UPSTREAM PRODUCT MARKET REGULATIONS,

ICT, R&D AND PRODUCTIVITY

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Abstract

Our study aims at assessing the actual importance of the two main channels usually contemplated in the literature through which upstream sector anticompetitive regulations may impact productivity growth: business investments in R&D and in ICT. We thus estimate what are the specific impacts of these two channels and their shares in total impact as against alternative channels of investments in other forms of intangible capital we cannot explicitly consider for lack of appropriate data such as improvements in skills, management and organization. For this, we specify an extended production function relating productivity explicitly to R&D and ICT capital as well as to upstream regulations, and two factor demand functions relating R&D and ICT capital to upstream regulations. These relations are estimated on the basis of an unbalanced panel of 15 OECD countries and 13 industries over the period 1987-2007. Our estimates confirm the results of previous similar studies finding that the impact of upstream regulations on total factor productivity can be sizeable, and they provide evidence that a good part of the total impact, though not a predominant one, goes through both investments in ICT and R&D, and particularly the latter.

I. Introduction

Competition is an important determinant of productivity growth. Much firm-level microeconomic research has supported the idea that competitive pressure enhances innovation and is a driver of productivity (among others, see Geroski, 1995a, 1995b; Nickell, 1996; Nickell *et al.*, 1997; Blundell *et al.*, 1999; Griffith *et al.*, 2002; Haskel *et al.*, 2007; Aghion *et al.*, 2004), especially for incumbent firms that are close to the technological frontier (Aghion *et al.*, 2005; Aghion *et al.*, 2006). Reinforcing evidence has also been found in investigations at a macroeconomic level, either using country panel data (Conway *et al.*, 2006; Aghion *et al.*, 2009) or country-industry panel data (Nicoletti and Scarpetta, 2003; Griffith *et al.*, 2010; Inklaar *et al.*, 2008; Buccirossi *et al.*, 2009). Most of these empirical studies have provided within country-industry evidence of the link between competitive conditions and productivity enhancements.

In contrast to these studies who investigated the direct influence of product market regulations in industries on these industries themselves, our paper focus on the cross-industry influence of product market regulations in non-manufacturing industries, called "upstream" industries thereafter, on productivity outcomes in the industries, often called for convenience "downstream" industries, which are using the intermediate inputs from these upstream industries.[1] Regulations that protect rents in upstream industries can reduce incentives to search for and implement efficiency improvements in downstream industries, since they will have to share the expected rents from such improvements with upstream industries.[2] This is a particularly important issue, since mostly due to increasing international competition the downstream non-manufacturing industries have become more competitive in the last twenty

1 Note that the distinction between upstream and downstream industries is not a priori clear-cut, since upstream industries use intermediate inputs from other upstream industries. As will become clear in the implementation of our analysis the non-manufacturing upstream industries are kept in our study sample. We thus estimate the overall average influence of upstream product market regulations (that is precisely the average influence of regulations in each upstream industry on all industries excluding that upstream industry).

2 A formalization of such links between upstream competition and downstream productivity based on an extension of the endogenous growth model of Aghion *et al.* can be found in the working paper version of Bourlès *et al*. (2010) and in chapter 2 of Lopez (2011).

years or so in most OECD countries, while upstream service industry have been generally sheltered and anticompetitive product market regulations have to a large extent remained significant in these industries.

Only very few studies have investigated the influence of upstream competition on the performances of downstream industries. Some of them are panel data analyses for one country at the industry level, like Allegra et al. (2004) for Italy or at the firm level like Forlani (2010) on France and Arnold et al. (2011) on the Czech Republic and they use specific indicators of upstream competition. Other studies like Faini *et al*. (2006), Bourlès *et al.* (2010) and Barone and Cingano (2011) are relying on country-industry panel data analyses and on the OECD regulation indicators in upstream industries and they are thus similar to what we do ourselves in this paper but with more or less pronounced differences in terms of sample coverage, model specification and estimation methods.

The goal of the present investigation is not only to confirm the results of these previous studies but also to understand better the economic mechanisms at work in an attempt to characterize the channels through which upstream regulations impact downstream productivity growth. As it is generally agreed, we consider investments in R&D and innovation as being a vital channel and we estimate how important it is actually. We consider jointly investments in ICT, since they are also deemed to be a key channel for competitiveness.[3] In order to implement such investigation, as explained in Section II, we consider a three equations model that is simple enough to be specified and estimated with the data available at country-industry level. We thus estimate a relation where the distance of country-industry multifactor productivity to the corresponding industry multifactor productivity in the USA (where the USA is taken as the country of reference) depends not only on the upstream regulatory burden indicator, but also on the distance of country-industry R&D and ICT capital intensities to that in the USA. In parallel we estimate two factor demand relations, for R&D and ICT capital respectively, which both include the upstream regulation

3 Investing in training and investing in skilled labor and investing in organization and management are also potentially important channels that we could not consider here for lack of data or good enough data at the country--industry level. It is likely that these channels are to some extent complementary to the ICT and R&D channels, and thus that the regulatory impact working through them may be partly taken into account in our estimates. Note also that although patents are not as good a predictor of innovation output as R&D investment, the numbers of country-industry patents would be a worthwhile indicator to consider in the future (see Aghion *et al.* 2013).

burden indicator. To assess the robustness and validity of our results we consider in fact different econometric specifications of our model.

Our investigation is performed on a cleaned unbalanced country-industry panel dataset for fifteen OECD countries and thirteen manufacturing and market service industries over the twenty one years 1987 to 2007. We consider thirteen industries covering a large part of the non-agricultural business economy and leaving aside only industries that are (almost) not investing in both ICT and R&D. Among these thirteen industries we also exclude five of them to estimate the R&D investment demand equation, since they are almost not investing in R&D.[4]

We rely on the same basic upstream regulatory burden indicator than in Bourlès *et al.*, which is computed from the OECD indicators of anti-competitive regulations on product market in the six following non-manufacturing industries: energy, transport, communication, retail, banking and professional services. However, our main variable of multifactor productivity is defined differently since we have to explicitly include ICT and R&D capital as regressors in the productivity equation. We explained our data and present a number of descriptive statistics in section III and Appendix A.

In terms of identification strategy and estimation method, as discussed in Section IV, we focus on the long-term estimates of our parameters of interest and the discussion of their robustness In particular we systematically compare the estimation results obtained in two econometric specifications: the first one in which we interact country and year fixed effects in each of the three equations of the model, and the second in which we also interact industry and year fixed effects. We consider likely that the first one provides optimistic or “upper bound” estimates, while the second provides pessimistic or “lower bound” estimates.

We present our estimation results in Section V, and illustrate them by presenting in Section VI simulations of what would be the long term multifactor productivity gains if all countries were to adopt the observed best or lightest anticompetitive upstream regulations. In spite of

4 Note that because of our choice of specification and of Dynamic OLS (DOLS) as our preferred method of estimation (as explained in Section II and IV), we actually estimate our model on a sample of fourteen countries (the USA being taken as the country of reference) over the period 1989 to 2006 (because of the introduction of lags and lead when using DOLS), that is a country-industry-year unbalanced data sample of 2612 observations for the productivity and ICT demand equations and a subsample of 1478 observations for the R&D demand equation.

the substantial differences in sample, model specification and estimation, we find that our upper and lower bound estimates of the total long term impacts concur to confirm overall the results of previous showing that upstream anticompetitive regulations can slow down multifactor productivity importantly. We find for example that the upper and lower bound estimates of the total productivity impacts of upstream regulations are the highest for Italy and the Czech Republic, of about 11-12% and 4-5% respectively, and the lowest for the United Kingdom and the USA, of about 2-3% and 1% respectively. We also find that the indirect productivity impact for the R&D investment channel is generally higher than the one for ICT investment, but that the direct productivity impact is also much higher than both of them, pointing to the fact that the channels through which upstream regulations manifest themselves must be many and pervasive. In Appendix B we document three informative robustness checks we did to confirm our main results and present two extensions of our analysis that thought appropriate to consider but are at the frontier of what we can reasonably do with our country-industry aggregate data and the OECD regulation indicators in our present framework.

In Section VII we conclude by indicating the limits of our present findings and sketching what should and could be done to extend and deepen them, and in particular by stressing the need to investigate jointly the productivity impacts of product and labor regulations and to rely on different types of data and levels of analysis from micro to macro.

II. Econometric model specification

Our model consists of three simple equations: the productivity equation and two similar factor demand equations respectively for R&D and ICT. We shall explain now in some details our choice of specifications for these equations.

Productivity equation

Our productivity equation is based on the assumption of a cointegrated long term relationship linking the levels of (multi-factor) productivity between countries and industries, which includes our product market regulation variable of interest or regulatory burden indicator *REG*. This equation can be simply written as a relation between the industry productivity in a given country of reference $\bar{c}$ and all the other countries c. Although it is convenient to interpret this relation as a catch-up relation where the country of reference $\bar{c}$ can be considered as a leading country and the other countries c as followers countries, it is important to realize that such interpretation need not to be taken strictly and can be misleading. The basic hypothesis, which we actually test in Section IV, is that of cointegration for the set of country-industry time series that are considered in the analysis. In fact as long as the equation includes controls for country, industry and year unobserved common factors, we checked that the choice of the country of reference does not practically affect our results. In this work, for the sake of simplicity we take the USA as the leading country $\bar{c}$.[5] We can thus write our long term productivity relation as the following log linear regression equation:

$$\widetilde{mfp}_{ci,t} = cst + \widetilde{mfp}_{\bar{c}i,t} - \mu\, REG_{ci,t-1} + u_{ci,t} \qquad (1)$$

The variables $\widetilde{mfp}_{ci,t}$ and $\widetilde{mfp}_{\bar{c}i,t}$ are respectively the multifactor productivity in logarithms for year t of industry i in country c and in the leading country $\bar{c}$ (the USA), where $t \in T, i \in I$, $and\ (c, \bar{c}) \in C\ with\ c \neq \bar{c}$.

The variable $REG_{ci,t-1}$ is the regulatory burden indicator lagged one year for industry i in country c, and μ is a parameter of main interest measuring an average long term "direct" impact of regulation on multifactor productivity, where direct means here that this impact does not operate through the channels of ICT and R&D investments as made explicit below.[6]

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5 The USA is in fact leading for 85% of the country-industry-year observations of our panel. As just mentioned, our estimates remain practically unaffected if we choose the leading country-industry-year definition. Note more generally that when we include industry*year effects θ_{it} in the specifications of our productivity and R&D and ICT investments equations (see below), these effects will proxy for the evolution of productivity and R&D and ICT investments for the country-industry pairs taken as reference as long as the reference country for a given industry will not change over time. Hence our lower bound estimates based on specifications including such effects are strictly identical irrespective of the choice of the country-industry pairs of reference.

6 Note that in equation (1) we impose that the coefficient of $\widetilde{mfp}_{\bar{c}i,t}$ is 1, implying that the difference between the multifactor productivity of the follower countries and the leader country is bounded in the long term for given common factors $\theta's$. This is a reasonable identification hypothesis generally made in the literature. As shown in Appendix tables B2.1 and B2.2, our results remain roughly the same if this hypothesis is relaxed; they are strictly identical if we include industry*year effects θ_{it} as in our lower bound specification. We have also considered a variant of equation (1) in which the regulatory burden indicator is included in difference to its value for the country-industry of

The term $u_{ci,t}$ stands for the error in the equation that can be specified in different ways. In a panel analysis such as ours, it is generally found appropriate to control for separate country, industry and year unobserved common factors or effects θ_c , θ_i and θ_t, in addition to an idiosyncratic error term $\varepsilon_{ci,t}$. Here for reasons of econometric identification which we discuss in Section IV, we privilege two specifications that also include interaction effects: either country*year effects θ_{ct} or both country*year effects $\theta_{ct}$and industry*year effects θ_{it}. As we shall explain, we can consider that the first of these specifications provides an upper bound estimate of the direct regulatory impact parameter μ, while the second one provides a lower bound estimate of μ.

The major novelty in our approach here with respect to previous similar studies is that we want to assess to what extent the effects on productivity of anticompetitive regulations (as measured by REG) work through the two channels of R&D and ICT investments or otherwise. To do so we have to modify in two ways the "conventional" measure of multifactor productivity used previously. We have to take into account explicitly the contribution of ICT capital to productivity and for that to separate ICT capital (*D*) from the other forms of physical capital (*C*) in total capital (*CT*). We also have to take into account explicitly the contribution of R&D capital (*K*), which is ignored in the "conventional" measure of total capital (*CT*), since R&D is not yet integrated in official national accounts as an investment. As explained in Section III, the explicit integration of R&D implies that we had to correct the measures of industry output and labor from respectively expensing out R&D intermediate consumption and double counting R&D personnel.

Precisely, using small letters for logarithms (i.e., $x \equiv Log\ X$), we have two conventional measures of multifactor productivity $mfpc1$ and $mfpc2$ and the appropriate measure $\widetilde{mfp}$ to be used in the present analysis, where:

$$mfpc1 = y - \alpha(ct) - \beta l \quad \text{and} \quad mfpc2 = y - \alpha c - \beta l - \gamma d \ ,$$

while

$$\widetilde{mfp} = y - \alpha c - \beta l - \gamma d - \ \delta k \ .$$

reference: $(REG_{ci,t-1} - REG_{\bar{c}i,t-1})$. This variant provides estimates that are strictly identical in the specification with industry*year effects θ_{it}, and very close without them.

We can define partial multifactor productivity before taking into account the ICT and R&D contributions, which will noted *mfp* for simplicity, as:

$$mfp \equiv \widetilde{mfp} + \gamma d + \delta k$$

and thus rewrite regression equation (1) to include explicitly ICT and R&D contributions as regression equation (2):

$$mfp_{ci,t} = cst + mfp_{\bar{c}i,t} + \gamma\big(d_{ci,t} - d_{\bar{c}i,t}\big) + \delta\big(k_{ci,t} - k_{\bar{c}i,t}\big) - \mu\, REG_{ci,t-1} + u_{ci,t} \quad (2)$$

In equation (2), we estimate jointly the productivity elasticities γ and δ of ICT and R&D capital stocks and μ the parameter of direct regulatory impact on productivity. While we can estimate the ICT and R&D productivity elasticities, however, in order to measure our multifactor productivity variable *mfp* it remains to calibrate the non-ICT capital and labor elasticities α and β. As usually done and explained in Section III and Appendix A, we did in two ways: first by calibrating α and β respectively by the shares $\tilde{\alpha}$ and $\tilde{\beta}$ of the user cost of non-ICT capital and the labor cost in the nominal value-added; second by still calibrating the elasticity of labor β by the share of labor cost $\tilde{\beta}$ but calibrating *a priori* the returns to scale λ to be constant, that is $\lambda = \tilde{\alpha} + \tilde{\beta} + \gamma + \delta = 1$, and thus implying that α is estimated as well as γ and δ . Since trying to assess returns to scale on aggregate industry data such as ours does not really make sense, and measuring industry shares of user cost of capital not too reliable, we much preferred the second option. In fact, as documented in Appendix B on robustness, when we do not impose constant returns to scale and rely on the first option, our results are practically unaffected with an estimated scale elasticity λ that negligibly differs from 1.

Finally, calibrating α by $\tilde{\alpha}$ and assuming constant returns to scale implies that we normalize regression (2) with respect to labor and modify slightly the measure of our multifactor productivity variable *mfp*. We can express (2) equivalently as:

$$\begin{aligned} mfp_{ci,t} = {} & cst + mfp_{\bar{c}i,t} + \gamma[\big(d_{ci,t} - l_{ci,t}\big) - \big(d_{\bar{c}i,t} - l_{\bar{c}i,t}\big)] \\ & + \delta[\big(k_{ci,t} - l_{\bar{c}i,t}\big) - \big(k_{\bar{c}i,t} - l_{\bar{c}i,t}\big)] - \mu\, REG_{ci,t-1} + u_{ci,t} \end{aligned}$$

with $mfp_{ci,t} = \big(y_{ci,t} - l_{ci,t}\big) - \tilde{\alpha}\big(c_{ci,t} - l_{ci,t}\big)$ and $mfp_{\bar{c}i,t} = \big(y_{\bar{c}i,t} - l_{\bar{c}i,t}\big) - \tilde{\alpha}\big(c_{\bar{c}i,t} - l_{\bar{c}i,t}\big)$

Or denoting $\big[\big(x_{ci,t} - l_{ci,t}\big) - \big(x_{\bar{c}i,t} - l_{\bar{c}i,t}\big)\big]$ more simply by $x\_gap_{ci,t}$, we can rewrite it as regression (3):

$$mfp\_gap_{ci,t} = cst + \gamma d\_gap_{ci,t} + \delta k\_gap_{ci,t} - \mu\, REG_{ci,t-1} + u_{ci,t} \qquad (3)$$

ICT and R&D capital demand equations

The specifications of our ICT and R&D capital demand are very simple. They are based on the long term equilibrium relationships derived from of the assumption of firms' intertemporal maximization of their profit, augmented by the regulatory burden indicator REG.

Assuming the Cobb-Douglas production function underlying our productivity equation $y = \alpha c + \beta l + \gamma d + \delta k$, we can write simply:

$$\log(P_D D/WL) = \log(\gamma/\tilde{\beta}) - \mu_D . REG_{-1}$$
$$\log(P_K K/WL) = \log(\delta/\tilde{\beta}) - \mu_K . REG_{-1}$$

where $P_D D/WL$ and $P_K D/WL$ are of the user costs shares of ICT and R&D capitals relative to the labor cost share. Rewriting these equations in terms of ICT and R&D capital user cost ratios to average employee cost (or ICT-labor and R&D-labor cost ratios for short) , and adding errors terms to control for country, industry and year unobserved common factors as in the productivity equation (and with $x \equiv Log\ X$) we obtain the regression equations:

$$(d-l)_{ci,t} = \text{Cst} + (p_D - w)_{ci,t} - \mu_D REG_{ci,t-1} + u^D_{ci,t}$$
$$(k-l)_{ci,t} = \text{Cst} + (p_K - w)_{ci,t} - \mu_K REG_{ci,t-1} + u^K_{ci,t}$$

These equations are strictly consistent with the hypothesis of a Cobb-Douglas production function, implying that the elasticity of substitution between factors are all equal to 1 and that the price elasticities are constrained to be 1. Since these constraints may be too restrictive and although they do not lead to significantly different estimates of our two parameters of interest μ_D and μ_K , we actually prefer to consider equations (4) in which they are not *a priori* imposed and can be tested:

$$(d-l)_{ci,t} = \text{Cst} + \sigma_d (p_D - w)_{ci,t} - \mu_D REG_{ci,t-1} + u^D_{ci,t}$$
$$(k-l)_{ci,t} = \text{Cst} + \sigma_k (p_K - w)_{ci,t} - \mu_K REG_{ci,t-1} + u^K_{ci,t} \qquad (4)$$

These equations can be viewed as deriving from a CES (Constant Elasticity of Substitution) production function, and the parameters σ_d and σ_k interpreted as elasticities of substitution between factors. Note, however, that the CES production function with more than two factors is also restrictive since it imposes that these elasticities would be the same for all pair of factors: that is here $\sigma_d = \sigma_k$ $(= \sigma_l = \sigma_c)$, which will see is not far from being the case for our results.

III. Main Data and Analysis of Variance

We now explain the construction of the central explanatory variable of our analysis: the upstream regulatory burden indicator REG, while we give details on the measurement of our multifactor productivity and ICT and R&D capital variables and on our sample in Appendix A. We also present here important descriptive statistics and an analysis of variance for all the variables in terms of separate country, industry and year effects, and a relevant sequence of two-way effects.

Regulatory burden indicator

Our empirical analysis focus on the productivity and ICT and R&D impacts of the regulatory burden indicator REG, which is constructed on the basis the OECD Non-Manufacturing Regulations (NMR) indicators. These indicators measure "to what extent competition and firm choices are restricted where there are no a priori reasons for government interference, or where regulatory goals could plausibly be achieved by less coercive means", in six non-manufacturing industries. Referred here as upstream industries they are: energy (gas and electricity), transport (rail, road and air), communication (post, fixed and cellular communication), retail distribution, banking services and professional services. Undoubtedly they constitute the most regulated and sheltered part in OECD countries economies, while few explicit barriers to competition remain in markets for the products of manufacturing industries.

The NMR indicators are based on detailed information on laws, rules and market and industry settings, which are classified in two main areas: state control, covering specific information on public ownership and public control on business activity, and barriers to entrepreneurship, covering specific information on legal barriers to entry, market structure and or industry structure. For a given upstream industry the NMR indicators can take at minimum a value of 0 in the absence of all forms of anticompetitive regulations and at maximum a value of 1 in the presence of all of them, and they thus vary on a scale of 0 and 1 across countries and industries. They also available for all years of our estimation period in energy, transport and communication, for 1998, 2003 and 2007 in retail distribution and professional services, and for 2003 only in banking. More information on the construction of the NMR indicators is given in Appendix A; and a detailed presentation can be found in Conway and Nicoletti (2006) for all six non-manufacturing industries except banking, and in De Serres *et al*. (2006) for banking.

The NMR indicators have the basic advantage that they establish relatively direct links with policies that affect competition. Econometric studies using them to measure imperfect competition are also much less concerned by endogeneity problems that affect studies depending on traditional indicators of product market competitiveness, as mark-ups or industry concentration indices (see Boone 2000 for a discussion of endogeneity issues in such studies).

In a macro-econometric analysis as ours, however, NMR indicators cannot separately be used in practice to assess the upstream regulatory impacts on productivity as well on ICT and R&D, and they have to be combined in a meaningful way. We do, as usually done, by considering that their individual impacts are most likely to vary with the respective importance of upstream industries as suppliers of intermediate inputs. Our regulatory burden indicator REG is thus constructed in following way:

$$REG_{ci,t} = \sum_{j \neq i} NMR_{c,t}^{j} . w_i^j \ with \ w_i^j \equiv \frac{input_{i,R}^{j}}{output_{i,R}}$$

where $NMR_{c,t}^{j}$ is the NMR indicator of the upstream industry *j* for country *c* in year *t*, and w_i^j stands for the intensity of use of intermediate inputs from industry *j* by industry, as measured from the input–output table for a given country and year as the ratio of the intermediate inputs from industry *j* to industry *i* over the total output of industry *i*. We prefer to use a fixed reference input-output table to compute the intensity of use ratios rather than the different country and year input and output tables, to avoid endogeneity biases that might arise from potential correlations between such ratios and productivity or R&D and ICT, since the importance of upstream regulations may well influence the use of domestic regulated intermediate inputs. We have actually used the 2000 input-output table for the USA, already taken as reference for the productivity gap and R&D and ICT gap variables. For similar endogeneity as well as measurement error concerns, note also that in estimating REG for the upstream industries we exclude within-industry intermediate consumption (or $w_J^j = 0$) .

Insert Graph 1 and Graph 2 about here

Graph 1 shows the country averages of REG for 1987, 1997 and 2007. The relatively restrictive regulations, which prevailed overall in 1987 in most countries, weakened in the two following decades in all countries at different paces. The cross-country variability of REG appears quite important in all three years, with the USA, UK and Sweden remaining the most pro-competitive countries and Austria and Italy followed by France in 1987 and by Canada in 2007 being the less pro-competitive countries.

Graph 2 shows the six average country NMR components of REG in 2007. Their relative contributions to REG differ significantly, reflecting country-industry variability, although they appear roughly proportional to the average country level of REG as could be expected. The first left bar of the graph correspond to the value of REG for an hypothetical country in which the six NMR indicators are at their 'lightest' levels defined as the country average of their three lowest values in 2007. We will use this lightest REG value as a target for the hypothetical long run simulation policies we consider in Section VI to illustrate our estimation results.

Descriptive statistics and analysis of variance

Table 1 gives the means and medians, first and third quartiles for the eight variables of our productivity, ICT and R&D regressions, both in levels and annual growth rates. These statistics are computed for the complete study sample (i.e., 2612 observations for levels and 2430 for growth rates), except for the R&D variables computed for the subsample without industries with low R&D intensity (i.e., 1478 observations for levels and 1366 for growth rates). We can see in particular that on average for our sample over the twenty year period 1987-2007 REG has been reduced at a rate of 3.3% per year while the MFP gap with the USA has been slowly decreasing by 0.2% per year. In parallel, ICT capital intensity has been very rapidly increasing at a rate of 11.3% per year, while its gap with the USA has been slowly augmenting by 0.3% per year. R&D capital intensity has also been increasing at a rapid rate of 5.8% per year, while its gap with the USA has been widening very significantly by 1.5 % per year. Similarly we observe that our measures of the ICT and R&D labor cost ratios have respectively been decreasing at very high rates of about 10% and 5.8% per year, which largely reflects the actual use of quality-adjusted hedonic prices for ICT and of overall manufacturing prices for R&D for lack of more appropriate prices.

Insert Table 1 about here

Table 2 summarizes the results of an analysis of variance for all the variables of our analysis in terms of separate country, industry and year effects θ_c, θ_i and θ_t , as well as a sequence of two ways interacted effects θ_{ct} , (θ_{ct} and θ_{it}) and (θ_{ct} , θ_{it} and θ_{ci}). The first column documents the variability of the variables lost in terms of "first step" R2 in first step when we include in the regressions of our model the three one-way effects separately, as a basic control for the usual sources of specification errors, such as omitted (time invariant) country and industry characteristics. The three following columns document what is the additional variability lost in terms of "second step" R2 when we also include interacted two-way effects, in order to control for other potential sources of specification errors to be discussed in the next Section on identification and estimation. They are ordered in a sequence going from the most plausible source of endogeneity (2nd column), to the next plausible source (3rd column) and to a third one (4th column) that we will argue is very unlikely.

We see that the three country, industry and year effects taken alone already account for large shares of variability of the eight variables of our model which are ranging from 45-60% for the MFP, ICT and R&D gap variables of the productivity regression, to 75-85% for the ICT and R&D capital intensity and labor cost ratio variables, and to nearly 95% for our central explanatory variable REG. We see that the shares of left variability accounted by interacting country and year effects alone is at most of 45% (for the ICT-labor cost ratio but much less for the other variables), and by interacting also industry and year effects at most of 50% (for REG and the ICT-labor cost ratio but much less for the other variables). Interacting in addition the country and industry effects account in total up to a minimum share of 70% for all eight variables and of 90-95% for five of them.

Insert Table 2 about here

Focusing on REG, the share of its variability in total variability, which is left to estimate the regulatory impact parameters of interest in the productivity, ICT and R&D regressions, decreases from 7.2% with separate country, industry and year effects, to 5.0% adding country-year effects, 3.% adding also industry-year effects, and 0.3% adding finally country-industry effects. It is good that the absolute total variability of REG is large enough so that even a share of a few percent is enough to obtain estimates which are statistically significant as we shall see in Section V. It is also fortunate that there are both strong and *a priori* reasons for considering that it is very likely that the country-industry component of the data, contrary to the country-year and industry-year components, is indeed an appropriate source of exogenous variability for the estimation of our model.

IV. Identification and estimation

In order to estimate consistently the long term impacts of REG in the productivity, R&D and ICT demand regressions (3) and (4), we have to take into consideration intricately related potential sources of specification errors, mainly: (i) inverse causality, when governments reacting to economic situations and political pressures implement changes in product market regulations; (ii) direct effects of such changes, in so far as they can be correlated over time within-country and across-industry as well as within- industry and across-country; (iii) omitted variables such as country specific and/or industry specific technical progress and changes in international trade, etc… We will explain in a first sub-section how we can take care of such specification errors by including country*year and industry*year effects in our regressions and thus largely mitigate the biases they potentially generate. We will also argue to the contrary that there is no need to control for country*industry effects, and that we can rely on the country*industry variability of the explanatory variables in our regressions to identify and estimate consistently the upstream regulatory impact parameters of interest.

To be fully confident that we are estimating long term parameters, we have also to corroborate that our regressions are cointegrated. We have also to make sure that short term correlations between the idiosyncratic errors in the regressions and our variables are not another possible source of biases for our estimates, in particular those of the elasticities of ICT and R&D capital intensities and relative user costs. To deal with this issue we implement the Dynamic OLS (DOLS) estimators proposed by Stock & Watson (1993). In a second sub-section we will thus briefly report on the cointegration tests we have performed showing that by and large we can accept that our model is cointegrated, and on the Hausman specification tests of comparison of the OLS and DOLS estimates showing that the former are biased and the later are indeed to be preferred.

<u>Specification errors and country, industry and year interacted effects</u>

Firms' political pressures to change regulations are an important potential source of econometric specification errors. In particular, if firms respond to negative productivity shocks by "lobbying" for raising anticompetitive regulations, thereby protecting their rents, inverse causality would entail negative correlations between productivity and product market regulation indicators. Therefore, the negative impacts of anticompetitive regulations on productivity could be overestimated. Obviously, such biases could also arise and eventually be larger when estimating the regulatory impacts on the demand for R&D and ICT. However, we can distinguish three cases depending on whether such productivity shocks and lobbying reactions occur over time at the country level across industries, and/or they occur at the industry level across countries, and/or they are country and industry specific.

The first case appears the most likely, because of imitation behavior by government and decisions or recommendations taken at the international level (in particular by the EU, the OCDE or the World Trade Organization). Including country*year interacted effects in our regressions will take care of the corresponding endogeneity biases in this case.

The second case is very similar to the first. Although probably less prevalent than the first case, it may concerns particularly upstream industries as energy, transport, communications and banking, in which international agreements and regulations are widespread. Likewise, including industry*year effects in our model will take care of the resulting endogeneity biases.

The last case of potential occurrence of biases arising from lobbying and productivity shocks at specific country-industry levels would apply if we were concerned by assessing the impacts of existing regulations in industries on the productivity and ICT and R&D of these industries themselves, but not in the present analysis in which we focus on estimating the impacts of regulations in upstream industries on other downstream industries. Actually although we are estimating average impacts of upstream regulations over all industries by keeping upstream industries in our sample, we are abstracting from the possible regulatory impacts of upstream industries on their own productivity and ICT and R&D, by being careful to impute a value of zero for upstream industries own to intermediate consumption ($w_J^j = 0$) in measuring REG in these industries.[7]

Besides that they can correct for or at least alleviate potential endogeneity biases, it is also important to stress that country*year fixed effects and industry*year either alone or taken together can act as good proxies for a variety of omitted variables. In particular they can take into account differences between countries and/or industries in technical progress, in the development of education and skills of labor force, in the evolution of own-industry regulatory environment, in the change of international trade conditions, etc…

To wrap-up, in view of the inherent difficulties and uncertainties of our study, rather than choose one preferred model econometric specification, we have thought proper to keep two that provide a range of plausible consistent estimates. The first one with only interacted country*year effects takes care of the endogeneity and omitted variables specification errors that we consider most likely and gives generally higher negative estimates (in absolute values) of the upstream regulatory impact parameters that can be viewed as “upper bound” estimates. The second with both interacted country*year and industry*year effects takes care more fully of such specification errors and give estimates that can be deemed as “lower bound” estimates.[8] In the next two sections we will center the discussion of our estimation results and simulations on these two types of estimates.

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7 It can be noted in this regard that the estimated negative impacts of REG are significantly higher in absolute value if we did not take such precaution than when we do, which can be taken as a confirmation of an endogeneity bias.

8 As we shall see in a few cases the upper bound estimates will be lower than the lower bound estimates, which is actually not surprising since the country*year and industry*year effects are expected to take care of a variety of potential specification errors.

Cointegration and DOLS estimators

To support our long term interpretation of our estimation results and our reliance on the DOLS estimators, we have to test the cointegration of our model. Precisely, we have to test that: i) MFP, R&D and ICT capital intensity and relative user cost variables stocks and their relative costs are integrated of order 1 (I(1)); (ii) MFP is cointegrated with the leading country We have performed Levin, Lin and Chu (2002) and Im, Pesaran and Shin (2003) panel data unit-root tests and Pedroni (1999, 2004) panel data cointegration tests. All the unit-root tests confirm that the MFP, R&D and ICT capital intensities and user costs variables are I(1), whereas the cointegration tests are somewhat less clear-cut, four out of seven of them rejecting the no-cointegration null hypothesis. However, it is important to stress that our unit-root and panel cointegration tests have necessarily a relatively weak power because of the short time dimension of our panel data sample (maximum 20 years but in average about half since it is seriously unbalanced).

In principle when non-stationary variables are cointegrated, the Ordinary Least Squares (OLS) estimators are convergent under the standard assumptions (Engle and Granger, 1987). However, there are reasons to suspect that the OLS estimates of the elasticities of ICT and R&D capital intensities and relative user costs (γ and δ) and (σ_d and σ_k) in the productivity regression and the demand regressions may be biased, because of short term correlations between these variables and regression idiosyncratic errors. The DOLS estimators get rid of these correlations by including in the regressions leads and lags of the first differences of the potentially endogenous explanatory variables if they are non-stationary.[9] The Hausman specification tests implemented on the three regressions show that the OLS and DOLS estimates differ quire significantly, confirming clearly our preference for the latter.

V. Main estimation results

We now comment what we consider our upper and lower estimates for the multifactor productivity regression (3) and the ICT and R&D capital demand regressions (4), presented in

9 Given that the time dimension of our sample is already short, we have only included one lead and one lag. Our estimates are practically unaffected when we add one or two more leads and lags.

a similar format in Tables 3, 4 and 5. In addition to these estimates that are obtained, as we explained, with the model specifications including country*year effects and both country*year and industry*year effects, we also show in these Tables for reference the estimates obtained when only including separate country, industry and year effects in the regressions, as usually done in country-industry panel data as ours.

We also give for comparison in Table 3 the estimates of overall impact of upstream regulations on productivity that we would find if we were omitting the ICT and R&D capital intensity gap variables and not tryingto assess the importance of ICT and R&D channels through which these regulations affect productivity growth. In Tables 4 and 5, we similarly give the estimates we would find if we assumed that the ICT and R&D were strictly derived from a Cobb-Douglas production function.

<u>Multifactor productivity regression</u>

Looking first at the direct upstream regulatory impact parameter μ in Table 3 we see that the upper bound estimate (column 1) is statistically quite significant and of a high order of magnitude implying that a 0.10 decrease in the level of the regulatory burden indicator REG would contribute to a long term average increase of 2.3% of multifactor productivity MFP, that is about as much as 0.2% per year if we assume a long term horizon of some 12 years. The lower bound estimate (column 3) is not statistically significant and much lower, though not entirely negligible magnitude implying that a 0.10 decrease in REG would contribute to a long term average increase in MFP of 0.6% (0.05% per year).

Insert Table 3 about here

It is important to stress that this small lower bound estimate does not mean a small overall productivity impact of upstream regulations, but only that this impact works through the ICT and R&D channels, as confirmed by a statistically significant and high estimated μ (-0.16 in column 4), if we omit the ICT and R&D capital intensities variables in the regression. It is of course also important to consider that the interquartile range of the burden regulatory indicator REG in our sample is of 0.40 (see Table 1) and that a variation of 0.10 of REG is very small. A decrease of 0.40 of REG is actually the one that would occur if the hypothetic country with the median REG of 0.65 was able to implement the lightest anticompetitive regulatory practices of only 0.25 (see Graph 2), and it will imply a long term upper bound increase of MFP of 11.7% and a lower-bound increase of 3.2%.[10]

Finally it must kept in mind that we can only estimate on a country-industry panel as ours average parameters and that in particular the regulatory impact parameters can be quite heterogeneous across industries. In an attempt to account in part for such heterogeneity, we have considered a specification of our model in which the impact parameters in the productivity and ICT regressions could be different in the 8 industries investing both in ICT and R&D and in the 5 industries not investing significantly in R&D (and hence excluded from the estimation of the R&D regression). The results of this attempt are recorded in Appendix B on Robustness analyses. Interestingly, we find that the lower bound estimated μ is statistically significant and high in the non-R&D doing industries and not in the R&D doing industries (respectively equal to –0.19 and -.04). Together with the corresponding estimates for μ_D and μ_K , this is plausible evidence that in R&D doing industries the R&D and ICT channels account basically for the overall upstream regulatory impact, while in the non-R&D doing industries other channels along with the ICT channel play the main role.

Turning now to the ICT and R&D elasticities, we see that they are precisely estimated with orders of magnitude consistent with the most reliable results in the literature. In spite of being quite precise, the upper and lower bound estimates are not statistically very different, respectively 0.05 and 0.07for ICT and 0.08 and 0.07 for R&D.

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10 Keep in mind that these two estimates correspond only to direct productivity impacts of REG for a hypothetical country and do not include the indirect impacts working through ICT and R&D. The first simulation presented in the next Section shows such estimates for each of the 15 countries in our sample and compares them to the corresponding indirect impacts working through the ICT and R&D channels.

ICT and R&D capital demand regressions

The upper and lower bound estimates of the two upstream regulatory impact parameter μ_D and μ_K (columns 1 and 3) in Tables 4 and 5, are statistically significant and of a high order of magnitude, particularly for R&D. It can be noted that the estimate we dubbed the lower bound estimate appears markedly higher than the upper bound estimate, but that actually the two are not statistically different because of their rather large standard errors. Taken at face value, we thus find that a 0.10 decrease in the level of the regulatory burden indicator REG would thus contribute to a long term average increase in a range of 2.6% to 3.4% for ICT capital intensity and in a range of 8.7% to 14.0% for R&D capital intensity.

Insert Table 4 and 5 about here

The upper bound and lower estimates of the elasticities of ICT and R&D relative user costs of capital σ_d and σ_k are practically equal and quite significantly smaller than 1 in absolute value, of 0.75 for ICT and 0.60 for R&D. These estimates thus provide strong evidence rejecting the hypothesis of an underlying Cobb-Douglas production function to derive factor demand equations in favor of that of CES type production with elasticities of substitution between ICT and R&D and other factors much smaller than 1.

VI. Simulations

To illustrate the implications of our results more fully and to put them in perspective, we propose two simple and tentative simulations. The first one that we shall present in detail can be considered as a prospective evaluation of what could be at the national level the long term impact in terms of growth of ICT and R&D capital intensity and multifactor productivity if countries were implementing the lightest upstream anticompetitive regulatory practices. The second that we comment briefly is a retrospective evaluation of the regulatory impact on the growth of national multifactor productivity over the twenty year period 1987-2007 which can be imputed to the observed reduction in upstream anticompetitive regulations.

Prospective evaluation of gains from reductions in upstream regulations

Based on the estimates of the ICT and R&D demand regressions, we can evaluate directly for each country the gains in ICT and R&D capital intensities that would result in the long term, say 2020, from a progressive implementation of the lightest upstream regulatory practices starting from their 2007 level. Using our productivity regression estimates, we can compute both the corresponding (or indirect) multifactor productivity MFP gains working through the ICT and R&D channels, and the direct ones working through other channels. The computations of these gains are performed on the basis of both our lower and upper bound estimates. Since they are obtained at the country-industry observation level, we have to aggregate them at the country level. We do by weighting the 13 industries included in our sample proportionally to their 2007 Value Added to GDP ratios. We thus assume no gains from the industries excluded from our sample, which amount to some 45 % of country GDP in average.

In these computations, we think more appropriate to use a slightly modified regulatory burden indicator (REG-D) based on domestic input-output table, and not on the (REG) indicator which is based on the USA input-output table. As we have explained, we used REG in estimation in order to avoid potential endogeneity biases, but we prefer to rely on (REG-D) to take into account in our evaluation of MFP gains the differences across countries in the intensity of downstream intermediate consumption of products from regulated upstream sectors. As documented in Appendix B (Table B3), since the intensity of use of regulated upstream intermediate consumption is low in the USA, the choice of REG instead of REG-D will result in underestimation in all countries, ranging from 20% to 45% and of 30% in average.

Graphs 3 and 4 show the prospective evaluations of the upper and lower bound long term regulatory impacts on the growth of ICT and R&D capital intensitiesfor the 15 countries of our sample, if they were implementing the lightest upstream anticompetitive regulatory practices. These impacts are much larger for R&D than for ICT: in average fourfold for the upper bound evaluations and threefold for the lower bound ones. They are for example in the case of R&D highest for Italy and Austria, ranging respectively from about 60% to 90% and from about 50% to 80%, and lowest for the United Kingdom and the USA, ranging from about 15% to

20% in both countries. In the case of ICT, the upper bound and lower estimates are close, highest for Italy and Austria and lowest the United Kingdom and the USA, respectively around 15-20% and 2-5%. The ranking of the countries from the lowest to highest impacts for R&D and ICT are almost the same, and reflects closely enough, as could be expected, the country ranking in terms of the regulatory burden indicator REG-D (and practically also REG).

Graph 3 and 4 about here

In the same format as the two preceding graphs, Graph 5 presents the prospective evaluations of the upper and lower bound long term regulatory impacts on the growth of multifactor productivity MFP for the 15 countries of our sample, under the assumption they have implemented the lightest upstream anticompetitive regulatory practices. It shows not only the total impacts but also the corresponding indirect and direct impacts which are respectively working through the ICT channel, the R&D channel and other channels.

Graph 5 about here

We can see that upper bound evaluations of the total productivity impact are much higher than the lower bound evaluations: in average of about 6.5% as against 2.5%, that is about 0.5% as against 0.2% per year if we assume a long term horizon of some 12 years. They are highest for Italy and the Czech Republic of about11-13% % against 4-5% (roughly 1.0% and 0.4% per year), and they are lowest for the UK and the USA of about 2-3% against 1% (roughly 0.5% and 0.1% per year). We also observe that the upper bound evaluations of the direct impacts are much higher, by a factor of about 2.5 in average, than those of indirect impacts of ICT and R&D together, while the lower bound evaluations of the direct impacts are also higher, by 25% in average, than those of the indirect impacts. Since the regulatory impacts on R&D are much larger than on ICT and the productivity elasticities of ICT and R&D capital are not too different, we can finally remark that the indirect productivity impacts for R&D are more important than for ICT.

Retrospective evaluation of gains from reductions in upstream regulations

As we have noted, the regulatory burden indicator REG has decreased rapidly, at an average rate of 3.3% per year, over our 1987-2007 study period (see Graph 1 and Table 1). It is thus interesting to complement our prospective evaluation by a retrospective one, and to assess especially the regulatory impact on multifactor productivity MFP gains over this twenty year period. These gains are basically computed in the same way as in the prospective simulation on the basis of our upper and lower bound estimates. In particular, we use the slightly modified REG-D indicator based on domestic input-output tables and we use the value added industry shares in country GDP for the aggregation of the gains simulated at the observation level at the country level.

Graph 6 about here

Graph 6 shows in the format of adjacent bars measured on the left y-axis as in the previous graphs, the upper and lower estimates of MFP growth that can be imputed in total (i.e., through the ICT, R&D and other channels) to the reduction on upstream anticompetitive regulations in the 15 countries of our sample over the twenty years 1987-2007. It also shows as a point of comparison, by small triangles measured on the right y-axis, the overall MFP growth for the 13 industries covered in our sample.[11]

We see clearly that the contributions of the reduction in upstream regulations to country MFP growth over the last two decades are on the whole quite significant both in absolute an relative terms, but that they vary greatly across countries, largely reflecting the extent of these

[11] These estimates of “total MFP” computed on the basis of our sample according our definition of MFP (see Section 2) are thus different from the conventional measures of multifactor productivity that are based on national accounts and are hardly comparable to them.

reductions in the different countries (see Graph 1). The average upper and lower bound estimated contributions to MFP growth are respectively of 7.6% and 3.0% over the whole period (0.35% and 0.15% per year), to be compared to a doubling of overall MFP growth (3.6% per year). These contributions are highest for Germany and the Czech Republic ranging respectively from 4.4% to 11% and from 3.9% to 9.9%, and lowest for the USA and Canada ranging respectively from 0.8% to 2.0% and from 1.9% to 4.8%. In terms of their shares to overall MFP growth they are highest for Spain and Japan with shares ranging respectively from 9.2% to 23.4% and from 6.0% to 14.9%, and lowest for USA and Australia with shares ranging respectively from 0.9% to 2.3% and from 1.2% to 3.2%.

VII. Conclusions

In this paper we have investigated empirically through which channels and mechanisms upstream industry anticompetitive regulations impact productivity. To our knowledge it is the first attempt to address this important and challenging question. Using a country-industry unbalanced panel dataset as comprehensive as we could reasonably construct it for estimation and relying mainly on an upstream regulatory burden indicator built from the OECD Non-Manufacturing Regulations (NMR) indicators, we have tried to assess the actual importance of the two main channels usually contemplated in the literature through which upstream sector anticompetitive regulations may impact productivity growth: business investments in R&D and in ICT. We have thus estimated the upstream regulatory impacts on productivity working through these two channels and their shares in total impact as against those working through alternative channels of investments in other forms of intangible capital such as improvements in skills, management and organization, which we could not explicitly consider for lack of appropriate data,. For this, we have specified a simple econometric model consisting of an extended production function relating productivity explicitly to R&D and ICT capital as well as to the upstream regulatory indicator, and two factor demand functions relating R&D and ICT capital to this indicator. In specifying and estimating this model we have been particularly careful to control for potential econometric specification errors and we have focused on two sets of long-term estimates that we can consider as providing respectively optimistic or “upper bound” estimates and pessimistic or “lower bound” estimates.

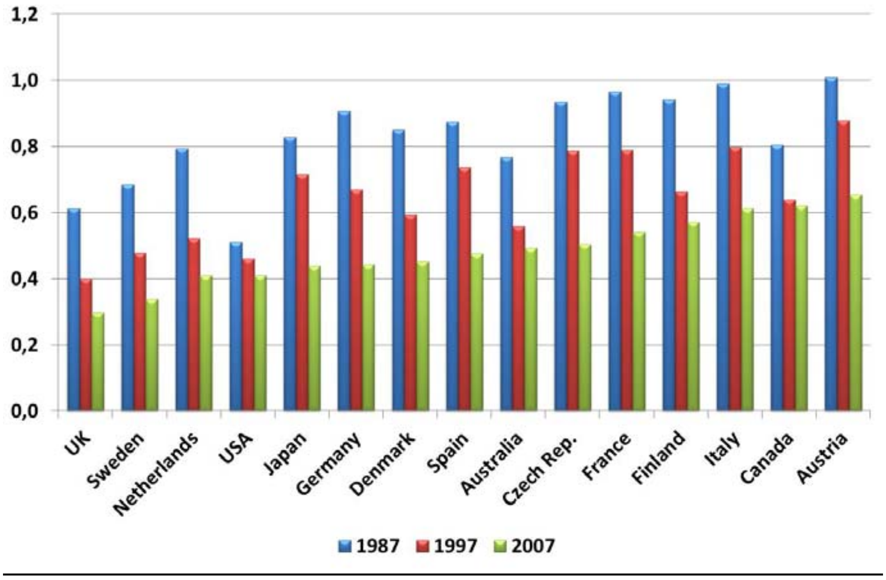
Our results are best illustrated by the prospective evaluations of the upper and lower bound long term regulatory impacts on the growth of multifactor productivity for the fifteen countries of our sample, under the assumption they have implemented the lightest upstream anticompetitive regulatory practices (defined in each upstream industry as the average of the three lowest levels of regulations observed in 2007 among them). We thus estimate that the upper bound and lower bound evaluations of these impacts are in average of about respectively 0.5% and 0.2% per year if we assume a long term horizon of some twelve years. They are highest for Italy and the Czech Republic of about respectively 1.0% and 0.4% per year, and lowest for the UK and the USA of about respectively 0.5% and 0.1% per year. We find that in proportion of these overall upper and lower bound evaluations the average shares of the productivity impacts working through the ICT and R&D channels are of about 20% and 40% respectively, corresponding to a smaller share for the ICT channel between 5% and 15% and a larger one for the R&D channel of about 20%.

As usual there are limitations to our study and its findings and many directions in which it should be extended and improved for a better understanding of the relations between product market regulations and productivity and for pointed policy implications. In particular it will be worthwhile, if more comprehensive and detailed data would permit, to assess the differences in the productivity impacts of upstream regulation for different channels beyond the ICT and R&D channels we could consider here, for different industries and types of product market regulation (beyond the two limited attempts presented in Appendix B). It will be also most important to into account labour market regulations. Several studies (see among others Aghion *et al.* 2009) have shown that labour market regulations could impact productivity either directly or through an interaction with product market regulations, and the large impacts of the upstream industry regulations on productivity we have found could also be linked to labour market regulations.

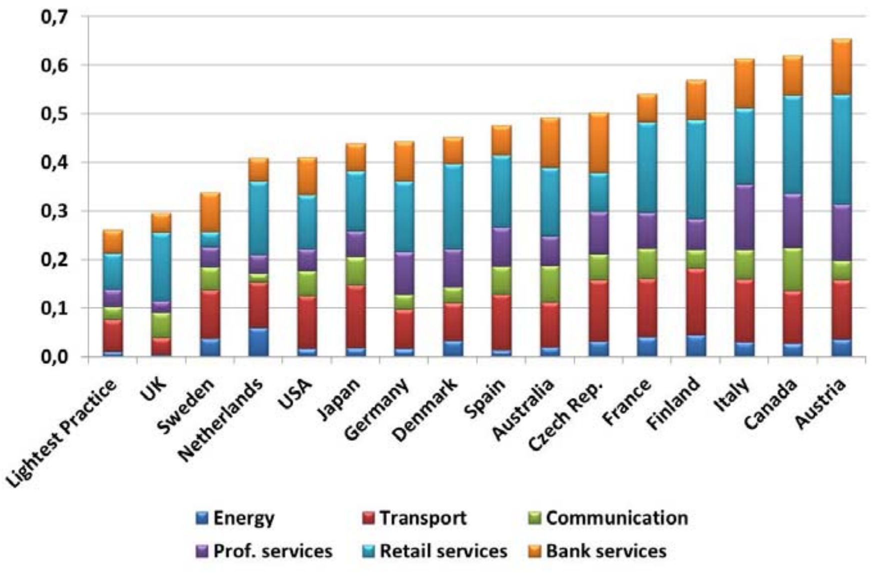
We have nevertheless the feeling that we could not go much further in such directions with our country-industry aggregate data and in our present framework on the basis of the OECD product market indicators. Still with the same data and framework, one possibility we may explore is to confirm and enrich our present findings by relying on the more traditional accounting measures of product and labor market measures despite the endogeneity issues that this will raise. To go much beyond such macro-economic study, one will need to appeal to micro-econometric analyses of firm data for different countries and industries.

GRAPHS 1 TO 5 and Tables 1 o 5

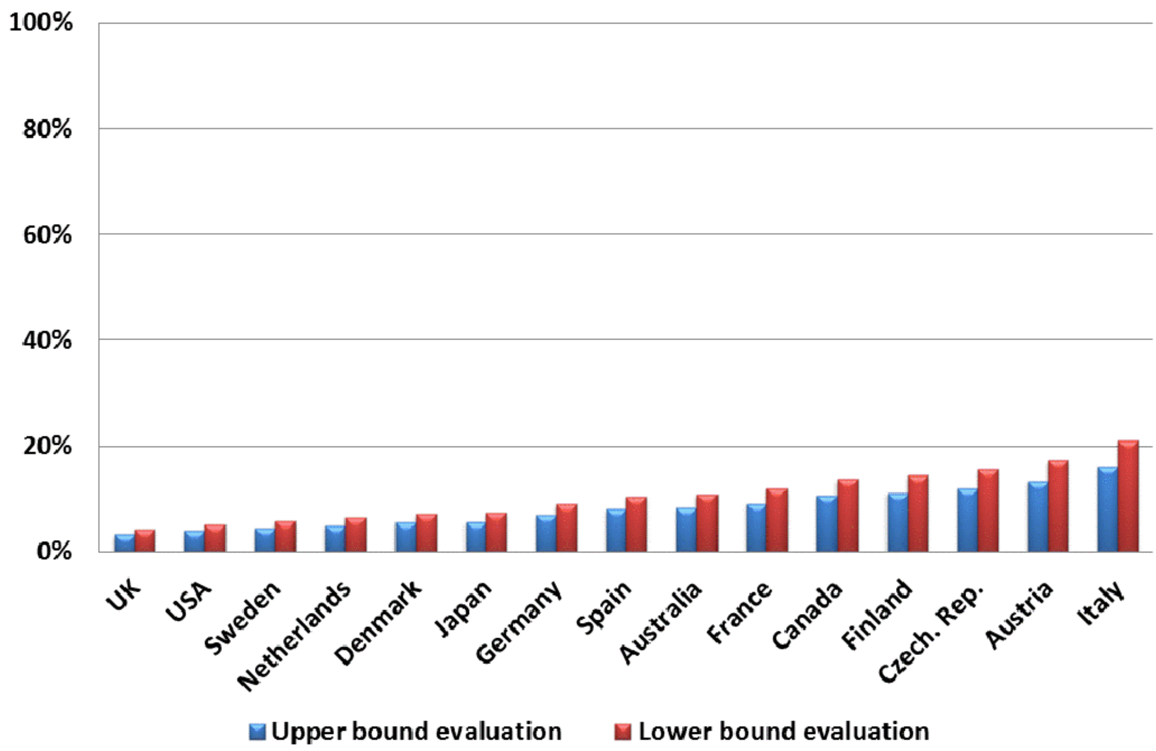
Graph 1: Country averages of REG in 1987, 1997 and 2007



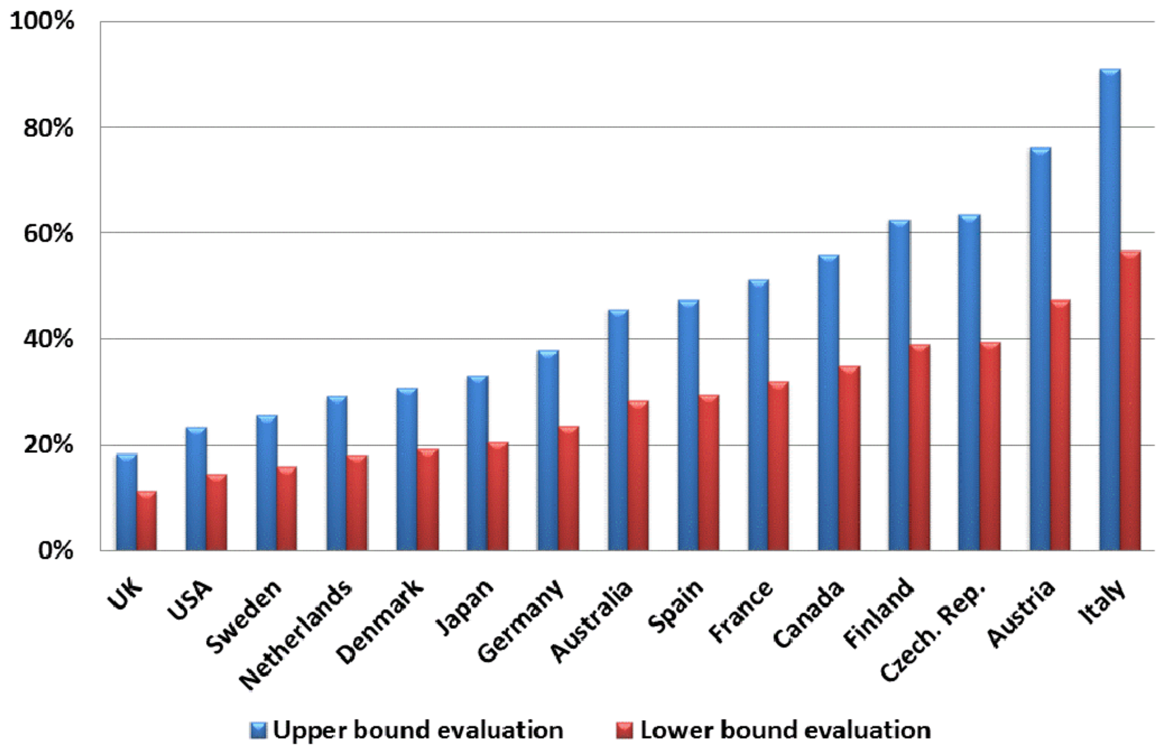
Graph 2: Average country contributions of six NMR indicators to REG in 2007



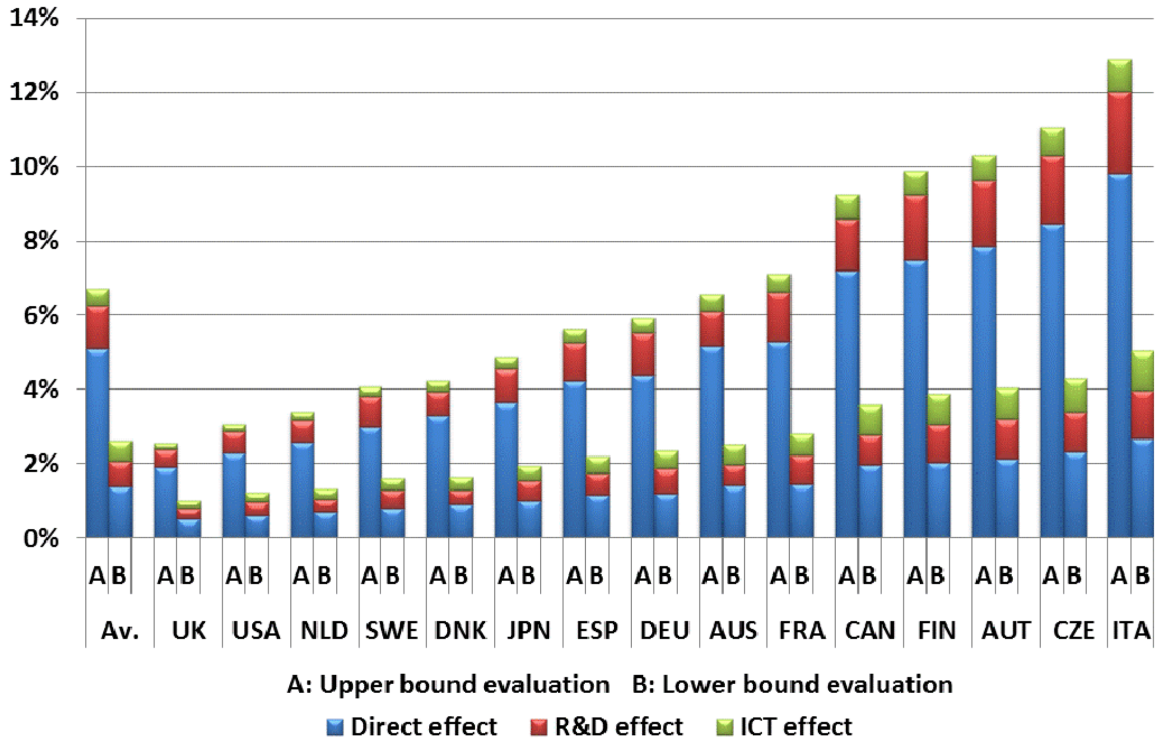
Graph 3: Simulated long term regulatory impacts on ICT capital



Graph 4: Simulated long term regulatory impacts on R&D capital



Graph 5: Simulated long term regulatory impacts on multifactor productivity



Graph 6: Estimated regulatory impacts on multifactor productivity for 1987-2007

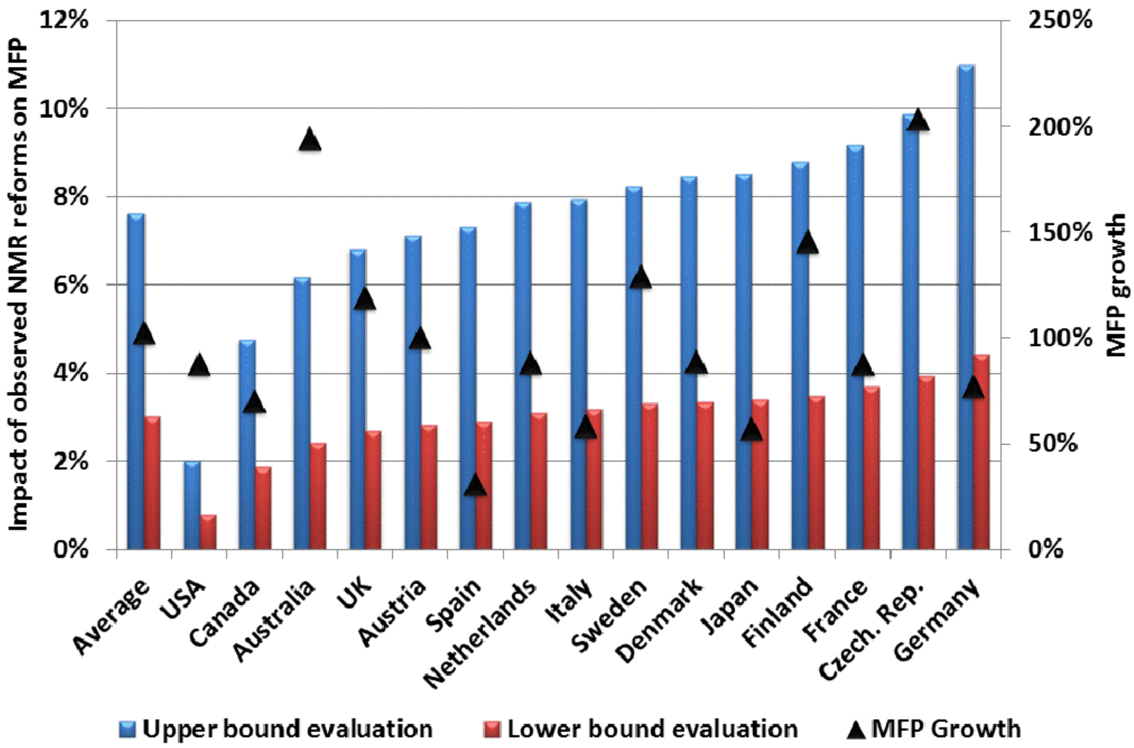


Table 1: Simple descriptive statistics

	Levels in logs except for REG				Annual log growth rate in % also for REG			
	Q1	Median	Q3	Mean	Q1	Median	Q3	Mean
Regulatory burden indicator REG	0.40	0.65	0.89	0.65	-4.75	-2.62	-1.17	-3.33
MFP gap	-0.55	-0.39	-0.25	-0.42	-4.06	-0.20	3.59	-0.20
ICT capital intensity gap	-1.10	-0.75	-0.27	-0.73	-5.22	-0.13	5.30	0.28
R&D capital intensity gap	-1.28	-0.54	-0.04	-0.62	-4.94	1.01	7.02	1.55
ICT capital intensity	5.30	5.96	6.74	6.01	5.93	10.39	15.55	11.34
ICT - labor cost ratio	-0.18	0.18	0.61	0.24	-16.20	-9.11	-2.94	-9.98
R&D capital intensity	5.63	6.52	7.65	6.54	1.06	5.12	10.22	5.85
R&D - labor cost ratio	-0.07	0.03	0.18	0.05	-7.18	-3.10	0.73	-3.28

All statistics are computed for the complete study sample, except for the R&D variables computed for the subsample without industries with low R&D intensity.

Table 2: Analysis of variance

	First step R^2	Second Step R^2		
	Separate country, industry and year effects	Country*year	Country*year and industry*year	Country*year, industry*year and country*industry
	(1)	(2)	(3)	(4)
Regulatory burden indicator REG	0,938	0.196	0.520	0.959
ICT capital intensity gap	0,471	0,083	0.235	0.840
R&D capital intensity gap	0,458	0,093	0.209	0.915
ICT capital intensity	0,606	0,017	0,112	0,937
ICT - labor cost ratio	0,824	0.095	0.1620	0.9120
R&D capital intensity	0,837	0.4470	0.507	0.801
R&D - labor cost ratio	0,790	0,018	0,070	0,9360
ICT capital intensity gap	0,758	0,217	0,265	0,690

See footnote to Table 1.

Table 3: Multifactor productivity regression

Dependent variable: **MFP gap**	(1)	(2)	(3)	(4)	(5)	(6)
ICT capital intensity gap	0.052*** [0.009]		0.074*** [0.009]		0.048*** [0.008]	
R&D capital intensity gap	0.078*** [0.007]		0.069*** [0.007]		0.083*** [0.007]	
Regulatory burden indicator REG	-0.234*** [0.055]	-0.253*** [0.057]	-0.064 [0.067]	-0.155** [0.071]	-0.226*** [0.050]	-0.212*** [0.051]
Effects:						
Country, industry, year separately	Y	Y	Y	Y	Y	Y
Country*year	Y	Y	Y	Y	N	N
Industry*year	N	N	Y	Y	N	N
Observations	2612	2612	2612	2612	2612	2612
R-squared	0.565	0.518	0.646	0.596	0.526	0.474
RMSE	0.1821	0.1911	0.1720	0.1835	0.1818	0.1910

*** significant at 1%; ** significant at 5%; *significant at 10% - Standard errors between brackets. The DOLS estimates are performed with one lag and one lead of the first differences of the ICT and R&D capital intensity gap variables; the corresponding coefficients are not presented in the Table.

Table 4: ICT capital demand regression

Dependent variable: **ICT capital intensity**	(1)	(2)	(3)	(4)	(5)	(6)
ICT capital user cost	-0.758*** [0.041]	-1	-0.728*** [0.045]	-1	-0.507*** [0.032]	-1
Regulatory burden indicator REG	-0.263** [0.125]	-0.166 [0.125]	-0.342** [0.164]	-0.251 [0.166]	-0.089 [0.115]	-0.059 [0.120]
Effects:						
Country, industry, year separately	Y	Y	Y	Y	Y	Y
Country*year	Y	Y	Y	Y	N	N
Industry*year	N	N	Y	Y	N	N
Observations	2612	2612	2612	2612	2612	2612
R-squared	0.863	0.845	0.871	0.837	0.842	0.824
RMSE	0.4139	0.4169	0.4220	0.4277	0.4252	0.4450

See footnote to Table 3.

Table 5: R&D capital demand regression

Dependent variable: **R&D capital intensity**	(1)	(2)	(3)	(4)	(5)	(6)
R&D capital user cost	-0.628*** [0.128]	-1	-0.619*** [0.135]	-1	-0.607*** [0.108]	-1
Regulatory burden indicator REG	-1.395*** [0.385]	-1.563*** [0.382]	-0.868** [0.425]	-1.051** [0.424]	-0.717** [0.283]	-0.831*** [0.283]
Effects:						
Country, industry, year separately	Y	Y	Y	Y	Y	Y
Country*year	Y	Y	Y	Y	N	N
Industry*year	N	N	Y	Y	N	N
Observations	1478	1478	1478	1478	1478	1478
R-squared	0.801	0.763	0.810	0.746	0.796	0.787
RMSE	0.6599	0.6624	0.6776	0.6855	0.6242	0.6273

See footnote to Table 3.

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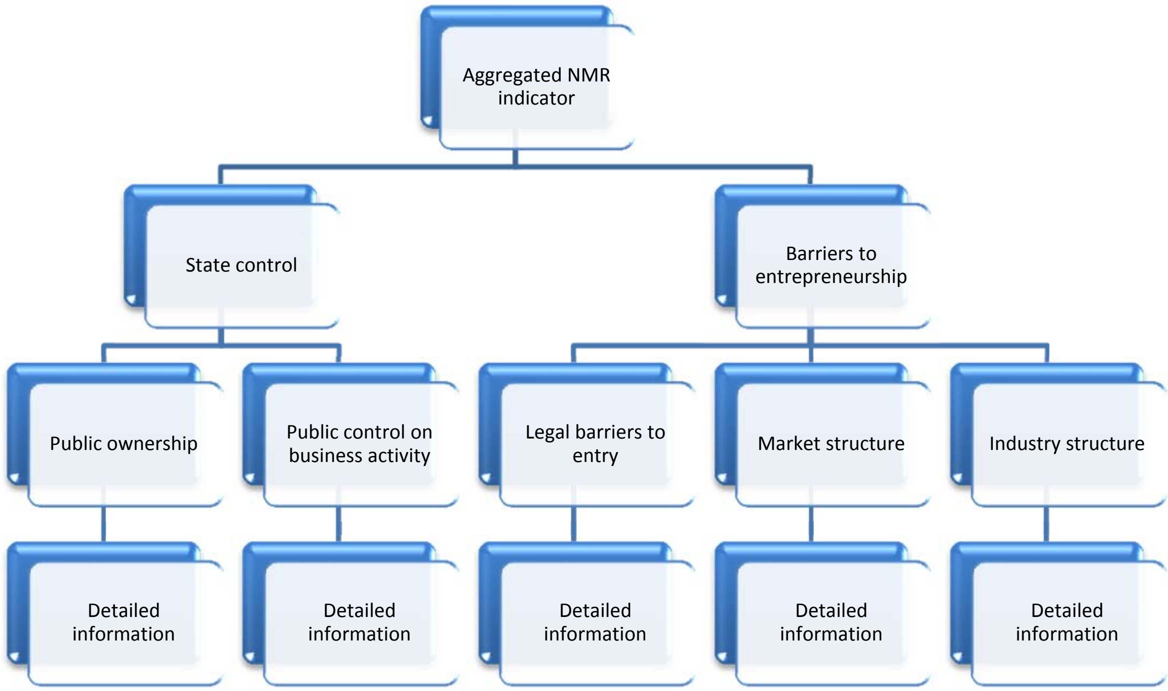
APPENDIX A: DATA

In this Appendix, we first provide additional information on the underlying OECD Non-Manufacturing Regulation (NMR) indicators for a better understanding of the regulatory burden indicator REG. We then explain the measurement of the ICT, non-ICT and R&D capital stocks, and that of our multifactor productivity variable MFP, and we document the construction of our sample.

(1). Non-manufacturing product market regulation indicators

Diagram A1: Aggregation of the detailed information on regulations



The OECD Non-Manufacturing Regulations (NMR) indicators measure to what extent competition and firm choices are restricted where there are no a priori reasons for government interference, or where regulatory goals could plausibly be achieved by less coercive means. They are based on detailed information on laws, rules and market and industry settings. This information is the raw material allowing calculating the aggregate indicators according to the Diagram A1. For each NMR indicator, the detailed information is first aggregated into five sub-level indicators: public ownership, public control on business activity, legal barriers to entry, market structure and industry structure, or eventually only part of them in some upstream industries (see Conway and Nicoletti, 2006). These sub-level indicators are then aggregated into one indicator for each upstream industry. As shown in the diagram they can also be aggregated at a step level of 'state control' and 'barriers to entrepreneurship'. We have considered them in an attempt to differentiate the impacts of both kind of regulations on which we report briefly in Appendix B.

Table A3 gives the example of the questions and corresponding involved in the construction of the 'legal barriers to entry' sub-level regulation indicator for professional services. The answers to each question are coded between 0 and 6. These codes are indicated in the Table under each possible answer, with 0 for the most procompetitive regulation and 6 for the most anticompetitive one.

Table A3: Construction of the 'legal barriers to entry' sub-level regulation indicator for Professional services

Scale 0-6, 0 for the most pro-competitive regulations

	Weights by theme (b_j)	**Question weights (c_k)**	Coding of data				
Licensing:	2/5						
How many services does the profession have an exclusive or shared exclusive right to provide?			0	1	2	3	>3
		1	0	1,5	3	4,5	6
Education requirements (only applies if Licensing not 0):	2/5						
What is the duration of special education/university/or other higher degree?		0.33	equals number of years of education (max of 6)				
What is the duration of compulsory practice necessary to become a full member of the profession?		0.44	equals number of years of compulsory practice (max of 6)				
Are there professional exams that must be passed to become a full member of the profession?		0.22	no		Yes		
			0		6		
Quotas and economic needs tests	1/5						
Is the number of foreign professionals/firms permitted to practice restricted by quotas or economic needs tests?			no		Yes		
		1	0		6		

The coding of each question is indicated under each possible answer.

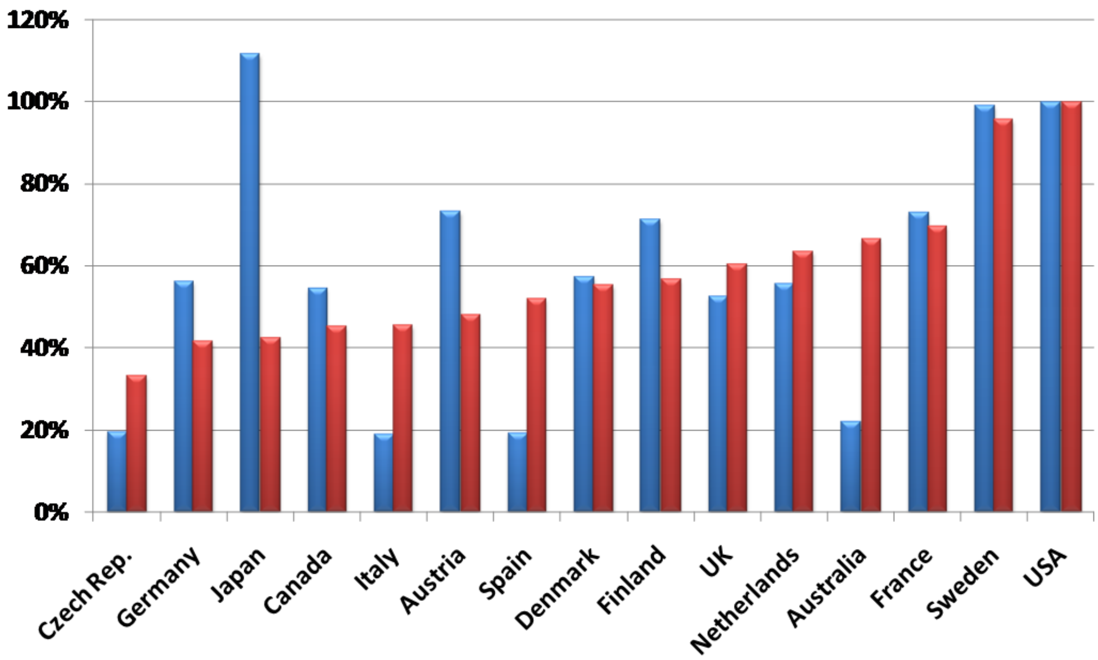
(2). Capital stocks

Data on R&D investments at the country-industry level come from the OECD ANBERD database whereas physical investments values and prices come from the EU KLEMS database. To compute investments in constant prices we have used investment deflators at the national level. Because of the lack of specific price information for R&D, we have used as proxy the manufacturing production deflator from the OECD STAN database. For the prices of ICT investments in hardware, software and telecommunications equipment, we have adopted for all countries the same prices relative to that of GDP than those for the USA. This is much better for comparability since is the USA is by far the country that rely most extensively on hedonic methods to measure these prices.

Capital stocks are calculated at the level of the three ICT and the three non-ICT investment series in constant prices obtained from the EU-KLEMS database, using the so-called Permanent Inventory Method (PIM) and assuming constant geometric rates of depreciation: 5 % for non-residential structures, 10 % for transport and other non-ICT equipment, 15 % for communication equipment, 25 % for R&D and 30 % for hardware and software. We then aggregate them into non-ICT and ICT capital stocks. R&D capital is computed in the same way using a depreciation rate of 25%. To implement the PIM we need an initial capital stock estimate. For ICT capital stocks, we simply assumed an initial capital stock of zero in 1971. Investment series at the industry level are available for non-ICT physical assets since 1970 and for R&D only since 1987. We thus first estimated an R&D capital stock at the aggregate level which we could do for 1981 and apportioned it to the different industries proportionally to their shares in total R&D investment in 1987. Note that to estimate the initial capital stocks K_0 of non-ICT physical capital by industry in 1970 and of aggregate R&D capital in 1981, we used the formula $K_0 = I_0^q/(\delta + g)$ with I_0^q the investment in constant price the first year available, δ the depreciation rate and g the value added growth rate over the previous decade.

Chart A1 shows the average R&D and ICT capital intensities (i.e., R&D or ICT capital stocks per employee) by country relative to the USA (=100%), where these ratios are computed on the 2001-2005 period, for which our sample is nearly balanced. We observe very important differences between countries and in their ranking by R&D and ICT capital intensities.

Chart A1: **R&D and ICT capital intensity ratios relative to the USA (=100%) country average 2001-2005**



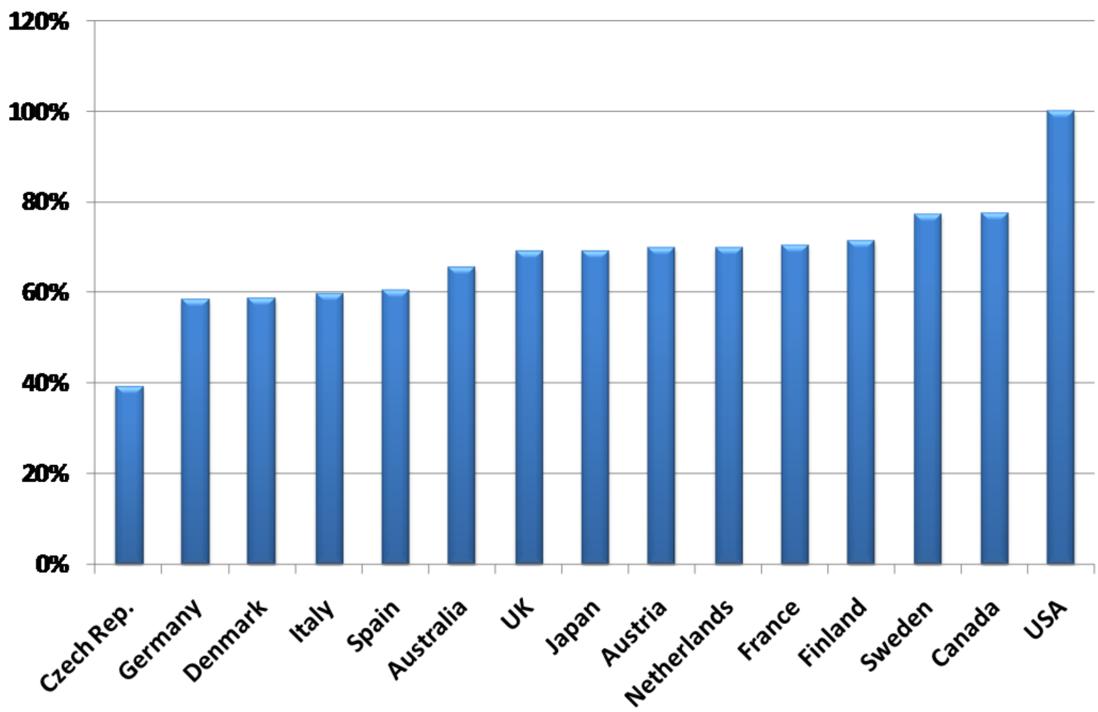
(3). Multifactor productivity

The measurement of our multifactor productivity MFP requires data at the country-industry level on value added in constant price and employment in number of persons in addition to non-ICT capital stocks. These data come from the OECD STAN database, but they need a number of corrections. Since R&D is not treated as in investment in the national accounts data gathered by OECD, we had to correct both the industry value added by adding ("expensing out") the intermediate consumption of their R&D activities and the industry number of employees by subtracting the number of R&D personnel (to avoid "double counting"). Note also that we had also to modify the price index of value added, and hence its value in constant price, for the "Electrical and optical equipment" industry. This industry includes communication and computing equipment, for which prices in the USA are extensively based on the hedonic price method but not in the other countries. It appeared that indeed the differences in the evolution of the value added price in this industry between the USA and the other countries, and hence also in the labor productivity growth, were much too large to be credible. We thus adopted for the other countries in this industry the value added prices (relative to that of GDP) in the USA, as we did for the ICT investment prices.to the domestic prices in this industry.

To compute MFP, as explained in Section II, we have chosen to calibrate the non-ICT capital stock elasticities ($\tilde{\alpha}_i$) at the industry level by the average shares of their user cost in total costs computed for the USA over the whole estimation period. It is important, however, to stress that our main results remain basically unchanged when instead of calibrating the non-ICT capital elasticity we estimate it in the productivity equation and do not impose the constant returns to scale hypothesis (see Appendix Table B1).

Finally, in order to ensure comparability across countries of our measure of MFP, we have converted the value added and capital stocks level variables into prices denominated in a common currency using OECD aggregate purchasing power parities. Chart A2 shows the average country MFP relative to the USA (=100%) for the 2001-2005 period. We see that MFP in the USA is much greater than all the other countries, with an average MFP ratio ranging between a low 40% for the Czech republic and a high 80% for Sweden and Canada At the country-industry-year level the USA MFP is also for 85% of the observations and among the three highest for the 15% other observations.

Chart A2: MFP ratio relative to the USA (=100%), country average 2001-2005



(4). Country-industry panel data sample

On the basis of the OECD STAN data base, we can consider eighteen manufacturing and service industries, covering the whole business economy, with the exception of 'Agriculture, hunting, forestry and fishing', 'Mining and quarrying' and 'Real Estate activity'. Table A1 gives the list of these eighteen industries with the industry averages of the ICT and R&D investment to value added ratios over the years 2001-2005.

Table A2: Sample composition by industry and ICT and R&D investment to value added ratios, industry averages on the 2001-2005 period

INDUSTRIES	In Sample	ISIC rev. 3 code	ICT ratio (%).	R&D ratio (%).
FOOD PRODUCTS, BEVERAGES AND TOBACCO	I*	15-16	1,6	1,1
TEXTILES, TEXTILE PRODUCTS, LEATHER AND FOOTWEAR	E	17-19	1,2	1,2
WOOD AND PRODUCTS OF WOOD AND CORK	E	20	1,1	0,4
PULP, PAPER, PAPER PRODUCTS, PRINTING AND PUBLISHING	I*	21-22	2,8	0,6
CHEMICAL, RUBBER, PLASTICS AND FUEL PRODUCTS	I	23-25	1,8	8,1
OTHER NON-METALLIC MINERAL PRODUCTS	I	26	1,4	1,4
BASIC METALS AND FABRICATED METAL PRODUCTS	I	27-28	1,5	1,3
MACHINERY AND EQUIPMENT, N.E.C.	I	29	2,2	5,01
ELECTRICAL AND OPTICAL EQUIPMENT	I	30-33	4,3	16,0
TRANSPORT EQUIPMENT	I	34-35	2,2	10,3
MANUFACTURING NEC; RECYCLING	E	36-37	1,4	1,4
ELECTRICITY GAS AND WATER SUPPLY	I	40-41	2,7	0,4
CONSTRUCTION	E	45	0,7	0,1
WHOLESALE AND RETAIL TRADE; REPAIRS	I*	50-52	2,1	0,2
HOTELS AND RESTAURANTS	E	55	1,0	0,0
TRANSPORT, STORAGE, POST AND TELECOMMUNICATIONS	I*	60-64	6,6	0,5
FINANCIAL INTERMEDIATION	I*	65-67	5,7%	0,3
RENTING M&EQ AND OTHER BUSINESS ACTIVITIES	I	72-74	4,7	1,9

I: Industries included in the sample; I*: Industries with ICT investment but almost no R&D investment included in the sample but not used in the estimation of the R&D demand; E: Industries with almost no ICT and R&D investments excluded from the sample. Upstream industries are underlined

The five industries (listed with an E in the 2nd column) have very low ICT and R&D to value added ratios, respectively 1.1% and 0.6% on average, as against 3.1% and 3.6% for the thirteen other industries. We had to exclude them from our study since we could not measure reliably enough our ICT and R&D capital stocks variables. Our study sample thus covers the thirteen other industries (with an I or I* in the 2^{nd} column). Among them, however, there are still five of them (with an I* in the 2^{nd} column) that are almost not investing in R&D with very low R&D to value added ratios of 0.6% in average as against 5.5% for the eight others industries. We had to exclude them when estimating the R&D demand equation.

APPENDIX B: ROBUTNESS AND EXTENSION ANALYSES

This Appendix presents briefly a three robustness ant two extension analyses we thought important to perform and document. (1) We study how much our main results vary if we estimate also the non-ICT capital and labor elasticities in the productivity equation and we do not impose constant returns to scale nor calibrate the non-ICT capital elasticity. (2) We similarly investigate what differences it makes in our results to specify more symmetrically the productivity and ICT and R&D demand equations by introducing explicitly a "catch-up" variable in these equations. (3) We also report the differences it makes in evaluations of the long term MFP gains by country when we use in our prospective simulation the regulatory burden indicator REG based on the USA input-output table as we do in estimation. (4) We document how much the estimated impact of upstream regulations in the productivity and ICT demand equations differs between industries investing or not on R&D. (5) Similarly we compare the estimated impact of upstream regulations in the productivity and ICT and R&D demand equations when we separate the "state control" and "barriers to entrepreneurship" components in our regulatory burden indicator REG.

(1). <u>Robustness with respect to the hypothesis of constant returns to scale and the choice to calibrate the non-ICT capital elasticity</u>

In specifying and estimating our productivity equation (relation (3) in Section II), we have assumed constant return to scale and we have calibrated the non-ICT capital elasticity by its share on total costs. We show that on the whole our estimation results are robust enough are if instead we estimate the following productivity equation in terms of labor productivity (LP) gap, instead of multifactor productivity (MFP) gap:

$$lp\_gap_{ci,t} = \pi l\_gap_{ci,t} + \alpha c\_gap_{ci,t} + \gamma d\_gap_{ci,t} + \delta k\_gap_{ci,t} - \mu\, REG_{ci,t-1} + u_{ci,t}$$

with: $lp\_gap_{ci,t} \equiv (y_{ci,t} - l_{ci,t}) - (y_{\bar{c}i,t} - l_{\bar{c}i,t})$, $c\_gap_{ci,t} \equiv (c_{ci,t} - l_{ci,t}) - (c_{\bar{c}i,t} - l_{\bar{c}i,t})$, $l\_gap_{ci,t} \equiv l_{ci,t} - l_{\bar{c}i,t}$ and $\pi \equiv \alpha + \gamma + \delta + \beta - 1$

We have thus to estimate now two more parameters: π, that is the deviation to 1 of the elasticity of scale, previously assumed to be null under constant returns to scale, and α the non-ICT capital elasticity, instead of calibrating it to be industry specific and equal to the industry average of the share of its user cost in total cost for the USA, that to be in average about 0.19. We also indirectly estimate the labor elasticity β as previously.

Table B1 recalls the upper and lower bound estimates previously obtained (Table 3 in the text) in columns (1) and (5) respectively and presents the new ones in columns (4) and (8). In columns (2) and (6) it gives the corresponding estimates when the hypothesis of constant returns to scale is relaxed and the non-ICT capital elasticity remains calibrated,, and in columns (3) and (7) when it is the reverse.

We see that the estimated impacts of the elasticity of scale and non-ICT capital intensity gaps are close to what we assumed them to be: π is next to zero and α is a little smaller than its average calibrated value. Our estimates of our main parameter of interest are not too much changed: the ICT capital elasticity γ and the impact of upstream regulations μ remain roughly the same, and the R&D elasticity δ is lower but still significantly positive.

Table B1: **Robustness to production function constant returns to scale assumption and non-ICT capital elasticity calibration**

Dependent variable	**MFP gap**		**LP gap**		**MFP gap**		**LP gap**	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Gap in labor		-0.012 [0.013]		-0.026** [0.013]		-0.024* [0.013]		-0.043*** [0.013]
Gap in non-ICT capital intensity			0.151*** [0.012]	0.161*** [0.013]			0.145*** [0.012]	0.158*** [0.013]
Gap in ICT capital intensity	0.052*** [0.009]	0.060*** [0.009]	0.046*** [0.009]	0.048*** [0.009]	0.074*** [0.009]	0.079*** [0.009]	0.064*** [0.009]	0.066*** [0.009]
Gap in R&D capital intensity	0.078*** [0.007]	0.077*** [0.007]	0.040*** [0.007]	0.038*** [0.007]	0.069*** [0.007]	0.068*** [0.007]	0.037*** [0.006]	0.034*** [0.006]
Regulatory burden indicator$_{-1}$	-0.234*** [0.055]	-0.240*** [0.055]	-0.205*** [0.051]	-0.203*** [0.051]	-0.064 [0.067]	-0.078 [0.067]	-0.050 [0.063]	-0.034 [0.064]
Fixed effects: **Country, industry, year** **Country*year** **Industry*year**	Y Y N	Y Y N	Y Y N	Y Y N	Y Y Y	Y Y Y	Y Y Y	Y Y Y
Observations **R-squared** **RMSE**	2612 0.565 0.1821	2612 0.577 0.1797	2612 0.627 0.1686	2612 0.631 0.1679	2612 0.646 0.1720	2612 0.653 0.1705	2612 0.688 0.1614	2612 0.692 0.1607

See footnote to Table 3.

(2). Robustness with respect to "catch-up" hypotheses

The specification of our multifactor productivity equation assumes for given fixed effects a bounded cointegrated long term relationship between the MFP of the reference or "leader" country and the MFP of the "follower" countries by imposing a coefficient of 1 for the MFP of the reference country, or catch-up term, and writing the estimated equation in terms of MFP gap (see section II). We have specified differently the long term ICT and R&D demand equations considering that common shocks are already taken into account by the price effects and the different fixed effects and implicitly assuming a coefficient equal to zero for the catch-up term. We investigate the influence of these assumptions on our main parameter estimates and find that overall they are robust

We thus estimate now the following multifactor productivity and ICT and R&D demand equations:

$$mfp_{ci,t} = cst + \rho\left(mfp_{\bar{c}i,t} - \gamma\left(d_{\bar{c}i,t} - l_{\bar{c}i,t}\right) - \delta\left(k_{\bar{c}i,t} - l_{\bar{c}i,t}\right)\right) + \gamma\left(d_{ci,t} - l_{ci,t}\right) + \delta\left(k_{ci,t} - l_{ci,t}\right) - \mu\, Reg_{ci,t-1} + u_{ci,t}$$

and

$$(d-l)_{ci,t} = \text{Cst} + \varphi_1 (d-l)_{\bar{c}i,t} + (p_D - w)_{ci,t} - \mu_D REG_{ci,t-1} + u_{ci,t}^{D}$$

$$(k-l)_{ci,t} = \text{Cst} + \varphi_2 (k-l)_{\bar{c}i,t} + (p_K - w)_{ci,t} - \mu_K REG_{ci,t-1} + u_{ci,t}^{K}$$

These equations are strictly equivalent to our previous ones, if $\rho = 1$, $\varphi_1 = 0$ and $\varphi_2 = 0$.

Tables B2.1 and B2.2 recall our previous upper bound estimates for these three equations and show the new ones. Our lower bound estimates are strictly the same, since the interacted industry*year effects take fully care of the catch up variables. Although the estimated ρ of 0.87 is significantly smaller than 1 and the estimated φ_2 of 0.25 is significantly higher than 0 (while the estimated φ_1 of -0.09 is not), we see that the ICT and R&D capital elasticity as well as the impact of upstream regulations remain basically unchanged.

Table B2.1: Robustness of the multifactor productivity equation estimates with respect to catch-up hypothesis

Dependent variable	MFP gap	MFP
	(1)	(2)
Gap in ICT capital intensity	0.052*** [0.009]	0.046*** [0.008]
Gap in R&D capital intensity	0.078*** [0.007]	0.077*** [0.007]
Regulatory burden indicator$_{-1}$	-0.234*** [0.055]	-0.180*** [0.051]
MFP USA		0.869*** [0.016]
Fixed effects: **Country, industry, year** **Country*year** **Industry*year**	 Y Y N	 Y Y N
Observations **R-squared** **RMSE**	2612 0.565 0.1821	2612 0.562 0.1709

See footnote to Table 3.

Table B2.2: **Robustness of the ICT and R&D demand equation estimates with respect to catch-up hypothesis**

Dependent variable	ICT capital intensity	ICT capital intensity	R&D capital intensity	R&D capital intensity
	(1)	(2)	(3)	(4)
ICT or R&D capital costs	-0.758*** [0.041]	-0.759*** [0.042]	-0.628*** [0.128]	-0.615*** [0.128]
Regulatory burden indicator$_{-1}$	-0.263** [0.125]	-0.278** [0.129]	-1.395*** [0.385]	-1.383*** [0.389]
ICT or R&D capital intensity USA		-0.091 [0.073]		0.252*** [0.096]
Fixed effects: **Country, industry, year** **Country*year** **Industry*year**	 Y Y N	 Y Y N	 Y Y N	 Y Y N
Observations **R-squared** **RMSE**	2612 0.863 0.4139	2612 0.864 0.4135	1478 0.801 0.6599	1478 0.802 0.6585

See footnote to Table 3.

(3). Differences in the prospective simulations of multifactor productivity gains with respect to the choice of domestic or USA input-output tables

We finally report the differences it makes in evaluations of the long term MFP gains by country, if instead of using in our prospective simulation the slightly modified regulatory burden indicator REG-D based on the different country input-output tables, we use in our prospective simulation the regulatory burden indicator REG based on the USA input-output table as in estimation.

Table B3: Simulated long term MFP gains from reforms, depending on I-O tables

Simulated MFP gains	**Upper-bound estimate (1)**	**Upper-bound estimate (2)**	**Lower-bound estimate (3)**	**Lower-bound estimate (4)**
	Domestic I-O table	**USA I-O table**	**Domestic I-O table**	**USA I-O table**
UK	2,6%	1,7%	1,0%	0,7%
USA	3,1%	3,1%	1,2%	1,2%
Netherlands	3,4%	2,8%	1,3%	1,1%
Sweden	4,1%	3,0%	1,6%	1,2%
Denmark	4,3%	3,6%	1,6%	1,4%
Japan	4,9%	3,8%	1,9%	1,5%
Spain	5,6%	3,8%	2,2%	1,5%
Germany	5,9%	4,4%	2,4%	1,7%
Australia	6,6%	4,6%	2,5%	1,7%
France	7,1%	5,7%	2,8%	2,2%
Canada	9,2%	7,5%	3,6%	2,9%
Finland	9,9%	6,8%	3,9%	2,6%
Austria	10,3%	7,6%	4,1%	2,9%
Czech. Rep.	11,1%	5,9%	4,3%	2,2%
Italy	12,9%	7,2%	5,0%	2,8%
Country Average	6,7%	4,8%	2,6%	1,8%

Table B3 recalls in columns (1) and (3) the prospective evaluations of the upper and lower bound long term regulatory impacts in total (i.e., through all channels) on the growth of multifactor productivity MFP for the fifteen countries of our sample, under the assumption they have implemented the lightest upstream anticompetitive regulatory practices (as shown in Graph 5 in the text). It compares them to the alternative corresponding evaluations given in columns (2) and (4). We see that the choice of the input-output table of the USA to compute the regulatory burden indicator of each country would have implied, since the intensity of use of regulated intermediate inputs is relatively less in this country, much lower simulated evaluations, by about 20% (for example in the case of Netherlands) to nearly 50% (for the Czech Republic). It remains, nevertheless, that these evaluations would still appear sizeable, ranging in average from long term MFP gains between 1.8% and 2.6% as against 4.8% and 6.7%.

(4). Differences in the impacts of upstream regulations between R&D doing and non-R&D doing industries

As we have explained (see Appendix Table A2), while all thirteen industries in our study sample are investing on ICT, only eight of them are investing in R&D. Although we cannot investigate thoroughly the potential differences in the impacts of upstream regulations across industries with our aggregate country-industry data, it seems appropriate to check whether these impacts differ significantly between the two groups of R&D and non-R&D doing industries.

Tables B4.1 and B4.2 recall our previous upper and lower bound estimates for the productivity and ICT demand equations in columns (1) and (3) and contrast them to the new ones in columns (2) and (4), our estimates for the R&D demand equation remaining of course the same (see Table 5 in the text). We see that the upper bound estimates of upstream regulation impacts show marked differences between the two groups of R&D and non-R&D doing industries, although they are not statistically significant since they are not too precisely estimated: about -0.25 as against -0.19 for multifactor productivity and -0.42 as against -0.25 for ICT capital intensity. These differences are wider and statistically significant for our lower bound estimates: about -0.04 as against -0.19 for multifactor productivity and -0.40 as against -0.14 for ICT capital intensity.

On total we thus find reasonably strong as well as a priori very plausible evidence that upstream regulation on productivity works mainly through the R&D and ICT channels in the R&D doing industries the ICT and other channels in the non R&D channels.

Table B4.1: Differences in upstream regulation impacts on multifactor productivity between R&D and non-R&D doing industries

Dependent variable: MFP gap		(1)	(2)	(3)	(4)
Gap in ICT capital intensity		0.052*** [0.009]	0.053*** [0.009]	0.074*** [0.009]	0.073*** [0.009]
Gap in R&D capital intensity		0.078*** [0.007]	0.077*** [0.008]	0.069*** [0.008]	0.071*** [0.008]
Regulatory burden indicator$_{-1}$	**All industries**	-0.234*** [0.054]		-0.064 [0.062]	
	R&D industries		-0.250*** [0.055]		-0.044 [0.062]
	no-R&D industries		-0.187*** [0.067]		-0.188*** [0.073]
Fixed effects:					
Country, industry, year		Y	Y	Y	Y
Country*year		Y	Y	Y	Y
Industry*year		N	N	Y	Y
Reg impact equality test			0.2037		0.0029
Observations		2612	2612	2612	2612
R-squared		0.565	0.566	0.646	0.647
RMSE		0.1821	0.1821	0.1720	0.1718

See footnote to Table 3.

Table B4.2 Differences in upstream regulation impacts on ICT capital intensity between R&D and non-R&D doing industries

Dependent variable: ICT capital intensity		(1)	(2)	(3)	(4)
Gap in ICT capital intensity		-0.741*** [0.041]	-0.732*** [0.042]	-0.712*** [0.044]	-0.723*** [0.045]
Gap in R&D capital intensity		-0.281** [0.126]		-0.368** [0.165]	
Regulatory burden indicator$_{-1}$	**All industries**	-0.245* [0.128]		-0.398** [0.166]	
	R&D industries	-0.417*** [0.154]		-0.144 [0.210]	-0.044 [0.062]
	no-R&D industries	Y	Y	Y	-0.188*** [0.073]
Fixed effects:		Y	Y	Y	Y
Country, industry, year		N	N	Y	Y
Country*year			0.1253		0.0866
Industry*year		2612	2612	2612	2612
Reg impact equality test		0.862	0.862	0.870	0.870
Observations		0.4163	0.4162	0.4237	0.4235
R-squared		-0.741***	-0.732***	-0.712***	-0.723***
RMSE		[0.041]	[0.042]	[0.044]	[0.045]

See footnote to Table 3.

(5). Differences in the impacts of barriers to entrepreneurship and state control

As explained in Appendix A.1 the OECD non-manufacturing regulation indicators can be viewed as the sum of two sub-indicators corresponding to two main types of regulations: barriers to entrepreneurship and state control that take into account legal barriers to entry, market structures and industry structure for the first and information on public ownership of leader firms and on public control on business activity (mainly price control) for the second. This is thus also the case of our regulatory burden indicator REG which we can divide in the corresponding two components. Since the purpose of state control is largely to internalize market externalities or provide public services, it may not lead to increase the upstream rents unlike the barriers to entrepreneurship. It thus seems of particular interest, even at our aggregate level of analysis, to do the tests of comparison of the estimated impacts of these two components of REG on multifactor productivity and ICT and R&D capital.

Table B5.1 presents the results of these tests. We can see that the hypothesis of the equality of the impact coefficients of the two upstream regulation components cannot be rejected, even at the 10% level of confidence, in the productivity equation and the ICT demand and for both our upper and lower bound estimates, but that it is on the contrary strongly rejected for the R&D demand equation and both estimates.

Table B5.1: Tests of equality of the coefficients of the regulatory burden components for state control and barriers to entrepreneurship

P-values	**Productivity equation**		**ICT demand**		**R&D demand**	
	(1)	(2)	(3)	(4)	(5)	(6)
Equality test	0.825	0.407	0.122	0.186	0.000	0.000
Fixed effects:						
Country,	Y	Y	Y	Y	Y	Y
Country*year	Y	Y	Y	Y	Y	Y
Industry*year	N	Y	N	Y	N	Y
Observations	2612	2612	1478	1478	2612	2612

Tests based on the DOLS estimates with one lag and one lead

Table B5.2 thus records the estimation results for R&D demand equation only. It recalls for comparison in columns (1) and (5) our previous upper and lower bound estimates (from Table 5 in the text), the corresponding new estimates with the two REG components in columns (4) and (8), as well as in the intermediate columns the estimates obtained when only one of these two components are included in the equation. We find that both the upper and lower estimated impacts of the regulatory burden barriers for the entrepreneurship component are negative and statistically significant as previously, and possibly stronger, while for the state control component they are positive and statistically significant. Although these two components appear negatively correlated, these estimates are not statistically different when one of them is included alone in the equation. These results contrasting sharply with the ones for productivity and ICT capital intensity would be worthwhile investigating in their own sake with more appropriate and richer data. A possible explanation is that firms' incentives to invest in R&D and innovate would be higher because state control of upstream firms would prevent them to appropriate a large part of downstream innovative rents.

Table B5.2: Impact of direct state control on R&D demand

Dependent variable: ICT capital intensity	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
R&D capital costs	-0.628*** [0.128]	-0.547*** [0.126]	-0.618*** [0.125]	-0.511*** [0.129]	-0.619*** [0.135]	-0.547*** [0.133]	-0.627*** [0.132]	-0.512*** [0.135]
Regulatory burden indicator$_{-1}$	-1.395*** [0.385]				-0.868** [0.425]			
Barriers to entrepreneurship		-4.156*** [0.546]	-3.824*** [0.540]			-3.649*** [0.604]	-3.324*** [0.601]	
State control		2.242*** [0.642]		1.389** [0.646]		2.535*** [0.678]		1.946*** [0.681]
Fixed effects:								
Country, industry, year	Y	Y	Y	Y	Y	Y	Y	Y
Country*year	Y	Y	Y	Y	Y	Y	Y	Y
Industry*year	N	N	N	N	Y	Y	Y	Y
Observations	1478	1478	1478	1478	1478	1478	1478	1478
R-squared	0.801	0.808	0.806	0.799	0.810	0.816	0.814	0.810
RMSE	0.6599	0.6475	0.6504	0.6621	0.6776	0.6661	0.6699	0.6764

See footnote to Table 3.