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ICT Stochastic Externalities and Growth: *Missed Opportunities*, *Beyond Sustainability or What?*

Bernardo Maggi*

Abstract

In this paper we present an analysis of the OECD production process and consider the ICT as driver of growth. In doing so the production function approach adopted underlines the externalities exploited or not and, possibly, when the production process overpasses the countries capacities implied by the technical parameters. In line with the general purpose theory such externalities are attributed to ICT. Business services are relevant as a vehicle to better exploit the innovative capital embedded in the production process. We develop and implement a methodology for the evaluation of the different effects on growth related to ICT. Our main conclusion is that even if a competitive solution is viable there are possible, though small, margins for a sustained growth in the long run for the OECD countries considered. We also point out some conclusions on the capital and labour shares showing that the latter is "too small" both in the long and short run.

JEL: C33, O11, O47, D62

Keywords: Growth and externalities, ICT, Technology, Business Services, Panel Data Econometrics.

1. *Introduction*

Notably ICT has been considered in the literature as the channel through which countries growth may be nowadays enhanced. About that, Maggi et al. (2009), Maggi and Muro (2013), addressed how such an issue may be modelled dynamically in a European context *vis a vi* the rest of the

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world. There, the ICT sector works as a specific tool capable to make effective the technology effort in the innovation, however, the general contribution, referred to the whole economy, of the ICT on growth is not specifically evaluated. Indeed, ICT may be conceived as a General Purpose Technology (GPT) as in Fagerberg, Mowery and Nelson (2005) and Lipsey, Carlaw and Bekar (2005). These authors stress on the complexity and the generality of the innovation brought about by ICT, with the consequence that a traditional representation of such an item inside the production function as an input would be reductive.

In this paper we develop a methodology for the evaluation of the several effects on growth related to ICT and model TFP to this aim. We first move from the Schreyer (2000) accounting framework by following Cardoni et al. (2007) in order to decompose the Solow residual and then emphasize on the externalities for the OECD countries. In particular, our gains are: 1) to succeed in the estimation of a panel production function for the OECD countries in which ICT capital exerts a leading role in representing the innovations, 2) to discern, within the Solow residual, between missed opportunities of growth and excesses of production per each country, 3) to qualify and quantify the ICT impact on growth through business services. This last point refers expressively to the conception of ICT as a GPT thus requiring the necessary competencies -here represented by business services- in order to be applied to any specific context. Our main conclusion is that even if a competitive solution is viable there are possible though small margins for a sustained growth in the long run for OECD. We also draw some implications for the capital and labour shares showing that the latter is too small both in the long and short run.

The paper is organized as follows. The second section deals with the logic framework and the methodology adopted to calculate the stochastic externalities. The third section presents the estimation of an aggregate production function for the OECD area. The fourth section is concerned with the estimation of the missed opportunities or excess of production. The fifth section concludes.

2. *ICT stochastic externalities*

ICT is a wide concept difficult to represent with a standard category of elements like those ones involved in the classical production function. Such an aspect has been treated in depth by Schreyer (2000), who adopted an accounting approach to underline the varieties of roles covered by ICT. His tool is still a production function extended to incorporate such varieties. Analogously, we adopt a Cobb-Douglas functional specification since we are interested in the structural effects of the ICT capital parameters on the production rather than in the effects of the technical progress on capital. In particular, we consider explicitly and estimate the effects due to the generality of application of the ICT capital to the economic system (GPT). The result of such a general effect, at macro level, is characterized by a specific spillover parameter, ϕ. In the logarithmic production function:

Model 1

(1) $Y_{it} = \alpha_{Y_{t-1}} Y_{it-1} + \alpha_L L_{it} + \alpha_K K_{it} + TFP_{it}$

with

$K_{it} = K_{ICTit} + K_{Nit}$, $\alpha_{K_{ICT}} = \alpha_{K_N} = \alpha_K$ and $A_t = A_0 + at$

$$TFP_{it} = A_t + \alpha_{K_{ICT}} \delta\phi K_{ICT_{it}} + (1-\delta)\varphi_i \alpha_{K_{ICT}} K_{ICT_i} + \varepsilon_{it}$$

where Y, L, TFP, K_{ICT} and K_N represent respectively output, labour, the Solow residual, ICT capital and normal capital. The alphas are the elasticities of the inputs production function. $\alpha_{K_{ICT}}$ and α_{K_N} are the parameters reflecting respectively the direct effect of ICT and normal capital in the production process. Here the total factor productivity is not described solely by the traditional Solow residual A_t. Rather, as an outcome of the ICT generality we assign it with a central role in characterizing the TFP and define two parts: a first one exploited (δ) is captured in the estimation, together with A_t, whilst the second one, not exploited or exploited above the possibility implied by the structural estimable parameters, is leaved unknown. As such, the latter is to be derived from its generating random process underlying the TFP and not modelled in the estimation, i.e. in the residuals of the regression equation. On this point, differently from other authors who worked only with cross-sectional data (see for instance Eaton and Kortum (1999)), we may interpret the panel-data residuals as free from a pre-defined density function, and obtain the potential effect of the unexploited ICT capital in terms of a random effect. In order to represent coherently the countries specificities related to K_{ICT}, in the TFP of formula (1) such an item is indexed only to *i*. As usual, the reference value is the time average on the realistic assumption that while, in terms of growth, countries with good level of interdependence may tend in the future to be uniform, this is not true over the whole time span. We consider the not exploited TFP as an effect of a missed spillover for the country under question. Further, among the explicative variables we insert also the lagged dependent variable to control for any endogenous growth process not contemplated in the other regressors. Given the production function approach adopted, where the levels of the production-factors stocks play the leading role, we reckon the effect of the one lagged variable represents mostly the timing of the production depending on the past orders.

This reasoning means that for each country *i* and time *t*:

Model 2

(2) $Y_{it} = A_t + \alpha_{Y_{t-1}} Y_{it-1} + \alpha_L L_{it} + \alpha_{K_{ICT}} (1+\delta\phi) K_{ICT\,it} + \alpha_{K_N} K_{N\,it} + \zeta_{it}$, $t = 1,...,T$; $i = 1,...,N$

where the term ζ_{it} refers to the following two effects:

(3) $\zeta_{it} = \varepsilon_{it}$ + *missed spillover effect*$_i$, with $\varepsilon_{it} \sim \text{i.i.d.}\left(0, \sigma_\varepsilon^2\right) \forall i$

We are assuming that the exploited spillover $\delta\phi$ may be estimated, being revealed explicitly by the data, whilst the missed spillover may be discovered only in the residuals where its role is that of regulating the distance from the OECD production frontier. We then stress that, from the countries productive capacity point of view, the main differences are to be attributed to the employment of the general purpose technologies, here represented by the K_{ICTi} variable. Our implicit hypothesis is that at national level the firms X-inefficiency, referred to labour and traditional capital, tends to vanish through the aggregation between the more and the less inefficient firms contributing to GDP, and it remains the externality not exploited referred to the ICT capital which is evaluated as a *missed spillover effect*$_i$: $\alpha_{K_{ICT}}\varphi_i\left(1-\delta\right)K_{ICT_i}$. Of course, in case of negative sign we know that the spillover might have been exploited whilst if the sign is positive it has been beyond the possibility implied by the structural parameters of the production function. In the former case we are considering countries where ICT infrastructures might have a major employment in the production process at national level. In the latter case even if the production is attainable in practice, it results structurally not viable according to the estimated technical coefficients. Then, as commented more deeply later, in case of positive sign the unsustainability of the production is to be referred to the uncertain part of the spillover. Actually, we assume that φ_i consists of two pieces, one representing the country specific effect in the spillover (u_i) and another one the constant spillover term itself (ϕ). Still, (1-δ) plays a crucial role in determining the missed spillover, in that refers to all those effects, not considered in the production function, which both regulate, in a constant way, the capacity of using the ICT and characterize the structure of the economy. The environmental phenomena affecting these now mentioned aspects may be classified into organizational and innovative. Examples of the former type may be constituted by the organization of the institutions, regulation, incentives, fiscal laws, the level of social inclusion etc. while the latter type by an efficient broad band system, an appropriate integrated production model among firms etc… Of course, in our scheme, the effects pertaining δ are considered stable across countries and over time while the others, pertaining u_i, country specific. However both of them are not identifiable from the structural part of the regression: the effects of the former are represented in the coefficients function related to ICT, the latter by a random term. The inclusion of such a random term is to account also for variable phenomena in the quantification of the return (share) to the spillover. These may also depend on random effects deriving from the presence of a developed public sector (Barro, 1990) or credit system used by sectors involved in ICT such as those of real estate or mortgages etc…(Evangelista et al. 2012). Of course, even if we are interested in ICT capital, these sort of externalities may involve also normal capital. Therefore we leave to the empirical analysis the task of verifying the presence of the spillovers in the two capital terms.

The empirical counterpart of such an idea departs from the hierarchical regression models where coefficients are random and the residual terms contains the regressors together with the parameters not estimable. Our approach, in addition, refers both to that one underlying the free efficiency, where the random distribution is not considered, and to the generalized linear models -say probit, logit and their variants- where the random process assumes a form containing the parameters of interest. According to the latter approach such parameters are obtained from the random variable under question by averaging over time to zero according to the former approach. Of course, in the estimation phase the structure of the residuals needs to be appropriately taken into account.

Then, by averaging over time the first term on the r.h.s. of (3) to zero, it will be possible to quantify the missed spillover[1]:

(4) $$\frac{\sum_t \zeta_{it}}{T} = -\left[\alpha_{K_{ICT}}\left(\phi+u_i\right)\left(1-\delta\right)\right]\frac{K_{ICT_i}}{T}$$

and so

(5) $$\left[\alpha_{K_{ICT}}\left(\phi+u_i\right)\left(1-\delta\right)\right] = -\frac{\sum_t \zeta_{it}}{K_{ICT_i}}$$

which is the evaluation of the missed spillover coefficient for the *i*-th country drown from the corresponding unknown underlying distribution.

According to the well known literature, we expect, in such a formulation, the summation of the elasticities related to the traditional inputs to be lower or equal than 1 in order to guarantee a competitive solution, and that the inclusion of the spillover term possibly makes countries capable to surpass such a critical value to allow for economic growth.

But there is more to it than that. In fact, because of the pervasive nature pertaining ICT, we reckon it is assisted by a support capable to vehicle its innovative content to the production phase, which

[1] Of course, in doing so we take into account the implicit negative sign of the missed spillover.

may be found in the business services (*BS*) that are involved in the production (Maggi et al. (2009)). According to this idea, business services interact with ICT by generating a second order effect in the production function, i.e. an effect that comes from the impact of the latter after the implementation of the former. In this way we are confident to capture in the residuals of formulas (4) and (5) only the effect of the missed spillover once controlled for the necessary support to implement in the production the technology embedded in ICT capital. Continuing with the previous formulation:

Model 3

(6) $Y_{it} = \alpha_{Y_{t-1}} Y_{it-1} + \alpha_L L_{it} + \alpha_{K_N} K_{N\,it} + \alpha_{K_{ICT}} \left(1+\delta\phi\right) K_{ICT\,it} + \alpha_{K_{ICT}}^{BS} \left(\overline{K}_{ICT\,it}\, \overline{BS}_{it}\right) + A_t + \zeta_{it}$

where the barred variables stand for the differences from the representative points to calculate the mentioned second order effect, which may be as usual the mean or the zero point. Further, such a representation allows to identify a country –and possibly time- specific indication of growth based on the variable coefficient $\alpha_{K_{ICT}}^{BS} \overline{BS}_{it}$ to be summed to the other stocks' coefficients.

3. *Data and empirical methodology*

3.1. *The database*

The panel data used is of 16 years and 15 countries: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, Spain, Sweden, United Kingdom and United States. We select the period 1989-2005 in order to focus on the countries' productivity in the ICT era without the contamination of other problems such as the current crisis started after that period[2]. All the variables adopted for this study are from Groningen Growth and Development Centre, 60-Industry Database. They are: GDP, ICT capital, non-ICT capital, labour and business

[2] We performed also regressions by extending the sample period to the current one. However, the use of the dummies necessary to obtain significant results would force the analysis towards other problems that would deserve a specific treatment in another research.

services. Data on GDP, capital and business services are expressed in millions of euro and at 2000 constant prices. Labor is counted as number of workers expressed in thousands.

The peculiar variable of this study, the ICT capital, refers as usual to IT equipment, communication equipment and software; while data on non-ICT capital concern non-ICT equipment, transport equipment and non residential structures. The other peculiar variable, business services, refers to the manufacturing industries (financial, communication and business services). More specifically are considered those services linked to ICT capital: inland transport, water transport, air transport, supporting and auxiliary transport activities, activities of travel agencies, communications, financial intermediation (except insurance and pension funding), insurance and pension funding (except compulsory social security), activities auxiliary to financial intermediation, real estate activities, renting of machinery and equipment, computer and related activities, research and development, legal, technical and advertising, other business activities.

In Table 1 are presented some descriptive statistics of our database for the period considered.

Table 1. Descriptive statistics.

Country	Statistics	K_{ICT}	K_N	Y	L	BS
Austria	Mean	9707.038	307320	161743.6	3489.278	39.03217
	S.Q.E.	5655.935	59101.04	27033.41	241.1313	10.218
Belgium	Mean	11505.16	396903	187656.5	3719.106	60.06217
	S.Q.E.	9924.224	39679.4	29313.68	156.6741	13.15042
Denmark	Mean	7103.092	226529.8	127205.6	2583.922	33.40261
	S.Q.E.	5811.52	47985.47	23103.08	100.3597	8.274703
Finland	Mean	6288.847	207060.6	95272.64	2310.743	25.1187
	S.Q.E.	5632.96	23762.98	15605.68	127.7444	6.523658
France	Mean	42967.66	2051628	1085372	22236.45	355.1735
	S.Q.E.	30170.94	435782.4	160732.7	1046.515	74.25966
Germany	Mean	94229.04	3034768	1552440	36260.42	458.323
	S.Q.E.	47732.07	365932.4	231677.5	554.2408	118.7946
	Mean	4787.993	196286	94091.07	3755.049	26.03391

Greece	S.Q.E.	3709.395	35448.14	15076.47	206.1096	4.351456
Ireland	Mean	1770.384	88178.35	59920.13	1307.364	13.33391
	S.Q.E.	2069.211	24318.43	27224.33	247.8715	6.35805
Italy	Mean	53802.58	1467628	921875.2	22436.58	271.6861
	S.Q.E.	36087.5	247533.8	121790.2	912.3115	62.75154
Netherland	Mean	12582.23	637030.1	295681.7	6588.15	84.77957
	S.Q.E.	10059.74	81335.63	56755.84	919.2623	25.05645
Portugal	Mean	3883.143	118563.6	86437.2	4467.608	19.40913
	S.Q.E.	3101.912	30577.73	17973.58	380.5506	4.987693
U. K.	Mean	57432.33	1529126	1056403	25817.69	328.3748
	S.Q.E.	51185.98	264640.7	202596.4	1401.219	89.07434
Spain	Mean	21365.82	877036.2	452433.2	13033.44	118.1783
	S.Q.E.	15529.17	268964.2	97969.35	1800.224	27.16555
Sweden	Mean	587308.1	9996397	6282594	120267.6	62.42478
	S.Q.E.	445003.7	2159590	1702880	13139.6	4.987693
Europe	Mean	65338.1	1509604	889937.6	19162.38	135.3809
	S.Q.E.	35365.96	874009.9	480882.5	10814.64	153.0154
U.S.A.	Mean	14448.44	393386.8	205923.2	4234.131	2117.112
	S.Q.E.	9063.403	20889.13	16739.53	149.5678	728.2639
O.E.C.D.	Mean	61945.45	1435189	844336.6	18167.17	267.4963
	S.Q.E.	184618.4	2501838	1587963	29415.57	549.1569

All data are in millions of euro but labor which is in thousands of workers.

3.2 *Econometric Approach*

Given the time dimension and the lagged effect of the models presented in section 2, our straightforward method is the Arellano-Bond dynamic panel GMM estimator with one lag, which in this case displays as:

- the estimation equation

(7) $Z'\Delta Y = Z'\Delta Y_{t-1}\alpha_{Y_{t-1}} + Z'\Delta \underline{X}\,\underline{\beta} + Z'\Delta\zeta$

where vectors and matrices refer to variables stacked by space and time;

- Among $\underline{X'}_{it}$ the strictly (i.e. lagged) predetermined (k_1=5) together with the exogenous (k_2=2, i.e: t, j) regressors[3] are used to obtain the necessary instruments ($\underline{Z'}_i$)

(8) $\underline{X'}_{it} = \left(L_{it}, K_{ICT\,it}, \overline{K}_{ICTit}\, \overline{BS}_{it}, K_{N\,it}, t, j \right)$, $E\left(\underline{X'}_{it}\,\underline{\varepsilon}_{is}\right) \neq 0$ with $t \geq s$, and $X_{it} \neq t, j$, j =1,.........,1;

- the parameters vector is

(9) $\underline{\beta}' = \left(\alpha_L, \alpha_{K_{ICT}} (1+\delta\phi), \alpha^{BS}_{K_{ICT}}, \alpha_{K_N}, a, A_0 \right)$;

- the errors term structure is

(10) $\Delta\zeta_{it} \sim \text{MA(1)}, i = 1, ... N, t = 1...T$

(11) $\underline{V}_i = E\left(\Delta\zeta_{it}\Delta\zeta_{it-k}\right) = \begin{cases} 2\sigma^2_{\varepsilon}, k=0 \\ -\sigma^2_{\varepsilon}, k=1 \\ 0, k>1, k=1,..,T-3 \end{cases}$, of order T-2, and $\underline{V} = I_N \otimes \underline{V}_i$ of order $N(T$-2);

- the instruments matrices are

(12) $\underline{Z} = I_N \otimes \underline{Z}_i$ of order $N(T$-2)L

where $\underline{Z'}_i$ is the individual instrument matrix of order (T-2)L, and $L = k_1 \sum_{l=1}^{T-2} l + k_2 \sum_{h=1}^{T} h$ is the number of instruments per each instant of time;

- finally the one step GMM consistent estimator is

(13) $\underline{\hat{\beta}} = \left\{ \underline{\Delta H'}_t \underline{Z} \left[\underline{Z'}\left(\underline{I}_N \otimes \underline{V}_i\right)\underline{Z}\right]^{-1} \underline{Z'}\underline{\Delta H}_t \right\}^{-1} \underline{\Delta H'}_t \underline{Z} \left[\underline{Z'}\left(\underline{I}_N \otimes \underline{V}_i\right) Z\right]^{-1} \underline{Z'}\underline{\Delta Y}_t$

with variance regression $E\left(\underline{Z'}\underline{\Delta\varepsilon}\underline{\Delta\varepsilon'}\underline{Z}\right) = \sigma^2_{\varepsilon}\underline{Z'}\left(\underline{I}_N \otimes \underline{V}_i\right)\underline{Z}$ and $\underline{H'}_t = \left(Y_{t-1}, \underline{X'}_t\right)$. Further, given that such an estimator consists in the application of the GLS method to (7), it is also efficient and correct.

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[3] Of course t and j are non stochastic and therefore strictly exogenous ($E\left(\underline{X'}_{it}\,\underline{\varepsilon}_{is}\right) = 0 \forall t, s$), however j may be omitted given that the model is estimated after differencing.

4. *Estimation results*

In this section we present the estimation of models 1-3 and evaluate the possibility of a competitive solution and a sustainable growth for the OECD countries in the short and long run after the adjustment of the endogenous variable. We also asses on the nature of ICT as a GPT.

Table 2.

regressors	Parameters	Model 1	Model 2	Model 3
Y_{t-1}	α_{Yt-1}	0.426**	0.344**	0.094*
	S.E.	0.037	0.025	0.039
K	α_K	0.430**	-	-
	S.E.	0.035		
K_N	α_{KN}	-	0.319**	0.260**
	S.E.		0.020	0.033
K_{ICT}	$\alpha_{KICT}(1+\delta\phi)$	-	0.173**	0.138**
	S.E.		0.010	0.016
L	α_L	0.220**	0.180**	0.260**
	S.E.	0.051	0.031	0.046
$\overline{K}_{ICT}\ \overline{BS}$	$\alpha^{BS}_{K_{ICT}}$	-	-	0.014**
	S.E.			0.001
t	a	0.003**	-0.011**	-0.011**
	S.E.	0.001	0.001	0.001
Cons	A_0	-0.449	0.976**	3.956**
	S.E.	0.406	0.265	0.452

**, * Significance at 1% and 5% respectively.

As for Model 1 we observe that all coefficients are significant and with correct sign but the constant term which is not significantly different from 0 -and negative- and therefore close to 1 in natural numbers. The model reveals a strong stationary dynamic endogenous component (α_{yt-1}) compared to the exogenous one (a), which is much smaller. This means that, as a whole, there is an important endogenous growth effect not adequately represented, other than an exogenous one reflecting the political and the institutional effects. Looking at the first column of Table 2, the competitive solution is guaranteed by the summation of the production-factors elasticities less than one. Such a result is valid in the short run for the presence of the endogenous lagged variable and, accordingly, a steady endogenous and balanced growth is not viable. Further but not secondarily, the elasticities of labour (α_L) and total capital (α_K) reveal that, the repartition of the cost shares between labour and capital amounts to around 20% (rising to more than 30% taking into account the standard error) and 40% respectively, which is quite dissimilar from the one of 70% and 30% adopted to obtain the TFP in other studies (see for instance Coe and Helpman (1995) and Coe et al. (2008)). Comparing these figures points out that the share of labour is considerably lower while the one of capital higher than those reported by the traditional shares. Our conjecture is that it could be due to an increase in the productive capacity of capital consisting in new and innovative capital added to the previous normal one: the sequence of our models to be estimated enables to examine such a question properly by decomposing total capital in the normal one and in the part relative to ICT.

Moving to Model 2 we introduce the ICT capital in our regression by splitting in two the total capital. In such a way we try to asses not only on the relevance of the ICT in the production process but also on the pervasive nature it may have according to the general endogenous effects it exerts at aggregate level.

The coefficient of the ICT capital is significant and with positive correct sign with a value slightly below 20%. We observe a contextual reduction in the stationary dynamic endogenous component and a change of sign in the exogenous one which is still significant. Conversely, the constant term turns out to be significant and positive. Finally, traditional capital coefficient lowers to a more reasonable value of roughly 30% while the labor one still remains around 20%, which is expected because ICT capital was considered also in Model 1 as part of the total capital. Such a result is a first evidence in accordance with our previous observation that the new capital with innovative content has risen the share of the total capital and possibly limited the one of labor. Moreover, such a result is another confirmation –other than that one from the accounting framework (Schreyer, 2000)- that the spillover term is correctly related to ICT. The reduction in the coefficient of the lagged production –given that GMM estimation method appropriately accounts for simultaneity- witnesses that much endogeneity of the growth process, described in Model 1, is due to an interdependence between ICT and output. This means that the endogenous growth process in an aggregate production function is possible thanks to the pervasive effect of ICT through the whole economy. Such an effect continues to allow for the competitive solution at micro level in the short run as in Model 1 but doesn't allow for a steady balanced growth notwithstanding the inclusion of the spillover effect. However, the lagged effect, though stationary, is still too high and important with respect to the stocks to assert that this production function is our final specification. As far as the exogenous trend component of growth is concerned, the change of sign into negative clearly points out that its original meaning has been assumed by the new introduced variable. Actually, the major part of the policy actions oriented to growth have been undertaken in the ICT sector. Notably, both Europe and the US adopted policies of economic growth even at institutional level – as an example, among others, there are the Direction General of Information Society, inside the European Commission, the Inter American Telecommunication Commission (CITEL) and the several Federal member states ICT commissions for the US. Therefore, the mentioned negative sign represents the purely exogenous events not passing through ICT and, as such, related to negative shocks and tendencies. We check further this evidence by testing a year effect which turned out to be negative and highly significant per each year[4]. Still, Czernich et al. (2011) obtains the same finding in a context where growth depends on endogenous ICT. A part from the negative shocks, such a negative trend reveals a tendency imprinted worldwide in the structure of the economy, especially in those fields not pertaining the ICT policy, that is financial legislation, labor and industrial organization legislation, fiscal distortions etc.

[4] Results available upon request.

In the third column of Table 2 we proceed with the aim of characterizing the pervasive and endogenous nature of ICT by considering explicitly the way in which it is implemented in the production process: here we refer to a production function that accounts, among the explicative variables, also for business services.

The coefficient of the cross product proves that there is a significant, though small, relationship between production and ICT passing through business services. The small magnitude of such a coefficient is justified in that represents the interaction effect of the two mentioned variables. Such a coefficient, therefore, has the task of correcting – i.e. reducing - that one related to ICT for contribution to the production which may be obtained thanks to business services. Moreover, since such a cross product contains ICT by definition, even this new term is endogenous and contributes to explain growth, with the outcome of reducing again the endogenous growth effect of the lagged variable. About that, the low-pace stationary endogenous dynamics of Model 3 is quite coherent in a production function context where the role of the stocks traditionally predominates. Still, the smaller magnitude of such a coefficient fits with the idea that the production process is linked to the past in order to finish the semi-processed products due to the past orders. Then, the empirical counterpart of Model 3 is our final estimation where: normal capital has a plausible elasticity, but not so the total capital which is still high, and labor force is drastically undervalued. Further, the standard short run value, slightly below 30%, of the normal capital allows to conclude that the externality effects are to be associated mainly to the ICT capital. The short run estimation is still in favor of a possible competitive solution but, once again, not of a steady and balanced growth. We therefore reach our first conclusion that, in the presence of the ICT spillovers, though the share of capital rises, the small labor share doesn't allow for a stable growth at least when the adjustment process is at work.

The empirical evidence of Blanchard (1997) is coherent with our result. He found for the OECD countries a change in the trend, from upward to downward, of the labor cost-share starting at the beginning of our sample period. Guscina (2006) documented the same evidence and tested several causes for such a decline, which led the actual value of the labor's share in terms of national income account data to around 50% at the beginning of the new millennium. The first explanation is the effect of the ICT capital-augmenting technical progress[5] which boosted high capital's return and share together with the fast fall in the price of computer equipment. Consequently, the increase in the computing capital brought about an additional share imputed here to K_{ICT} and the new productive structure observed in Table 2 where labor, in our final specification, has a share of production slightly below 40% together with the effect of the standard error on the point estimate. However, the shares measured here are those referred to competitive prices which are different from those of a cost function who would have reflected the actual market ones. Mun and Nadiri (2002) confirm the same evidence of Blanchard (1997) and Guscina (2006) estimating a labor cost-share around 50%, with a sectorial cost function approach. Therefore, according to our estimation, the technological process associated to ICT capital has not yet finished to lower the actual labor share if its pattern is toward a competitive solution, i.e. without labor protection. This means that highly skilled workers are favoured at the expenses of those with fewer skills who are paid less, hence the decreasing total labor share. Such a conclusion is corroborated also by Czernich et al (2011), where normal workforce is not significant in explaining growth in the presence of ICT capital expressed in terms of broadband infrastructure[6].

In this last estimation the exogenous part of production is always characterized by a scenario represented by negative events over time but by a more solid fixed term. Again, we verify such a result by substituting the time trend with time dummy variables[7] which all –i.e. not occasionally-scored a negative sign over the entire sample period 1989-2005. It might be assessed as a detrimental political and institutional trend on which further research is certainly requested.

[5] Guscina (2006) shows that globalization and trade openness strengthen this phenomenon.
[6] We also tested that, in the same context, skilled human capital performed significantly contrarily to normal human capital.
[7] In order not to overload the text with a result quite similar to the one of Table 2, we prefer to let such a result available upon request.

Finally, in Table 3 we report the long-run relations obtainable from the equations studied. Moreover, also the speeds of adjustment and the mean time lags to reach the long run relations have been calculated.

Table 3. Long run parameters

dependent variable	regressors	Parameters	Model 1	Model 2	Model 3
Y_t	K	α_K	0.749	-	-
Y_t	K_N	α_{KN}	-	0.486	0.286
Y_t	K_{ICT}	$\alpha_{KICT}(1+\delta\phi)$	-	0.263	0.152
Y_t	L	α_L	0.383	0.273	0.285
Y_t	$\overline{K}_{ICT}\ \overline{BS}$	$\alpha_{K_{ICT}}^{BS}$	-	-	0.015
Y_t	t	A	0.0052	-0.016	-0.012
Y_t	*Cons*	A_0	-0.782	1.488	4.358
ΔY_t	-	Speed of Adjustment	0.574	0.656	0.906
ΔY_t	-	Mean time lag	1.742	1.524	1.103
-	-	Sum of cumulative factors parameters	1.132	1.022	0.723

In Models 2 and 1 the long run coefficients are higher than in Model 3 and, from the last line, we observe how after the adjustment completion, the possibility of growth, precluded in the analysis of the short run by a summation of the elasticities of the cumulative factors less than one, is now allowed, but only slightly, by a surpass of such a critical value. Actually, this is true only for models 1 and 2 while for Model 3 this condition may be reached for the major OECD countries by considering also the country variable coefficient based on *BS* in that associated to the ICT capital stock [8]. Such an evidence denounces the poor capacity of growth among the developed countries

[8] This means to consider the time country average of the business services variable (in logarithms) multiplied by the corresponding coefficient of Model 3. Countries with a summation of coefficients major than 1 are: Germany, U.K., France and Italy (sum of elasticities close to 1 in this case), which were the core group of the initial European countries, and the US for the rest of the world.

and, consequently, raises the problem to count the missed production opportunities, if any, or the excess of production[9] for those countries who, at least apparently, grew fast.

5. *Model implementation*: *ICT spillovers and production capacity*

The calculation of the missed spillovers, as showed in section 2, is based on formula (5). We apply it to the estimates of Model 3 and obtain the results reported in Table 4. The figures with minus sign are the coefficients representing the missed spillovers or, in other words, the output that might be produced. The figures with positive sign instead refer to a production in excess according to the estimated coefficients of the productive factors involved in the production function. From Table 4 it is possible to calculate the gap to recover and associated to ICT. Naturally, this is much higher, and so the benefit in case of recovery, for those countries which used less such a resource because either not focussed in this sector, in particular Portugal and Greece during the period considered, or especially hit by the recession of the early nineties like Finland. Countries with minor missed opportunities are the US and Sweden thus making the difference with the remaining countries[10]. Conversely, the major excesses of production are imputed to Ireland followed by France, U.K., Italy and Germany, which revealed a model of growth whose sustainability is to be justified on the basis of additional explanations in terms of externality referable to the residual u_i. In particular for those countries where the public sector intervention is relevant we know that the externality effect, ϕ, may receive further support. However, as afore mentioned, other causes that may engender higher levels of production may be linked to the credit system. This is the case of Ireland where a credit policy out of control brought about an unsustainable excess of production.

[9] As usual, the "excess" under consideration is to be intended with reference to the production that a representative country of the panel would have been adopted as a consequence of the estimated technical coefficients.

[10] Such results are coherent with those of obtained by Maggi and Muro (2013) with a simultaneous system estimated in continuous time where the adoption of new technologies is measured by granted patents and the US and Sweden resulted with the highest growth rate affected by technology.

Table 4. Coefficients for missed opportunities or excess of production; % values.

Country	$\alpha_{KICT}(1\text{-}\delta)\,\varphi_i$
Austria	-0.05
Belgium	-0.24
Denmark	0.19
Finland	-1.66
France	1.29
Germany	0.39
Greece	-2.64
Ireland	2.48
Italy	0.61
Netherland	0.56
Portugal	-1.19
U. K.	0.84
Spain	0.11
Sweden	-0.82
U.S.A.	-0.04
OECD	-0.011

The estimates of the ICT capital parameters, $\alpha_{K_{ICT}},\phi,\delta$, are possible with the reasonable assumption that $\frac{\sum_i \hat{\varphi}_i}{N} \cong \hat{\phi}$ because $\frac{\sum_i u_i}{N} \cong 0$. In fact, from expression (5) and the estimate of Table 4, we obtain

$$(14)\quad \frac{1+\hat{\phi}}{\left(1-\hat{\delta}\right)\hat{\phi}} \cong \frac{\hat{\alpha}_{K_{ICT}}\left(1+\hat{\delta}\hat{\phi}\right)}{\sum_{i=1}^{N}\hat{\alpha}_{K_{ICT}}\left(1-\hat{\delta}\right)\hat{\varphi}_i \big/ N}+1,\quad \hat{\alpha}_{K_{ICT}} \cong \frac{\left[\hat{\alpha}_{K_{ICT}}\left(1+\hat{\delta}\hat{\phi}\right)\right]+\sum_{i=1}^{N}\hat{\alpha}_{K_{ICT}}\left(1-\hat{\delta}\right)\hat{\varphi}_i \big/ N}{\hat{\phi}+1}$$

which allow to pinpoint the critical intervals for the three coefficients under exam. In particular, $\hat{\alpha}_{K_{ICT}}$ is constrained to be lower than 0.138 which corresponds to the estimated value of $\hat{\alpha}_{K_{ICT}}\left(1+\hat{\delta}\hat{\phi}\right)$ and, as an outcome of formula (14), δ and $\hat{\phi}$ belong respectively to the intervals [0.7, 1) and [0.085, +∞). To qualify further such results we observe, from our database, that the empirical value of the average capital ICT share for the OECD in the considered period is about 0.058 which allows to restrict the choice of $\hat{\phi}$ to an expected quite consistent value of about 1.5 and to a small unexploited spillover with a value of δ at about 0.87. The implicit implication of such a finding is that the random effect is the main explanation of the missed opportunities. Moreover, this result validates our initial conjectures and methodology in that, coherently with our estimation assumptions, δ turned out to be rather stable given its narrow interval of definition. To check the robustness of our result, we implemented also the same procedure for Model 2 obtaining similar evidence. We therefore observe that the stochastic externality term only partially alleviate the problem of a weak possibility of growth in case of missed opportunity. Such a result is also in line with the high and stable value at 90% found for δ which confirms that the majority of the spillover effect linked to ICT has been exploited within the OECD area.

Summing this evidence to that one of the previous section, it seems that the effective question within the OECD countries is not much the growth implied by the spillovers but the repartition of output and the rise of inequality.

We then conclude that the model of growth for the OECD countries is weakly sustainable and underline that, other than to concentrate the growth policies towards a correct and complete exploitation of the ICT externalities, what is still needed and deserves important research efforts is a restructuring of the labor and capital markets by empowering the former for an enhancement of their overall weight in terms of shares of production. La Grandville (2012), by simulating (with historical values) an intertemporal optimizing model in a competitive framework, demonstrates analytically the same conclusions that the increase in the capital share we observe does not fit with the aims of growth and competitive equilibrium.

6. *Conclusions*

The analysis conducted in this paper presented a scenario where in some cases the OECD countries miss opportunities of growth or in some other cases exceed the production implied by the technical parametes. These scenarios are pictured by examining in details the Solow residual and the production function itself. However, after having presented a methodology to calculate the ICT spillovers, we found that, even if the ICT potentialities would have been appropriately exploited, the margins for growth would be overall limited by a summation of the elasticities of the cumulating factors slightly above 1. Moreover, such a scenario worsens for those countries revealing an unsustainable level of production though technically attainable. This leads to the conclusion that, considering the technology available, the model of growth undertaken by the OECD countries is difficult to be maintained even if susceptible of a competitive equilibrium. A promising research area is therefore a rethinking of the growth policy in the developed countries focused not only on the correct and efficient exploitation of all the ICT externalities, but also and importantly on a restructuring of the productive factors market with particular care of labor for an improvement of their total contribution.

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