The Impact of e-Government Promotion in Europe: Internet Dependence and Critical Mass

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Abstract. Governments and public bodies have been fostering the development of e-Government services during the last decade. By promoting more and better administrative services through digital channels, many governments have been very active in this process. Its impact, however, has not been fully assessed.

The diffusion of e-Government services depends mainly on the Internet rate. But governments have the possibility to invest in more and better government services. The aim of the article is to analyze to which point the government efforts to foster the development of e-Government services is comparable to the dependency of e-Government on the number of Internet users. This should let to establish the reasonable effort in the promotion of e-Government so as to have as many impact as possible on citizenship adoption.

The paper provides evidence of the way in which governments promote the use of e-Government by investing in more and better services. Results show that when Internet users are scarce, policies to foster e-Government adoption will have little impact, although not negligible. But at certain Internet level, focused e-Government policies have a substantial impact on citizens' adoption of the technology. The paper, then, addresses the factors that make public policy more effective.

Data comes from European countries. The cross-sectional dataset has been analyzed using a Bayesian linear model. Bayesian inference allows the researcher to avoid artificial assumptions currently done in comparative politics, to present the results in a more natural way, and to design more flexible models.

1. Introduction

Does e-Government promotion increases its adoption? Does the public investment in electronic services has increased its adoption by citizens or does e-Government adoption depends only on Internet adoption rate? The e-Government, considered as a major opportunity to improve the efficiency of public administration, has captured many attention in the last recent years. While governments have devoted many resources to foster e-Government adoption by its citizens, the impact of those policies still remains unclear. Moreover, many international organizations (UN, World Bank) recommend the introduction of e-Government programmes when in developing countries the mechanisms through which policies transform into outcomes have not been deeply understood.

Using data from European countries, measured in 2007 and 2009, a Bayesian linear model is fitted in order to assess the adoption of e-Government against Internet

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adoption, transparency and e-Government supply. Results show strong evidence of a clear link between e-Government supply and adoption, whereas transparency is not explanatory of the level of adoption.

The paper provides evidence of the way in which governments promote the use of e-Government by investing in more and better services. It focuses on the effect that a governmental invest in more and better e-Government services has on the adoption rate of e-Government by citizens. By estimating the potential impact of e-Government and the conditions that favor its adoption, the paper aims to help policymakers to decide the level of investment and the best moment to achieve their goals. The analysis also accounts for the fact that institutional features, such as having a culture of transparency in the administration, may play a role in the way in which e-Government is adopted.

The paper argues that it is important to take into account the moment in which policies can be more effective. More specifically, it deals with the conditions under which policies to foster e-Government development can be more effective in terms of achieving greater impact in the society. Based on the empirical findings, the paper explains that the best strategy for a country is to focus its efforts in raising the general population adoption of Internet and once a critical mass of Internet adopters has been reached, focus the efforts on giving more and better e-Government services. This argument is not based only on the fact that investing in a service that only few citizens would be able to use is of discussed social justice, but also in the fact that few impact is attained if there are not enough Internet adopters.

The paper is organized as follows: Section 2 discusses the determinants of e-Government adoption and presents the research hypothesis. Data and methods used for empirical validation are presented in Section 3. Section 4 explains the results obtained, while section 5 discusses the policy implications, followed by the conclusion.

2. e-Government adoption

In June 2005, the European Commission developed a new frame for the Information Society, i2010 which was called "A European Information Society for growth and employment". The document (European Commission 2005), amongst other aspects, presented an overview of the development of the Information Society in Europe after the launch of eEurope 2005 in 2003. The document was addressed to member state government and recommended to enhance the development of e-Government policies in order to achieve the society of "growth and employment" of the title of the report. The development of e-Government is, thus, perceived as important for societies and critical in developed countries.

The definition of e-Government used in this paper is somewhat restrictive, in the sense that it does not include political participation, is focused on a single channel and a single target (avoiding business to government relations or inter-governmental relationships). e-Government will be considered as the delivery of public services (services) using Internet (channel) between public administrations and citizens (impact) for personal purposes (use). This definition is the most accurate to the indicator used by the European Union to compare performance in e-Government supply between member states. Notice that by limiting e-Government to the Internet channel, its adoption is restricted to be either equal to that of the parent technology or less.

Despite the efforts made by governments, few attention has been driven to capture the effect of the policies of e-Government adoption in European countries. The relationships between Internet adoption, e-Government supply and e-Government adoption have not been deeply empirically analyzed. Is it that Internet adoption fosters e-Government adoption directly? Is it that this effect is mediated by the existent level of e-Government services? Or it may even be that e-Government supply increases the utility of using Internet and, so, raises Internet adoption and e-Government as a consequence? Moreover, what is the role that institutional features such as a culture of transparency in the provision of public services has both on the way governments are more likely to create better electronic services and the way citizens adopt those services?

2.1. **Internet adoption and e-Government supply.** Policy intervention has been reported to have an impact on the adoption of Internet. At least, when the intervention is focused and the policies are somewhat complex (Jordana, Fernández-i-Marín, Sancho & Welp 2005). However, the link between policy intervention (e-Government supply, or more and better services) and e-Government adoption (demand) has not been yet established and needs clarification.

A plausible scenario would be to think of the link as going from Internet adoption (I) to e-Government supply (S) and then to e-Government adoption (eG_a). That is, as more people is connected, governments realize that there is a potential for using this technology to provide some services through it. Then, by the increase in the supply, the adoption of e-Government raises as well. This view assumes that governments are independent actors that can not effect Internet adoption *only* by e-Government services, but that they may affect it through other means.

$$I \rightarrow S \rightarrow eG_a$$

A second scenario would be to assume that e-Government supply has no effect on e-Government adoption, and that the adoption is only explained by the parent technology limit. This view would see e-Government adoption simply as a function of Internet adoption. Hence, e-Government adoption rates differ in countries only because they are different in their Internet adoption rates, but have similar percentage of e-Government adopters *amongst* Internet adopters.

$$I \rightarrow eG_a$$

A third way to understand the link is by considering that e-Government supply is able to produce a great impact on society. It can be so great as to imply that citizens that were not Internet adopters now revise the reasons of their non-adoption and realize that they should adopt Internet *because* of the appeal of e-Government services. This situation would link e-Government supply indirectly with adoption through the increase in Internet adoption. Although the impact of e-Government services can be of general interest in the society, it is highly unlikely that individuals base their decisions to adopt the technology only on the basis of the electronically provided government services.

$$S \rightarrow I \rightarrow eG_a$$

The view with weaker assumptions thinks of e-Government adoption as a function of both Internet adoption and e-Government supply, independently. It assumes that e-Government supply is fixed and given by the government, determined maybe by the political will and institutional features of the country, but not determined by the level of Internet adoption. This differential supply affects the e-Government adoption in addition to the Internet adoption rate, which is also important to explain the level of e-Government adoption. In this scenario, Internet adoption and e-Government supply are independent.

$$I + S \rightarrow eG_a$$

If this last scenario is true, then it must be hold that both Internet adoption and e-Government supply explain the e-Government adoption. So the following hypothesis must hold:

Hypothesis 1. *More and better e-Government services increase the adoption of e-Government.*

Hypothesis 2. *Internet adoption increases the adoption of e-Government.*

If there is evidence only for Hypothesis 1 but not for Hypothesis 2, then only the first scenario is possible($I \rightarrow S \rightarrow eG_a$). On the contrary, if there is evidence for Hypothesis 2 but not for 1, then it can be either the second or the third scenarios ($I \rightarrow eG_a$ or $S \rightarrow I \rightarrow eG_a$).

Finally, besides the logical mechanism by which Internet and e-Government supply transfer their importance to e-Government adoption, it is plausible to think that e-Government supply has the same effect at different levels of Internet adoption. That is:

Hypothesis 3. *The effect of e-Government supply on the adoption of e-Government is constant at any given Internet adoption level.*

2.2. **e-Government and Transparency.** Many work has been done on e-Government and transparency. It highlights the advantages of e-Government to increase government control through transparency (Welch, Hinnant & Moon 2005, Welch & Hinnant 2002). A recent article from Bertot, Jaeger & Grimes (2010) focus on the use of Information and Communication Technologies to create a culture of transparency. Even policy recommendations from the United Nations or the World Bank consider its potentially beneficial effects (UN 2010, Sudan 2005). But while it seems clear that transparency and e-Government are somewhat related, it is less clear what is the underlying causal mechanism.

The interest in this paper, however, is not in the potential effect of e-Government on transparency, but the reverse relationship. The paper aims to account for the fact that transparency has an effect on the likelihood of e-Government adoption. That is, is transparency a pre-requisite for e-Government? Blakemore & Lloyd (2007) find that although e-Government supply is important for the adoption of e-Government, the institutional characteristics —such as transparency and trust— are also important. In their own words, “While investment in infrastructure and e-Government service development is fundamental to service delivery, the governance characteristics of transparency and trust are critical in legitimating the investment and in creating the conditions for widespread usage of services” (Blakemore & Lloyd 2007)[4]. This suggests that both mechanisms are equally important. Gefen, Pavlou, Warkentin & Rose (2002) and Warkentin, Gefen, Pavlou & Rose (2002) analyze the individual components of egovernment adoption and find that citizen trust is the most important predictor of individual adoption. Carter & Bélanger (2005) find support for trustworthyness to have effect on intention of adopting e-Government, but not on the current use. They suggest as well that ease of use is the most important predictor, although it is difficult to measure at the aggregate level.

But even if the findings in the literature are quite robust, it is less clear what is the underlying mechanism through which transparency may foster the development of e-Government adoption. It may be simply that more transparent societies and governments are less hesitant to privacy concerns and, so, they invest more resources on more and better e-Government services. In this case, transparency would not be directly linked to e-Government adoption, but only through the provision of services. So controlling for e-Government supply would allow to clarify whether there is a direct or indirect link of transparency on e-Government adoption.

Moreover, although at the individual level it seems clear that trust and transparency is a major explanatory variable for e-Government adoption, it remains unclear on the aggregate level. The last hypothesis aims to test empirical evidence for the existence of a direct link between transparency and e-Government adoption at the aggregate level. It states that:

Hypothesis 4. *Less corruption increases the adoption of e-Government*

3. Data and Methods

This section presents the data sources employed to create the variables, the model specification, discusses the priors and explains briefly the estimation technique.

3.1. **Outcome variable: e-Government adoption.**

e-Government adoption is measured as the percent of individuals using Internet for interaction with public authorities. Figure 1 presents its spatial distribution in Europe in 2009. It ranges from 6 to 65 percent of the population. Lower values tend to correspond to Eastern European countries, while nordic countries and Iceland show the highest values.

e-Government adoption has been measured in Europe since 2003, but the series presents some problems to be used in a research design. First, only few countries do have the complete series. And second, there are years in which this measure is not reported. Instead of having to impute many missing value information in order to capture prior temporal developments, the paper only presents a fixed picture of the distribution of e-Government in 2009. While the temporal dynamics has been removed, the variation of e-Government adoption is greater than relying only on few data for the first years, only available for the countries with best e-Government adoption. So limiting the temporal scope widens the variation of the outcome. Data for e-Government supply in Croatia and e-Government adoption in Switzerland is missing, and both have been excluded. The final dataset contains 29 observations.

The advantage of restricting the sample to countries in Europe is that the sources of data are the same, making comparisons of indicators more likely to measere exactly the same. When dealing with the measurement of new technologies, the definitions of an Internet user are somewhat different for different International agencies. And restricting the analysis to Europe avoids this problem.

3.2. **Covariates.**

The covariates used in the analysis have been the Internet adoption, the e-Government supply and the transparency level. For robustness checks, a model controlling for wealth (GDP per capita) and education has also been specified. Internet adoption is measured as the percent of individuals using internet at least once a week. The indicator measures "the on-line availability of 20 basic

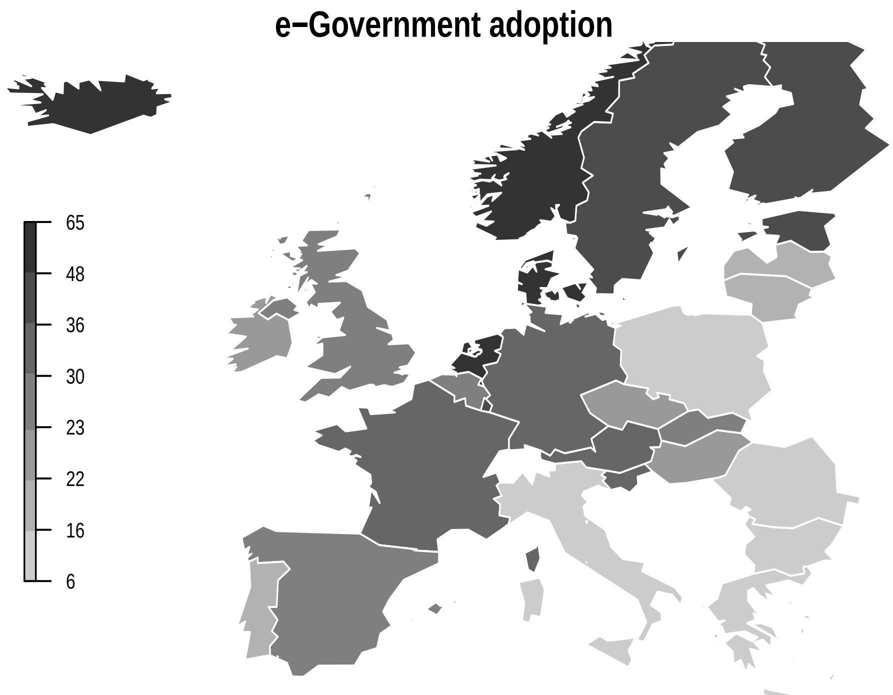

Figure 1. Map of the spatial distribution of e-Government adoption in Europe in 2009. Source: Eurostat.

ublic services" of publich authorities such as central, regional and local governments, police and social security organizations. The availability is understood in four levels of sophistication (information, one-way interaction, two-way interaction ad full electronic service). It is the standard measure of governmental effort in e-Government to meet the objectives of the i2010 initiative aforementioned. The indicator ranges from 0 to 100, but the observed values are only between 15 and 100. It has been centered to the mean and divided by 100, so values between -0.45 and 0.40 are obtained. Transparency measures the degree of perceived transparency in the society, using the Corruption Perception Index 2009 from Transparency International. It has been rescaled to be between -0.27 and 0.28, with higher values representing countries with less perceived corruption, or more transparent countries. This variable shows high correlation with GDP per capita, with the log of Internet adoption and with the log of e-Government adoption (0.7, 0.87 and 0.86, respectively). So specifying a plausible prior specification may help to disentangle its effect. GDP per capita is measured as deviations from the EU being 100, and education is measured as a percent of population having completed at least upper secondary education. Except the level of transparency, the rest of the indicators come from Eurostat. Except for transparency as well, all the covariates are measured with a temporal lag, corresponding to 2007. Hence, the idea is to explain current levels of e-Government adoption by covariates lagged one point in time.

More information about the data employed and its source can be found in the appendix. Table 1 presents the summary statistics of the variables employed. They appear in the scale used in the analysis.

	Min.	25%	Mean	Median	75%	Max.	SD
eGovernment adoption (2009)	0.06	0.21	0.31	0.27	0.43	0.65	0.16
Internet adoption (2007)	0.22	0.42	0.54	0.51	0.65	0.86	0.18
eGovernment supply (2007)	-0.45	-0.15	-0.00	0.03	0.14	0.40	0.22
Transparency	-0.27	-0.16	0.00	0.01	0.15	0.28	0.18
GDP per capita	-0.64	-0.33	-0.00	0.01	0.19	1.70	0.47
Education	-0.46	-0.04	-0.00	0.03	0.12	0.18	0.16

Table 1. Descriptive statistics of the distributions of the variables.

3.3. **Model Specification.** The aim is to explain differences in the levels of e-Government adoption (eG_a). This rate is constrained to be a number between 0 and 1, representing a percentage of adoption in the population. A natural log transformation has been used to limit the values that the outcome can take. It is assumed, hence, that the systematic component has a linear relationship with the log of the rate of e-Government adoption. On the other side, the Internet adoption is a rate that can raise up to 1, but never reaching it. So another natural log transformation has to be done. Having transformed both rates into the log scale leads to a log-log model where the relationship between the outcome and the covariate is in terms of elasticities: a percent change in the covariate is associated with a percent change in the outcome. Appart from restricting the rates to be bounded into reasonable values, the use of the log transformation has other desirable properties. The rate for high values of e-Government adoption is limited to be lower than Internet adoption. Hence, the model restricts the e-Government adoption to be higher than Internet adoption, which is a realistic assumption. Although this restriction would have been possible by using a logit-logit transformation, this last option forces e-Government adoption to tend to Internet adoption in the asymptotics. This is a strong limitation of the logit-logit model that is avoided using the log-log.

Let y be the natural logarithm of e-Government adoption ($y = log(eG_a)$) in 2009, I be the natural logarithm of Internet adoption ($I = log(Internet_a)$) in 2007, S be the e-Government supply centered at 0 and T in 2007 and let T be a measure of the transparency of European countries. The model estimates that y is distributed normally with a systematic component μ and a stochastic component σ:

$$y \sim \mathcal{N}(\mu, \sigma)$$

The systematic component is defined as the lineal addition of the effects of Internet adoption, e-Government supply and transparency:

$$\mu = \beta_1 + \beta_2 I + \beta_3 T + \theta S$$

The main parameter of interest is θ, which represents the effect of e-Government supply on the adoption of e-Government, having controlled by the rate of Internet adoption and the transparency level in that country.

3.4. **Unequal Variance.** Previous model specifications have found evidence of unequal variance of the residuals at different levels of education. Since it may lead to inefficient estimates, the model controls for heteroskedasticity. That is, the model tries to capture the fact that e-Government adoption is more variable for those countries that are in the extremes of the educational levels ($Ed = abs(\text{education})$). This is achieved by letting the stochastic component to vary by education:

$$\sigma = exp(\lambda_1 + \lambda_2 Ed)$$

It is unrealistic to conceive spatial diffusion for the adoption of e-Government adoption, since individuals are restricted to use their own country services. Hence, no parameters have been introduced to account for any sort of spatial lag or spatial error structures.

3.5. **Prior Specifications.** Bayesian estimation requires the researcher to supply *prior* distributions for the parameters in the model, in addition to the data. In a context with few observations, as it is the case, is very useful to specify priors. The estimations process is improved and possible problems of collinearity are not important anymore. This leads to more precise parameters. The advantages of using prior information to distinguish the effect of two collinear variables in the context of comparative research with sparse dataset have been discussed in Western & Jackman (1994).

The meaning of the intercept (β_1) is the expected e-Government adoption rate in the log scale when transparency and e-Government supply are at their mean and the log of Internet adoption is 0. That is, when Internet adoption is 1. In this scenario the e-Government adoption can only be positive. Let's center it at 0.5, implying that when Internet is fully adopted e-Government is adopted by 50 percent of the population. This implies a prior centered at $log(0.5) = 0.7$ and let's vary it with a standard deviation of 0.25. Although e-Government adoption is not restricted to be less than Internet adoption (recall from the definitions of the variables that Internet adoption is the percentage of individuals who use Internet on a weekly basis and e-Government adoption the percentage of individuals who use Internet to contact public authorities), the fact that an individual has to be Internet user (but not weekly Internet user) makes the e-Government adoption, on practical terms, be restricted to lower values of Internet adoption.

If Internet adoption and e-Government adoption were increasing at the same rate, it would imply that the country would have the same percentage of e-Government adopters *amongst* Internet adopters every time. Hence, the expected effect would be equal to 1 (one percent increase in Internet adoption increases e-Government adoption by one percent —not one percent unit—). But the use of e-Government services requires some Internet skills and formal educational level (Thomas & Streib 2005, Akman, Yazici, Mishra & Arifoglu 2005). Hence, it is expected that when Internet adoption raises in the general population, the increase in e-Government services would not increase that much. Simply because the latest Internet adopters are less skilled and may have more difficulties when dealing with e-Government services. Hence, it is expected that as Internet becomes more popular, e-Government does so as well, but at a lowest rate. The effect of Internet adoption on e-Government adoption is expected to be less than one. That is, a one percent increase in Internet adoption is expected to increase e-Government adoption by slightly less than 1 percent. Let's center the prior density on 0.9 with a standard deviation of 0.5.

The effect of transparency is expected to be positive, according to the literature. The standard deviation of the variable is 0.18. Let's center the prior at an expected effect equal to increasing e-Government adoption by 50 percent when transparency increases from the minimum to the maximum. That is, 4 standard deviations lead to an increase in 50 percent ($4sd = log(1.5)$). Its prior uncertainty is about 0.08 standard deviations, implying that 90 percent of the prior density is above 0 (positive effect of transparency).

The rest of the priors are normally distributed centered at 0 with a huge standard deviation that turns them to be non-informative about the final location of the parameter. The results have been checked for robustness on prior sensitivity and they do not alter substantively the conclusions.

3.6. **Formal Model.** To sum up, Equation 1 presents the complete model specification:

$$
\begin{aligned}
y &\sim \mathcal{N}(\mu, \sigma) \\
\mu &= \beta_1 + \beta_2 I + \beta_3 T + \theta S \\
\beta_1 &\sim \mathcal{N}(-0.7, 0.25) \\
\beta_2 &\sim \mathcal{N}(0.9, 0.5) \\
\beta_3 &\sim \mathcal{N}(0.1, 0.02) \\
\theta &\sim \mathcal{N}(0, 30) \\
\sigma &= exp(\lambda_1 + \lambda_2 Ed) \\
\lambda_1 &\sim \mathcal{N}(0, 30) \\
\lambda_2 &\sim \mathcal{N}(0, 30)
\end{aligned} \tag{1}
$$

3.7. **Estimation.** Bayesian methods for inference and data analysis show clear advantages over more traditional frequentist views, specially in the context of comparative data. Amongst the most important characteristics are the "ability to model a wide class of data types and complex models", a systematic way to make overt assumptions, the clear and intuitive way (probability statements) in which results are presented, the possibility of updating those statements as new information is obtained, the systematic way in which previous knowledge about the subject is Incorporated in the analysis and a clear way of assessment of model quality and sensitivity to assumptions (Gill 2002, Chapter 1).

The idea of using a Bayesian framework that allows for a more intuitive way of presenting results is specially relevant for public administration research and has deep implications for social science methodology. Since it has a strong prescriptive orientation, the role of public administration research is not only to *explain* what happens, but also to "inform practitioners and interested scholars about how managerial decisions *should* be made (Wagner & Gill 2005, 7).

The model has been estimated using Markov Chain Monte Carlo methods, more specifically, the Gibbs sampler. JAGS (Plummer 2010), has been used for the estimation, while the chains have been analyzed under `R` (R Development Core Team 2010) with the `coda` (Plummer, Best, Cowles & Vines 2010) and `boa` (Smith 2007) libraries. Models have been run for 200,000 iterations (thinned by 50) under different initial values, with a burn-in period of 50,000 iterations.

There is no evidence of non convergence of the series according to the Geweke test (Geweke 1992). Results and substantial interpretations of some of the parameters are presented preferably using graphical figures, in accordance with statisticians' advice of "turning tables into graphs" (Gelman, Pasarica & Dodhia 2002). The model specification in JAGS can be found in the appendix.

4. RESULTS

The model used to report the results is the most comprehensive model, having discarded parameters that are statistically and practically different from zero. Keeping those variables into the model would only add noise into the estimation. In a context with few data as this one, avoiding nuisances can help into the estimation process. Table 2 reports the estimated mean, standard deviation and 90 percent credible intervals of the posteriors of the parameters in the model without non relevant variables. Table 3 in section 4.1 on robustness checks shows the results for the model with all the variables.

	Mean effects	Standard deviation	5% CI	95% CI
Intercept (β_1)	-0.39	0.08	-0.52	-0.25
Internet demand (β_2)	1.40	0.11	1.20	1.50
Transparency (β_3)	0.19	0.17	-0.10	0.45
eGovernment supply (θ)	0.34	0.12	0.15	0.54
Intercept (λ_1)	-1.50	0.22	-1.80	-1.10
Education (λ_2)	-3.20	1.60	-5.80	-0.53

Table 2. Estimated mean, standard deviation and 90 percent credible interval of the parameters from model 1.

The effects reported in Table 2 are on the log scale of the outcome. The intercept has a mean effect of -0.39, which indicates that for a country with 0.5 Internet adoption and the rest of the variables at their mean, the expected e-Government adoption is $exp(-.39 + 1.40 * .5) = 0.26$. So slightly more than half of the Internet adopters (0.5) are also e-Government adopters (0.26). When the Internet rate reference is 0.05 percent, however, the expected e-Government adoption is much lower $(exp(-.39+1.4*.05) = 0.011$. So in this case, only 1 of 5 Internet adopters are e-Government adopters. The effect of Internet adoption is on the log-log scale. This allows the term to be easily interpretation in terms of "elasticity" or proportional changes in the outcome explained by proportional changes in the covariates. So a 1 percent increase in the Internet adoption increases the e-Government adoption by 1.4 percent. Results suggest that more e-Government adoption is associated with highest rates of Internet adoption, at least for European countries with Internet adoption rates between 0.2 and 0.8.

The effect of Internet adoption on e-Government adoption was expected to be less than one, and a prior was defined accordingly, as explained in Section 3.5. The posterior density of the Internet adoption parameter, however, has most of its density above one. This implies that e-Government is relatively more adopted in countries with yet more Internet adopters, not only in absolute terms but also in relative terms. That is, countries with higher Internet adoption are more likely to have a bigger percentage of e-Government adopters than countries with less Internet adopters.

The effect of e-Government supply is captured by θ, which represents the main parameter of interest. Its effect is centered on 0.34 with a 90 percent credible interval between 0.15 and 0.54. This means that increasing the supply of e-Government by .20 percent points (which corresponds to an increase of approximately one standard deviation) multiplies the adoption of e-Government by $exp(0.34*0.20) = 1.07$. In other words, *an increase in the e-Government supply indicator in 20 points is associated with a 7 percent increase in e-Government adoption.* Figure 2(a) shows the density of the θ parameter. It can be seen that almost all density is on the positive side and centered around .34. Hypothesis 1 stated that there is a positive link between the government provision of more and better e-Government services and the adoption of e-Government on citizens. The support for Hypothesis 1 according to model in Equation 1 is 99.75%. The supply of e-Government services, hence, has an effect on the adoption of e-Government.

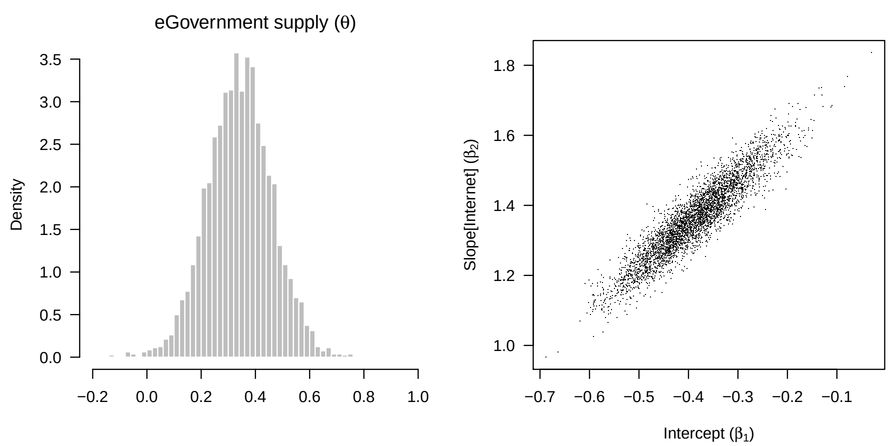

Figure 2. (a) Posterior of the effect of e-Government supply on the adoption of e-Government. (b) Densities of the posteriors for the Intercept and the slope for the effect of Internet adoption. Notice that both parameters exhibit a high correlation. Source: estimated from model in Equation 1.

Although the mean effect of transparency on e-Government adoption is positive (0.19), the uncertainty associated to the parameter is almost its value (0.17) and the 90 credible interval that includes 0 (-0.1, 0.45). The support for the effect of transparency on e-Government adoption being positive is only 88 percent, a relatively low probability which does not allow to reject the null hypothesis of on effect of transparency on e-Government.

The λ parameters account for the fact that there is heteroskedasticity on the model. The λ_2 parameter, associated with the absolute value of the education is positive. This finding indicates that for countries with education far from the mean of the EU the expected residual of the e-Government adoption is lower than for countries in the mean. In other words, that the model predicts better those cases which are either countries with high levels of formal education and countries with low levels of formal education.

Finally, Hypothesis 3 is not directly interpretable from parameters of the model. Instead, Figure 3 presents the differential effect of e-Government supply over the range of Internet adoption. The figure shows the expected difference that a 20 percent points increase in e-Government supply makes on the e-Government adoption. It can be observed that the effect is not linear over the Internet adoption range. It goes from 5 percent at lowest levels of Internet adoption to 20 percent at highest levels of Internet adoption. This finding supports Hypothesis 3 in the sense that the effect of e-Government supply to increase e-Government adoption is not constant for every Internet adoption.

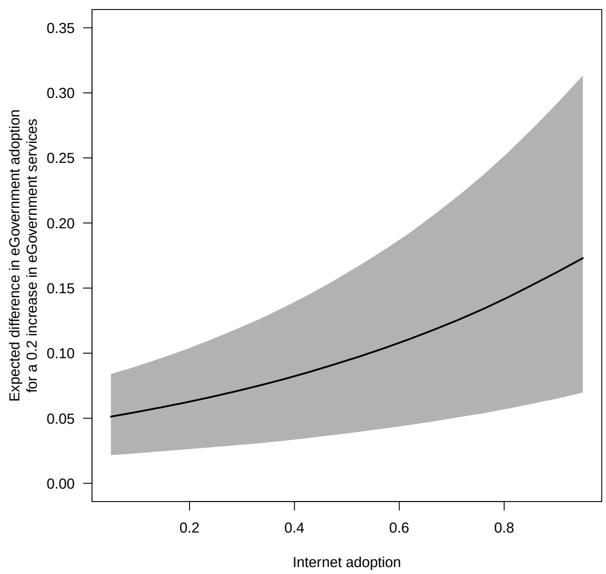

Figure 3. Expected e-Government adoption difference for the whole range of Internet adoption, when the e-Government supply increases by 20 percent points. Notice that at higher Internet adoption, an increase in the supply of e-Government services has a biggest impact in the percentage of citizens that adopt e-Government. Bands show 90 percent credible intervals. Source: computed from the model in Equation 1.

4.1. **Robustness checks.** Robustness checks include assessing the fit of the model to the data, model comparison and sensitivity to the prior specifications.

The model fit to the data can be seen in at Figure 4. The figure shows the European countries in their Internet adoption rate in 2007 in the x axis and their e-Government adoption in 2009. Notice that the upper left space delimited by the dashed line is the area where it is not possibility to observe any country. That is, an area where e-Government adoption is greater that Internet adoption. The red line is the expected fit for the countries with the minimum observed value of e-Government supply, whereas the green one represents the expected fit for the countries with the highest observed value of e-Government supply. Notice again how the difference in e-Government adoption between countries with low and high e-Government supply is greater at highest Internet adoption. The model represents quite accurately the data. Aside from the fit of the model to the data, Figure 4 provides a clear way to understand how Internet adoption and e-Government adoption are related in the intuitive natural scale in which they are measured.

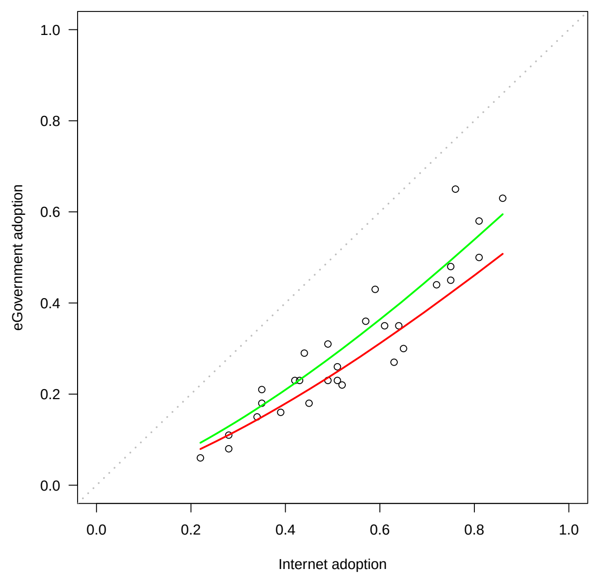

Figure 4. Observed e-Government adoption in 2009 against Internet adoption in 2007. Lines represent the fitted model with e-Government supply at the minimum (red) and maximum (green) observed values. The dashed line represents the situation where all Internet adopters would also be e-Government adopters. The lines have been estimated from results of model in Equation 1.

Results have proven to be quite robust to different settings and model specifications. Table 3 shows the results from a model including all the potential covariates. The effect of the parameter of interest (θ, e-Government supply) is 0.37, compared to 0.31 in the working model. The uncertainty, however, is much greater, with a 90 percent credible interval ranging from 0.03 to 0.8 (compared to 0.14 to 0.50 of the working model). So excluding some variables from the final model does not affect substantively to the mean effect of the parameter of interest, which suggest that the model is quite robust.

The logit-logit specification has also been tested (logit transformations of the e-Government adoption and the Internet adoption), with similar results. Support for the hypothesis in this scenario is 98.8 percent. The parameter for the e-Government supply is not in the same scale as the main model and, hence, the effects are not directly comparable. In this case, 20 percent points increase in e-Government supply would multiply the expected e-Government adoption by 9 percent. In any

	Parameter mean	Standard deviation	5% CI	95% CI
Intercept (β_1)	-0.32	0.13	-0.54	-0.12
Internet demand (β_2)	1.50	0.18	1.20	1.70
Transparency (β_3)	-0.01	0.40	-0.63	0.67
GDP per capita (β_4)	0.03	0.09	-0.10	0.17
Education (β_5)	0.07	0.25	-0.30	0.51
Political Constrains (β_6)	-0.66	0.57	-1.50	0.33
eGovernment supply (θ)	0.37	0.24	0.03	0.80
Intercept (λ_1)	-1.20	0.44	-1.80	-0.39
abs(Education) (λ_2)	-4.10	2.50	-8.70	-0.38
abs(eGovenrment supply) (λ_3)	-1.00	1.70	-3.70	1.90
GDP per capita (λ_4)	-0.91	0.91	-2.40	0.49
Transparency (λ_5)	1.40	2.00	-1.80	4.80

Table 3. Estimated mean, standard deviation and 90 percent credible interval of the parameters from model 1.

case, the effect holds in a different model specification, supporting the robustness of the results.

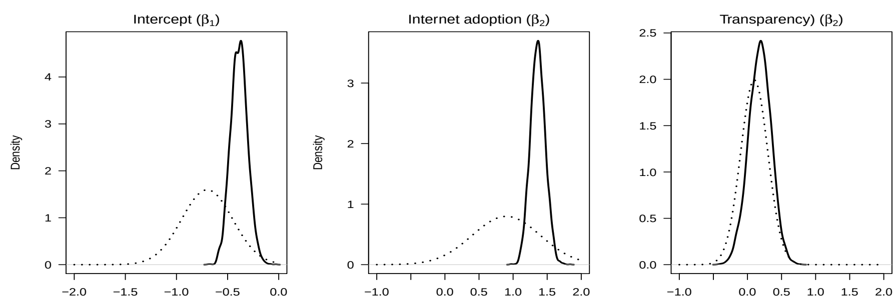

Figure 5. Posterior density (continuous line) and prior (dashed line) for the Intercept and slope parameters of the model in Equation 1.

The final robustness check has to do with the sensitivity of the posterior to the prior specifications. Figure 5 shows the posterior (continuous line) and prior (dashed line) densities for the Intercept and slope parameters of the model. Notice that the specified prior for the slope of internet adoption was less than 1, but the evidence contained in the data has shifted this effect to be greater than 1. Moreover, notice that the uncertainty of the posteriors is lower, because the data has provided evidence af its final distribution. The effect of transparency has proven to be quite close to the posterior, but without much increase in its precision, suggesting that the data incorporates few evidence of this effect to be able to shift the posterior or to narrow its uncertainty. In a frequentist scenario with transparency highly correlated with other covariates, the model would have been less robust and the effects of each of the variables less clear.

Apart from comparing the prior and posterior distributions after fitting the model, it is important to compare the resulting model with another specified with uniform priors. Figure 6 provides a comparison of the 95 percent credible intervals of the posteriors of the model (continuous line) with the same intervals for a model specified with uniform priors (dashed line). The density of the main parameter of interest (θ) is virtually identical in both models, increasing again the robustness of the conclusions. The first aspect to notice is that specifying non-uniform priors for the β parameters has helped to narrow its uncertainty. The effect of Internet adoption on e-Government adoption appears to be slightly lower in a model with uniform priors (the dashed line is shifted towards 0) and the effect of transparency appears to be slightly higher. However, any results change substantively, providing additional evidence of the robustness of the model.

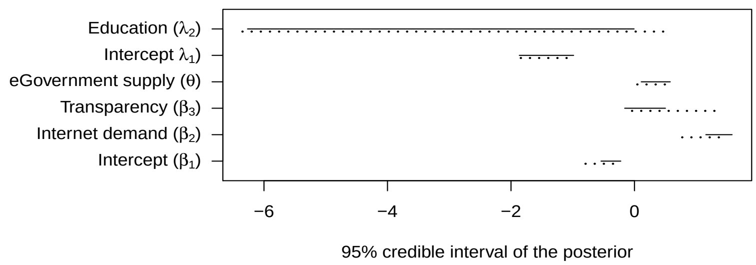

Figure 6. 95 percent credible interval for the posteriors of the model with informative priors (continuous line) and the model with uninformative uniform priors (dashed line).

5. Discussion

Empirical evidence for e-Government supply having an effect on the adoption of e-Government has been found. This effect is robust when controlling for transparency and Internet adoption. But transparency has proven not to be an relevant variable for e-Government adoption. Moreover, e-Government adoption raises more steeper than Internet adoption. So although Internet adoption comes first, and certain level of Internet adoption must be attained, e-Government adoption increases relatively quicker than Internet.

Figure 4 complements the results from Table 2 and shows the expected e-Government adoption against the Internet adoption, for a country with highest observed level of e-Government services (strong red) compared with a country with the lowest observed level of e-Government services (light red). The figure shows an important feature of the data: the difference that e-Government supply does in the expected adoption of e-Government is higher at high levels of Internet adoption. This is a relevant finding, since it suggests that public investments in e-Government services are more or less likely to have potential effect at different stages of Internet adoption. So for a country with, say, 20 percent of Internet adopters (in the minimum of the range of Internet adoption observed in Europe), having the minimum or the maximum index of e-Government supply can lead only to a small difference, whereas for a country with 80 percent of Internet adopters this difference leads to a much wider impact.

Results from Figure 3 suggest that governments must choose the appropriate moment to invest carefully in e-Government services in order to achieve certain outcomes. The best strategy for a country is to focus its efforts in attracting citizens to the use of Internet, and once a critical mass of users has been reached, focus the efforts in more and better e-Government services. But unless there is enough Internet adoption, investing resources in e-Government adoption is a non optimal way to allocate the resources.

The practical policy recommendations can be more easily understood by inspecting Table 4. The first column shows the predicted increase in e-Government adoption when the country increases its e-Government supply from its current value to the maximum of the e-Government readiness index. Notice that countries with expected negative increases are those which e-Government supply is yet at the maximum or very close. Notice also that the 50 percent credible intervals overlap 0 in some cases. By contrast, the third column shows the predicted change in e-Government adoption when Internet adoption raises 10 percent points. The table provide a clear way to compare the counterfactuals of what would happen to e-Government adoption if the country would focus its efforts in increasing the e-Government supply in contrast of what would happen it the efforts are centered in achieving higher Internet adoption. Iceland would increase its e-Government adoption by 7.8 points by increasing the supply of e-Government to the maximum, whereas the adoption would increase by 6.1 points if there were 10 percent poins more Internet adopters. Whether it is easiest for Iceland to impact e-Government adoption by focusing on the supply or on the Internet adoption and their associated costs would depend on policy choices of public decisionmakers.

This table with counterfactual information provides a useful tool for policymakers to take decisions. And, again, stresses the necessity for choosing carefully the moment to which policies have to be carried out. The same interpretation can be learned: there is a low impact on e-Government adoption at early stages of Internet adoption. So it may be desirable to invest in achieving more Internet adoption before serious invests in e-Government policies are considered. Obviously, this statement only applies if the aim of the policy is to have impact in terms of technology adoption. There are many desirable impacts of investing on e-Government regarding regime accountability —which have been discussed in Section2— that may be more important for policies. But in terms of outcomes, the message is to first focus in Internet adoption.

Results have shown that high Internet adoption rates are associated with higher e-Government adoption rates. So it seems that the demographical explanation, which stated that the laggards in Internet adoption are individuals less formally educated and with less technical skills, is hard to sustain. A possible interpretation may be that countries with higher Internet adoption are usually those in which individuals have been exposed to Internet for more time. And veteran Internet adopters, by having more experience, are also less likely to mistrust Internet and more likely to trust the technology

The role of transparency on the adoption of e-Government must be considered as well. Countries with higher perceived transparency were expected to show higher levels of e-Government adoption. But results have proven that once controlling for Internet adoption, what really matters to explain e-Government adoption is not the transparency, but the supply of e-Government services. That is, the finding suggest that if transparency has an effect on e-Government it does so by altering the supply of e-Government, and not by affecting itself its adoption. So the link

	Δ eGov. adoption	50% CI	Δ Int. adoption	50% CI	eGov supply
Iceland	7.80	(0.078, 16)	6.10	(-0.86, 15)	50
Latvia	7.80	(4.4, 12)	8.00	(4.9, 12)	30
Luxembourg	7.80	(1.7, 15)	6.50	(0.64, 13)	40
Slovakia	7.30	(4.1, 11)	7.90	(5, 11)	35
Belgium	6.30	(0.55, 13)	8.90	(3.2, 16)	60
Lithuania	6.00	(3.4, 8.9)	7.50	(5, 10)	35
Netherlands	5.60	(-2.8, 16)	8.20	(-0.44, 19)	63
Poland	5.50	(3.2, 8.2)	6.60	(4.4, 9.1)	25
Hungary	4.60	(1, 8.5)	6.90	(3.2, 11)	50
Denmark	4.30	(-3.1, 13)	6.60	(-0.94, 15)	63
Czech Republic	4.20	(2, 6.5)	7.60	(5.3, 10)	55
Bulgaria	4.10	(2.1, 6.2)	5.90	(3.9, 8.1)	15
Ireland	4.10	(-0.22, 8.9)	6.40	(2.3, 11)	50
Estonia	3.90	(0.67, 7.6)	8.30	(4.6, 12)	70
Finland	3.90	(-2.7, 11)	6.70	(0.35, 14)	67
France	3.40	(-1.2, 8.8)	8.40	(3.1, 14)	70
Cyprus	3.20	(0.46, 6.5)	6.10	(3.2, 9.7)	45
Greece	2.50	(1.1, 4.2)	5.90	(4.2, 7.8)	45
Italy	2.40	(0.91, 4.2)	7.50	(5.6, 9.5)	70
Romania	2.30	(0.89, 3.9)	5.60	(3.8, 7.6)	35
Germany	2.20	(-2.2, 6.9)	7.20	(2.1, 13)	74
Spain	2.00	(0.15, 4.2)	6.90	(4.5, 9.5)	70
Sweden	1.90	(-3.9, 8.5)	6.80	(0.5, 13)	75
Norway	1.80	(-5.1, 10)	7.50	(-0.33, 16)	78
Malta	1.10	(0.042, 2)	8.60	(7.3, 9.9)	95
Slovenia	0.97	(-2.3, 4.6)	8.00	(4.1, 12)	90
Portugal	0.51	(-0.15, 1.2)	7.10	(6.1, 8.2)	90
United Kingdom	-0.02	(-5.9, 6.9)	7.10	(0.033, 15)	89
Austria	-0.55	(-5.1, 4.7)	8.20	(2.8, 15)	100

Table 4. Predicted change in the adoption of eGovernment in 2009 if countries would have raised the supply of eGovernment services at the maximum in 2007, or if the countries have raised Internet adoption by 10 percent points. Median of the prediction and 50% credible interval. Countries are sorted by higher increase in eGovernment. Notice that prediction intervals are wider than expected intervals, since the uncertainty associated to the model (and not only to the parameters) is also introduced in the estimation. Estimated from model in equation 1. The last column is the observed level of e-Government supply.

between the variables is as follows: there is a certain degree of transparency in a country that causes the government to invest in more (high transparency) or less (low transparency) e-Government services. It is this supply which explains why do some countries have higher and lower levels of e-Government adoption, but not the transparency by itself. However, more research is needed to fully support this view. It would be necessary to help clarify which are the institutional features in a country that favour the introduction of e-Government.

Recall from section 2 that Blakemore & Lloyd (2007) suggested that both e-Government supply and institutional characteristics were important. The empirical findings, however, tell a different story: there is direct evidence that e-Government supply has an effect on e-Government adoption, and indirect evidence that transparency is not directly linked to e-Government adoption, but through the e-Government supply.

The data used only covers democratic countries in Europe, which show relatively small variation in some of the variables, compared to other regions and countries in the world. This makes the results somewhat limited in scope for all regions and countries in the world. But many lessons can be extracted, at least for developing countries that aim to foster the development of electronic services.

Future research may make use of more data regarding the temporal dimension of the process of adoption. Capturing the temporal dynamics may offer more detailed estimation of the effects of the supply on the adoption and also a dynamic story about the process. In addition to the temporal dynamics, more research is needed to clarify the determinants of e-Government supply. Is may be determined by transparency, as suggested by the results of this paper Or maybe other institutional features (political constrains and relevant political players vetoing the invests in more and better services, the administrative structure of the state favoring competition on the provision of services, or other) may have a role as well.

6. Conclusions

The paper has reported empirical evidence of the impact of e-Government policies of European countries in the adoption of e-Government services by citizens. An increase of 20 points in the standard scale of e-Government availability has an expected increase of 7 percent in the citizens' adoption of e-Government. Moreover, the expected increase of e-Government adoption due to the effect of policies is higher at countries with high Internet adoption rates.

Institutional features such as governmental transparency are usually linked to more e-Government adoption. But the findings suggest that there is not a direct link between more institutional transparency and more e-Government adoption. The determinants of the adoption of e-Government are both the level of Internet adoption and the strength of governmental policies.

The results emphasize the importance of selecting the appropriate moment to launch a policy that aims at extending the diffusion of a new technology. In the case of e-Government adoption, it has been found that a strong policy favouring electronic services has the highest impact when there is a critical mass of Internet adopters that may be willing to adopt it. Otherwise, the impact, in global terms, is scarce. The lessons learned about the conditions under which public intervention is more effective may provide a way to focus governmental efforts to make policies more effective.

Data Sources

eGovernment adoption: Individuals using Internet for interaction with public authorities (isoc_pibi_igov). http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=isoc_pibi_igov&lang=en

Internet adoption: Individuals using Internet, accessed, on average, once a week. http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=isoc_pi_a2&lang=en

eGovernment supply: E-government availability (supply side) (isoc_si_sseg). http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=isoc_si_sseg&lang=en and http://epp.eurostat.ec.europa.eu/cache/ITY_SSDS/en/tsiir120_esms.htm.

Education: Total population having completed at least upper secondary education - [tps00065]. http://epp.eurostat.ec.europa.eu/tgm/table.do?tab=table&init=1&language=en&pcode=tps00065&plugin=0

Transparency: Corruption Perception Index, Transparency International. http://www.transparency.org/policy_research/surveys_indices/cpi/2009/cpi_2009_table

Model specification in JAGS/BUGS

Model in Equation 1.

```
data {
  for (c in 1:C) {
    li[c] <- log(D[1,c,3]/100)                    # log of Internet adoption
    le[c] <- log(D[2,c,2]/100)                    # log of eGovernment adoption
    es.c[c] <- (D[1,c,1] - mean(D[1,,1])) / 100    # eGovernment supply centered at mean
    cpi.c[c] <- (D[2,c,9] - mean(D[2,,9])) / 10    # transparency centered
    educ.c[c] <- (D[1,c,7] - mean(D[1,,7])) / 100  # education centered
  }
}

model {
  for (c in 1:C) {
    le[c] ~ dnorm(mu[c], tau[c])
    mu[c] <- beta[1]
           + beta[2] * (li[c])
           + beta[3] * (cpi.c[c])
           + theta[1] * (es.c[c])
    tau[c] <- pow(sigma[c], -2)
    sigma[c] <- exp(lambda[1] + (lambda[2] * abs(educ.c[c])) )
  }

  # priors for heteroskedastic component
  for (l in 1:2) {
    lambda[l] ~ dnorm(0, 0.001)
  }

  # informative priors
  beta[1] ~ dunif(-0.7, 16)
  beta[2] ~ dnorm(0.9, 4)
  beta[3] ~ dnorm(0.1, 25)
  theta[1] ~ dnorm(0, 0.001)
}
```

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