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ABSTRACT/RÉSUME

How do Taxes affect Investment and Productivity? - An Industry-Level Analysis of OECD Countries

This paper analyses how different tax policies can affect investment and productivity. To address this question the paper uses industry-level data from a set of OECD countries and examines whether different industries are affected differently by taxation. Investment is shown to respond negatively to an increase in the corporate tax rate and a decrease in capital depreciation allowances through changes in the user cost of capital. The analysis of potential links between taxes and productivity test the hypothesis that taxes affect productivity through different channels and that due to some salient industry characteristics some industries are inherently more affected than others by certain taxes. The paper finds evidence that corporate and top personal income taxes have a negative effect on productivity. In contrast, tax incentives for research and development (R&D) are found to have a positive effect on productivity. These effects are stronger in those industries that are inherently more profitable, have more entrepreneurial activity and are more R&D intensive, respectively.

JEL Classification: E22; H30; H24; H25; C23.

Key Words : investment; total factor productivity; user cost of capital; corporate and personal income taxation.

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L'effet des politiques de taxation sur les investissements and la productivité dans les pays de l'OCDE : une analyse sectorielle

Cette étude vise à étudier l'effet des politiques de taxation sur les investissements et la productivité des entreprises. Nous utilisons des données sectorielles pour un ensemble de pays de l'OCDE et analysons dans quelle mesure l'impact de la taxation diffère selon les secteurs. Selon nos résultats, une hausse de l'impôt sur les sociétés ou une baisse des provisions pour amortissement du capital provenant de variations du coût d'usage du capital induisent une baisse de l'investissement des entreprises. Nous analysons les mécanismes de l'impact de la taxation des entreprises sur leur productivité et nous testons si certains secteurs y sont plus sensibles que d'autres. Selon nos estimations, l'impôt sur les sociétés, mais aussi les dernières tranches de l'impôt sur le revenu, ont un impact négatif sur la productivité. En revanche, les avantages fiscaux visant à promouvoir la recherche et développement semblent avoir un effet bénéfique sur la productivité. Ces effets sont plus forts dans les secteurs plus rentables, dans les secteurs caractérisés par un niveau plus élevé d'activité entrepreneuriale, et dans les secteurs caractérisés par un niveau plus élevé de recherche et développement.

Classification JEL : E22; H30; H24; H25; C23.
Mots clés : Investissement ; productivité globale des facteurs ; impôt sur le revenu ; impôt sur les sociétés ; coût d'usage du capital

TABLE OF CONTENTS

HOW DO TAXES AFFECT INVESTMENT AND PRODUCTIVITY? - AN INDUSTRY-LEVEL ANALYSIS OF OECD COUNTRIES

by Laura Vartia[1]

Introduction

1. Taxes can have an effect on countries' material living standards by affecting the determinants of GDP per capita – labour, capital and productivity. For instance, by distorting factor prices and returns to market activities, they can alter households' labour supply decisions and incentives to enrol in higher education, as well as firms' incentives to invest and to hire employees, and thus, lead to an inefficient allocation of factor inputs and lower productivity.

2. This paper focuses on two important engines of GDP growth, namely investment and productivity. The purpose is to provide new information on how different tax policies can affect these determinants which is essential for assessing the effectiveness of these policies. To address this question the paper takes a semi-disaggregate approach by using industry-level data and analyses how investment and productivity in different industries are affected by taxation. The advantage of this more disaggregate analysis is that it provides information on how taxes can affect the behaviour of firms operating in different industries. Thus, it can also shed some light on whether tax effects are similar for different industries. If there are differences in the effect of taxes across industries then the relevant tax policy considerations may differ accordingly.

3. The empirical approach to model investment patterns in this paper relies on the investment theory in which taxes affect the cost and return to investment. In particular, the analysis is based on the user cost theory which states that taxation affects investment by increasing the user cost of capital. The novelty of this approach is that it considers a new industry-specific tax adjusted user cost measure constructed for the purpose of this paper. Moreover, most studies in this field of research focus only on few countries at the time, whereas this paper considers a larger set of countries facilitating the interpretation and generalisation of the results.

4. The analysis of the potential links between productivity and taxes is based on the idea that taxes affect productivity through different channels and that due to some salient industry characteristics some industries are inherently more affected than others by certain taxes. More specifically, this paper highlights three specific channels through which taxation affect productivity, namely distortions in factor prices and factor allocation, entrepreneurship and research and development (R&D) activity. While there are several studies analysing the effects of taxes on these channels, there exists little research on these tax effects directly on productivity. The novel approach of this paper is to test whether taxes and tax incentives affect

1 . This work has benefitted greatly from important contributions from Jens Arnold, Bert Brys, Christopher Heady, Åsa Johansson, Stefano Scarpetta and Cyrille Schwellnus. The author would like to thank Julien Dupont, Jørgen Elmeskov, Giuseppe Nicoletti, Jeffery Owens, Jean-Luc Schneider, and Paul Schreyer for their valuable comments, Ana Cebreiro-Gomez for helpful inputs as well as Irene Sinha for excellent editorial support. The views expressed in this paper are those of the author and do not necessarily reflect those of the OECD or its member countries. The author correspondence is laura.vartia@oecd.org.

productivity in different industries due to differences in factor allocation, entrepreneurship and private R&D spending.

5. The paper is organised as follows. The first part of the paper focuses on the links between taxes and investment. It briefly reviews theoretical and empirical literature discussing differences in the studies in this field. This is followed by the description of the empirical methodology and the data used in the analysis. Finally, the main results are presented with several robustness checks. The second part analyses the linkages between taxes and productivity by examining the specific channels through which taxes may affect productivity. A brief review of recent research on how taxes can affect productivity is first provided after which the empirical approach and data are described. The final section of this part discusses the main findings and presents a sensitivity analysis.

Main findings

Investment

6. The findings of this paper suggest that taxes have an adverse effect on industry-level investment. In particular, corporate taxes reduce investment by increasing the user cost of capital. The long-run user cost elasticity of investment-to-capital ratio is estimated to vary between -0.35 and -1.0 depending on the empirical specification. This is in line with recent empirical studies (*e.g.* Hassett and Hubbard, 2002).

Productivity

7. The paper finds new evidence that both personal and corporate income taxes have a negative effect on productivity. The results seem to support the hypothesis that there are different channels through which these taxes can affect productivity, measured by total factor productivity (TFP). These results can be summarised as follows:

- The evidence shows that corporate income taxes reduce TFP and that this effect is more pronounced in industries that are characterised by high corporate profitability as these taxes are levied on corporate profits.
- High top marginal personal income tax rates are found to impede long-run productivity working through the channel of entrepreneurial activity and this effect is estimated to be stronger the higher the entrepreneurial activity is in an industry.
- R&D tax incentives are found to enhance long-run productivity through the channel of R&D intensity, but the effect is modest, although it is stronger in R&D intensive industries.
- The results also support the assumption that social security contributions have a negative influence on TFP and that this effect is more pronounced in industries that are characterised by high labour intensity.

Taxes and investment in fixed capital

Theoretical background

8. A vast number of empirical and theoretical studies have looked at the determinants of fixed business investment. Accelerator models are one of the early theories in this field. They emphasise the role of demand conditions as the main determinant of investment. The simple version of this theory suggests that the change in the capital stock is equal to a fraction of the change in output. These models heavily rely

on the empirical observation that investment is highly correlated with changes in output and despite their simplicity they are amongst the most successful empirical models of investment.

9. Many of the more recent investment models are based on the neoclassical theory where a representative firm maximises its present value, *i.e.* the discounted value of its expected profits. The two most commonly used theoretical investment models following this neoclassical tradition are the theory of the user cost of capital and the Q-theory. The basic reasoning behind the former theory, introduced by Jorgenson (1963) and Hall and Jorgenson (1967), is that a firm weighs the costs and benefits of investment and invests when the benefits exceed the costs. Thus, if capital inputs can be adjusted freely, the marginal product of capital equals the user cost for a price-taking firm. The Q-theory suggests that the firm will invest if the market value of an additional unit of capital (the shadow value) exceeds the cost of purchasing it, taking into account that there are costs associated with the adjustment of capital to its desired level. Thus, the firm's marginal investment decision is determined by the ratio of the market value to the purchase (replacement) cost of capital, called the marginal q.[2] Under certain assumptions, this ratio can be shown to equal the ratio of the total value of the firm to the replacement value of its total capital stock, the so-called average q which can be measured using stock market information on the value of the firm (Hayashi, 1982).[3] Both the user cost and the Q-theory can be adjusted for taxes. These tax-adjusted theories suggest that increases in corporate taxes (capital depreciation allowances) will reduce (increase) investment and the capital stock.

10. Until recently, the standard approach of the neoclassical models was to isolate firms' "real" decisions from financial concerns. This approach was based on the so-called Modigliani-Miller theorem which states that in the absence of taxes firms' financial structure and policy are irrelevant for their investment decisions (Modigliani and Miller, 1958). The necessary assumption underlining this theorem is the existence of perfect capital markets. Under the assumption of imperfect capital markets with adverse selection and moral hazard, using external funds to finance investment projects becomes relatively more expensive than financing them with internal funds (see Hubbard, 1998, for an extensive review). Several studies have tested this assumption and found that proxies for internal funds, such as cash flow, have explanatory power after controlling for the average q, user cost or accelerator variables. The interpretation is that firms with low internal funds or net worth are financially constrained and cannot carry out all profitable investment projects. In the presence of taxes there may, thus, be an additional effect on firms' investment decisions beyond the user cost and average q as taxes affect the after-tax earnings from existing projects and hence the internal funds available to finance future investment. Furthermore, tax policies may have an effect on the financial structure of firms by affecting the choice between debt and equity financing.[4]

Theory of user cost versus Q-theory – pros and cons

11. The advantage of the Q-theory is that it takes into account the observation that adjustment in the capital stock is costly and takes time, whereas the user cost theory often assumes that adjustment is costless and takes place immediately.[5] On the other hand, the user cost theory has the advantage that it can, in

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2. This emphasises the fact that the firm's investment decision depends on the value of a marginal unit of capital. The marginal q is likely to be unobservable due to the difficulty to measure the value of a marginal unit of capital.

3. The average q is also called Tobin's q, named after James Tobin who was among the first economists to formally suggest using stock market information to measure the average q (Tobin, 1969).

4. This was also noted by Modigliani and Miller in several follow-up papers of the original paper.

5. The Q-theory is based on a dynamic formulation of the firm's value maximisation problem including an additional term in the profit function capturing adjustment costs.

principle, be measured for all types of firms, while the Q-theory can only be used in empirical applications with data on firms that are quoted in the stock market. Therefore, studies based on this theory cannot assess the determinants of investment decisions in unlisted firms. Moreover, it is difficult to compute a representative and meaningful measure of the average *q* at the industry level. Due to these drawbacks, the empirical approach chosen in this paper relies on the user cost theory. However, the empirical investment model is extended to capture the potential persistence in investment and the adjustment process.

Overview of the empirical research on investment and the user cost of capital

12. The pioneering work by Hall and Jorgenson (1967) concluded that developments in the user cost of capital could explain aggregate investment relatively well. However, this finding was later criticised (*e.g.* Chirinko and Eisner, 1983). It was argued that the user cost specification by Hall and Jorgenson (1967) was capturing accelerator effects since in their original specification this variable enters the investment equation as the ratio of output to user cost. When the contribution of the user cost to explaining investment was isolated from that of output, it was found that its effect was negligible.

13. In their survey, Hassett and Hubbard (2002) conclude that the early studies based on aggregate-level analysis were unable to distinguish the effects of the various determinants of investment because aggregate variables, such as investment and tax policy, tend to move together over business cycle. For example, Cummins *et al.* (1994) report that policymakers introduce investment tax credits when investment is perceived to be low and remove them when investment is perceived to be high. In contrast, at a disaggregated level, tax policies affect individual firms differently as the composition of the stock of capital varies across firms. Thus, tax policies are likely to be exogenous to firms' investment decisions at this level of analysis. An additional advantage of disaggregated analysis is that the problem of measurement errors in independent variables may be addressed using panel estimation techniques and disaggregated data as suggested by Griliches and Hausman (1986).

14. Indeed, the failure of aggregate time-series studies to provide evidence on the impact of taxes on firms' investment decisions led to a new wave of empirical literature, which tried to take advantage of the cross-sectional variation of more disaggregated data rather than the time-series variation of aggregated data. Chirinko *et al.* (1999) modify the user cost formula à la Jorgenson and Hall and construct an asset- and industry-specific measure of the user cost of capital.[6] Cummins *et al.* (1994 and 1995) provide another extension to the original formula of the user cost by expressing it at the firm level.[7] Furthermore, they take a new methodological approach and use major tax reforms as natural experiments to identify the effect of the tax-adjusted user cost on investment.[8] Caballero *et al.* (1995) exploit the cross-sectional variation in plant level data and report estimates of elasticity of investment to the user cost ranging from -0.01 to -2.0 across different industries, with the average being about -1.0. Summarising recent research, Hassett and Hubbard (2002) suggest that the long-run elasticity of investment to user cost varies between -0.5 and -1.0.

6 . In Chirinko *et al.* (1999) the industry-specific user cost of capital is obtained by taking the weighted average over asset-specific user costs. The weights reflect the proportion of capital accounted for by each asset for 26 industries.

7 . In particular, they derive firm-specific depreciation rates and required rates of return. The asset-specific investment tax credits are, however, constructed to reflect the asset composition of the firm's two-digit industry classification in a similar way as in Auerbach and Hassett (1992) and Chirinko *et al.* (1999).

8 . Crepon and Gianella (2001) also use tax reforms in some what similar way to capture the effects of changes in the user cost.

Summing up

15. The early empirical research using the user cost theory of capital failed to find strong evidence of responsiveness of investment to changes in taxes. However, the results of more recent studies show that taxes may have larger effect on firms' investment decisions working through the user cost than previously suggested. However, there is no clear consensus on the magnitude of these effects.[9]

From theory to empirical modelling

16. The methodological approach used in this paper to model the potential effect of taxes on investment relies on the user cost theory, with taxes increasing the user cost of capital, thereby affecting firms' investment decisions. In contrast to static user cost models, the specification adopted here allows for dynamics due to, for example, the adjustment costs of capital. Dynamics are introduced in the model by including a lagged dependent variable in the following industry-level specification of the investment rate:

$$\ln\left(\frac{I_{cit}}{K_{cit-1}}\right) = \alpha \ln\left(\frac{I_{cit-1}}{K_{cit-2}}\right) + \beta \ln UC_{cit-1} + \varphi \ln\left(\frac{Y_{cit-1}}{K_{cit-2}}\right) + \lambda PMR_{cit-1} + \gamma_{ci} + \gamma_t + \varepsilon_{cit} \quad (1)$$

where *I/K, UC*, *Y/K* and *PMR* are the investment-to-capital ratio, user cost of capital, output-to-capital ratio and a measure of product market regulation, respectively. The terms γ_{ci} and γ_t capture unobserved country-industry and year fixed effects. ε_{cit} is a random error term. The elasticity of the user cost of investment-to-capital ratio is given by β and the long-run elasticity can be computed as $\beta/1-\alpha$. The measure of product market regulation is included in the model as it has been shown by Alesina *et al.* (2005) that product market regulatory reforms have a significant, positive effect on industry-level investment.

17. Different lag structures were considered and it seems that the relevant and most robust dynamics of the dependent variable are autoregressive of order one AR(1). In addition, this baseline specification is adjusted to reflect the accelerator theory by suggesting that investment is determined by the change in output. One important limitation of this baseline specification is that it does not control for firms' financial constraints, as measured, for instance, by their cash flow. This may create bias in the estimated user cost elasticity if the cash flow and the user cost of capital are correlated. The omission of this covariate is purely due to data limitations in measuring cash flow at the industry level.

18. An alternative way to specify a dynamic model would be to estimate the Euler equation derived from the neo-classical model of profit maximising firms. This approach often assumes a convex functional form for the adjustment costs (quadratic in investment and homogenous of degree one) resulting in different dynamics which include the lagged dependent variable and its squared term as the determinants of investment.[10] This model specification is also taken as an alternative approach to capture investment dynamics.

19. The estimation of the empirical model is based on the least squares dummy variable technique (LSDV). Nickell (1981) shows that this estimation technique may lead to inconsistent estimates for dynamic models with unobserved fixed individual effects (in Equation (1) industry-country fixed effects)

9 . Some studies (*e.g.* Goolsbee, 1997) even suggest that taxes and tax incentives for investment do not affect investment, but rather increase the price of capital goods.

10 . For example, see Bond and Meghir, 1994, Bond *et al.* 2003 and Becker and Sivadansan, 2006. The user cost is in these studies, however, proxied by time and firm-specific dummies.

because the lagged dependent variable is correlated with the fixed effects and thus with the disturbance term even though the disturbances would not themselves be serially correlated. This inconsistency is shown to be of order 1/T where T refers to the number of time observations in panel data. Thus, the longer the time dimension, *i.e.* the larger T, the smaller is the inconsistency. The period analysed in this paper is fairly long and, therefore, this inconsistency is likely to be relatively small. However, as a robustness check the preferred specification is also estimated with the system GMM technique correcting for the inconsistency by using lagged levels and first-differences of the dependent variable as instruments.

Data and definitions

Computation of the tax-adjusted user cost of capital

20. The underlying user cost of capital formula, based on the pioneering work by Hall and Jorgenson (1967), is written as follows:

$$UC_a = \underbrace{\frac{p_a}{p}(\rho + \delta_a - E(\Delta p_a / p_a))}_{(1)} \underbrace{\frac{1-\tau Z_a}{1-\tau}}_{(2)}, \qquad (2)$$

where a refers to an asset. p_a/p, ρ, δ_a and $E(\Delta p_a/p_a)$ indicate the price of the asset relative to output price, the required rate of return, the rate of economic depreciation and the expected change in the asset price, respectively.[11] τ and Z refer to the corporate tax rate and the present value of depreciation allowances. The RHS of Equation (2) is the product of two terms. The first term, the standard user cost measure, can be divided into three components: *i)* the cost of financing the asset or the expected rate of return to the investment in the asset, *ii)* the economic rate of depreciation and *iii)* the effect of an anticipated capital gain/loss due to a change in before-tax price of the asset. The second term on the RHS captures the tax adjustment, including corporate taxes on profits and the present value of the tax savings from depreciation allowances. This is a simple version of the user cost formula where personal income taxes (*e.g.* dividend taxes) are ignored and no differential tax treatment of different forms of financing investment are considered.[12]

21. The data for the first term in the user cost formula is obtained from the OECD Productivity database. This database provides information on the user cost of capital by seven asset types (*hardware, communication equipment, other machinery & equipment, transport equipment, non-residential buildings, software and other assets*). The prices of these asset types, p_a, are measured by an asset price deflator with a base year equal to 1995. The expected nominal rate of return is derived by choosing an aggregate-level real long-term rate for each country and by inflating this rate with trend inflation measured using the consumer price index.[13] This rate is assumed to be the same for all asset types. Asset-specific depreciation

11 This is a simple form of the user cost of capital. Depending on the assumption on the timing of investment (beginning or end of the period) and the timing of its effectiveness as a capital good (operational immediately or only at the next period), an additional interaction term between the depreciation rate and capital gains/losses should be included in the formula (for further details, see Measuring Productivity OECD Manual, 2001).

12 An interpretation would be that the investment project is assumed to be financed by retained earnings or equity since the possibility of the deductibility of interest payments and personal income taxes are ignored.

13 . The long-term real interest rate is chosen so as to reflect the different maturity of nominal interest rates. See Schreyer, 2008, for detailed discussion.

rates are computed using the age-price profile of each asset. Finally, the capital gain or loss due to the change in the asset price is captured by the change in the actual asset price deflator.

22. Information required for computing the tax adjustment term in the user cost formula is drawn from a database provided by the Institute for Fiscal Studies (IFS). This database includes information on statutory corporate tax rates and the net present value of capital depreciation allowances (Devereux and Griffith, 2003). The net present value depends on the allowance rate, but also on the asset type – *machinery* or *structures* - and the different depreciation methods which countries adopt for tax purposes, *e.g.* a straight-line or a declining balance basis.[14] In addition, it depends on the nominal discount rate which is assumed to be equal to the nominal interest rate.[15]

23. The industry-specific tax-adjusted user cost of capital used in the empirical analysis is based on the idea that the user cost varies across assets and that the asset composition differs across industries. The industry-specific user cost is constructed as a weighted average of the asset specific user costs where the weights are the shares of each asset in total industry investment. Assuming that the industry asset composition is similar in all countries, data on the asset shares of one country (here the United States) can be used as weights or alternatively the weights may be computed by averaging data on the asset shares across OECD countries. The data on asset shares is drawn from the Bureau of Economic Analysis (BEA) and the EUKLEMS database (November 2007 release).

24. The summary statistics of the user cost variable and its tax components are shown in Table 1. The average industry-specific user cost for this period is around 13.5%. It has declined from 15% in early 1990s to around 12% in the early part of 2000. Tax policies have contributed to the decline in the user cost through tax cuts in several OECD countries. However, the fall in the depreciation allowance has pushed up the user cost of capital in some countries (Austria, Finland, Japan and United States for machinery and Australia, Austria, Finland and France for structures).

Table 1. Summary statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Investment-to-capital ratio	3818	0.07	0.03	0.00	0.43
Tax adjusted user cost	3818	0.14	0.03	0.06	0.26
Relative change in value added	3818	0.03	0.07	-0.79	0.88
value added-to-capital stock ratio	3818	0.54	0.32	0.05	2.41
Anti-competitive regulation impact	3818	0.19	0.16	0.04	0.91

Notes: Summary statistics are based on the sample in the specification in Table 3, Column 3.

Dependent variable and other covariates

25. Table 1 summarises the descriptive statistics of the dependent variable and all the covariates used in the analysis of investment and taxes. The dependent variable is the investment-to-capital stock ratio where investment is measured as current year (t) gross fixed capital formation (*INV*) and capital stock is the beginning of the period stock, *i.e.* the stock at the end of the previous period (t-1). The gross fixed capital stock (*GCS*) is constructed using the perpetual inventory method. This method uses the initial level

14 . If switching between straight-line and reducing balance methods is allowed, the IFS assumes that such switching takes place at the optimal point. If special first year allowances are allowed they are incorporated in the present value.

15 . The assumed real interest, r, (10%) and inflation, π, (3.5%) rates are assumed to be constant over time and across assets and countries. This implies that the nominal interest rate, i, is 13.85%, as $i=(1+r)(1+\pi)-1$.

of capital stock and gross fixed capital formation (*INV*) to recursively compute capital stock for adjacent dates:

$$GCS_{cit} = \delta_{ci} GCS_{cit-1} + INV_{cit} \tag{3}$$

where δ_{ci} describes the capital depreciation and is determined as $\left(1-(1/ASL_{ci})\right)$ where *ASL* denotes the average service life of capital.

26. In addition to the user cost of capital, other covariates of interest include the output-to-capital ratio and the change in output where output is measured by industry value-added. To capture potential effects of product market regulation on investment**,** a time-varying indicator of anti-competitive regulation across industries developed by Conway and Nicoletti (2006) is used as an additional covariate.[16]

27. The industry data on value-added, investment and real capital stock are based on an industry-level dataset from Scarpetta and Tressel (2002) covering years between 1970 and 1998. The data series on value-added and investment are updated using the growth rates of these variables in the most recent version of the OECD STAN database, 2005.[17] The value-added series are deflated using industry-specific deflators. Industry-specific deflator series for the fixed capital formation series are incomplete in the dataset for several countries and industries. Thus, more aggregated deflators were used to obtain fixed capital formation volume series.

Data coverage

28. The final dataset obtained by merging data on the user cost with the dataset on industry investment and other covariates includes 16 OECD countries and covers 21 two-digit industries (or groups of two-digit industries) in manufacturing and business services (see Table 2). It is an unbalanced panel covering the period 1983-2001. The following countries are covered: Australia, Austria, Belgium, Canada, (West) Germany, Finland, France, Greece, Italy, Japan, Netherlands, Portugal, Spain, Sweden, United Kingdom and United States.

16 . See Alesina *et al.* (2005) for a further discussion on the impact of regulatory reforms on investment.

17 . The STAN database is currently ongoing an extensive update. However, the updates were not available at the time of writing this study.

Table 2. Industry list

ISIC Rev.3	Industry name
15-16	Food products, beverages and tobacco
17-19	Textiles, textile products, leather and footwear
20	Wood and products of wood and cork
21-22	Pulp paper, paper products, printing and publishing
24	Chemicals and chemical products
25	Rubber and plastics products
26	Other non-metallic mineral products
27-28	Basic metals and fabricated metal products
29	Machinery and equipment n.e.c.
30-32	Electrical equipment
33	Medical precision and optical instruments
34	Motor vehicles, trailers and semi-trailers
35	Other transport equipment
36-37	Manufacturing nec; recycling
45	Construction
50-52	Wholesale and retail trade; repairs
55	Hotels and restaurants
60-63	Transport and storage
64	Post and telecommunications
65-67	Financial intermediation
70-74	Real estate renting and business activities

Results

29. This section presents the benchmark results of the analysis linking the tax-adjusted user cost to business investment. The analysis focuses on a specification with simple dynamics where the dependent variable is lagged once. As mentioned above, specifications using a longer lag length are also tested, but these further lags were not statistically significant. Moreover, the inclusion of these lags does not alter the main results.

30. In the baseline results, the coefficient of the user cost is highly statistically significant and has the expected sign in all specifications, supporting the hypothesis that high user costs reduce the return to investment, and hence, investment (see Table 3). Further, the coefficient of the lagged dependent variable is positive and highly significant suggesting that there is persistence in investment (see Table 3, Column 1). This may be interpreted as evidence of costs in adjusting the capital stock. Similarly, the estimated coefficients of the output-to-capital ratio and the relative change in output are statistically significant and have the expected signs (Table 3, Columns 2-4). The statistically significant positive coefficient of the output change supports the basic hypothesis of the accelerator theory, which relates investment to changes in demand. The estimated effects of product market regulation are less stable across specifications.

31. As discussed in the previous section, the LSDV estimation method used to estimate the benchmark results may result in bias in dynamic models with unobserved fixed effects. Due to the rather long sample period in this analysis the bias in the above estimations is likely to be relatively small. However, to assess the potential bias the preferred specification (Column 3) is re-estimated using the System GMM estimator developed by Blundell and Bond (1998).[18] The results of this re-estimation are

18 . The first-differences dated t-2 and higher are used as instruments for the levels equation and the lagged levels dated t-3 and higher are used as instruments in the transformed (differenced) equation. The test of

show in Column 4 of Table 3. These results confirm the previous findings on the negative effect of the user cost on investment, but the size of the estimated elasticity is larger than in the LSDV estimates. However, the estimated coefficients are less stable when the instrument set is changed in the system GMM estimation.

Table 3. Benchmark results on the links between investment and the user cost

	(1)	(2)	(3)	(4)
Dependent variable: log of investment-to-capital ratio	OLS	OLS	OLS	System GMM
Log of investment-to-capital ratio (t-1)	0.73	0.66	0.66	0.73
	(0.03)***	(0.02)***	(0.02)***	(0.05)***
Log of tax adjusted user cost (t-1)	-0.17	-0.14	-0.12	-0.26
	(0.02)***	(0.03)***	(0.03)***	(0.11)***
Log of output-to-capital stock ratio (t-1)		0.16		
		(0.03)***		
Relative change in value added (t-1)			0.35	0.65
			(0.10)***	(0.07)***
Anti-competitive regulation impact (t-1)		-0.07	-0.21	0.33
		(0.08)	(0.08)***	(0.39)
Long-run tax adjusted user cost elasticity	-0.62	-0.41	-0.35	-0.98
Observations	4191	4062	3818	3818
Hansen J test				
Prob > chi2 =				0.334
Fixed effects				
country*industry	yes	yes	yes	
year	yes	yes	yes	yes

Notes: In the estimated empirical model the dependent variable is investment-to-capital ratio and the terms on the RHS refer to lagged investment-to-capital ratio, tax-adjusted user cost, change in output and impact of anti-competitive regulation.The long-run elasticity is computed using the coefficient of the user cost divided by one minus the coefficient of the lagged investment-to-capital ratio. In the GMM estimation first differences are used as instruments for the levels equation and the lagged levels are used as instruments in the transformed (differenced) equation. The test of serial correlation suggests that there is first order serial correlation in the disturbance term, but no second order serial correlation is detected. Furthermore, the Hansen *J* statistics does not suggest any gross misspecification of the estimated equation. The estimation sample includes 16 OECD countries and 21 industries for period 1983-2001. Robust standard errors are reported in parentheses. * denotes significant at 10%; ** at 5%; *** at 1%.

32. The estimated short-run coefficient of the user cost of investment-to-capital ratio is relatively small. However, the long-run effect of the user cost on investment (computed as $\beta/1-\alpha$) is estimated to be three to four times larger than the short-run effect. The log-specification of the user cost and the investment-to-capital ratio has the convenient feature that the coefficient of the user cost can be directly interpreted as an elasticity. The results suggest that in the long run a 1% increase in the user cost leads to a decrease in investment-to-capital ratio between 0.35% and almost 1% depending on the empirical specification.

33. To assess how changes in corporate taxation translate into a change in investment through the user cost it is necessary to first examine the effect of a tax change on the user cost. Evaluated at the mean of the user cost (14%), a five percentage point decrease (from 35% to 30%) in the statutory corporate tax rate translates into a 2.6% decrease in the user cost resulting in an increase in the investment-to-capital

serial correlation suggests that there is first order serial correlation in the disturbance term, but no second order serial correlation is detected. Furthermore, the Hansen *J* statistics does not suggest any gross misspecification of the estimated equation.

ratio by 1.0% to 2.6% in the long-run depending on the empirical specification.[19] This increase corresponds to a rise in the investment-to-value-added ratio by 0.2 to 0.5 percentage points, evaluated at the mean of the ratio (20%). As a result of the user cost formula (Equation (2)), the magnitude of this effect depends on the level of corporate taxes: countries with higher corporate tax rates experience a somewhat larger positive effect on the investment-to-capital ratio from a similar decrease, varying from 1.4% to 3.8%.[20]

34. In addition to statutory corporate tax rates, the user cost of capital takes into account depreciation allowances that tend to reduce the user cost. Evaluated at the mean of the net present value of the depreciation allowance (around 40% for *structures* and 80% for *machinery*) and the user cost (14%), the effect of a five percentage point increase in the net present value of the allowances of both asset types approximately results in a 2.5% decrease in the long-run user cost which, in turn, is estimated to increase the investment-to-capital ratio by 0.9% to 2.5% depending on the empirical specification. Since the depreciation allowances are deductible from firms' tax liability at the rate of the corporate tax, the magnitude of the impact of a change in capital depreciation allowances also depends on the level of corporate tax rates. For example, an increase of five percentage points in the allowance rates leads to a 0.2 to 0.6 percentage points larger positive effect on investment in high corporate tax countries (tax rate 50%) than in an average tax country (around 40% in the estimation sample).

Endogeneity and simultaneity issues

35. Several empirical studies discuss potential endogeneity issues and simultaneity problems related to estimating the effects of the user cost of capital on investment. These problems may arise because investment is positively correlated with business cycles which, in turn, are correlated with interest rates and industry output. To partly avoid the potential endogeneity and simultaneity problems the user cost and the output measures are expressed in lagged terms.[21] Furthermore, the potential endogeneity of the interest rate is less of a problem at the industry level as it is less likely that the macro-level aggregate interest rate would be driven by developments in investment in individual industries.[22]

Robustness of results

Alternative measure for industry-specific user cost

36. The results presented in this section rely on the industry-specific user cost measured computed using the information on the industry asset composition prevailing in the United States. To test whether the

19 . This effect is computed by using the estimated long-run user cost elasticity and by changing the corporate tax rate by five percentage points holding the value of all the other components of the user cost at their means.

20 . This is because the corporate tax rate enters non-linearly into the user cost formula. This example is computed for a country with a corporate tax rate of 50%.

21 . A commonly used method to solve these problems is to apply instrumental variable techniques and this technique could be used in the further analysis. However, using disaggregated data and including country-time specific fixed effects to capture the macroeconomic co-movements also partly allows for controlling for the bias created by such problems.

22 . Another type of endogeneity problem at the disaggregate level arises when the interest rates reflect the endogenous decisions of firms determined by their investment, financial policies and potentially taxes. This problem mainly concerns studies at the firm level based on firm-specific interest rates derived using, *e.g.* data on the corporate-specific bonds yields or firms' interest expenses and long-term debt. The present paper is not subject to this endogeneity problem as the interest rate used in the empirical analysis is assumed not to vary across industries (firms). The industry variation in the user cost is obtained through differences in the asset prices, depreciation rate and depreciation allowances.

results are sensitive to this assumption, the empirical model was re-estimated using a measure of user cost which uses the average industry asset composition in a sample of OECD countries. The results are robust to this change in the measure of the user cost (Table 4).

Table 4. Investment and alternative measures of the user cost

	(1)	(2)	(3)
Dependent variable: log of investment-to-capital ratio	OLS	OLS	OLS
Log of investment-to-capital ratio (t-1)	0.73	0.66	0.66
	(0.02)***	(0.02)***	(0.02)***
Log of tax adjusted user cost (t-1)	-0.17	-0.14	-0.12
	(0.03)***	(0.03)***	(0.03)***
Log of output-to-capital stock ratio (t-1)		0.16	
		(0.03)***	
Relative change in value added (t-1)			0.23
			(0.08)***
Anti-competitive regulation impact (t-1)		-0.06	-0.21
		(0.08)	(0.07)***
Long-run tax adjusted user cost elasticity	-0.62	-0.41	-0.36
Observations	4191	4062	3818
Fixed effects			
country*industry	yes	yes	yes
year	yes	yes	yes

Notes: In the estimated empirical model the dependent variable is investment-to-capital ratio and the terms in the RHS refer to lagged investment-to-capital ratio, tax adjusted user cost, change in output and impact of anti-competitive regulation.The long run elasticity is computed as using the coefficient of the user cost divided by one minus the coefficient of the lagged investment-to-capital ratio. Estimation sample includes 16 OECD countries and 21 industries for period 1983-2001. Robust standard errors are reported in the parentheses. * denotes significant at 10%; ** at 5%; *** at 1%.

Results for non-log specification

37. The benchmark results are estimated using a log-transformation of the dependent variables and the user cost measure. This transformation is convenient as the estimated coefficient can be directly interpreted as the user cost elasticity. To check that the results are not driven by the transformation of these variables, the specifications (1-3) in Table 5 are re-estimated using a non-log version of these variables. The results are robust to this re-estimation.

Table 5. Non-log specification of the investment model

	(1)	(2)	(3)
Dependent variable: log of investment-to-capital ratio	OLS	OLS	OLS
Investment-to-capital ratio (t-1)	0.73	0.70	0.72
	(0.03)***	(0.03)***	(0.03)***
Tax adjusted user cost (t-1)	-0.08	-0.08	-0.07
	(0.02)***	(0.02)***	(0.02)***
Output-to-capital stock ratio (t-1)		0.02	
		(0.00)***	
Relative change in value added (t-1)			0.01
			(0.00)***
Anti-competitive regulation impact (t-1)		-0.01	-0.01
		(0.01)	(0.01)**
Long-run tax adjusted user cost elasticity	-0.60	-0.55	-0.52
Observations	4191	4062	3818
Fixed effects			
country*industry	yes	yes	yes
year	yes	yes	yes

Notes: In the estimated empirical model the dependent variable is investment-to-capital ratio and the terms in the RHS refer to lagged investment-to-capital ratio, tax adjusted user cost, change in output and impact of anti-competitive regulation.The long run elasticity is computed using the coefficient of the user cost divided by one minus the coefficient of the lagged investment-to-capital ratio and is evaluated at the mean of the user cost and the investment-to-capital ratio variables. Estimation sample includes 16 OECD countries and 21 industries for period 1983-2001. Robust standard errors are reported in the parentheses. * denotes significant at 10%; ** at 5%; *** at 1%.

Different dynamic specification

38. Another way to check for the robustness of the results is to test their sensitivity to a change in the dynamic specification of the model. The previous results are based on a simple dynamic specification with a lagged dependent variable as an explanatory variable. As discussed in the previous section, an alternative approach is to introduce a squared term of the lagged dependent variable in the model. This dynamic model is tested using a non-log specification and the results concerning the effect of the user cost on investment are not sensitive to this change. However, at the industry level data do not seem to support this dynamic specification as the coefficient of the squared term is not statistically significant. These results are available upon request.

Taxes and productivity

39. This section reviews the recent literature and reports the main findings on the linkages between taxes and productivity. The focus of the analysis is on three specific channels through which taxation may affect productivity: *i*) taxes may distort the efficient allocation of resources, *ii*) taxes may affect incentives to become an entrepreneur by reducing the expected post-tax return of a successful entrepreneur and *iii*) taxes (incentives) may discourage (encourage) investment in R&D by increasing (reducing) the after-tax cost of such investment.

Background and recent empirical research

Distortions in relative factor prices and allocation of resources

40. There is little theoretical and empirical research on the effect of taxes on productivity through their distortive effects on resource allocation. However, theory of public finance suggests that taxes create distortions by affecting prices and the decision making of firms and households (Auerbach and Hines,

2002). These distortions result in reallocation of inputs within and between firms and/or industries that could have transitional growth effects. For instance, a change in the relative factor price could lead to less usage of one of the production inputs (or possibly both) in a firm and/or industry. It is possible that all inputs not used in this firm/industry are either re-allocated to other less productive firms/ industries or not used at all, thereby lowering the efficiency in the use of production inputs, *i.e.* the so-called total factor productivity (TFP) growth.[23]

Entrepreneurial activity

41. Economic theory is ambiguous as to how taxes can affect productivity via their effects on individuals' risk-taking behaviour and entrepreneurship (see Poterba, 2002, for a review on the effects of taxes on individuals' risk-taking). While high taxes on risky investment lower the post-tax return of a successful entrepreneur relative to an unsuccessful one and can reduce entrepreneurial activity and productivity, they also reduce the variance of the returns providing a form of insurance.[24] The literature examines different characteristics of the tax system such as, *i)* the progressivity of the tax rate schedule; *ii)* the limited loss off-set rules in the tax code; *iii)* the difference between corporate and personal income tax rates; and *iv)* a combination of the three previous characteristics, which may affect risk-taking and entrepreneurial activity.[25] In addition, some studies (*e.g.* Pissarides and Weber, 1989; Baker, 1993; Schuetze, 2002) emphasise that self-employment allows for more opportunities to avoid taxes and thus under high personal income taxes more individuals tend to choose self-employment to take advantage of such opportunities.[26]

42. Empirical research on the linkages between personal taxation and entrepreneurship provides different approaches to assess these links (see Schuetze and Bruce, 2004, for a survey). Some studies have focused on the effects of differential taxation between self-employment and working as an employee (*e.g.* Bruce, 2000 and 2003).[27] Most of these studies find that higher tax rates on income from self-employment increase self-employment and start-ups supporting the theory that taxes can serve as insurance against the greater risk in entrepreneurial activity. Gentry and Hubbard (2000 and 2002) use a different approach and compare the after-tax return of successful and unsuccessful entrepreneurs. They suggest that in the case of a less than full loss offset against other taxable income a progressive tax schedule (measured as the difference between the marginal tax rates when the entrepreneur is successful and unsuccessful) discourages risk-taking as the extra tax that applies to high profits is greater than the tax saving that is produced by losses. Cullen and Gordon (2002) provide further evidence on the linkages between personal tax rates and entrepreneurship. They suggest that successful entrepreneurs opt to incorporate to avoid high personal income taxes when personal income is taxed at higher rates than corporate income whereas

23 TFP measures the change in output that cannot be accounted for by a change in inputs and is thus a measure of how efficiently the inputs are used.

24. High tax rates provide an increased risk-sharing with the government if potential losses can be written off against other income (tax payments), which may encourage entrepreneurial activity (Myles, 2008; Cullen and Gordon, 2002). For the original idea see Domar and Musgrave (1944).

25. The loss off-set rules imply that there is a possibility to deduct losses or a part of losses from other taxable income of future taxable income (loss carry-forward).

26 . This tax avoidance may be due to possibilities to misreport income or to report personal consumption as business expenses.

27. While these differentials in the tax treatment may arise due to differences in statutory rates, it is often argued that they are typically caused by differences in tax bases between the two employment options, *e.g.* differences in the treatment of deductions and allowances.

unsuccessful entrepreneurs prefer to be non-incorporated so that the entrepreneur can benefit from the full loss offset from other taxable income.[28]

43. Another approach in this field of empirical research is to assess the impact of personal taxes on the performance of existing entrepreneurs instead of the entry decision of new entrepreneurs. Using the exogenous variation created by the Tax reform Act of 1986 in the United States, Caroll *et al.* (2000a,b) show that personal income taxes have a negative impact on labour use and investment decisions of entrepreneurs. In a successive paper, Caroll *et al.* (2001) apply a similar method to identify links between tax rates and the growth rate of small firms, showing that high marginal personal income tax rates result in low firm growth rates.

R&D spending

44. Corporate taxes and tax incentives for R&D may affect productivity by influencing business R&D spending. Most theoretical and empirical studies on the effect of taxes on R&D are based on the theory of the user cost of capital and assume that firms maximise their profits and invest in R&D until the marginal product of R&D is equal to its marginal cost, measured as the user cost of R&D (see *e.g.* Hall and van Reenen, 2000; Bloom *et al.* 2002; Jaumotte and Pain, 2005 a,b). Here, the user cost is adjusted so that it captures special R&D tax credits in addition to corporate taxes and depreciation allowances.

45. The empirical studies testing the user cost approach find that R&D is responsive to changes in taxation through the user cost. The general conclusion of this research is that the short-run user cost elasticity is relatively small, but in the long run the elasticity may be much larger, approaching unity (in absolute terms). For example, using a sample of OECD countries Bloom *et al.* (2002) estimate the short-run elasticity to be of order -0.1, whereas their long-run estimate is on average close to minus one. However, they show that there is considerable heterogeneity in the user cost elasticity across countries and industries. Using an error correction model and data on OECD countries, Jaumotte and Pain (2005a) also suggest that the long-run user cost elasticity of R&D is around minus one. To check the robustness they also split the user cost into two terms: the tax component and the remaining part consisting of the sum of real interest rate and depreciation rate. Their results show that although the estimated long-run coefficient of the tax component tends to be larger than that of the other term, the two coefficients are not statistically different.

Summing-up

46. Overall, it seems that there is not much research on the effect of taxes on productivity, measured as total factor productivity, through the channel of distortions in the factor allocation whereas there is more evidence on the effect through the channels of entrepreneurial activity and R&D. However, theory and empirics are inconclusive about the overall effect personal income taxes on the probability of entrepreneurship. One disadvantage of many of these studies is that they mainly focus on the United States making it difficult to generalise the results.[29] The evidence on R&D tax incentives is based on wider country coverage and suggests that R&D spending is responsive to these tax incentives. However, although

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28. This argument relies on assumptions about the possibility to change firms' organisational form and about the way entrepreneurs behave under uncertainty concerning whether and when the firm is profitable. Many of the studies analysing the effect of loss off-set rules implicitly also assume that there is other taxable income or future taxable income from which losses can be deducted. If a self-employed does not have any taxable income then even a full loss off-set possibility does not have the risk sharing effect as discussed above.

29. Furthermore, the research questions may be driven by the specific issues of the tax system design in this one country.

the evidence shows that tax incentives for R&D are effective, empirical results do not necessarily imply that they are desirable.[30]

Methodological approach and empirical specification

Baseline specification

47. The empirical specification in this paper is based on the TFP model of Aghion and Howitt (2006). This model allows for the possibility of technology transfer from a country at the technology frontier, *i.e.* the country with the highest productivity, to countries lagging behind the technology frontier within the same industry. It also implies that the productivity growth at the frontier generates faster growth in countries behind the technology frontier by expanding their production possibility set. Moreover, the theory suggests that the productivity growth in a country depends on how far behind it is with respect to the productivity level in the technology frontier country.

48. This model is based on a standard neo-classical production technology, $Y_{cit} = A_{cit}F(L_{cit}, K_{cit})$, where value-added ($Y$) in each country, c, and industry, i, at time, t, is produced with labour (L) and capital (K). A is the industry productivity parameter of a country and is the focus of this analysis. Using a discrete time version of the model, the change in the productivity parameter is expressed as follows

$$\Delta \ln A_{cit} = \beta_{cit}\Delta \ln A_{Fit} - \gamma_{cit} \ln(A_c / A_F)_{it-1} + u_{cit} \qquad (4)$$

where F indicates the country with the highest productivity, *i.e.* the frontier country, and u_{cit} captures all other stochastic factors affecting productivity growth. $\ln(A_c/A_F)_{it}$ is the relative level of productivity measuring how far each country lags behind the frontier country in each industry. As the productivity in the frontier country is higher than that in other countries, $\ln(A_c / A_F)_{it} \leq 0$. Thus, the smaller $\ln(A_c/A_F)_{it}$, the further behind a country is relative to the frontier country and the greater the potential technology transfer, i.e. catch-up with the frontier. Finally, β_{cit} captures the immediate impact from changing productivity in the frontier country on the productivity in other countries and γ_{cit} measures the rate of technology transfer.

49. The estimation approach adopted in this paper follows closely Griffith *et al.* (2000) and Scarpetta and Tressel (2002). They note that Equation (4) is an error correction mechanism derived from the following autoregressive Distributed Lag ADL(1,1) model:

$$\ln A_{cit} = \alpha_1 \ln A_{cit-1} + \alpha_2 \ln A_{Fit} - \alpha_3 \ln A_{F\,it-1} + \omega_{cit} \qquad (5)$$

where ω_{cit} captures both observed factors and non-observable fixed effects. This specification also imposes common coefficients for all observations.

50. Under the long-run homogeneity assumption, $\alpha_2 + \alpha_3 = 1 - \alpha_1$, Equation (5) can be rewritten as:

$$\Delta \ln A_{cit} = \alpha_2 \Delta \ln A_{Fit} - (1 - \alpha_1)\ln(A_c / A_F)_{it-1} + \omega_{cit} \qquad (6)$$

30. Bloom *et al.* (2002) argue that one way to asses their desirability is to use cost-benefit analysis and that several factors other than the estimate of the R&D responsiveness should enter into this analysis (*e.g.* administrative cost of monitoring the tax credit system and the perverse incentives distorting economic activity).

suggesting that there is a potential co-integration relationship, i.e. a common long-run trend, between the productivity level in an industry, *i*, in a "follower country" and the productivity level of the frontier country in the same industry.

51. Equation (6) forms the basis for the econometric analysis. However, to assess the potential links between taxes and productivity the empirical specification is augmented with the relevant tax policy variables and control variables such as human capital and other policies, including product market regulation and employment protection legislation.

Tax augmented specification

52. The analysis of the effect of taxes on productivity is based on the assumption that taxes affect productivity through different channels and that due to some salient industry characteristics, such as technology or organisational features, some industries are more affected than others by the relevant tax. For instance, the potential distortion in the allocation of production factors caused by labour taxes may be more pronounced in industries that are typically more labour intensive. Similarly, R&D tax incentives may have a stronger impact in R&D intensive industries (see Table 6 for more examples).

Table 6. Examples of interactions between taxes and industry characteristics

Taxes	Industry characteristics
Tax wedge on labour income	Labour intensity
Top marginal personal income tax rate	Entrepreneurial activity (entry rates)
Statutory corporate tax rate	Operating profitability
R&D tax incentives	R&D intensity

53. To test this assumption the empirical analysis identifies industry-specific characteristics relevant for different tax policies and examines the interaction between these characteristics and the appropriate taxes (see Rajan and Zingales ,1998).[31] This interaction term is then introduced in the empirical model as the main variable of interest together with other relevant variables affecting productivity growth. Thus the complete specification can be written as:

$$\Delta \ln A_{cit} = \beta_1 \Delta \ln A_{Fit} - \beta_2 \ln(A_c / A_F)_{it-1} + \varphi HK_{cit-1} + \tau\left(TaxRate_{ct-1} * INDfactor_i\right) + \lambda_x X_{cit-1} + \gamma_{ct} + \gamma_i + \varepsilon_{cit} \qquad (7)$$

where $\beta_1 = \alpha_2$ and $\beta_2 = 1 - \alpha_1$ and *HK*, *TaxRate*INDfactor* and *X* refer to the industry-specific measure of human capital, the interaction term between taxes and industry characteristics and other policies, respectively.[32] γ_{ct} and γ_i are country-year and industry fixed effects. ε_{cit} is a random error term.

54. If the results of the econometric analysis support the hypothesis that the negative effect of taxes on TFP is stronger in certain industries due to these salient characteristics, then the estimated coefficient of the interaction term should be negative whereas if tax incentives have a stronger positive effect on TFP in industries with certain characteristics, the coefficient should be positive. When interpreting the estimated effect it is, however, important to keep in mind that this approach captures only the differential effect of a tax working through the interaction term, but not the direct effect of taxation which is captured by the fixed effects. In so far as there are any direct tax effects on TFP (unrelated to industry characteristics) or some additional tax effects working through some other channels, the estimated effects may under/overestimate

31 . Rajan and Zingales (1998) used this approach in assessing the effect financial development on economic growth.

32 . Note that the constituent terms do not enter into the equation, since Equation (7) includes country-year and industry fixed effects.

the impact of taxes depending on whether the additional effect is negative or positive. For example, the possible impact of taxes on industry or structure is not accounted for in the estimated coefficients.

55. A crucial assumption in this method is that the differences in the industry characteristics are broadly similar across countries. Thus, for instance, pharmaceuticals or telecommunications are more R&D intensive than basic metals or if textiles is more labour intensive than car manufacturing in a certain OECD country, this is likely to be true in other OECD countries. This assumption makes it possible to compute a measure capturing industry characteristics that is exogenous to country-specific taxation by using quantitative industry information of a benchmark country or industry averages for a group of countries. In the present analysis, these characteristics are mainly measured by using industry data from the United States. However, data permitting, robustness tests are provided using OECD averages as well.[33]

Data and definitions

Measuring Productivity

56. The model discussed in the previous section implies a relationship between productivity growth, productivity growth in the frontier country, the level of productivity relative to the frontier, tax policies and other economic variables affecting productivity. Following Griffith *et al.* (2004) and Scarpetta and Tressel (2002) productivity is measured as total factor productivity (TFP) using the superlative index number approach by Caves *et al.* (1992 a,b) and assuming a translog production function with constant returns to scale:

$$\Delta \ln TFP_{cit} = \Delta y_{cit} - \frac{1}{2}(\alpha_{cit} - \alpha_{cit-1})\Delta l_{cit} - \left(1 - \frac{1}{2}(\alpha_{cit} - \alpha_{cit-1})\right) \cdot \Delta k_{cit} \qquad (8)$$

where c denotes countries, i denotes industries and t time; y, l and k are respectively the logarithms of real value-added, total employment (or hours worked) and real capital stock. α is a smoothed estimate of the share of labour compensation in value-added. $\Delta \ln TFP_{cit}$ is the empirical counterpart of the growth rate of the productivity parameter in Equations (6) and (7).

The level of TFP of a country, c, in an industry, i, relative to that of the frontier country in the same industry is measured using an analogous superlative productivity index:

$$TFP_{cit} = \frac{Y_{cit}}{\overline{Y}_{cit}} \cdot \left(\frac{\overline{L}_{it}}{L_{cit}}\right)^{\sigma_{cit}} \cdot \left(\frac{\overline{K}_{it}}{K_{cit}}\right)^{1-\sigma_{cit}} \qquad (9)$$

where a *bar* denotes a geometric average over all the countries for a given industry i and year t and σ is a simple average of the labour share, α_{cit}, and the geometric mean labour share across countries. This index

33 . The OECD-wide average allows taking into account differences in the industry composition across countries and thus it may better reflect average industry characteristics. However, these country-specific differences also reflect possible policy-induced distortions (such as tax distortions) in industry characteristics making this measure less exogenous. Under the assumption that industry characteristics do not vary too much across the OECD sample of countries in a low distorted environment, using the US industry data may provide a better proxy for the industry characteristics driven by technology, organisational features and other non-policy related factors. Admittedly, the United States is included in the empirical estimation, which could potentially still cause endogeneity problems. However, excluding this country from regressions does not change the empirical results.

has the desirable properties of superlativeness and transitiveness which makes it possible to compare national productivity levels (see Caves *et al.* 1982a).

57. The data used to compute TFP (*i.e.* value-added, capital and labour inputs and labour compensation) are based on the same industry-level dataset described in the previous section. The capital stock is also computed in a similar way using the perpetual inventory method. The basic measure of labour input is total employment adjusted by using data on hours worked in each industry and country. As a robustness check the measure of labour input is also adjusted for differences in skill-levels as there may be cross-country and cross-industry differences in employment according to the skill composition of employees. The data on hours worked and labour compensation are obtained from the from the EUKLEMS database (March 2007 release).

58. The comparison of productivity levels across countries requires the conversion of underlying data into a common currency, while also taking into account differences in purchasing powers across countries. Thus, the computation of TFP levels incorporates information on comparative product price levels adjusted for purchasing power. Ideally, comparative product prices should be measured at the producer level, but survey data on production prices are usually available only for a few countries and for even fewer products. Thus, the empirical analysis uses the estimates of industry-specific expenditure PPPs provided in Scarpetta and Tressel (2002).

Measuring other variables

59. The main explanatory variables of interest in the industry-level analysis are the interaction terms with country-specific tax indicators and variables capturing the characteristics of each industry. The following key tax indicators used are also described in greater detail in Annex 1:

- **The tax wedge and employee and employer social security contributions:** The tax wedge expresses the sum of personal income taxes and employee and employer social security contributions as a share of total labour cost.
- **The top personal income tax rate** measures the tax rate on gross labour income (excluding social security contributions) which is applied at the highest income threshold for a single person.
- **The statutory corporate tax** is levied on corporate profits at a flat rate and applies to the majority of the corporations.
- **Tax incentives for R&D** include R&D tax credits deductible from taxable income, investment and depreciation allowances deductible from tax liability. To measure the generosity of R&D tax incentives, this paper employs a measure of R&D tax treatment called B-index (see Warda, 2006).
- **The average effective corporate tax rate (AETR)** is a broad measure of corporate tax burden summarising different elements of corporate taxation.

60. All the tax policy variables discussed above are time-varying country-specific indicators and they are interacted with the relevant industry-specific characteristics. The industry-specific variables considered in the empirical analysis are:

- **Labour intensity** is defined as the labour-capital ratio and is based on the employment and capital stock series used in computing total factor productivity.
- **Entrepreneurship** is measured as firm entry rates. The data on firm entry is obtained from Haltiwanger *et al.* (2006).

- **Profitability** is determined as a ratio of operating profits over value-added and is obtained from the OECD STAN (2005) database, except for the United States, where the data on profits are obtained from input-output tables provided by the Bureau of Economic Analysis (BEA).
- **R&D intensity** is defined as the ratio of business expenditure in research and development (BERD) over value-added. The data on R&D expenditure are drawn from the OECD ANBERD database and the data on value-added is from the main dataset used in computing total factor productivity.

61. These industry characteristics are expressed relative to the total economy average. Finally, the measures for specific industry characteristics are obtained by selecting the United States as a benchmark. As a robustness check these industry measures are also computed by using information on OECD countries and taking averages across these countries.[34]

62. To measure product market regulation at the industry-level, the analysis uses the time-varying indicators of anti-competitive regulation across industries developed by Conway and Nicoletti (2006). These indicators are based on the idea that anti-competitive regulations in non-manufacturing sectors not only have a direct influence on market conditions in these sectors, but also have a less visible impact on the cost structures faced by firms that use the output of non-manufacturing sectors as intermediate inputs in the production process.[35] Hence, these regulation indicators are a measure of the degree to which each sector in the economy is exposed to anti-competitive regulation in non-manufacturing sectors.

63. The regulatory stance in the labour market is captured in a similar manner as in Bassanini and Venn (2007) by the OECD summary indicator of the stringency of Employment Protection Legislation (EPL) (see OECD, 2004). This indicator varies over time and across countries. However, it does not have any industry dimension and to analyse whether industries with higher job turnover are more sensitive to the EPL, this indicator is interacted with average job flows for each industry in the United States. The source for this information is Haltiwanger *et al.* (2006). The measure of job flows is the so-called job reallocation rate which is defined as the sum of job creation and destruction rates in each industry.

64. In order to capture the impact of human capital on productivity, the empirical analysis is extended to include an industry-level proxy of human capital based on data about skills. The measure of human capital is defined as (the subscripts *j*, *i* and *t* are omitted):

$$HumanCapital = \log\left[1 + \frac{\omega_H}{\omega_L} . \frac{L_H}{L} + \frac{\omega_M}{\omega_L} . \frac{L_M}{L}\right] \quad (10)$$

where ω_H, ω_M, ω_L are respectively the wage rate for high, medium and low-skilled workers. L_H, L_M and L are respectively high-skill labour input, medium-skill labour input and total labour input measured by hours worked. Thus, this measure is rising with the wage premium of high-skilled workers relative to medium-skilled workers and medium-skilled workers relative to low-skilled workers, weighted with the proportion of high- and medium-skilled workers in total employment, respectively.

34 . However, there are limitations in the data availability of the industry variables in several OECD countries, for example there are only a few countries in the dataset that have wide industry coverage on firm entry rates over the same sample period.

35. This is especially the case given the large and increasingly important role of the non-manufacturing sector as a supplier of intermediate inputs in OECD countries over recent years.

Data coverage

65. The basic dataset includes data on 13 OECD countries and covers 21 two-digit industries (or groups of two-digit industries) in manufacturing and business services over the period 1981-2001 (see Table 2). The countries covered are Austria, Belgium, Denmark, (West) Germany, Finland, France, Italy, Japan, Netherlands, Spain, Sweden, United Kingdom and United States. The country-industry coverage of the TFP data is presented in Table 7. The number of observations in the empirical specifications may vary due to limitations in the data availability for some explanatory variables and due to the fact that the observations for the frontier country are dropped from the estimation to avoid endogeneity.

Table 7. Coverage of the hours adjusted TFP data (number of observations)

Industry code	Industry	AUT	BEL	DEW	DNK	ESP	FIN	FRA	GBR	ITA	JPN	NLD	SWE	USA
15-16	Food products, beverages and tobacco	21	21	9	21	20	21	21	21	21	14	21	21	21
17-19	Textiles, textile products, leather and footwear	21	21	9	21	20	21	21	21	21	14	21	21	21
20	Wood and products of wood and cork	21		9	21	20	21	10	21	21		21	21	21
21-22	Pulp paper, paper products, printing and publishing	21	21	9	21	20	21	21	21	21	14	21	21	21
24	Chemicals and chemical products	21	21	9	21	20	21	10	21	19	13	15	21	21
25	Rubber and plastics products	21		9	21	20	21	21	21	21	13	21	21	21
26	Other non-metallic mineral products	21	21	9	21	20	21	21	21	21	14	21	21	21
27-28	Basic metals and fabricated metal products	21	21	9	21	20	21	21	21	21	13	21	21	21
29	Machinery and equipment n.e.c.			9	21		21	10	21	19	13	15		
30-32	Electrical equipment			9	12		21	3	16	19	13	10		
33	Medical precision and optical instruments	21	12	9	12	14	21	10	16	21	13	12	21	12
34	Motor vehicles, trailers and semi-trailers			9	8		21	21	14	9	13			21
35	Other transport equipment		12	9	8		12	21	14	9	13	12		21
36-37	Manufacturing nec; recycling						21	10		19		3		21
45	Construction		21	9	21		21	21	21	21		21	21	21
50-52	Wholesale and retail trade; repairs		21	9	21		21	21	16	21		15	21	21
55	Hotels and restaurants		21	9			21	21	16	21		15	21	21
60-63	Transport and storage		15	9	20		21	21	14	14		12	21	21
64	Post and telecommunications		15	9	20		21	21	14	14		12	21	21
65-67	Financial intermediation		21	9	21		21	9	16	21		3	21	21
70-74	Real estate renting and business activities				21		21	9	15	19		15	21	21

Main results

66. Table 8 presents the results for the baseline specification, before augmenting the model with tax variables. In line with the theoretical model presented in the previous section, the relative TFP term is consistently estimated with a negative and statistically significant coefficient implying that, within industries, countries that lie further behind the frontier experience higher productivity growth rates than countries that are closer to the TFP level of the frontier country. The coefficient of productivity growth in the frontier country is found to have a positive effect on the growth of other countries. This baseline specification is extended to capture the effect of taxes on TFP by examining the interaction effects between taxes and specific industry characteristics as shown in Equation (7).

Table 8. Baseline TFP specification

Dependent variable: TFP growth	Basic model	Basic model+ outlier control
Basic model		
TFP growth in the frontier country	0.07	0.06
	(0.02)***	(0.02)***
TFP relative to the frontier TFP (t-1)	-0.02	-0.01
	(0.00)***	(0.00)***
Human capital (t-1)	0.004	0.006
	(0.004)	(0.003)**
Observations	3106	3001
Fixed effects:		
Country*year	yes	yes
Industry	yes	yes

Notes: The dependent variable is TFP growth in a country c, industry *i* and year *t,* and the explanatory variables in the baseline estimation are TFP growth in an industry in the frontier country, relative difference between TFP in an industry and in that industry in the frontier country and human capital measure. All estimations include country-year and industry-specific fixed effects. Estimation sample includes 13 OECD countries and 21 industries for period 1981-2001.The results are robust to introducing other interaction terms with other tax variables. Robust standard errors are reported in the parentheses. * denotes significant at 10%; ** at 5%; *** at 1%.

Tax effects through distortions in factor prices

Social security contributions impede TFP

67. The results in Table 9 (Columns 1 and 2) provide some evidence that certain labour taxes, namely social security contributions (SSC), have negative effects on TFP with the effect being stronger in industries characterised as being relatively more labour intensive. To the extent that labour taxes affect the relative prices of capital and labour, the interpretation of this finding may be that increases in these taxes lead to combining capital and labour inputs in ways that differ from the most efficient technology available, thereby lowering TFP.[36] The size of this effect on the level of TFP is, however, estimated to be relatively small.

36. This interpretation suggests that by distorting factor prices taxes adversely affect the marginal productivity of factor inputs and thus the factor shares. (In the TFP computation this refers to α's in the production function.) Of course, taxes can also have an effect on the accumulation of factor inputs (L and K in the production function) which would be another channel through which taxes affect economic growth. Due to the empirical way TFP is measured distinguishing the two effects is difficult. One possible approach to separate these effects is to analyse potential tax effects by using a two-step equation system which first controls for effects on the factor inputs and then uses the tax-controlled factor inputs to examine whether

68. In addition, the analysis suggests that this effect is larger in countries with a sizeable administrative extension of collective wage agreements (Table 9, Column 3).[37] To the extent that such agreements put a floor to the negotiated wage, administrative extension may amplify the rise in labour cost due to an increase in SSC by making it more difficult to shift the burden of this rise onto workers' wages.

Corporate taxes negatively affect TFP

69. As with labour taxes, corporate taxes can distort relative factor prices resulting in an inefficient factor input combination which may lower total factor productivity.[38] The empirical analysis assumes that one mechanism through which corporate taxes may affect TFP is corporate profitability. Due to some salient characteristics, firms in certain industries are on average more profitable (high return) than in other industries and, therefore, may be more affected by corporate taxes.[39] The results of the analysis show that statutory corporate tax rates have an adverse effect on TFP (Table 9, Column 4), with this effect being larger in industries that are inherently characterised by a high return. A simulation experiment indicates that the effect of a reduction of the corporate tax rate from 35% to 30% on the yearly TFP growth rate (over 10 years) would be 0.08 percentage points higher for industries with the median profitability than for industries with the lowest level of profitability.[40] Under the assumption that the effects from corporate taxation are close to zero for firms with the lowest tax base, this may be interpreted as a median effect. For comparison purposes, the average annual trend TFP growth rate in OECD countries is 1.1% (see OECD, 2007). While the empirical estimation provides reliable estimates of the qualitative effect of corporate taxes, the estimated quantitative effects should be interpreted with caution.

70. The magnitude of the effect of decreasing the corporate tax rate also depends on a country's industry structure; more specifically, on whether countries have a large share of industries characterised as having a high average return. The estimates suggest that that the five percentage points reduction in the corporate tax rate would over ten years increase the average yearly TFP growth rate by 0.08 percentage points more in an industry at the 75th percentile of profitability than in an industry at the 25th percentile of profitability.

Tax effects on entrepreneurial activity

71. Evidence in Table 9, Column 5, suggests that there is a negative relationship between top marginal personal income tax rates and the long-run level of TFP working through the channel of entrepreneurial activity (as measured by firm entry rates). The idea is to test whether industries that

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taxes have a bearing on TFP beyond the effects on the accumulation of factor inputs. The preliminary results of such an analysis suggest that taxes, indeed, have effects on TFP that are not explained by the tax effects on the accumulation of factor inputs. Thus, the tentative conclusion from this analysis is that while taxes affect factor accumulation, they also influence TFP through distortions in factor prices and shares.

37. A large administrative extension of collective agreements implies that a country has a low union density, but an extensive coverage of the agreements.

38. For example, Boersch-Supan (1998) shows that differences in the allocation of capital across sectors have a considerable effect on aggregate productivity. Using company and plant-level data his study finds that US private businesses have used physical capital more efficiently than those in Germany and Japan, explaining why capital productivity in these countries was lower than in the United States in the early 1990s.

39 . For example, some industries may tend to be more profitable not because of pure economic rents, but because they rely on high expected return to capital to compensate for high-risk investment projects such as R&D or other intangible factors.

40 . This effect is evaluated at the median TFP growth in the frontier country and at the median level of relative TFP.

typically have higher rates of enterprise creation suffer most from taxation. Indeed, the estimated effect of a change in top personal income taxes differs across countries depending on the industry structure. A simulation experiment indicates that the effect of a reduction of the top marginal tax rate from 55% to 50% on the average yearly TFP growth rate (over 10 years) would be 0.05 percentage points larger for industries with the median firm entry rate than for those with the lowest level of firm entry.[41] Under the assumption that the effect of top marginal rates are close to zero in industries with the lowest level of firm entry, this may be interpreted as a median effect. Furthermore, the size of this effect depends on a country's industry structure, more specifically, on whether countries have a large share of industries characterised by strong firm entry. The estimates suggest that this five percentage points reduction in the top marginal rate would increase the average yearly TFP growth rate by 0.06 percentage points more in an industry with a high level of firm entry (the 75th percentile of the distribution of firm entry rates) than in an industry with a low level of firm entry (the 25th percentile).

72. These findings seem to be in line with previous empirical work suggesting that high tax progressivity discourages the decision to become an "entrepreneur" (*e.g.* Gentry and Hubbard, 2000; Gentry and Hubbard, 2002; Caroll *et al.* 2000a,b). One possible policy implication may be that countries with a large share of their industries characterised by high firm entry (or wishing to move in this direction) may gain more from lowering their top marginal tax rate than other countries.

73. However, it is likely that some other policies and institutional settings, such as product market regulation, have a more direct impact on entrepreneurship (Scarpetta and Tressel, 2002; Brandt, 2005; Conway *et al.* 2006). The magnitude of the effect of the tax reform may depend on the stance of these policies. For example, the empirical analysis shows that the negative effect of top marginal tax rates is stronger in countries with a high level of the OECD indicator of product market regulation (PMR)[42], suggesting complementarities between taxation and product market policies (Table 9, Column 6). This finding may reflect that potential entrepreneurs weigh the total cost against the potential return of starting up a business. Since taxes add to cost on top of the regulatory costs, the overall cost is increased, which may tilt the balance towards not becoming an entrepreneur in business environments where taxes are high at the same time as regulations are burdensome.

Tax effects through R&D activity

74. Corporate taxes can have a negative effect on investment in R&D, and thus TFP, in a similar way as taxes affect physical investment. Due to the particular risky nature of R&D investment and its positive externalities on productivity, many OECD countries have introduced some type of R&D tax incentives in order to stimulate private-sector innovative activity.[43] The results presented in Table 9, Column 7, support results from previous research suggesting that tax incentives for R&D enhance TFP. This effect is identified assuming that R&D intensive industries benefit most from increases in tax incentives. The average effect of tax incentives on TFP seems to be rather small, corroborating the conclusion of Jaumotte and Pain (2005a,b) that tax policies can do relatively little to enhance innovative activity. For example, a simulation exercise suggests that the effect of increasing these tax incentives from 10% to 15% (equivalent to a 5 cents increase in tax subsidy per dollar invested in R&D) would be 0.01 percentage points larger for

41 . This effect is evaluated at the median TFP growth in the frontier country and at the median level of relative TFP.

42 . The PMR indicator includes, among other things, measures of the administrative burden on firms and regulatory barriers for start-ups.

43 . The outcomes from innovative activities are often uncertain making firms reluctant to invest sufficiently in R&D. Also, firms face difficulties in appropriating the benefits of their investments in innovation while preventing their competitors from doing so. The extent to which this is possible depends on both the strength of competition and the degree of protection of intellectual property rights.

an industry having the median R&D intensity than for an industry with the lowest level of R&D intensity.[44] Again, this may be interpreted as a median effect if it is assumed that the effect of tax subsidies is close to zero in industries with very low R&D intensity. However, the tax effect could potentially be larger in R&D intensive industries. Indeed, the analysis supports this assumption as the five percentage points change in tax incentives is estimated to increase the average annual TFP growth rate by 0.09 percentage points more in an industry at the 75th percentile of R&D intensity than in an industry at the 25th percentile of R&D intensity.

Table 9. Taxes effects and TFP

Dependent variable: TFP growth	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Basic model								
Leader TFP growth	0.06	0.06	0.06	0.04	0.05	0.05	0.05	0.05
	(0.02)***	(0.02)***	(0.02)***	(0.02)*	(0.02)**	(0.02)**	(0.02)**	(0.02)**
TFP relative to leader TFP (t-1)	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.02
	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***
Human capital (t-1)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	(0.00)**	(0.00)**	(0.00)**	(0.00)**	(0.00)**	(0.00)**	(0.00)**	(0.00)*
Interaction between industry characteristics & tax								
Labour intensity & social security contributions (t-1)	-0.01							-0.01
	(0.00)**							(0.00)***
Labour intensity & employer's social security contributions (t-1)		-0.01						
		(0.00)**						
Labour intensity & social security contributions (t-1) with low adm. extension			-0.01					
			(0.01)					
Labour intensity & Social security contributions (t-1) with high adm. extension			-0.01					
			(0.00)**					
Profitability & Corporate tax (t-1)				-0.04				-0.04
				(0.01)***				(0.01)***
Entry rate & top personal income tax (t-1)					-0.04			-0.03
					(0.01)***	-0.03		(0.01)**
Entry rate & top personal income tax (t-1) with low PMR						(0.01)*		
						-0.05		
Entry rate & top personal income tax (t-1) with high PMR						(0.01)***		
R&D intensity & R&D tax incentives (t-1)							0.003	0.003
							(0.001)**	(0.001)***
Other policy variables								
Anti-competitive regulation impact (t-1)	-0.03	-0.03	-0.03	-0.01	-0.01	-0.01	-0.01	-0.03
	(0.01)***	(0.01)***	(0.01)***	(0.01)**	(0.01)	(0.01)	(0.01)**	(0.01)***
Job turnover & employment protection legislation				-0.00	-0.00	-0.00	-0.00	
				(0.00)	(0.00)	(0.00)	(0.00)	
Observations	2802	2802	2802	2910	2910	2910	2767	2584
Fixed effects:								
Country*year	yes	yes	yes	yes	yes	yes	yes	yes
Industry	yes	yes	yes	yes	yes	yes	yes	yes

Notes: The dependent variable is TFP growth in a country c, industry *i* and year *t,* and the explanatory variables in the estimations are TFP growth in an industry in the frontier country, relative difference between TFP in an industry and in that industry in the frontier country, human capital measure, the interaction terms between industry characteristics and relevant tax, other policy variables. The anti-competitive regulation impact is an industry-specific measure of the degree to which each industry in the economy is exposed to anti-competitive regulation in non-manufacturing sectors. In Columns (1)-(3) the interaction term with job turnover and employment protection legislation is dropped as there may be some collinearity problems related to job turnover and labour intensity. In Column (3) the coefficients of the interaction term with social security contributions and labour intensity are distinguished by the degree of administrative extension of collective wage agreements. In Column (6) the coefficients of the interaction term with the top personal income tax rate and firm entry are distinguished by the degree of product market regulation in a country. All estimations include country-year and industry-specific fixed effects. The estimation sample includes 13 OECD countries and 21 industries for period 1981-2001. Robust standard errors are reported in the parentheses. * denotes significant at 10%; ** at 5%; *** at 1%.

Sensitivity of the results to the inclusion of different taxes in the same specification

75. Table 9, Column 8, reports the results of the estimated model including all the four tax indicators interacted with the relevant industry characteristics. The estimated coefficients are robust to this

44 . This change in the R&D tax incentives corresponds to more than a half of the standard deviation in the tax incentives.

specification. Furthermore, their magnitude is also similar to that of the estimated coefficients in separate specifications.

Robustness of results and extensions

Different measures of TFP

76. The TFP measure used in the main analysis is computed using data on labour input adjusted for hours worked. A more simple measure of TFP can be based on the number of employees. This measure is used to test the robustness of the main findings in this section. In addition, using this measure allows for extending the country coverage to include four more countries in the sample as there is more data available on employees than on hours worked. As shown in Table 10 (Columns 1 to 4), the main findings are similar when this simpler measure of TFP is used. In addition to the adjustment for hours worked, the TFP measure can be adjusted for the skill composition of employees in each industry and country. The main results are generally robust to this adjustment in the TFP measure (Table 10, Columns 5 to 8).

Table 10. Tax effects – different measures of TFP

	Non-adjusted TFP				TFP adjusted for hours and skill composition			
Dependent variable: TFP growth	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Basic model								
TFP growth in the frontier country	0.01	-0.01	-0.01	-0.01	0.03	0.02	0.02	0.02
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
TFP relative to the frontier TFP (t-1)	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***
Human capital (t-1)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	(0.00)***	(0.00)***	(0.00)***	(0.00)**	(0.00)**	(0.00)*	(0.00)**	(0.00)**
Interaction between industry characteristics & tax								
Labour intensity & social security contributions (t-1)	-0.005				-0.01			
	(0.003)*				(0.00)**			
Profitability & Corporate tax (t-1)		-0.03				-0.05		
		(0.01)***				(0.01)***		
Entry rate & top personal income tax (t-1)			-0.04				-0.04	
			(0.01)***				(0.01)***	
R&D intensity & R&D tax incentives (t-1)				0.003				0.002
				(0.001)***				(0.001)
Other policy variables								
Anti-competitive regulation impact (t-1)	-0.02	-0.01	-0.01	-0.01	-0.02	-0.01	-0.01	-0.01
	(0.01)***	(0.01)*	(0.01)	(0.01)*	(0.01)***	(0.01)*	(0.01)	(0.01)**
Job turnover & employment protection legislation		-0.00	-0.00	-0.00		-0.00	-0.00	-0.00
		(0.00)	(0.00)	(0.00)		(0.00)*	(0.00)	(0.00)*
Observations	2910	3020	3020	2836	2728	2826	2826	2688
Fixed effects:								
Country*year	yes	yes	yes	yes	yes	yes	yes	yes
Industry	yes	yes	yes	yes	yes	yes	yes	yes

Notes: The dependent variable is TFP growth in a country c, industry *i* and year *t,* and the explanatory variables in the estimations are TFP growth in an industry in the frontier country, relative difference between TFP in an industry and in that industry in the frontier country, human capital measure, the interaction terms between industry characteristics and relevant tax, other policy variables. In Columns (1)-(3) the interaction term with job turnover and employment protection legislation is dropped as there may be some collinearity problems related to job turnover and labour intensity. All estimations include country-year and industry-specific fixed effects. Robust standard errors are reported in the parentheses. * denotes significant at 10%; ** at 5%; *** at 1%.

Alternative computation of the industry characteristics

77. The results presented in this section rely on the industry characteristics based on the industry information from the United States. To test whether the results are sensitive to this measurement issue, the empirical model is re-estimated using measures for the industry characteristics computed with the information on a sample of OECD countries. In this case the industry measures are obtained by taking a simple average across the sample countries. Table 11, Columns 1-3, shows the results of the estimations

using these measures. The main findings are robust to this change in the measurement of the industry characteristics.[45]

Table 11. Tax effects – additional robustness tests

Dependent variable: TFP growth	(1)	(2)	(3)	(4)
Basic model				
TFP growth in the frontier country	0.06	0.05	0.05	0.04
	(0.02)***	(0.02)*	(0.02)**	(0.02)*
TFP relative to the frontier TFP (t-1)	-0.01	-0.01	-0.01	-0.02
	(0.00)***	(0.00)***	(0.00)***	(0.00)***
Human capital (t-1)	0.01	0.01	0.01	0.01
	(0.00)**	(0.00)**	(0.00)*	(0.00)**
Interaction between industry characteristics & tax				
Labour intensity & social security contributions (t-1)	-0.01			
	(0.00)***			
Profitability & Corporate tax (t-1)		-0.07		
		(0.02)***		
R&D intensity & R&D tax incentives (t-1)			0.005	
			(0.002)***	
Profitability & EATR (t-1)				-0.04
				(0.01)***
Other policy variables				
Anti-competitive regulation impact (t-1)	-0.03	-0.01	-0.01	-0.01
	(0.01)***	(0.01)	(0.01)**	(0.01)**
Job turnover & employment protection legislation		-0.00	-0.00	-0.00
		(0.00)	(0.00)	(0.00)
Observations	2802	2910	2872	2663
Fixed effects:				
Country*year	yes	yes	yes	yes
Industry	yes	yes	yes	yes

Notes: The dependent variable is TFP growth in a country c, industry *i* and year *t,* and the explanatory variables in the estimations are TFP growth in an industry in the frontier country, relative difference between TFP in an industry and in that industry in the frontier country, human capital measure, the interaction terms between industry characteristics and relevant tax, other policy variables. . In Columns (1)-(3) the interaction term with job turnover and employment protection legislation is dropped as there may be some collinearity problems related to job turnover and labour intensity. All estimations include country-year and industry-specific fixed effects. The estimation sample includes 13 OECD countries and 21 industries for period 1981-2001. Robust standard errors are reported in the parentheses. * denotes significant at 10%; ** at 5%; *** at 1%.

Effective corporate taxes and TFP

78. It may be argued that the statutory corporate tax rates do not capture the total corporate tax burden as they do not take into account other elements of corporate taxation. Effective tax rates are broader measures than the statutory rate as they incorporate both the rate at which corporate profits are taxed and the tax base to which it is applied. The effective tax rates considered in this paper capture in addition to the statutory corporate tax rate the capital depreciation allowances. Based on the results in Table 11, Column 4, it seems that this broader measure of corporate tax burden has similar effects on TFP than the statutory corporate tax rate. A simulation experiment indicates that the effect of a cut in the effective tax rate from 35% to 30% on the average yearly TFP growth rate (over 10 years) would be 0.1 percentage

45. This robustness analysis could not be conducted for the interaction term of top marginal rates on personal income and industry firm entry rates as there was not sufficient data on different OECD countries and industries for the same period.

points larger for an industry with the median profitability than for an industry with the lowest level of profitability. As discussed in previous sub-section, this may be interpreted as a median effect. The effect of this tax cut on TFP depends on the industry structure and this reduction would increase the average annual productivity growth rate by 0.1 percentage points more in an industry at the 75th percentile of profitability than in an industry at the 25th percentile of the distribution of profitability.

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ANNEX 1: DESCRIPTION OF TAX INDICATORS

Social security contributions

Social security contributions are expressed as a ratio of the sum of employees' and employers' social security contributions and total labour costs, defined as the wage plus employers' social security contribution.

Source: Taxing Wages, OECD Tax Database

Top marginal rate of personal income tax

The top personal income tax rate combines central and sub-central statutory tax rates on gross wage income which are applied at the highest income threshold for a single person without children. It includes surtaxes and takes into account any relief given at a higher level of government for taxes paid at a lower level.

Source: OECD Tax Database

Statutory corporate tax rate

Central plus sub-central (non-targeted) tax rate levied on corporate profits, taking into account any relief given at a higher level of government for taxes paid at a lower level. This is the rate which applies to the majority of corporations. Where a progressive (as opposed to flat) rate structure applies, the top marginal rate is used.

Source: OECD Tax Database

Capital depreciation allowances

Capital depreciation allowances are captured by the net present value of deductions from taxable income due to depreciation of capital over time. The net present value depends on the allowance rate but also on the asset type, the discount rate, and on how the allowance can be deducted from tax liability over time (*e.g.* declining balance vs. straight line method). Where switching between straight-line and declining reducing balance methods is allowed, such switching is assumed at the optimal point. Special first year allowances are included if applicable. Other assumptions: the real discount rate is 10%, the rate of inflation is 3.5%.

Source: Institute for Fiscal Studies (IFS).

Average effective tax rate

The effective corporate tax rate is a forward-looking tax indicator and it measures the effective tax burden on corporations by summarising different elements of corporate taxation, *e.g.* depreciation allowance and statutory tax rate. The effective rate is computed for a hypothetical firm with investment in a certain asset assuming the financing structure and the rate of return to the investment. This paper uses the measure of the average effective tax rate (AETR) which applies to an investment project with positive profits (the rate of financial return assumed to be 20%). The firm is assumed to invest in two types of assets (machinery and structures) and the investment projects are assumed to be financed by retained earnings or equity. Taxation at the shareholder level is not included. Other assumptions: the real discount rate is 10%, the rate of inflation is 3.5% and the economic depreciation rate of machinery and structure is 12.5% and 3.6%. The average measure of the AETR over the two asset types is obtained by taking a weighted average of the asset-specific AETRs where the weights are the shares of each asset in total economy investment. To obtain an exogenous measure of the AETR for the empirical analysis, the average measure is computed using the assets shares for the United States.

Source: Institute for Fiscal Studies (IFS) and OECD Productivity database.

R&D tax incentives

Tax incentives for R&D include R&D tax credits that are deductible from taxable income, and investment and depreciation allowances that are deductible from tax liability. To measure the generosity of R&D tax incentives subsidies, this report employs a measure of R&D tax treatment called the B-index (Warda, 2006). The B-index measures the minimum value of before-tax income that a firm needs to cover the cost of R&D investment where the cost is standardised to one dollar. R&D tax incentives are determined as one minus the B-index which captures the tax subsidy per dollar invested in R&D. A value of zero of this measure means that the tax subsidy is just sufficient to offset the impact of the corporate tax rate.

Source: OECD Science, Technology and Industry Scoreboard.

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