the review of income and wealth

Review of Income and Wealth
Series 63, Supplement 1, February 2017
DOI: 10.1111/roiw.12252

# UPSTREAM PRODUCT MARKET REGULATIONS, ICT, R&D AND PRODUCTIVITY

BY GILBERT CETTE*

*Banque de France and Aix-Marseille School of Economics, CNRS & EHESS*

JIMMY LOPEZ

*Banque de France and Université de Bourgogne (LEDI)*

AND

JACQUES MAIRESSE

*CREST-ENSAE, Maastricht University (UNU-MERIT), Banque de France and NBER*

Our study investigates the importance of two main channels through which upstream anti-competitive sector regulations impact productivity growth: investments in R&D and in ICT, as opposed to alternative channels we cannot explicitly consider for lack of appropriate data such as improvements in skills, management and organization. We specify a three equations model: an extended production function relating total factor productivity to both R&D and ICT capital, and to upstream regulations, and two factor demand functions relating R&D and ICT capital to upstream regulations. We estimate these relations on an unbalanced panel of 15 OECD countries and 13 industries over the period 1987–2007. We find that the total impact of upstream regulations on total factor productivity is sizeable, a large part of which is transmitted through investments in R&D and ICT, mainly the former.

**JEL Codes**: C50, O43, 047

**Keywords**: growth, ICT, productivity, regulations, R&D

## 1. 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; Aghion *et al*., 2004; Haskel *et al*., 2007;), 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; Inklaar *et al*., 2008; Buccirossi *et al*., 2009; Griffith *et al*., 2010). Most of these empirical studies have provided within country-industry evidence of the link between competitive conditions and productivity enhancements. In other words,

*Correspondence to: Gilbert Cette, Banque de France and Aix-Marseille Univ. (Aix-Marseille School of Economics (CNRS & EHESS), Banque de France 46-2400 DEMS 75049 Paris Cedex 01, France (gilbert.cette@banque-france.fr).

these studies investigate the direct influence of competitive conditions in industries on these industries themselves.

In contrast to these studies, our paper focuses on the cross-industry influence of product market anti-competitive regulations in non-manufacturing industries, called "upstream" industries thereafter, on productivity in industries that are using intermediate inputs from these upstream industries, called "downstream" industries.[1] We distinguish six non-manufacturing industries, which are the upstream industries: energy, transport, communication, retail, banking and professional services. Regulations that protect rents in upstream industries can reduce incentives to implement efficiency improvements in downstream industries, since downstream industry firms will have to share the expected rents from such improvements with upstream industries.[2] Indeed, if firms in downstream industries have to negotiate the terms and conditions of their contracts with suppliers, part of the rents expected downstream from adopting best-practice techniques will be grabbed by intermediate input providers. This in turn will reduce incentives to improve efficiency and curb productivity in downstream industries, even if competition may be thriving there. Moreover, lack of competition in upstream industries can also generate barriers to entry that curb competition in downstream industries as well, further reducing pressures to improve efficiency in these industries.[3] From these mechanisms, upstream industry anti-competitive regulations are more harmful for downstream industries when these upstream industries produce a large share of intermediate inputs versus predominantly supply final consumption. Anti-competitive regulations correspond here to restrictions in competition and firms' choices. Corresponding indicators are based on detailed information on laws, rules as well as market and industry settings in two main areas: state control (covering specific information on public ownership and public control of business activities) and barriers to entrepreneurship (covering specific information on legal barriers to entry, market structure and/or industry structure).

The cross-industry influence of product market regulations is a particularly important issue, since—mainly as a result of increasing international competition—downstream manufacturing industries have become more competitive in the last 20 years or so in most OECD countries, while product market regulations in service industries have to a large extent remained significant. For instance, many years of compulsory practice are often required to become a full member of professional services (accounting, legal, engineering and architecture) and then to have the right to provide all the tasks assigned in these professions.[4]

[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 theoretical model of this mechanism is proposed in Bourlès *et al.* (2010, 2013) and in Barone and Cingano (2011).

[3]A formalization of such links between upstream competition and downstream productivity can be found in Bourlès *et al.* (2010) the working paper version of Bourlès *et al.* (2013) and in chapter 2 of Lopez (2011).

[4]For more regulation examples, please see the OECD indicators underlying data (www.oecd.org/economy/reform/indicatorsofproductmarketregulationhomepage.htm).

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 (such as Allegra *et al*., 2004, for Italy, or at the firm level, Forlani, 2010, on France and Arnold *et al*., 2011, on the Czech Republic), and they all use specific indicators of upstream competition, as for example Lerner index or concentration index. Other studies (like Faini *et al*., 2006; Barone and Cingano, 2011, and Bourlès *et al*., 2013) rely on country-industry panel data analyses and on the OECD regulation indicators in upstream industries, as we do in this paper.

The goal of the present investigation is to obtain a clearer understanding of the economic impact by attempting to pinpoint the exact mechanisms through which upstream regulations affect downstream productivity growth. As generally agreed, we consider investments in R&D as being a vital channel of productivity growth and we try to determine its importance as precisely as possible. Likewise, we analyse investments in ICT since these are also deemed to be a key channel for improvements in competitiveness.[5] In order to implement this investigation, as explained in Section 2, 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 a given country-industry multifactor productivity to the corresponding industry multifactor productivity in the U.S.A. (the U.S.A. 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 U.S.A. In parallel we estimate two factor demand relations, for R&D and ICT capital respectively, which both include the upstream regulation burden indicator. To assess the robustness and validity of our results, we consider different econometric specifications of our model.

Our investigation is conducted on a cleaned unbalanced country-industry panel dataset for 15 OECD countries and 13 manufacturing and market service industries over the 21 years from 1987 to 2007. These 13 industries cover a large part of the non-agricultural economy and leave aside only industries that are (almost) not investing in either ICT or R&D. Among these 13 industries we also exclude five of them to estimate the R&D investment demand equation, since they almost do not invest in R&D.

We rely on the same basic upstream regulatory burden indicator as Bourlès *et al*. (2013), computed from OECD indicators of anti-competitive regulations on product markets in the six non-manufacturing industries which are the upstream industries. We explain our data and present a number of descriptive statistics in Section 3 (see more information in the supplementary web appendix, Appendix A).

Section 4 discusses our identification strategy, the estimation method focusing on the long-term estimates of our parameters of interest and their robustness.

[5]Investing in training, in skilled labor, 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 and Franco *et al*., 2013).

In particular we systematically compare the estimation results obtained in two econometric specifications: 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 5, and illustrate them by presenting in Section 6 simulations of what would be the long term multifactor productivity gains if all countries were to adopt the observed best or lightest anti-competitive upstream regulations. These simulations confirm overall the results of previous analysis showing that upstream anti-competitive regulations can slow down multifactor productivity importantly. The total productivity impacts of upstream regulations are the highest for Italy and the Czech Republic, and the lowest for the U.K. and the U.S.A. An important part of this impact on productivity is transmitted through the R&D and ICT channels. The indirect productivity impact for the R&D investment channel is generally higher than the one for ICT investment, but the direct productivity impact is also much higher than both of them, suggesting that the channels through which upstream regulations manifest themselves must be many and pervasive. In Section 7 we conclude. Appendix A gives more details on the data and Appendix B presents five robustness analyses.[6]

## 2. Econometric Model Specification

Anti-competitive regulations in upstream industries can reduce incentives to search for efficiency improvements in downstream industries, as part of the rents expected from such improvements will have to be shared with suppliers of the intermediate inputs that are necessary for downstream production. We test this conjecture via three simple equations: a productivity equation and two similar factor demand equations, respectively for R&D and ICT. Below we explain in some detail our choice of specifications for these equations.

### 2.1. *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*. The introduction of this last variable allows us to assess that part of the upstream regulations impact on value added that is not already taken into account explicitly by the production function (see below), such as investments in training, organization and management.

The productivity 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 $\bar{c}$ is considered as a leading country and the other countries $c$ as follower countries, it is important to realize that such an interpretation can be misleading. The basic hypothesis, which we actually test in Section 4, 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

[6]Appendices A and B are available online at xxxx.

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 U.S.A. as the leading country $\bar{c}$.[7] We can thus write our long-term productivity relation as the following log linear regression equation:

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

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 U.S.A.), 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 $\mu$ 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.[8]

The term $cst$ is the constant term in this equation and the followings and 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 $\theta_c$, $\theta_i$ and $\theta_t$, in addition to an idiosyncratic error term $\varepsilon_{ci,t}$. Here, for reasons of econometric identification which we discuss in Section 4, we privilege two specifications that also include interaction effects: either country*year effects $\theta_{ct}$ or both country*year effects $\theta_{ct}$ and industry*year effects $\theta_{it}$. As we shall explain, we can consider that the first of these specifications provides an upper bound estimate of the direct regulatory impact parameter $\mu$, while the second one provides a lower bound estimate of $\mu$.

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 anti-competitive 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 previously used. We have to take into account explicitly the contribution on value added ($Y$) of ICT capital to

[7]The U.S.A. is in fact leading for 85 percent 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 $\theta_{it}$ in the specifications of our productivity, R&D and ICT investments equations (see below), these effects will proxy for the evolution of productivity, R&D and ICT investments for the country-industry pairs taken as reference as long as the reference country for a given industry does 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.

[8]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 $\theta_{it}$ as in our lower bound specification. We have also considered a variant of equation (1) in which the regulatory burden indicator is included as the difference to its value for the country-industry of 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 $\theta_{it}$, and very close without them.

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.[9] Precisely, using small letters for logarithms (i.e. $x \equiv \; Log\ X$), we have a conventional measures of multifactor productivity *mfp* and the appropriate measure $\widetilde{mfp}$ to be used in the present analysis that both take into account the labor (*L*) contribution, but differ in their capital factors' contributions:

$$mfp = y - \alpha(ct) - \beta l$$

while

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

In order to estimate simultaneously the direct impact of the regulatory burden indicator and the ICT and R&D elasticities, we rewrite regression equation (1) to include explicitly ICT and R&D contributions as regression equation (2):

$$(2) \quad \begin{aligned} mfp_{ci,t} = cst + mfp_{\bar{c}\,i,t} + \gamma[(d_{ci,t} - l_{ci,t}) - (d_{\bar{c}\,i,t} - l_{\bar{c}\,i,t})] + \delta[(k_{ci,t} - l_{ci,t}) - (k_{\bar{c}\,i,t} - l_{\bar{c}\,i,t})] \\ + (\lambda - 1)(l_{ci,t} - l_{\bar{c}\,i,t}) - \mu \; REG_{ci,t-1} \; + u_{ci,t} \end{aligned}$$

With $mfp_{ci,t} = (y_{ci,t} - l_{ci,t}) - \tilde{\alpha}(c_{ci,t} - l_{ci,t})$ a partial multifactor productivity, $\tilde{\alpha}$ the calibration of the non-ICT capital elasticity and $\lambda = \tilde{\alpha} + \beta + \gamma + \delta$ the returns to scale.[10]

As trying to assess returns to scale on aggregate industry data such as ours does not really make sense, we prefer to impose constant returns to scale $\lambda = 1$. In fact, 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 $\lambda$ that negligibly differs from 1 (see supplementary web appendix, Appendix B Table B1 column 2).

Finally, assuming constant returns to scale implies we can express (2) equivalently as relation (3):

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

Where $x\_gap_{ci,t} \; = [(x_{ci,t} - l_{ci,t}) - (x_{\bar{c}\,i,t} - l_{\bar{c}\,i,t})]$ , with $x = \{mfp; d; k\}$

## 2.2. *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 the

[9]As explained in Section 3, 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.

[10]The non-ICT capital elasticity $\bar{\alpha}$ is calculated as the share of the user cost of non-ICT capital over total costs. As shown in Appendix B, our results are robust when this elasticity is estimated simultaneously to the others rather than calibrated.

assumption of firms' inter-temporal maximization of their profit, augmented by the regulatory burden indicator REG.[11]

Assuming the Cobb-Douglas production function underlying our productivity equation we can write simply:

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

where $P_D D/WL$ and $P_K K/WL$ are the user costs shares of ICT and R&D capitals relative to the labor cost share, with $W$ the average labor compensation per person engaged and $P_D$, $P_K$ the user costs of ICT and R&D capital, respectively (see more information in supplementary web appendix, Appendix A). 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 error terms including fixed effects 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:

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

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 $\mu_D$ and $\mu_K$, we actually prefer to consider equations (4) in which they are not *a priori* imposed and can be tested:

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

These equations can be viewed as deriving from a CES (Constant Elasticity of Substitution) production function, and the parameters $\sigma_d$ and $\sigma_k$ 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 pairs of factors: that is here $\sigma_d = \sigma_k$ $(= \sigma_l = \sigma_c)$, which, as we will see, is not far from being the case for our results.

## 3. 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 and provide details on

[11]It is worth noting that the introduction of the regulatory burden indicator is not motivated by the input production marginal cost but by the competition distortion between innovative firms and followers as formalized in Lopez (2011) and Bourlès *et al.* (2013).

the measurement of our multifactor productivity (more information on ICT and R&D capital variables and on our sample in supplementary web appendix, 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 .

### 3.1. *Regulatory Burden Indicator*

Our empirical analysis focuses on the productivity, ICT and R&D impacts of the regulatory burden indicator REG, which is constructed on the basis of 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 to here as *upstream industries*, these 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 segments of OECD countries' economies, whereas 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 of business activities, 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 a minimum value of 0 in the absence of all forms of anti-competitive regulations and a maximum value of 1 in the presence of all of them, and they thus vary on a scale of 0 to 1 across countries and industries. They are 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.[12]

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 such as ours, however, NMR indicators cannot separately be used in practice to assess the upstream regulatory impacts on productivity as well as on ICT and R&D, and must therefore be combined in a meaningful way. We do this, as is customary in this field, 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:

[12]More information on the construction of the NMR indicators is given in supplementary web appendix, 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.

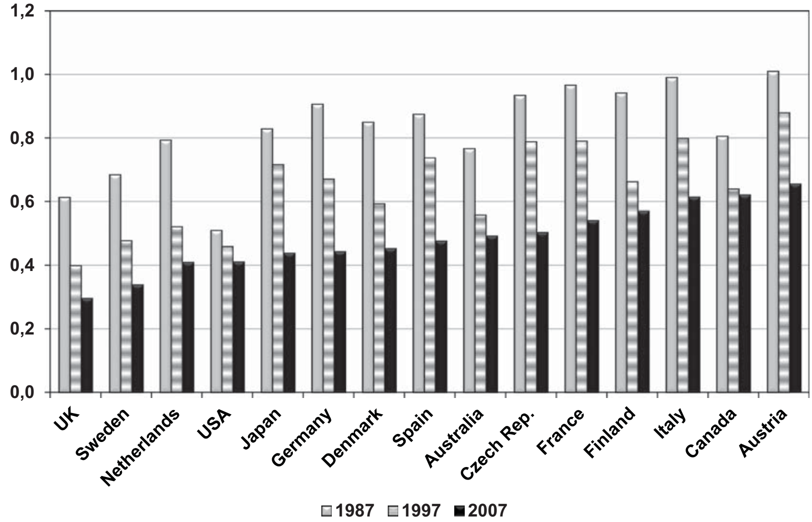


Figure 1. Country averages of REG in 1987, 1997 and 2007

$$REG_{ci,t} = \sum_{j \neq i} NMR^{j}_{c,t}.w^{j}_{i} \;\; with \;\; w^{j}_{i} \equiv \frac{input^{j}_{i,R}}{output_{i,R}}$$

where $NMR^{j}_{c,t}$ is the NMR indicator of the upstream industry $j$ for country $c$ in year $t$, and $w^{j}_{i}$ 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 U.S.A., already taken as a 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 $w^{j}_{j}=0$).

Figure 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. In European Union countries, this decrease of restrictive regulations is partly linked to deregulation successive decisions at the Union level, during the single market process. The cross-country variability of REG appears quite important in all three years, with the U.S.A., U.K. 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.

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 |

*Note*: 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.

### 3.2. *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. 2,612 observations for levels and 2,430 for growth rates), except for the R&D variables computed for the subsample without industries with low R&D intensity (i.e. 1,478 observations for levels and 1,366 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 percent per year while the MFP gap with the U.S.A. has been slowly decreasing by 0.2 percent per year. In parallel, ICT capital intensity has been very rapidly increasing at a rate of 11.3 percent per year, while its gap with the U.S.A. has been slowly augmenting by 0.3 percent per year. R&D capital intensity has also been increasing at a rapid rate of 5.8 percent per year, while its gap with the U.S.A. has been widening very significantly by 1.5 percent 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 percent and 5.8 percent 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.

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 $\theta_c$, $\theta_i$ and $\theta_t$, as well as a sequence of two ways interacted effects $\theta_{ct}$, ($\theta_{ct}$ and $\theta_{it}$ ) and ($\theta_{ct}$, $\theta_{it}$ and $\theta_{ci}$). The first column documents the R-squares of the regressions of our model variables on 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. Thus, this column indicates the variability taken into account by the one-way fixed effects. The three following columns document what is the additional variability lost 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

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 |
| MFP gap | 0.471 | 0.083 | 0.235 | 0.840 |
| ICT capital intensity gap | 0.458 | 0.093 | 0.209 | 0.915 |
| R&D capital intensity gap | 0.606 | 0.017 | 0.112 | 0.937 |
| ICT capital intensity | 0.824 | 0.095 | 0.162 | 0.912 |
| ICT—labor cost ratio | 0.837 | 0.447 | 0.507 | 0.801 |
| R&D capital intensity | 0.790 | 0.018 | 0.070 | 0.936 |
| R&D—labor cost ratio | 0.758 | 0.217 | 0.265 | 0.690 |

*Note*: See footnote to Table 1.

($2^{nd}$ column), to the next most plausible source ($3^{rd}$ column) and to a third one ($4^{th}$ 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 range from 45–60 percent for the MFP, ICT and R&D gap variables of the productivity regression, to 75–85 percent for the ICT and R&D capital intensity and labor cost ratio variables, and to nearly 95 percent for our central explanatory variable REG. We see that the share of residual variability accounted for by interacting country and year effects alone is, at most, 45 percent (for the ICT-labor cost ratio, but much less for the other variables), and by interacting also industry and year effects, at most 50 percent (for REG and the ICT-labor cost ratio but much less for the other variables). Interacting in addition the country and industry effects accounts, in total, for up to a minimum share of 70 percent for all eight variables, and of 90–95 percent for five of them.

Focusing on REG, the share of its variability in total variability decreases from 7.2 percent with separate country, industry and year effects, to 5.0 percent adding country-year effects, and to 3 percent adding also industry-year effects, and to 0.3 percent adding finally country-industry effects. In effect the absolute total variability of REG is large enough so that even a share of a few percent is sufficient to obtain estimates that are statistically significant, as we shall see in Section 5. It is also fortunate that there are 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.

## 4. IDENTIFICATION AND ESTIMATION

In order to consistently estimate 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, which are 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, insofar 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 subsection how we can account for 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 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 also have to corroborate that our regressions are cointegrated. We also have 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 and Watson (1993). In a second sub-section we will thus briefly report on the cointegration tests we 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 latter are indeed to be preferred.

### 4.1. *Specification Errors and Country, Industry and Year Interaction Effects*

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 keeping anti-competitive regulations against the general decrease observed everywhere, thereby protecting their rents, inverse causality could entail negative correlations between productivity and product market regulation indicators, possibly leading to an overestimation of the negative impacts of anti-competitive regulations on productivity. Obviously, such biases could also arise and eventually be greater when estimating the regulatory impacts on 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 government responses to the aggregate economic situation. Including country*year interacted effects in our regressions will offset 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 concern particularly upstream industries such as energy, transport, communications and banking, in which international agreements and regulations are widespread. Likewise, including industry*year effects in our model will offset 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 trying to assess the impacts of existing regulations in industries on the productivity and ICT and R&D of these industries themselves. However, this analysis only focuses on estimating the impacts of regulations in upstream industries on other downstream industries. In fact, 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 intermediate consumption ($w_j^j=0$) when measuring REG in these industries.[13]

In addition to their use in correcting for, or at least mitigating, 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 labor force education and skills, in the evolution of own-industry regulatory environments, and in changes in international trade conditions, etc.

Despite these efforts, there is another source of endogeneity that our fixed effects are not able to prevent: downstream industries that use regulated (upstream) intermediate inputs could lobby for and obtain upstream deregulation. In this case one would expect that firms in downstream industries that use most intensively the regulated upstream inputs would lobby more strongly and obtain deeper upstream deregulation. However, this would play against the conjecture that we test in this paper. Therefore, at worst the empirical results presented in this paper underestimate the negative effects of upstream regulation on downstream productivity and ICT and R&D demands.

In view of the inherent difficulties and uncertainties of our study, rather than choose one preferred econometric model specification, we considered it appropriate to keep two that provide a range of plausible consistent estimates. The first one, with only interacted country*year effects mitigates 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 more fully eliminates such specification errors and give estimates that can be deemed as "lower bound" estimates.[14] In the next two sections we will center the discussion of our estimation results and simulations on these two types of estimates.

### 4.2. *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.

[13]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.

[14]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 eliminate a variety of potential specification errors.

More precisely, we have to test that: (i) MFP, R&D and ICT capital intensity and relative user cost are integrated of order 1 (I(1)); and (ii) that MFP is cointegrated with the leading country. We have performed Levin *et al*. (2002) and Im *et al*. (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 cost 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 on average about half that, as 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 the relative user costs ($\gamma$ and $\delta$) and ($\sigma_d$ and $\sigma_k$) in the productivity and the demand regressions may be biased, because of short-term correlations between these variables and regression idiosyncratic errors. The DOLS estimators eliminate 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.[15] The Hausman tests implemented on the three regressions show that the OLS and DOLS estimates differ quite significantly, clearly confirming our preference for the latter.

## 5. 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 a similar format in Tables 3, 4 and 5. In addition to these estimates obtained, as explained above, 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 such as ours.

We also provide for comparison in Table 3 the estimates of the 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 trying to assess the relative importance of the ICT and R&D channels in the overall impact of these regulations on 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.

[15]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.

TABLE 3
Multifactor Productivity Regression

| Dependent variable: MFP gap | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| ICT capital intensity gap | 0.047*** | | 0.052*** | | 0.073*** | |
| | [0.008] | | [0.009] | | [0.009] | |
| R&D capital intensity gap | 0.081*** | | 0.076*** | | 0.067*** | |
| | [0.007] | | [0.007] | | [0.007] | |
| Regulatory burden | −0.216*** | −0.209*** | −0.226*** | −0.248*** | −0.075 | −0.161** |
| indicator REG | [0.050] | [0.051] | [0.055] | [0.057] | [0.067] | [0.071] |
| 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 | 2633 | 2633 | 2633 | 2633 | 2633 | 2633 |
| R-squared | 0.532 | 0.485 | 0.57 | 0.526 | 0.648 | 0.602 |
| RMSE | 0.1824 | 0.1909 | 0.1830 | 0.1915 | 0.1731 | 0.1838 |

*Note*: *** significant at 1%; ** significant at 5%; *significant at 10% - Newey-West 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.

### 5.1. *Multifactor Productivity Regression*

Looking first at the direct upstream regulatory impact parameter $\mu$ 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 percent of multifactor productivity MFP, that is about as much as 0.2 percent 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, with a magnitude implying that a 0.10 decrease in REG would contribute to a long-term average increase in MFP of 0.6 percent (0.05 percent per year).

TABLE 4
ICT Capital Demand Regression

| Dependent variable: ICT capital intensity | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| ICT capital user cost | −0.870*** | −1 | −0.840*** | −1 | −0.811*** | −1 |
| | [0.037] | [0.000] | [0.041] | [0.000] | [0.045] | [0.000] |
| Regulatory burden | −0.112 | −0.099 | −0.397*** | −0.362*** | −0.656*** | −0.665*** |
| indicator REG | [0.108] | [0.109] | [0.122] | [0.122] | [0.161] | [0.161] |
| 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 | 2633 | 2633 | 2633 | 2633 | 2633 | 2633 |
| R-squared | 0.857 | 0.845 | 0.868 | 0.837 | 0.874 | 0.824 |
| RMSE | 0.4055 | 0.4064 | 0.4066 | 0.4078 | 0.4174 | 0.4190 |

*Note*: 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 | −0.614*** | −1 | −0.630*** | −1 | −0.625*** | −1 |
| | [0.109] | [0.000] | [0.129] | [0.000] | [0.136] | [0.000] |
| Regulatory burden indicator REG | −0.675** | −0.788*** | −1.367*** | −1.535*** | −0.859** | −1.041** |
| | [0.283] | [0.283] | [0.385] | [0.382] | [0.426] | [0.422] |
| 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 | 1491 | 1491 | 1491 | 1491 | 1491 | 1491 |
| R-squared | 0.795 | 0.763 | 0.800 | 0.746 | 0.808 | 0.787 |
| RMSE | 0.6316 | 0.6341 | 0.6679 | 0.6698 | 0.6866 | 0.6886 |

*Note*: See footnote to Table 3.

Finally, it must kept in mind that we can only estimate average parameters on our country-industry panel 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 five 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 supplementary web appendix, Appendix B on the Robustness analyses). Interestingly, we find that the lower bound estimated $\mu$ is statistically significant and high in the non-R&D industries and not in the R&D industries (respectively equal to -0.21 and -0.05). Together with the corresponding estimates for $\mu_D$ and $\mu_K$, this is plausible evidence that in R&D industries, the R&D and ICT channels basically account for the overall upstream regulatory impact, while in the non-R&D 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 0.07 for ICT and 0.08 and 0.07 for R&D.

### 5.2. *ICT and R&D Capital Demand Regressions*

The upper and lower bound estimates of the two upstream regulatory impact parameter $\mu_D$ and $\mu_K$ (columns 1 and 3) in Tables 4 and 5 are statistically significant and of a high order of magnitude, particularly for R&D. It should 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 percent to 3.4 percent for ICT capital intensity and in a range of 8.7 percent to 14.0 percent for R&D capital intensity.

The upper bound and lower estimates of the elasticities of ICT and R&D relative user costs of capital $\sigma_d$ and $\sigma_k$ are practically equal and quite significantly smaller than 1 in absolute value, at 0.8 for ICT and 0.6 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.

## 6. Simulations

To illustrate the implications of our results more fully and to put them in perspective, we propose a simple and tentative simulation. This simulation 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 anti-competitive regulatory practices.

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 so 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 percent of country GDP on average.

In these computations, we think it 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. 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 percent to 45 percent and of 30 percent on average (see supplementary web appendix for more information, Appendix B Table B3).

Figures 2 and 3 show the prospective evaluations of the upper and lower bound long term regulatory impacts on the growth of ICT and R&D capital intensities for the 15 countries of our sample as if they were implementing the

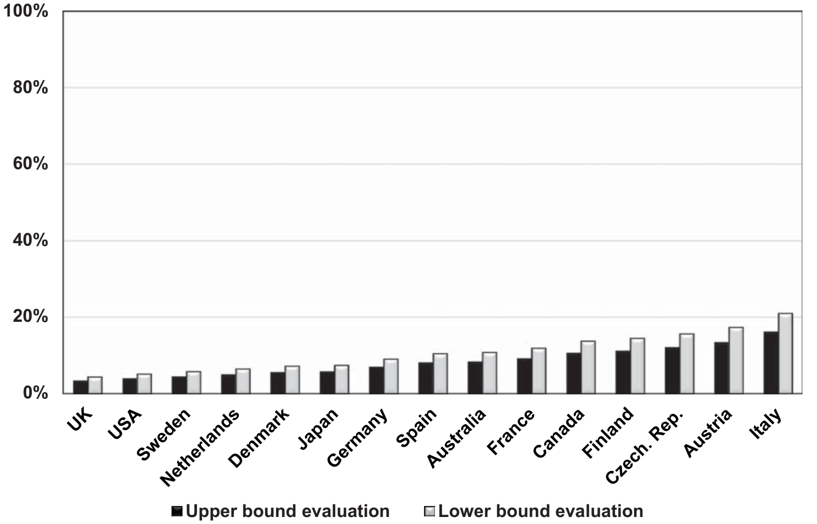


Figure 2. Simulated long-term regulatory impacts on ICT capital

lightest upstream anti-competitive regulatory practices. These impacts are much larger for R&D than for ICT: on 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 percent to 90 percent and from about 50 percent to 80 percent, and lowest for the U.K. and the U.S.A., ranging from about 15 percent to 20 percent in both countries. In the case of ICT, the upper and lower bound estimates are close, highest for Italy and

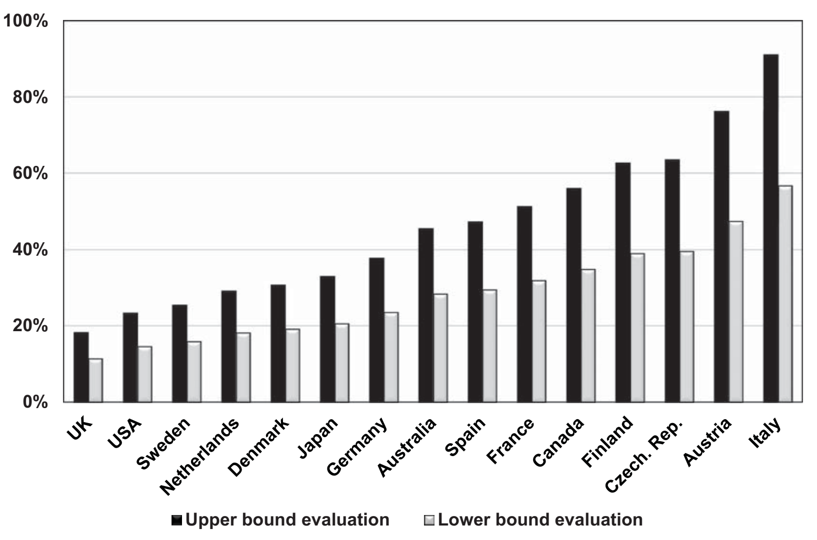


Figure 3. Simulated long-term regulatory impacts on R&D capital

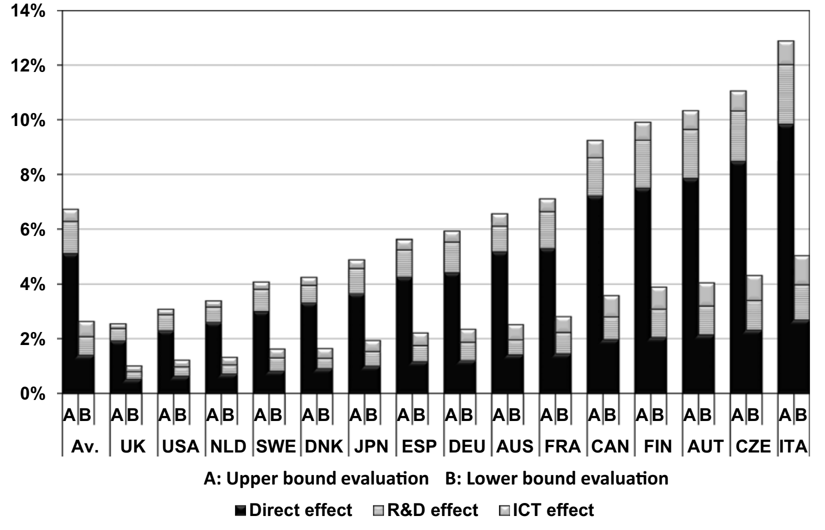


Figure 4. Simulated long-term regulatory impacts on multifactor productivity

Austria and lowest for the U.K. and the U.S.A., respectively around 15–20 percent and 2–5 percent. 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).

In the same format as the two preceding figures, Figure 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 anti-competitive 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.

We can see that upper bound evaluations of the total productivity impact are much higher than the lower bound evaluations: on average by about 6.5 percent as against 2.5 percent, that is about 0.5 percent as against 0.2 percent per year if we assume a long term horizon of some 12 years. They are highest for Italy and the Czech Republic of about 11–13 percent versus 4–5 percent (roughly 1 percent and 0.4 percent per year), and they are lowest for the U.K. and the U.S.A. with about 2–3 percent versus 1 percent (roughly 0.5 percent and 0.1 percent per year). We also observe that the upper bound evaluations of the direct impacts are much higher, by a factor of about 2.5 on 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 percent on 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 make a last observation that the indirect productivity impacts for R&D are greater than for ICT.

## 7. Conclusions

In this paper we have investigated empirically through which channels and mechanisms upstream industry anti-competitive regulations impact productivity. To our knowledge, this is the first attempt to address this important and challenging question. Using a country-industry unbalanced panel dataset that is as comprehensive as we could reasonably construct it, and relying mainly on an upstream regulatory burden indicator built from the OECD Non-Manufacturing Regulations (NMR) indicators, we have assessed the actual importance of the two main channels usually contemplated in the literature through which upstream sector anti-competitive regulations may impact productivity growth by acting as a disincentive for business investments in R&D and in ICT.

As usual there are limitations to our study and its findings and many directions in which it could be extended and improved for a better understanding of the relations between product market regulations and productivity and for specific policy implications. In particular it will be worthwhile, if more comprehensive and detailed data would permit, to assess the productivity impacts of upstream regulation on different channels beyond the ICT and R&D channels that we have assessed here, focusing on different industries and different types of product market regulation (beyond the two limited attempts presented in supplementary web appendix, Appendix B). Another dimension that is important to take into account is labor market regulations. Several studies (see among others Aghion *et al.*, 2009) have shown that labor 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 labor market regulations.

We are nevertheless convinced 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. Clearly, in order to go much beyond this type of macro-economic research, one would need to perform micro-econometric analyses of firm data for different countries and industries.

## References

Aghion, P., R. Blundell, R. Griffith, P. Howitt, and S. Prantl, "Entry and Productivity Growth: Evidence from Microlevel Panel Data," *Journal of the European Economic Association*, 2, 265–76, 2004.

Aghion, P., R. Blundell, R. Griffith, P. Howitt, and S. Prantl, N. Bloom, R. Blundell, R. Griffith, and P. Howitt, "Competition and Innovation: An Inverted U Relationship," *Quarterly Journal of Economics*, 120, 701–28, 2005.

Aghion, P., R. Blundell, R. Griffith, P. Howitt, and S. Prantl, and P. Howitt, "Joseph Schumpeter Lecture: Appropriate Policy Growth: A Unifying Framework," *Journal of the European Economic Association*, 4, 269–314, 2006.

Aghion, P., R. Blundell, R. Griffith, P. Howitt, and S. Prantl, Ph. Askenazy, G. Cette, N. Dromel, and R. Bourlès, "Education, market rigidities and growth," *Economics Letters*, 102, 62–5, 2009.

Aghion, P., R. Blundell, R. Griffith, P. Howitt, and S. Prantl, P. Howitt, and S. Prantl, "Patent Rights, Product Market Reforms, and Innovation," NBER Working Papers 18854, 2013.

Allegra, E., M. Forni, M. Grillo, and L. Magnani, "Antitrust Policy and National Growth: Some Evidence from Italy," *Giornale degli Economisti e Annali di Economia*, 63, 69–86, 2004.

Arnold, J., B. Javorcik, and A. Mattoo, "Does Services Liberalization Benefit Manufacturing Firms?," *Journal of International Economics*, 85, 136–46, 2011.

Barone, G. and F. Cingano, "Service Regulation and Growth: Evidence from OECD Countries," *The Economic Journal*, 121, 931–57, 2011.

Blundell, R., R. Griffith, and J. Van Reenen, "Market Share, Market Value and Innovation in a Panel of British Manufacturing Firms," *Review of Economic Studies*, 66, 529–54, 1999.

Boone, J., "Competition," CentER Discussion Paper 2000–104, Tilburg: Macroeconomics, 2000.

Bourlès, R., G. Cette, J. Lopez, J. Mairesse, and G. Nicoletti, "Do Product Market Regulations in Upstream sectors Curb Productivity Growth? Panel Data Evidence for OECD Countries," NBER Working Papers 16520, 2010.

Bourlès, R., G. Cette, J. Lopez, J. Mairesse, and G. Nicoletti, G. Cette, J. Lopez, J. Mairesse, and G. Nicoletti, "Do Product Market Regulations in Upstream sectors Curb Productivity Growth? Panel Data Evidence for OECD Countries," *Review of Economics and Statistics*, 95, 1750–68, 2013.

Buccirossi, P., L. Ciari, T. Duso, G. Spagnolo, and Ch. Vitale, "Competition Policy and Productivity Growth: An Empirical Assessment," CEPR Discussion Papers 7470, 2009.

Conway, P., D. de Rosa, G. Nicoletti, and F. Steiner, "Product Market Regulation and Productivity Convergence," *OECD Economic Studies*, 43, 39–76, 2006.

Conway, P., D. de Rosa, G. Nicoletti, and F. Steiner, and G. Nicoletti, "Product Market Regulation and Productivity Convergence: OECD Evidence and Implications for Canada," *International Productivity Monitor*, 15, 3–24, 2007.

De Serres, A., S. Kobayakawa, T. Slok, and L. Vartia, "Regulation of Financial Systems and Economic Growth in OECD Countries: An Empirical Analysis," *OECD Economic Studies*, 43, 77–113, 2006.

Engle, R. and C. W. J. Granger, "Co-integration and Error Correction: Representation, Estimation, and Testing," *Econometrica*, 55, 251–76, 1987.

Faini, R., J. Haskel, G. Barba Navaretti, C. Scarpa, and Ch. Wey, "Contrasting Europe's Decline: Do Product Market Reforms Help?," in T. Boeri, M. Castanheira, R. Faini, and V. Galasso (eds), *Structural Reforms Without Prejudices*, 15–126, Oxford University Press, Oxford, 2006.

Forlani, E., "Competition in the Service Sector and the Performances of Manufacturing Firms: Does Liberalization Matter?," CESifo Working Paper series 2942, 2010.

Franco, Ch., F. Pieri, and F. Venturini, "Product Market Regulation and Innovation Efficiciency," Universidad de Valencia, *Department of Applied Economics II Working Papers* 1313, 2013.

Geroski, P., "What do we know about entry?," *International Journal of Industrial Organization*, 13, 421–40, 1995a.

———, *Market Structure, Corporate Performance and Innovative Activity*, Oxford University Press, Oxford, 1995b.

Griffith, R., St. Redding, and H. Simpson, "Productivity Convergence and Foreign Ownership at the Establishment level," CEPR Discussion Paper 3765, 2002.

Griffith, R., St. Redding, and H. Simpson, R. Harrison, "The Link Between Product Market Reform and Macro-Economic Performance," European Commission Economic Papers No. 209, 2004.

Griffith, R., St. Redding, and H. Simpson, R. Harrison, and H. Simpson, "Product Market Reform and Innovation in the EU," *The Scandinavian Journal of Economics*, 112, 389–415, 2010.

Haskel, J., S. Pereira, and M. Slaughter, "Does Inward Foreign Direct Investment Boost the Productivity of Domestic Firms?," *Review of Economics and Statistics*, 89, 482–96, 2007.

Im, K. S., M. H. Pesaran, and Y. Shin, "Testing for Unit Roots in Heterogeneous Panels," *Journal of Econometrics*, 115, 53–74, 2003.

Inklaar, R., M. Timmer, and B. van Ark, "Market Services Productivity across Europe and the U.S.," *Economic Policy*, 23, 139–94, 2008.

Levin, A., Ch.-F. Lin, and J. Chu, "Unit Root Tests in Panel Data: Asymptotic and Finite-Sample Properties," *Journal of Econometrics*, 108, 1–24, 2002.

Nickell, St., "Competition and Corporate Performance," *Journal of Political Economy*, 104, 724–46, 1996.

Nickell, St., D. Nicolitsas, and N. Dryden, "What Makes Firms Perform Well?," *European Economic Review*, 41, 783–96, 1997.

Nicoletti, G. and St. Scarpetta, "Regulation, Productivity and Growth," *Economic Policy*, 36, 11–72, 2003.

Pedroni, P., "Critical Values for Cointegration Tests in Heterogeneous Panels with Multiple Regressors," *Oxford Bulletin of Economics and Statistics*, 61, 653–70, 1999.

———, "Panel Cointegration: Asymptotic and Finite Sample Properties of Pooled Time Series Tests with an Application to the PPP Hypothesis," *Econometric Theory*, 20, 597–625, 2004.

Stock, J. and M. Watson, "A Simple Estimator of Cointegrating Vectors in Higher Order Integrated Systems," *Econometrica*, 61, 783–820, 1993.

## Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's website:

**Chart A1:** Aggregation of the Detailed Information on Regulations
**Chart A2:** R&D and ICT capital intensity Ratios Relative to the USA (=100%) Country Average 2001–2005
**Chart A3:** MFP Ratio Relative to the USA (=100%), Country Average 2001–2005
**Table A1:** Construction of the 'Legal Barriers to Entry' Sub-level Regulation Indicator for Professional Services
**Table A2:** Sample Composition Per Industry and ICT and R&D Investment to Value Added Ratios, Industry Averages Over the 2001–2005 Period
**Table B1:** Robustness to Production Function Constant Returns to Scale Assumption and Non-ICT Capital Elasticity Calibration
**Table B2.1:** Robustness of the Multifactor Productivity Equation Estimates with Respect to Catch-up Hypothesis
**Table B2.2:** Robustness of the ICT and R&D Demand Equation Estimates with Respect to Catch-up Hypothesis
**Table B3:** Simulated Long Term MFP Gains from Reforms, Depending on I-O Tables
**Table B4.1:** Differences in Upstream Regulation Impacts on Multifactor Productivity Between R&D and Non-R&D Investing Industries
**Table B4.2:** Differences in Upstream Regulation Impacts on ICT Capital Intensity Between R&D and Non-R&D Investing Industries
**Table B5.1:** Tests of Equality of the Coefficients of the Regulatory Burden Components for State Control and Barriers to Entrepreneurship
**Table B5.2:** Impact of Direct State Control on R&D Demand