1. The graphical representation of the structural model. Squares indicate administrations, and ovals indicate policies. Rectangles with dull edges are the inputs to the production function, and the main variable of interest is the regional output of the private sector. Arrows indicate causality relationships.

3.2. Detailed presentation of the model

In what follows, all variables are observed at time "t", which represents a given year. For simplicity t is omitted whenever the variables in an equation are contemporaneous.

3.3. Persons

In the region there are N persons. Of these, N_A are employed in the only public administration of the region, N_I are employed in the private sector and U are unemployed, but are part of the labor force, and NFL are not part of the labor force

$$N = N_A + N_I + U + \mathrm{NFL}. \tag{1}$$

We assume that N is given and constant in time. Employment in the private sector is

$$N_{I_t} = \bar{N}_I - \sum_{j=0}^{\infty}(1-\delta^j)\Delta N_{A,t-j} + \sum_{j=0}^{k}\phi_j \mathrm{SI}_{t-j} + \sum_{j=0}^{h}\zeta_j \mathrm{SC}_{t-j} + \pi \cdot \mathrm{EGOV}_t^*. \tag{2}$$

$\bar{N}_I$ is a fixed quota of employment in the private sector. The public administration, by increasing its work force, absorbs part of the unemployed workers only in the short run, because eventually public employment completely crowds out private employment. The parameter δ describes the persistence of a variation in public employment on private employment, with $0 < \delta < 1$. For example, if $\delta = 0.5$ then an increase of 100 employees in the public administration at time t means a likewise contemporaneous increase in total employment, which reduces to 50 the year after, and to 25 two years on and so forth.

The number of workers in the private sector positively depends on services to firms, SI, that are provided by the regional administration. Such services favor the creation of new firms and jobs. Moreover, services dedicated to persons, SC, free them of many daily chores and encourage labor market participation.

E-government contributes to private employment because the availability of on-line services favors transactions and reduces the cost of new entrepreneurial activities. E-government may also reduce frictional unemployment by supporting a more efficient matching in labor markets. Last, a connected environment enables tele-work practices and favors a higher degree of labor force participation. These effects are delayed, their lags being expressed by the summation in the ϕ and ξ parameters, respectively, for services to firms and to citizens. *EGOV** is the overall e-government intervention that, as we will see, is the result of past e-government interventions.

3.4. The regional public administration

The regional administration allocates its labor force, N_A, as follows:

$$N_A = \mathrm{NSC}_A + \mathrm{NSI}_A + \mathrm{NAG}_A, \tag{3}$$

where NSC_A and NSI_A, respectively, indicate employees who contribute to the provision of services to citizens and to firms, and NAG_A are the employees dedicated to what we label "government activities" not directly linked to the provision of services, and including personnel training and the planning and management of policies, e-government interventions among them.

The central administration transfers parts of its resources to the regional administration, TR_A, without there being a direct link between the amount of resources collected through taxes within the region and the amount of resources made locally available.[4] The regional administration cannot raise taxes nor run a debt so that total resources available, G_A, equal transfers

$$G_A = \mathrm{TR}_A \tag{4}$$

Transfers are channeled to different ends

$$G_A = w \cdot N_A + \mathrm{IK}_A + \mathrm{IKP}_A + \mathrm{IKICT}_A + \mathrm{SPSC}_A + \mathrm{SPSI}_A + \mathrm{SPAG}_A. \tag{5}$$

Part of the resources available are used to pay wages (equal to the average wage, w, times the labor force, N_A). IK_A are investments contributing to the administration's stock of fixed capital (for example, its buildings, their furniture, etc., but not its computer-related equipment, to be considered separately). IKP_A is the investment by the regional administration in the usual public works such as roads and schools. IKICT_A is the investment in ICT related goods, both hardware and software. Such an expenditure category includes the whole set of the ICT infrastructure, but does not comprise the related complementary expenses, such as all costs related to the management of e-government projects.

Last, the regional administration provides services to firms, citizens, and also caters for the administration's other general activities: respectively, SPSI_A, SPSC_A and SPAG_A. This last category includes the costs incurred for the upkeep of the regional administration that are not linked to the direct provision of services to firms or to persons, including the costs of e-government projects beyond what refers to the construction and maintenance of the technological infrastructure.

E-government generates savings, equally reducing the costs of services to firms and to persons

$$\mathrm{SI}_A = \sigma \cdot \mathrm{SPSI}_A, \quad \mathrm{SC}_A = \sigma \cdot \mathrm{SPSC}_A, \tag{6}$$

where the parameter $1 \leqslant \sigma$ expresses the savings, equal to

$$\sigma = 1 + \vartheta\left(\frac{\mathrm{EGOV}^*}{\mathrm{EGOV}^{\max}}\right), \tag{7}$$

where EGOV* represents the contribution of e-government, and $\mathrm{EGOV}^{\max}$ is a hypothetic maximum possible level for e-government policies, to which it corresponds a saving factor $\sigma = 1 + \vartheta$. The more pronounced an e-government policy with respect to the hypothetical maximum, the higher the savings it allows.

Last, government activities, AG_A, are disaggregated between e-government related activities, EGOVAG_A, and other activities, AAG_A. Prefix SP indicates corresponding expenditures

$$\mathrm{SPAG}_A = (1 - \mathrm{cof}) \cdot \mathrm{SPEGOVAG}_A + \mathrm{SPAAG}_A. \tag{8}$$

3.5. The central public administration

In (8) the parameter multiplying regional e-government expenditures captures the possibility that these are co-financed by the central administration. Besides co-financing regional

4 Such an assumption correctly characterizes Italy, where local administrations have very limited possibilities of raising their own taxes.

e-government, the central administration has its own e-government policy resulting from the combination of ICT investments (hardware and software) and of any accessory intervention. The central administration is assumed to be able to modify both elements of its e-government policy without having to respect a budget constraint, reflecting the focus of the model on the regional economy.

3.6. Formation of the capital stock

Capital stocks – of all varieties: public, private, traditional and ICT related – are the result of the accumulation of past and present investment flows, according to a simple formulation of the permanent inventory rule:

$$\text{Capitalstock}_t = \sum_{j=0}^{\text{AS}} \text{Investment}_{t-j}, \tag{9}$$

where AS is the service life of the type of capital good.[5] We assume further that the capital of the public administration excluding hardware and software ($K_{A,t}$) is constant in time. An adjustment mechanism guarantees a constant ratio between private regional capital and the private regional output, possibly following an accelerator mechanism for private investments:

$$K_t = \tau \cdot Y_{I,t-1}. \tag{10}$$

3.7. Private output formation

The regional economy does not trade with the outside and regional output is the sum of regional private output, Y_I, and regional administration's expenditures

$$Y = Y_I + G_A \tag{11}$$

The production function determining private output is

$$Y_I = f(\text{A}, \text{K}, \text{KP}, N_I). \tag{12}$$

Private regional output depends on the prevailing technology, A, that describes how the three production inputs – private capital (K), public capital (KP) and the labor input (N_I) – are combined. The inclusion of public capital in the production function follows from empirical evidence on the statistical significance and economic relevance of infrastructure in determining output (see Gramlich, 1994 and Picci, 1999, for Italy). Moreover, the explicit consideration of public capital allows for the description of the allocation of resources between different types of public investments: traditional infrastructure on the one hand and e-government projects on the other. Given our focus on the regional economy, such an allocation dilemma here applies to the regional administration only. The production function is of the Cobb–Douglas type with constant returns to scale in all inputs, that is, $\alpha + \beta + v = 1$:

$$Y_I = A \cdot K^{\alpha} \cdot \text{KP} \cdot^{\beta} N_I^{v}. \tag{13}$$

[5] See the Appendix and, for further details on public inventory techniques and for the choice of average service lives, OECD (2001b).

Unlike what happens for its private counterpart, note that the ICT public capital does not enter the production function as a production input.

3.8. E-government

Investments in hardware and software are valuable only if they are accompanied by appropriate complementary interventions for general management and training activities. The opposite is also true: an e-government policy needs adequate hardware and software. In other words, e-government projects and the related hardware and software investments are scarcely substitutable.

We define the general e-government policy using a Constant Elasticity of Substitution (CES) production function, allowing for an explicit treatment of the substitutability between two inputs. Assume that the inputs (x_1 and x_2) concur to define an output Y according to the formula $Y = [a_1 x_1^{\rho} + a_2 x_2^{\rho}]^{\frac{1}{\rho}}$. Parameters a_1 and a_2 are simple scaling factors, while the parameter ρ describes the possibility of substitution between x_1 and x_2 ($-\infty < \rho \leqslant 1$). In particular, for ρ that tends to zero the CES production function boils down to a Cobb–Douglas production function.

At a given level of governance, the effect of an e-government policy depends on the interaction between the capital stock (hardware and software) with the activities to manage it. Respectively for the central and for the regional e-government, we write:

$$\mathrm{EGOV_C} = [ac_1 \mathrm{SPEGOVAG_C^{\rho}} + ac_2 \mathrm{KICT_C^{\rho}}]^{\frac{1}{\rho}}, \tag{14}$$

$$\mathrm{EGOV_A} = [aa_1 \mathrm{SPEGOVAG_A^{\rho}} + aa_2 \mathrm{KICT_A^{\rho}}]^{\frac{1}{\rho}}, \tag{15}$$

where ρ indicates the possibility of substitution between management expenditure and investments in hardware and in software. It is reasonable to assume that the two factors are scarcely substitutable (ρ tends to $-\infty$), approximating a Leontief technology where the two inputs have to be combined in a fixed ratio in order to produce a given level of output.

The relation between central and regional e-government policies is similarly modeled. The degree of substitutability between the two policies is uncertain. It could be that one administration compensates for the inaction of the other administration, and crafts an effective e-government policy when there is no analogous intervention from the other administration. However, the opposite situation could also prevail, as when it is only the union of efforts at different levels of governance that produces an effective overall policy.

Consider also that the characteristics of a policy by a given administration are likely to be influenced by the behavior at different levels of governance. An active and intelligent regional administration would shape its policy so as to make it complementary with the central government policy. It would design instead a more self-sufficient course of action if it has to move alone. Similar considerations apply to the central administration, that when designing its policies should discount for the likely characteristics of regional policies. In particular, a capable central administration dealing with a weak regional one would opt for polices that are more autonomous and assertive, applying the principles of subsidiarity.

A CES formulation is used to represent the substitutability of central and regional policies

$$\mathrm{EGOV} = \left[ae_1 \mathrm{EGOV_A^{\theta}} + ae_2 \mathrm{EGOV_C^{\theta}}\right]^{\frac{1}{\theta}}, \tag{16}$$

where θ indicates the possibility of substitution between policies just described. Overall, the e-government intervention within the region can be expressed as

$$\mathrm{EGOV} = \left[ae_1 \left[[aa_1 \mathrm{SPEGOVAG}_{\mathrm{A}}^{\rho} + aa_2 \mathrm{KICT}_{\mathrm{A}}^{\rho}]^{\frac{1}{\rho}} \right]^{\theta} + ae_2 \left[[aa_1 \mathrm{SPEGOVAG}_{\mathrm{C}}^{\rho} + aa_2 \mathrm{KICT}_{\mathrm{C}}^{\rho}]^{\frac{1}{\rho}} \right]^{\theta} \right]^{\frac{1}{\theta}}. \tag{17}$$

E-government policies require time in order to show their effects. To characterize such delay we use a distributed lag formulation for EGOV_t^*, defined as the cumulative effect of past and present e-government policies:

$$\mathrm{EGOV}_t^* = \sum_{j=0}^{\mathrm{lag}} \lambda_j \mathrm{EGOV}_{t-j}, \tag{18}$$

where λ_j represents the lagged effect of e-government policies, with $\sum_{j=0}^{K} \lambda_j = 1$.

3.9. The technology

The prevailing technology (A in (13)) is as follows:

$$A_t = \bar{A} \cdot \mathrm{EGOV}_t^{\gamma} \cdot \mathrm{SI}_{\mathrm{A},t}^{\psi}. \tag{19}$$

Besides the effects of a core component $\bar{A}$, technology is positively influenced by services to firms, SI, and by e-government: a highly connected organizational and economic environment favors a more efficient combination of the production inputs. For example, a job market supported by an adequate information system not only has lower frictional unemployment, but also produces a better matching between workers and their jobs.

In particular, let us consider the transaction costs between firms and the public sector. A well connected environment reduces the cost of red tape, a phenomenon here channeled through an improvement in technology. A successful e-government policy also reduces transaction costs among firms, particularly important in an economic context where they have strong mutual horizontal relations.[6]

In the above formulation an improved organizational technology, following an effective e-government policy, has a positive and permanent effect on technology. The possibility of substitution between the components of A are as implied by a Cobb–Douglas formulation.

4. An application

I here describe a structural model of e-government for an Italian region, Tuscany[7], using data referring to the year 2000. Data for only one year are sufficient because the model is solved along a hypothetical steady state-path[8], forming a benchmark against

[6] The presence of vigorous horizontal ties between small and medium enterprises is one of the main traits of those (Marshallian) clusters of firms that characterize much of the Italian industrial landscape.

[7] Tuscany is situated in the center-north of Italy. Italy, formerly a centralized state within the post-Napoleonic tradition, over the last 30 years has introduced a considerable degree of administrative decentralization and is gradually evolving toward a federal structure, formed by 20 regions endowed with a sweeping range of responsibilities.

[8] Such an approach requires a few simplifying assumptions regarding the accumulation of the stocks of capital, that are assumed to be somehow greater than in reality because the flow of investments is taken to be constant and equal to the year 2000 value. This simplification is necessary due to data availability problems.

Table 1
Simulations

Simulation	Substitutability central egov – regional e-gov	Central e-gov	Savings	E-gov lags (years)
1	Low	Weak	High	10
2	High	Weak	High	5
3	High	Robust	Low	5
4	High	Robust	High	5

which to gauge alternative scenarios. Appendix A reports the data used to solve the model[9].

All the scenarios considered imply a robust regional e-government policy that we assume to be well balanced between investments in ICT hardware and software and the other complementary interventions. We also assume that the increase in regional e-government is equivalent to a doubling of its historical level in 2000 and is financed by a decrease in traditional infrastructure (regional) investments and by a 30% co-financing from outside. Obviously, this is just one way for the regional administration to finance its e-government policy; it represents however an interesting possibility because it allows to consider the issue of scarce resource allocation between alternative policy options.

The exercises assess the impact of e-government as three parameters vary: the level of substitutability between central and regional intervention, the amount of savings following an e-government policy and the lags with which the effects of e-government manifest themselves. We assume that the variations of the e-government policy with respect to the historical value occur at a conventional "year 100" and we record the evolution of regional private income over the following years. Table 1 presents a synthesis of the assumptions of each of the four simulations that were carried out and Fig. 2 shows their outcome for regional private output, regional private employment and the cost index of regional services. For all of them the baseline solution is normalized to 100, so that the different simulations represent percentage variations.

Let us consider simulation no. 1, based on the least favorable assumptions. The central administration does not modify its policy, in a context were interventions at different levels of governance show little substitutability, and their effects take 10 years to fully materialize. More optimistically, we assume that e-government procures relatively high savings.

Immediately after the change in policy the private regional income is subject to a slight decrease, caused by the drop in public capital stock that is financing most of the e-government policy. In the short-run, public investments are relatively more productive because of e-government's long delay in reaching effectiveness. As this eventually happens, regional private output increases, peaks, and then decreases gradually. After about 50 years it reaches a new long-term level below the baseline of 100.

Such a path, again, is explained by the public capital stock's dynamics. The regional government decreases traditional public investments to make room for its e-government intervention. As old vintages of infrastructure reach their service lives, the stock of public capital gradually decreases, lowering in turn private regional input through the production

[9] The model is solved using Gauss–Seidel's algorithm. See Fair (1984) for details.

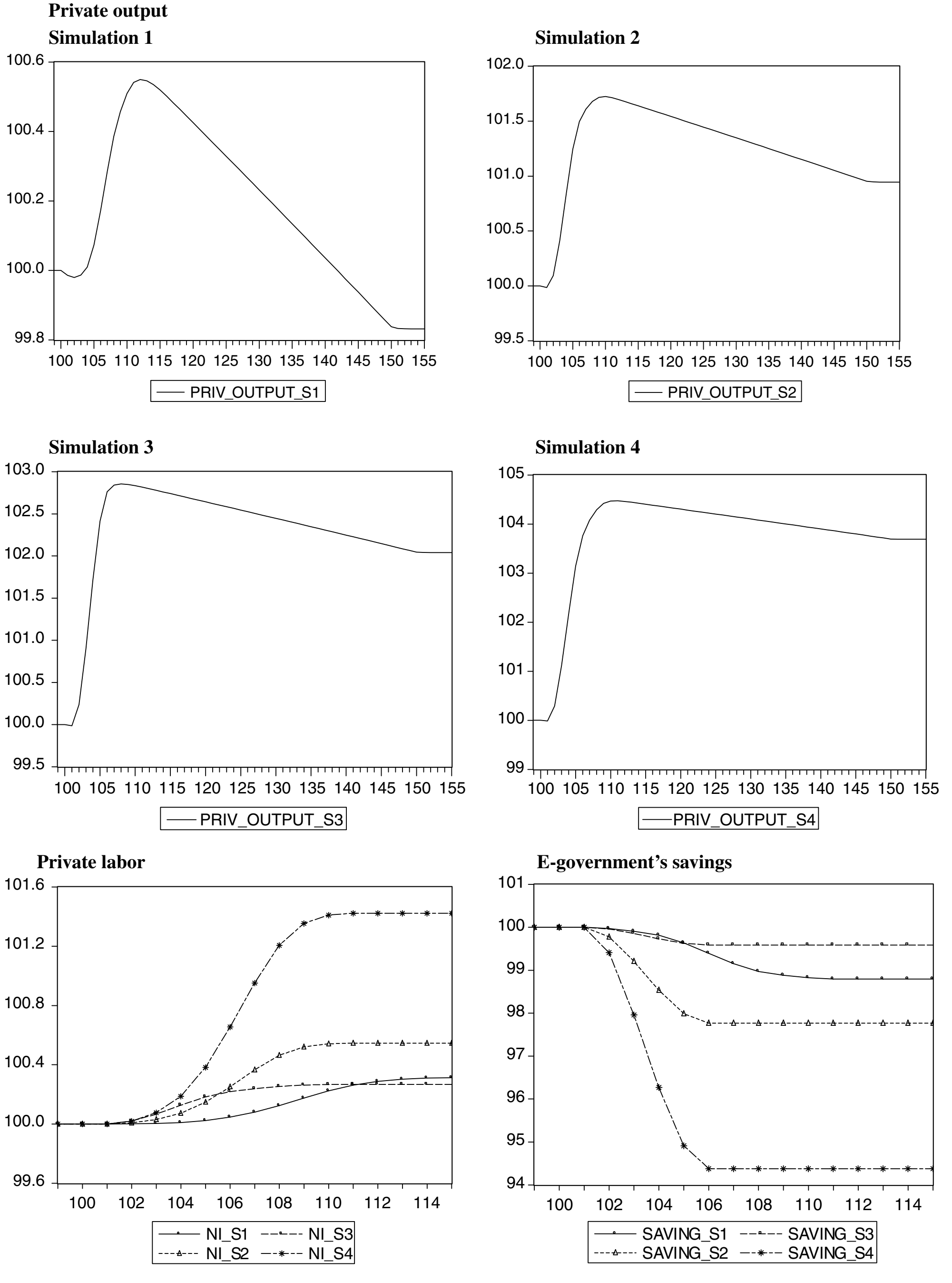

Fig. 2. Simulations' results. Deviations from the baseline solution.

function. However, such an effect has a different timing with respect to the impact of e-government and it is mediated by the influence of a flow variable – public investment – on the corresponding stock entering the production function (13).

The above result offers a glimpse of the relevance not only of the temporal lags separating a change in one variable with its measurable effects on another, but also of the existence of differing time profiles for such delays. In the present case the comparison of the allocation of resources between two alternative policies – here, e-government vs. building traditional infrastructure – depends on the time horizon. In the long run, the e-government policy implies a lower output, because the resources financing such a policy would have been more productive if channeled to traditional public investments.

The increase of the private sector employment is also modest and slow to fully materialize, as are savings, mostly due to an absentee central administration within a context of little substitutability between policies at different levels of governance.

Simulation 2 also assumes an "unbalanced" e-government policy. The center and the periphery are not able to effectively coordinate themselves in choosing an appropriate overall e-government policy and only the regional administration acts. This now happens in a situation where the policies are more substitutable. As in all following simulations e-governments takes up to 5 years to be fully effective, instead of the 10 years of Simulation 1.

The graphs show more pronounced deviations from the baseline solution compared to what we observed earlier. The difference is explained by the higher degree of substitutability between central and regional policies, allowing the region to partially compensate for the central administration's inaction.

Simulations 3 and 4 show what happens when the central administration also doubles its e-government efforts. Output now increases more. The comparison between Simulation 3 and 4 shows the role of e-government induced savings, that are low in Simulation 3, and high in Simulation 4. The difference in terms of output between the two simulations is roughly 1.5%, with Simulation 4, representing the most favorable assumptions here considered, showing a regional output that peaks at around 4.5% points above the baseline. Private employment increases following both the direct benefits of the e-government policy and its indirect effects, that are channeled by the saving induced increase in services to firms and to persons. Savings also are significant, thanks to a generous assumption regarding potential e-government induced savings (Eq. (7)), and to a high level of activation for the overall e-government policy. Both conditions are satisfied only in Simulation 4, producing an overall saving on services to firms and persons of over 5%.

5. Conclusions

In this paper, I have considered a structural model to analyze the effects of e-government in a multi-level governance environment. The model embodies an economic theory of e-government and focuses on a few critical aspects of e-government policies. Among them, most noteworthy are the presence of more than one level of governance, and the relevance of substantial lags between the enactment of e-government and its effects.

The model does not deliver forecasts based on statistical inference. It is important to realize that no alternative approach can today deliver such forecasts, for the simple reason that the necessary data are not available. However, the proposed approach not only will eventually allow for such forecasts, once the necessary data will be available, but as of now already delivers interesting results. In particular, the simulations have shown how different characteristics of e-government interact to produce the simulated results.

Both the presence of substitutability between policies at different levels of governance and of high savings following such policies are important in producing significant economic effects of e-government. We would then benefit from a better understanding of how and to what extent e-government produces savings. Also, we need a better understanding of what degrees of freedom a single administration has in shaping its policies, so as to make them more self-sufficient whenever it cannot coordinate with other administrations.

The dynamic behavior of the model showed an interesting possible contrast between the policies' short- and long-run effects. An e-government policy that is eventually productive, but that takes time to become such, could imply short-run losses whenever the negative effects of the needed resource reallocation have a quicker impact on the economy. The timing issue is of particular relevance. The presence of adverse dynamics, in face of a policy that would eventually turn out to be beneficial if protracted long enough, raises the issue of the sustainability of the long-term political will that is needed to stay the course. The management of ambitious long-term policies is particularly thorny within democratic governance (March and Olsen, 1995). Such an issue can hardly be considered using a quantitative approach only; the present exercise helps however in defining the problem within a precise theoretical framework.

Acknowledgments

I thank the editor and three anonymous referees for their valuable comments. The ideas behind this work and a preliminary version of the paper were initially discussed within the e-government Working Group of Astrid – Associazione per gli Studi e le ricerche sulla Riforma delle Istituzioni Democratiche e sull'innovazione nell'amministrazione pubblica, Rome. I am grateful to Franco Bassanini, Bruno Dente, Giampiero Giacomello and Roberto Golinelli for their useful comments on a preliminary version of the paper. Financial support from Fondazione Monte dei Paschi di Siena is gratefully acknowledged. A methodological note on the relations between the present exercise and the econometric tradition of structural modelling is available at: http://www.spbo.unibo.it/picci/egoveval-method.pdf.

Appendix A. Further information on the structural model

A.1. The data

A.1.1. Persons

In the year 2000, Tuscany had 3460835 registered inhabitants (*popolazione residente*). The number of people unemployed was equal to 92800, while employed units where 1618200 (Prometeia, 2002). Of the latter, respectively, 2581, 4235 and 33729 persons were employed in the regional, provincial and municipal administrations (Regione Toscana, 2002).

The number of employees of the regional administration is set equal to the sum of employees for the latter three type of local administrations (40544 units). The number of employees of the private sector is set equal to the difference between the total number of employees, and employees of the regional administration (1577655 units). The number of people who are not part of the labor force is set equal to the number of residents, less the sum of employed and unemployed persons (1749835 units).

A.2. The public administrations

The allocation of the regional administration's workers among tasks (Eq. (3)) is not needed in order to solve the model, and is introduced for illustrative purposes. In the year 2000, total resources used by the regional administration equaled 12508 millions of Euros, to which we subtract 7850 millions of Euros that the regional government spent on the health system. Expenditures by the provincial and municipal administrations, respectively, amounted to 1073 and 7781 millions Euros (Regione Toscana, 2002). Overall expenditures of the regional administration, net of contributions to the public health system, amount to 13512 millions Euros (Regione Toscana, 2002). Overall millions Euros. In the model, this corresponds to transfers from the central government to the regional administration.[10]

Total expenditure by the regional administration is allocated into wages, investments, and other current outlays (Eq. (5)). In order to solve the model, we consider, for each category of expenditure, wages and other expenditures together. Using data from the relevant budget sheets we assume that the sum of current expenditures (wages plus other current outlays) is equal to 8051 million Euros. Different local administrations use the remaining 4994 million Euros for investments of various kind, to be considered in the next section. Current expenditures are allocated as follows: 5957 millions Euros for services to persons, 663 millions Euros for services to firms, and 1431 Euros for other expenditures.[11]

A.3. Capital stock formation

Overall IT expenditure in Tuscany in the year 2000 amounted to 1153.2 million Euros, or 6.2% of the national total – 18959 million Euros (Assinform, 2003). We do not know the amount of resources spent by all regional administrations, so we assume that the ratio between public and total IT expenditure in Tuscany is equal to the national value 1152 million Euros (AIPA, cited in Ministero per l'Innovazione e le Tecnologie, 2003). The national ratio between public and total IT expenditure is 6.2%, and by applying this number to Tuscany, we obtain an estimate expenditure by the regional administration of 71.424 millions Euro. The central administration's expenditure in information technologies were equal to 1676 millions of Euros (AIPA, cited in Ministero per l'Innovazione e le Tecnologie, 2003).

Fixed private investments in Tuscany were equal to 11687.3 millions Euros (Prometeia, 2002). Public investments in Tuscany were equal to 1330 millions Euro (Picci, 2002).

Average lives of capital goods, used in the permanent inventory computations, are assumed to be as follows: KP_t: 20 years; $K_{A,t}$: 50 years; all ICT related capital stocks: 5 years.

[10] In fact, the budgets of all the local administrations should be consolidated, and not added together. The consolidated budget, however, shows that very little transfers occurred among the different regional administrations (Regione Toscana, 2002). The published consolidated budget could not be used due to the lack of some information that is needed to solve the model.

[11] Such disaggregation has been obtained by aggregating data contained in the budget sheets of regional and municipal government, as indicated in Regione Toscana (2002). Due to the lack of needed information, the data for the provincial governments are computed by applying to their total current expenditures the ratios that emerged from regional and municipal outlays.

A.4. Regional income

Regional GNP in Tuscany in the year 2000 was equal to 79683.8 millions Euros (Prometeia, 2002).

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