OECD Economics Department Working Papers No. 641

Do Corporate Taxes Reduce Productivity and Investment at the Firm Level? Cross-Country Evidence from the Amadeus Dataset

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https://dx.doi.org/10.1787/236246774048

OECD

Unclassified **ECO/WKP(2008)49**

Organisation de Coopération et de Développement Économiques
Organisation for Economic Co-operation and Development **30-Sep-2008**

English - Or. English

ECONOMICS DEPARTMENT

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JT03251567

English - Or. English

ABSTRACT/RESUMÉ

Do corporate taxes reduce productivity and investment at the firm level? Cross-country evidence from the Amadeus dataset

This paper uses a stratified sample of firms across OECD economies over the period 1996-2004 to analyse the effects of corporate taxes on productivity and investment. Applying a differences-in-differences estimation strategy which exploits differential effects of corporate taxes on firms with different profitability, it is found that corporate taxes have a negative effect on productivity at the firm level. The effect is negative across firms of different size and age classes except for the small and young, which may be attributable to the relatively low profitability of small and young firms. The negative effect of corporate taxes is particularly pronounced for firms that are catching up with the technological frontier. In the investment analysis, the results suggest that corporate taxes reduce investment through an increase in the user cost of capital. This may partly explain the negative productivity effects of corporate taxes if new capital goods embody technological change.

JEL classification codes: D21; D24; E22; E62; H25; H32.
Key words:Productivity; Growth; Tax Structure; Firm level data; Fiscal policy.

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Les impôts sur le revenu des sociétés réduisent-ils la productivité et l'investissement des firmes? Évidences empiriques des pays OCDE

Ce papier utilise un échantillon stratifié de firmes issues des pays de l'OCDE sur la période 1996-2004 pour analyser les effets de l'imposition des sociétés sur la productivité et l'investissement. En appliquant une stratégie d'estimation par différences-en-différences qui exploite des effets différentiels de l'imposition sur des firmes avec de différents niveaux de profitabilité, il s'avère que les impôts sur le revenu des sociétés ont un effet négatif sur la productivité des firmes. L'effet est négatif pour les firmes de toutes classes d'emploi et d'âge excepte pour les firmes à la fois petites et jeunes, ce qui peut être attribuable à la profitabilité relativement faible des firmes à la fois petites et jeunes. L'effet négatif de l'imposition est particulièrement fort pour les firmes qui sont en train de s'approcher à la frontière technologique. L'analyse de l'investissement indique que l'imposition des sociétés réduit l'investissement par une augmentation du coût du capital. Ceci expliquerait une partie des effets négatifs sur la productivité si les nouveaux biens de capital incorporent le progrès technologique.

Codes JEL : D21 ; D24 ; E22 ; E62 ; H25 ; H32.
Mots clé : Productivité ; Croissance ; Structure fiscale ; Données de firmes ; Politique fiscale.

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1. Introduction

1. The link between taxation and economic growth is a key issue of public policy. Not surprisingly, economists have put considerable effort into evaluating the effects of the tax level on the growth rate of GDP. Studies at the aggregate level have provided evidence for a link between taxes and economic growth[4], but can only provide a limited contribution to the understanding of the *channels* through which such a link may work. This paper uses firm level data to analyse the link between corporate taxation and two of the main drivers of economic growth, total factor productivity (TFP) growth and investment.

2. Studying the effect of corporate taxation on these variables at the disaggregate firm level has at least two advantages. Firstly, measures of TFP and investment are free of aggregation biases, which is particularly important in the light of the role that re-allocation of resources across industries and firms play for TFP developments (Arnold *et al.* 2007). Secondly, the firm level dimension of the data allows asking whether the effects of corporate taxation differ across firms with different characteristics. Indeed, any effect of corporate taxation on economic growth at the aggregate level may be driven by a subset of firms only.

3. The use of disaggregated data also allows to address a number of policy-relevant issues. For instance, if the effects of corporate taxation on TFP and investment differ across firms of different size and age, this may have implications for the effectiveness of exemptions or reduced tax rates for small firms or start-ups. Similarly, if the effects of corporate taxation on TFP and investment are stronger for "rising" firms that are in the process of catching up with the technological frontier than for "declining" firms that are falling behind, this may also have policy implications. A disproportionately strong effect of corporate taxation on rising firms implies that corporate taxation, over and beyond reducing the rate of TFP growth

1 This work has benefitted greatly from important contributions of Bert Brys, Christopher Heady, Åsa Johansson, Giuseppe Nicoletti, Stefano Scarpetta and Laura Vartia. The authors would like to thank Martine Carré, Jørgen Elmeskov, Jeffrey Owens and Jean-Luc Schneider for their valuable comments, as well as Irene Sinha for excellent editorial support. The views expressed in this paper are those of the authors and do not necessarily reflect those of the OECD or its member countries.

2 OECD, Economics Department. 2, rue André-Pascal, 75775 Paris CEDEX 16, France. The paper was written while this author was employed at the Centre d'Etudes Prospectives et d'Informations Internationales (CEPII) and consulting for the OECD.

3 OECD Economics Department. 2, rue André-Pascal, 75775 Paris CEDEX 16, France.

4 See Myles (2008) for a survey, and Romer and Romer (2007), Lee and Gordon (2005) or Arnold (2008) for recent examples.

and investment within firms, hinders the process of reallocation of market shares from declining to rising firms, which is one important factor behind aggregate productivity improvements.

4. Corporate taxation may influence firm level TFP and investment through various channels. First, high corporate taxes may reduce incentives for productivity-enhancing innovations by reducing their post-tax returns. If there is some implicit progressivity in the corporate tax schedule, for instance through loss offset provisions, this effect can be expected to fall disproportionately on the most successful and innovative firms, a proposition for which a specific test is devised in the empirical part of this paper[5] Second, high corporate taxes may reduce incentives for risk taking by firms with negative consequences for productivity. If profits are taxed at a higher rate than losses are compensated, firms pay the statutory corporate tax rate in the event the risky project is successful, but is only partly compensated in the event it is unsuccessful.[6] In general, innovative projects that test new ideas on the market are riskier than other projects. Finally, high corporate taxes may reduce incentives to invest in physical capital by increasing the user cost of capital. If new vintages of physical capital embody technological progress this also has a direct effect on TFP. Moreover, if there is some progressivity in the corporate tax schedule, its effects can be expected to fall disproportionately on the most successful and innovative firms.

5. For the identification of the effect of different types of taxes on productivity, this paper uses a differences-in-differences estimation technique following Rajan and Zingales (1998). While these authors test whether the effect of financial openness on growth differs across sectors with different degrees of financial dependence, the test here is whether the effect of corporate taxes differs across firms in industries with different degrees of profitability. The identification assumption is that there are inherent characteristics to the production conditions in a given sector that determine the average profitability of firms in the industry. At the same time, the tax base for corporate taxes is larger for firms in more profitable sectors than for firms in unprofitable sectors, where the tax base may be closer to zero. It is therefore reasonable to assume that firm level TFP in sectors with high profitability should be affected more strongly by corporate taxes than in low-profitability sectors.

6. With respect to the identification of corporate tax effects on investment, this paper follows a user cost of capital approach. According to this approach, firms trade off revenues and costs of investing and invest so long as the benefits exceed the costs. The user cost varies both across countries and within countries over time due to factors unrelated to taxes (required rate of return, economic rate of depreciation, anticipated capital gains/losses) and due to tax factors (depreciation allowances and corporate taxes). At a given level of the other components, higher corporate taxes increase the user cost of capital and should therefore reduce investment.

7. The main results are as follows. First, corporate taxes have a significant negative effect on TFP at the firm level. A simulation experiment indicates that over 10 years the effect on the annual TFP growth rate of a reduction of the corporate tax rate from 35% to 30% would be 0.4 percentage points higher for firms in the sector with median profitability than in the sector with the lowest level of profitability. 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. Given that trend TFP growth of OECD countries averaged around 1.1% over the period 2000-2005 (OECD, 2007) this is actually a large number.

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5 With loss offset provisions relatively unsuccessful firms that suffer losses in some years can offset these against profits in other years. Effectively they are thus subject to lower marginal tax rates than relatively successful firms earning positive profits in all years.

6 Zilcha and Eldor (2004) show that corporate tax schedules in most countries are characterised by an asymmetric treatment of profits and losses.

8. Second, the negative effect of corporate taxes is uniform across firms of different size and age classes, except for firms that are both small and young. This may be due to the low average profitability of small and young firms, which reduces the amount of corporate taxes effectively paid by them.[7]

9. Third, firms that are in the process of catching up with the technological frontier are particularly affected by corporate taxes. Even in sectors with low average profitability there is a subset of highly profitable firms that are on a fast upward trend towards the technological frontier. These firms' tax base is large so that a high corporate tax rate increases their effective tax burden disproportionately.

10. Fourth, the results are consistent with the view that part of the effect of corporate taxes on TFP is driven by a reduction in the rate of technological progress embodied in new physical capital. The estimates suggest that the long-run elasticity of the investment rate with respect to the tax adjusted user cost is negative and around -0.7. The effect is larger in relatively profitable sectors where the tax base is large, indicating that the tax component of the user cost contributes significantly to the estimated negative effect of the user cost of capital on firm level investment

11. The remainder of this paper is organised as follows. Section 2 reviews the theoretical background and the related literature. Section 3 describes the data and gives details about the measurement of the dependent and explanatory variables. Section 4 outlines the estimation strategy and reports the results from the econometric analysis, while Section 5 implements a number of robustness checks on the results. A final section presents the conclusions.

2. Background and Related Literature

12. This section reviews the theoretical literature on the main channels through which corporate taxation may affect productivity and investment. Moreover, it illustrates the links between the present empirical approach and methodological developments in the literature.

Taxation and Growth at the Macro Level

13. A full review of the literature on the effects of taxation on economic growth at the macro level would be beyond the scope of this paper, and the interested reader is referred to Myles (2008) who provides a comprehensive survey of the long debate surrounding aggregate growth regressions. Nonetheless, three recent studies are worth mentioning in the present context. Introducing some interesting methodological innovations, Lee and Gordon (2005) and Romer and Romer (2007) find that taxation has substantial growth effects. The reported magnitude of these effects seems too large to be explained by effects on factor accumulation alone which suggests that taxation may additionally have an impact on productivity.

14. The main methodological innovation of Lee and Gordon (2005) and Romer and Romer (2007) is their way to deal with the issue of simultaneity between tax and growth rates.[8] Using cross country data on 70 countries over the period 1970-1997, Lee and Gordon (2005) analyse the effect of the statutory corporate tax rate on the growth rate of GDP. They instrument corporate tax rates by the average corporate tax rate in all other countries weighted by the inverse of distance. The justification for the choice of this

7 . An alternative explanation could would be that small firms benefit from exemptions or reduced targeted rates, However, the empirical findings do not support this explanation. The results suggest that the role of exemptions or reduced rates is limited.

8 . Tax rates may be correlated with GDP growth rates if the share of tax revenue in GDP is used as a measure of taxes. If statutory rates are used they may be correlated if policymakers adjust rates in response to the economic conditions.

instrument is that corporate tax rates are highly correlated across nearby countries but that a small country's countries corporate tax rate should not have a causal effect on the weighted average in all other countries. They estimate both pooled OLS and fixed effects models and find that a reduction in the corporate tax rate of 10 percentage points increases the growth rate by 1-2 percentage points.

15. Romer and Romer (2007) use quarterly data on tax revenue and GDP from US National Accounts over the period 1947-2006 and include only revenue changes attributable to changes in tax legislation in their analysis. They further distinguish legislated tax changes taken to return output growth to normal or to compensate for changes in spending and changes taken to promote long-run growth or to reduce a long-run budget deficit. The former are likely to be influenced by current and projected economic conditions and Romer and Romer (2007) therefore consider them as endogenous whereas the latter are a more exogenous measure of legislated tax changes. Indeed Romer and Romer's (2007) results indicate that not taking into account potential endogeneity may lead to substantial bias, in the sense that the effect of legislated tax changes on GDP growth is substantially larger when only exogenous changes are included in the analysis. More specifically, they estimate that an exogenous legislated tax increase of 1% of GDP increases the level of GDP after ten quarters by around 3%.

16. Arnold (2008) takes a different angle and focuses on the structure of taxes conditional on tax levels, rather than on tax levels per se. This approach sidesteps the endogeneity concerns to a large degree, although additional robustness checks are made to control for possible endogeneity issues. The results show that there are sizeable differences in the relationship between different kinds of taxes and GDP per capita. The findings suggest that a stronger reliance on income taxes, particularly corporate income taxes, is associated with significantly lower levels of GDP per capita than consumption and property taxes.

17. Recent studies on the effect of taxation on economic growth thus point to substantial effects that seem difficult to reconcile with factor accumulation explanations alone. Potential effects of taxation on productivity have been the subject of studies at a finer level of disaggregation.

Taxation and Productivity at the Micro Level

Effects on the rate innovation through appropriability and risk taking by firms

18. At least since Arrow (1962), the literature has studied the effects of appropriability of innovations on the rate of technological progress. If firms cannot appropriate the full return to an innovation, this reduces their incentives to engage in innovative activities and thus the rate of technological progress. This paper argues that corporate taxation reduces the post-tax return on innovation and thus the share of the profit increase appropriated by the firm. One would therefore expect the effect of corporate taxes on firm level innovation and TFP to be negative. In addition, loss offset provisions make the corporate tax schedule progressive. Relatively unsuccessful firms that suffer losses in some years can offset these against profits in other years. Effectively they are thus subject to lower marginal tax rates than relatively successful firms earning positive profits in all years. Due to this progressivity, one could expect the effects of corporate taxes on innovation to fall disproportionately on the most successful and innovative firms. In this sense corporate taxes can be viewed as "success taxes" (Gentry and Hubbard, 2004). The empirical analysis below includes a test of this specific hypothesis.

19. Moreover, this paper argues that corporate tax schedules with limited loss offset provisions may have negative effects on risk taking by firms. The rationale is that with limited loss offset provisions relatively low risk-low return projects are effectively taxed at a lower rate than relatively risky projects that may yield high returns. As an example, consider two projects yielding the same expected return r. Suppose that the first project yields r with certainty and the second project yields either $3r$ or $-r$ with equal probabilities. Suppose the statutory corporate tax rate is 30% and there are no loss offset provisions. Then

the after-tax return of the first project is 0.7*r* while it is 0.55*r* for the second project. Even a risk neutral entrepreneur would choose the first project since she would be subject to the statutory corporate tax in the event the second project were successful but would not be compensated for losses in the event of failure. Given that innovative projects that try out new ideas are more risky than other possible projects, high corporate taxes in combination with limited loss offset provisions may therefore lead to a suboptimal rate of innovation through a reduction in risk taking by firms.

Effects on Investment at the Micro Level

20. A vast body of literature has analysed the effects of corporate taxes on business investment in physical capital. There are three broad types of empirical approaches: Q-theory frameworks, user cost specifications and "natural experiment" analysis.

21. According to Q-theory, investment at the firm level is determined by Tobin's (1969) marginal Q, the ratio of the market value to the replacement cost of capital. As long as the market value of a marginal investment exceeds its costs, firms decide to invest. Based on Hayashi (1982) who shows that under some assumptions the marginal Q is equal to average Q, empirical applications usually approximate Tobin's Q by the ratio of the total stock market value of the firm to the replacement cost of its capital stock. This average Q can be adjusted for corporate taxes on firm level investment but the tax adjusted Q usually fails to explain both short- and long-run investment behaviour (see Hasset and Hubbard, 2002 for a recent literature review).[9]

22. User cost specifications typically use either time series or panel data and exploit variation of the tax adjusted user cost over time or across sectors to identify the effect on investment. In a recent survey Hasset and Hubbard (2002) suggest that the elasticity of the capital stock with respect to the tax adjusted user cost is probably between -0.5 and -1. Using cointegration techniques and time series data over the period 1962-1999 on Canada, where changes in corporate taxes are more likely to be exogenous since they are driven by occasional changes in the U.S. rather than by the domestic business cycle, Schaller (2006) finds a user cost elasticity of -1.6. Vartia (2008) applies a tax-augmented user-cost approach to industry level data and finds significant negative effects of corporate taxes on investment and productivity at the industry level.

23. The "natural experiment" approach focuses on episodes where corporate tax changes are large and account for a large share of the variation in the user cost of capital. This strand of the literature finds strong support for the claim that a higher corporate tax rate has a negative effect on business investment. Cummins *et al.* (1994) use firm level data for the United States over the period 1953-1988 from the Compustat database and episodes of major tax reforms in the United States to estimate the effect of corporate taxation on investment at the firm level. They find a significant and negative effect that is robust across econometric specifications. In a cross-country extension of their 1994 study with firm level data over the period 1982-1992 from the Global Vantage database, Cummins *et al.* (1996) confirm their previous results. House and Shapiro (2008) use reforms of corporate taxation in the United States in 2002 and 2003, which temporarily increased depreciation allowances, and find a negative effect of the tax adjusted user cost on investment at the sectoral level.

24. The user cost approach appears to be the most appropriate method to evaluate the effects of corporate taxation on firm level investment. The Q-theory approach is restricted to the subset of firms listed on stock markets and the "natural experiment" approaches focus on specific tax reform episodes. In

9 More recently Philippon (2008) and Gilchrist and Zakrajsek (2007) use US data on corporate bonds instead of stock markets to construct new measures of Tobin's Q. They find that these measures are both statistically and economically significant in explaining business investment.

this sense, these studies are difficult to generalise. The user cost approach, in contrast, uses both variation of corporate taxes across countries and over time and results therefore appear to be more easily generalisable.

3. Data and Methodology

25. The analysis of taxation and growth poses particular challenges if the estimating equation omits some observed or unobserved variables that are possibly correlated with the variable of interest, and there is a limit to the kind of remedies available for macro level data. At a lower level of aggregation, however, a wider array of choices is available. Beyond the usual panel data techniques (Wooldridge 2002), Rajan and Zingales (1998) propose a differences-in-differences estimation technique. More specifically, they use differences in the effect of financial openness on sectors within the same country to identify the effect of financial openness on growth. Their (untestable) identifying assumption is that sectors that typically depend more strongly on external finance due to technological conditions of production should grow faster relative to less financially dependent sectors in an environment with well-developed financial markets, even after controlling for all observed and unobserved country-specific characteristics. The basic insight that variation across sectors within the same country can be used to analyse the effects of a country-specific variable applies directly to the present context. More specifically, the assumption is that the production technology in a sector determines average profitability of firms, which in turn determine the relative size of the tax base. The identifying assumption is that firm level TFP growth in very profitable sectors should be lower relative to sectors with low profitability in countries with high corporate taxes. The rationale is that the tax base in very profitable sectors is large whereas it may be small or close to zero in sectors with low profitability. Moreover, corporate tax schedules are in general progressive, among others due to loss offset provisions, thereby penalising firms with large tax bases.

26. The analysis of the effect of corporate taxation on productivity is further related to Griffith *et al.* (2006). In their analysis of the effect of multinationals on technological catch up using UK firm level data, they show that TFP growth in non-frontier firms depends on TFP growth at the technological frontier and on the distance to the frontier. This motivates the specification of the present empirical model of firm level TFP. More specifically, this paper carefully constructs measures of TFP growth at the technological frontier and distance to the frontier, and includes them as control variables in the estimating equation.

27. The analysis of investment at the firm level is closely related to Becker and Sivadasan (2007) who base their estimating equation on an Euler equation. In their analysis they do not use firm level Q as a control because the market to book value is not available for non-listed firms, and such firms account for the largest part of their sample. Instead, they control for investment opportunities by including firm level characteristics in their estimating equation and they control for the user cost of capital by including a vector of sector-year indicators. Here, this approach is modified by replacing the sector-year indicators with a sector-year specific measure of the tax adjusted user cost of capital (see Vartia, 2008 for a description of this measure).

28. The main results refer to a sample of firms extracted from the Amadeus (Bureau van Dijk) database. This database covers European OECD member countries over the time period 1996-2004.[10] However, Central and Eastern European Countries have been excluded from the analysis due to their particular situation as transition economies. If the firm population of these economies is structurally different from the remaining countries because they have been undergoing a process of transitional structural change from central planning to a market economy, this would risk contaminating the conclusions. Non-European OECD countries are covered in the Worldscope (Thomson Financial) database. However, the latter database covers only listed firms, which differ from the sample of firms in

10 . A few firms even contain data from earlier years but the coverage is small before 1996.

Amadeus along various dimensions, not least their size distribution. To include non-European OECD countries into the analysis, one has to restrict the Amadeus sample to relatively large firms, which reduces the sample size considerably. The results for the the joint Amadeus-Worldscope sample broadly confirm the findings from the larger Amadeus-only sample including small non-listed firms. These results are presented in the robustness checks.

29. The data have been cleaned for outliers and obvious keypunch errors. Observations with negative values for any variable entering the production function (value-added, wages, capital stock, material inputs) or with depreciation above net capital stock were eliminated from the sample. Firms that report extreme year-to-year variation in ratios between production function variables and extreme reversals in one of the production function variables were not retained either. Finally, outliers have been removed by eliminating the top and bottom percentile of the productivity estimates and subsequently re-estimating productivity without these extreme observations (the productivity estimation is described in more detail below).

30. The analysis is restricted to firms in the manufacturing and services sectors (Nace 15-93). The sectors recycling (Nace 37), refuse disposal (Nace 90) and utilities (Nace 40, 41) are excluded due to a high share of public ownership in some countries over the sample period. Financial services (Nace 65-67), real estate (Nace 70) and holding companies (Nace 7415) are excluded due to different reporting standards in these sectors. Similarly, public administration (Nace 75), education (Nace 80), health (Nace 85) and activities of membership organisations (Nace 91) have been excluded due to the non-profit character of these activities in many OECD countries.

Productivity and investment measures

31. For the productivity analysis, three measures of total factor productivity (TFP) are used. The first two measures are calculated as the residual from the estimation of a logarithmic Cobb-Douglas production function of the form:

$$\ln Y_{it} = \theta_{cs} + \alpha_{cs} \ln L_{it} + \beta_{cs} \ln K_{it} + \varepsilon_{it} \qquad [1]$$

where the subscripts *i* stand for the firm, *t* for time, *c* for country and *s* for sector.

32. The dependent variable of the production function is a firm's value-added, with labour and capital as production factors. In the Amadeus sample, primary information on value-added has been corrected for extraordinary profits.[11] In Worldscope, value-added is constructed by subtracting the cost of goods sold from net sales and adding total wages. Labour inputs are measured using primary information on the total wage bill, while primary information on net capital stocks has been used to account for capital inputs. Nominal values are deflated using sector-specific price indices from the EUKLEMS database, with the exception of capital stocks that have been deflated using deflators for gross fixed capital formation from the OECD Economic Outlook database. The production function is estimated at the country-sector level (hence the subscripts *cs* on the production function coefficients), in order to avoid strong assumptions about the homogeneity of production technologies across all OECD countries.

33. A first set of productivity estimates, used as the baseline specification, was obtained by estimating equation (1) using ordinary least squares (OLS). A second set of productivity estimates was based on the semi-parametric estimator proposed by Levinsohn and Petrin (2003). The latter technique is

11 . Extraordinary positions are revenues or expenses that are not related to the regular business activities of a company, such as insurance claims. In case primary information on value-added was not available, it was imputed as the residual between operating revenue and material inputs.

robust to the potential endogeneity of firms' input choices: Firms may observe shocks to TFP that are unobserved by the econometrician and may adjust their input choices accordingly. This would generate a correlation between the regressors and the error term in equation (1) and hence would cause OLS estimates of TFP to be biased. The Levinsohn and Petrin (LP) method avoids such a bias by using information on the intermediate input use of firms to proxy for unobserved productivity shocks. However, the LP method has the drawback that it requires additional information on material inputs, which was not available for all countries and sectors. As a result, TFP estimates based on this method could not be estimated for all the firms for which OLS estimates are available. Results using TFPs estimated with the LP method are presented in Section 5 as a robustness check.

34. One drawback of the production function approach is that the resulting estimates for TFP levels are not comparable across countries and industries, because they result from country-sector-specific estimations of the production function. For this reason, a third measure of TFP has been calculated using a superlative index number approach (see Caves *et al.* 1982a,b). While the index approach allows comparisons of TFP in levels, it is based on a number of potentially restrictive assumptions, including constant returns to scale and perfect competition on factor markets. Following Griffith *et al.* (2006), the index measures of TFP growth and TFP level in firm *i* at time *t* are calculated as

$$\Delta TFP_{it} = \Delta \ln Y_{it} - \sum_{z=1}^{Z} \widetilde{\alpha}_{it} \Delta \ln x_{it}^{z}, \qquad [2]$$

$$TFP_{it} = \ln\left(Y_{it} / \overline{Y}_{s}\right) - \sum_{z=1}^{Z} \sigma_{i}^{z} \ln\left(x_{it}^{z} / \overline{x}_{s}^{z}\right),$$

where Y is value added, x^z is use of factor z, $\widetilde{\alpha}_{it}^{z}$ is the Divisia share of value added ($\widetilde{\alpha}_{it}^{z} = \left(\alpha_{it}^{z} + \alpha_{it-1}^{z}\right)/2$), with α_{it}^{z} the share of factor z in value added at time t), $\overline{Y}_{s}$ and $\overline{x}_{s}^{z}$ are geometric means of value added and use of factor z of all firms in the same industry over all countries and years, and $\sigma_{i}^{z} = \left(\alpha_{i}^{z} + \overline{\alpha}_{s}^{z}\right)$ is the average of the factor share in firm i and the geometric mean factor share in industry s. There are two factors of production ($Z = 2$), capital and labour, and by imposing $\sum_{z} \widetilde{\alpha}_{it}^{z} = 1$ and $\sum_{z} \sigma_{i}^{z} = 1$ $\Sigma_z \sigma_i^z = 1$ constant returns to scale are assumed.

35. For the investment analysis, gross investment is calculated as first differences of net capital stocks plus depreciation in the Amadeus data, while the Worldscope data contains primary information on additions to fixed capital stocks. Following Becker and Sivadasan (2007) the analysis is restricted to observations with strictly positive investment-to-capital ratios. Moreover, observations with investment-to-capital ratios that are larger than one are excluded to make sure that the results are not driven by extreme outliers of the investment ratio. The fact that the results remain qualitatively unchanged in the robustness checks in Section 5, where 1.5 is chosen as the threshold above which investment ratios are dropped, suggests that this does not give rise to a truncation bias.

Achieving a representative dataset through resampling

36. Since only a subset of the firms in the Amadeus data reports information on all production function variables, the size of the original Amadeus dataset is significantly reduced once measures of productivity have been obtained. There is no assurance that the remaining sample, in which only firms with TFP estimates were retained, can be considered representative of the population distribution of firms across size classes, sectors, and countries. The TFP sample of firms was therefore brought in line with the distribution of the true firm population using the following re-sampling procedure. First, population weights for all size-sector-country strata were obtained from the Eurostat *Structural Business Statistics*

database for the year 2000, for European countries. For non-European OECD members data on sector and size distributions were obtained from the national statistical institutes. Then, random draws with replacement from each size-sector-country stratum in the TFP sample were taken until the weight of each stratum corresponds to its population weight.[12]

37. This method resulted in representative sample of the population distribution along the dimensions size, sector, and country for the years 1998-2004. The total sample size in the Amadeus sample is set to 100 000 firms which results in 537 309 firm-year observations. When adding firms from three additional countries using a joint Amadeus-Worldscope sample, the sample had to be restricted to firms above 100 employees, because Worldscope only includes listed firms which tend to be larger. As a result, the size of this second sample is smaller, with 43 599 firms and 198 940 firm-year observations.

Treatment of multinational companies

38. The firm level data used for this analysis contain a considerable number of multinational enterprises, and given their intra-firm trade relationships across borders, these firms are likely to be affected by taxes in a way that differs from firms with operations in a single country. Moreover some countries grant tax credits to multinationals for taxes paid abroad, thus making their effective tax rate independent of the statutory corporate tax rate faced in their country of operation. To make sure that the results are not contaminated by international tax optimisation or by a specific treatment of multinationals in the tax code, firms that form part of multinational enterprises are excluded from the Amadeus sample used here. After the re-sampling described above, in a first step consolidated accounts in the Amadeus dataset are dropped, which avoids problems of double-counting.[13] In a second step, firms with a foreign owner or a foreign subsidiary are eliminated from the sample.[14] The procedure for the Worldscope dataset is somewhat more approximate since detailed information on ownership structure is not available. For this dataset firms that report a strictly positive share of foreign assets are excluded. Note, finally, that the estimation sample is restricted to incorporated firms because only these firms are subject to corporate taxes.[15]

Taxes, the user cost of capital and profitability

39. Information on statutory corporate tax rates comes from the OECD Tax Database. The sector-specific user cost of capital measure is obtained as the asset-weighted sum of asset-specific user costs by

12. In the Amadeus sample the re-sampling procedure is restricted to firms with at least 20 employees since coverage for firms below this threshold is unsatisfactory. In the joint Amadeus-Worldscope sample the re-sampling procedure to firms is restricted to firms with at least 100 employees since the Worldscope data only cover listed firms which have, in general, employment figures above 100.

13. Only accounts with a value of "U1" (unconsolidated account, when there is no recorded consolidated companion), "U2" (unconsolidated account, when there is a recorded consolidated companion) or "LF" (limited number of financial items) for the "type of account" variable are retained.

14. Firms that report at least one subsidiary with a different value of the "subsidiary - country iso code" variable than its own "country iso code" are dropped, as well as firms that report a different value of the "global ultimate owner - country iso code" variable. The following definition of the ultimate owner is used: The ownership path from the firm to its ultimate owner is characterised by an ownership share of more than 50% and firms for which no shareholder is identified or for which ownership shares are unknown are also considered as ultimate owners. According to this definition, approximately 18% of the firms in the stratified sample of firms with more than 20 employees are multinational.

15. Practically, in the Amadeus sample, this is achieved by considering only firms with a strictly positive difference between reporting year and year of incorporation while it can plausibly be assumed that all firms in the Worldscope sample are incorporated since they are listed on stockmarkets.

sector. The asset-specific user cost of capital, in turn, combines *i)* an asset's required rate of return, the economic rate of depreciation, anticipated capital gains/losses due to a change in its before-tax price and *ii)* an adjustment for corporate taxes and depreciation allowances in the following formula:

$$UC_a = \frac{p_a}{p}\left(\rho + \delta_a - E\left(\Delta p_a / p_a\right)\right)\frac{1-\tau Z_a}{1-\tau} \qquad [3]$$

where a denotes an asset and p_a/p, ρ, δ and $E(\Delta p_a/p_a)$ the asset price of relative to the output price, the required rate of return, the rate of economic depreciation and the expected change in the asset price, respectively. τ and Z denote the corporate tax rate and the present value of depreciation allowances. Data on asset shares are from the Bureau of Economic Analysis (BEA). Asset and output prices, rates of return, economic depreciation are extracted from the OECD Productivity Database and data on the tax adjustment are obtained from the Institute for Fiscal Studies (IFS).

40. Finally, information on the profitability of industries is calculated from the 1997 Input-Output matrix for the United States (Bureau of Economic Analysis 1997).[16] The profitability ratio of a given industry has been expressed relative to the profitability of the median industry. Similarly to Rajan and Zingales (1998), profitability differences across industries in the United States are applied to all countries, assuming that most of these differences are due to inherent technological conditions of the industry. At the same time, the use of a predetermined measure of profitability reduces simultaneity with the dependent variable, firm level productivity. It is also independent of the level of the statutory corporate tax. This addresses *i)* the issue that in countries with high statutory corporate tax rates firms tend to underreport their profits and *ii)* that high statutory corporate taxes may be positively correlated with high levels of product market regulation, which may in turn affect profitability.

4. Econometric Results

Productivity results

41. The main productivity results reported in this section refer to firm level TFP estimated by OLS, with additional robustness checks using different TFP estimates presented below. Following Griffith *et al.* (2006) a specification that captures two empirical regularities, namely convergence of firm level TFP levels and persistence of TFP levels over time is estimated.[17] More specifically, firm level TFP levels are assumed to follow the following Autoregressive Distributed Lag ADL(1,1) process:

$$\ln A_{icst} = \alpha_0.\Delta \ln A_{icst-1} + \alpha_1.\ln A_{Fcst} + \alpha_2.\ln A_{Fcst-1} + \alpha_3.relprof_s.T_{ct-1} + \gamma_s + \gamma_{ct} + \varepsilon_{isct}, \qquad [4]$$

where A_{icst} is the TFP level of a non-frontier firm i, A_{Fcst} is the TFP level at the technological frontier F, $relprof_s$ is relative profitability in sector s, T_{ct-1} is the statutory corporate tax rate in country c at time t-1, and γ_s, γ_{ct} are sector and country-year fixed effects, respectively. ε_{isct} is a random error term.

16 More specifically, input-output tables for the year 1997 from the Bureau of Economic Analysis are used to compute profitability by sector in the United States. Profitability is defined as the share of profits in value added.

17. In contrast to Griffith et al. (2006), the present analysis does not account for firm heterogeneity in innovative capabilities by including firm specific fixed effects, since corporate taxes may affect TFP levels through a reduction of a firm's innovative capabilities.

42. The inclusion of the interaction $relprof_s \times T_{ct-1}$ implements the differences-in-differences identification strategy, in the sense that differences of TFP levels between firms in relatively profitable and unprofitable sectors in countries with different levels of corporate taxes are used for the identification of the effect of corporate taxes on TFP. The TFP level at the technological frontier is measured as average TFP of the 5% most productive firms in country *c*, in sector *s* in year *t*. Note that firms forming part of multinational groups are dropped from the sample only after the leader TFP level has been calculated. This reduces the potential dependence of the leader TFP level on the corporate tax: The share of multinational firms, which have enhanced possibilities to engage in international tax optimisation, turns out to be high at the technological frontier: In approximately 68% of countries, sectors and years a multinational firm enters the calculation of the leader TFP level. However, to ensure the robustness of the results even in the case of a possible correlation between corporate taxes and the leader TFP level, the superlative TFP index described in Section 3 is calculated by pooling firms within the same sector across countries. In this case, the dependence of the leader TFP level on the corporate tax level in country *c* at time *t* is very limited since only a small fraction of leading firms are from country *c*. The results from this specification reported in Section 5 are similar to the ones reported here.

43. The ADL(1,1) model requires a stationarity condition: If $\ln A_{icst-1}$ and $\ln A_{Fcst-1}$ are non-stationary, this can lead to spurious estimation results. To rule out such a possibility, Levin-Lin-Chu panel unit root tests have been run to test for non-stationarity. The results indicate that both $\ln A_{icst-1}$ and $\ln A_{Fcst-1}$ are indeed stationary. Even though this would allow estimating equation 5 directly, it is re-written in an error correction model (ECM) representation for interpretational ease:[18] Under the assumption of long-run homogeneity $(\alpha_1 + \alpha_2)/(1-\alpha_0) = 1$, the ADL(1,1) process has the following simple Error Correction Model (ECM) representation:

$$\Delta \ln A_{icst} = \beta_0 . \Delta \ln A_{Fcst} + \lambda . \ln\left(\frac{A_{ics,t-1}}{A_{Fcs,t-1}}\right) + \beta_1 . relprof_s . T_{ct-1} + \gamma_s + \gamma_{ct} + \varepsilon_{isct}, \qquad [5]$$

44. The ECM representation has the following straightforward interpretation. Productivity growth of firm *i* is expected to increase with productivity growth of the frontier firm *F* and with firm *i*'s distance from the frontier firm *F*. Note that, even though an ECM representation is estimated, the underlying ADL(1,1) model is in productivity levels and not in growth rates.[19] Note further that A_{icst-1} enters both the dependent variable and the relative TFP variable. This may lead to simultaneity bias due, for instance, to measurement error in A_{icst-1}. This issue is addressed in the robustness checks in Section 5 by instrumenting A_{icst-1} with higher order lags. The results from the instrumental variables specification are similar to the ones reported here.

45. The statutory corporate tax enters the ECM interacted with the relative profitability in sector *s*: $relprof_s relprof_s . T_{ct} \times T_{ct-1}$. Since both unobserved sector specific effects and unobserved country-year specific effects are controlled for, the constituent terms do not enter the estimating equation separately. The effect of corporate taxes is identified through a differences-in-differences strategy: Firms in relatively profitable sectors are expected to display relatively slower TFP growth in countries in which the statutory

18 ECMs are commonly estimated in the context of non-stationary data since first differencing and a correct specification of the long-run cointegrating relationship remove any non-stationarity from the data (Henry, 1996). However, ECMs are obtained from ADL(1,1) models by algebraic transformation only and as such fully equivalent. They are therefore also suitable for stationary data (De Boer and Keele, 2008).

19. There is firm heterogeneity in TFP levels in equilibrium because *i)* innovation potential of the frontier firm is higher than innovation potential of the non-frontier firms and *ii)* convergence to the frontier takes time.

corporate tax rate is high.[20] The rationale is that corporate taxes are expected to reduce the after-tax return of a TFP enhancing investment, and that the negative effect on investment is stronger in sectors in which the tax base is larger. Note that a pre-determined measure of relative profitability based on sectoral United States data is used, instead of primary information on firm level profitability. The latter would not seem like a good choice since it is likely to be contaminated, in the sense that firm level profitability could be endogenous to taxation. Standard errors are clustered by country and sector to allow the error term to be correlated in an unrestricted way across firms and time within sectors in the same country (Moulton, 1991, Bertrand *et al.* 2004).

Table 1. Corporate Taxes and TFP Growth at the Firm Level

The estimated equation is

$$\Delta lnTFP_{icst} = \delta_1 \Delta lnTFP_{Fcst} + \delta_2 ln(TFP_{ics,t-1}/TFP_{Fcs,t-1}) + \delta_3 Profit_s * TAX_{c,t-1} + \gamma_s + \gamma_{ct} + \varepsilon_{icst}$$

Dependent Variable: TFP growth	(1)	(2)	(3)	(4)
Basic Model				
Leader TFP Growth	0.173***	0.173***	0.173***	0.173***
	(0.019)	(0.019)	(0.019)	(0.019)
TFP Relative to Leader (t-1)	-0.190***	-0.190***	-0.190***	-0.190***
	(0.015)	(0.015)	(0.015)	(0.015)
Interactions between firm & sector characteristics & tax				
Profitability & tax	-0.307**			
	(0.128)			
Profitability & tax (Empl<30)		-0.238*		
		(0.128)		
Profitability & tax (Empl>=30)		-0.336**		
		(0.132)		
Profitability & tax (Age<6)			-0.218*	
			(0.130)	
Profitability & tax (Age>=6)			-0.335**	
			(0.131)	
Profitability & tax (Age<6&Empl<30)				-0.145
				(0.176)
Profitability & tax (Age<6&Empl>=30)				-0.275**
				(0.130)
Profitability & tax (Age>=6&Empl<30)				-0.285**
				(0.127)
Profitability & tax (Age>=6&Empl>=30)				-0.357***
				(0.134)
Observations	287 727	287 727	287 727	287 727
Fixed effects:				
Sector	yes	no	no	no
Sector-size	no	yes	no	no
Sector-age	no	no	yes	no
Sector-size-age	no	no	no	yes
Country-year	yes	yes	yes	yes
R^2	0.10	0.10	0.10	0.10

(i) In the estimated empirical model $\Delta lnTFP_{icst}$ denotes TFP growth in firm i, country c, sector s and year t, *(ii)* $\Delta lnTFP_{Fcst}$ denotes TFP growth in the technological leader firm, *(iii)* $(TFP_{ics,t-1}/TFP_{Fcs,t-1})$ denotes the inverse of distance to the leader, *(iv)* $Profit_s * TAX_{c,t}$ the interaction between profitability and the corporate tax, *(v)* γ_s and γ_{ct} sector and country-year fixed effects, respectively. The estimation sample contains 12 European OECD countries over the period 1998-2004. TFP is the residual of a Cobb-Douglas production function estimated at the country-sector level. Robust standard errors corrected for clustering at the country-sector level in parentheses. * denotes significant at 10%; ** at 5%; *** at 1%

20 Note that the interaction term may also be interpreted as an "effective tax rate", in the sense that the multiplication of the tax base with the statutory rate proxies the taxes effectively paid by the firm.

46. The results from estimating equation (2) are reported in Table 1. Column (1) shows that the estimated coefficients on frontier TFP growth and on the TFP gap have the expected signs and are significant at the 1% level. The interaction between relative profitability and the statutory corporate tax is negative and significant at the 5% level. Corporate taxes reduce productivity at the firm level. A simulation experiment indicates that over 10 years the effect on the annual TFP growth rate of a reduction of the corporate tax rate from 35% to 30% would be 0.4 percentage points higher for firms in the sector with median profitability than in the sector with the lowest level of profitability. 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. Given that trend TFP growth of OECD countries averaged around 1.1% over the period 2000-2005 (OECD, 2007) this is actually a large number.[21]

47. In Column (2), the coefficient on the interaction between relative profitability and the statutory corporate tax rate is split into a coefficient for firms with less than 30 employees and one for the remaining firms. This specification includes size-specific sector fixed effects to account for differences in average productivity growth across small and large firms in the same sector. The estimated coefficient for small firms is closer to zero than the estimate for medium-sized and large firms. There are two possible explanations for the reduced effect on small firms. Firstly, differences in profitability across sectors may be less pronounced for small firms than for large firms if small firms have a generally low level of profitability. Secondly, small firms may enjoy exemptions from the statutory corporate tax rate or reduced rates in some countries. The latter explanation, however, finds little support in the results presented in Column (4) (see below).

48. The specification in Column (3) allows for heterogeneity in the effect of corporate taxes across young and old firms. The estimated coefficient for young firms is closer to zero than the ones for the remaining firms. In other words, the TFP growth performance of young firms appears to be somewhat less affected by corporate taxes than the performance of the remaining firms. Possible explanations are again a generally lower profitability of young firms and exemptions or reduced rates if the group of young firms is composed of a disproportionately large share of small firms.

49. Going one step further, the coefficient on the interaction between relative profitability and the statutory corporate tax is split four ways in Column (4), allowing for heterogeneity in the effect of corporate taxes across size-age categories. This specification includes size-age specific sector fixed effects to account for differences in average productivity growth across firms in different size-age categories in the same sector. Interestingly, all firms are found to be negatively affected by corporate taxes except for the young-small.[22] Exemptions or reduced rates are, in general, targeted at small firms and not specifically at start-up firms. But since the group of small-old firms is negatively affected by corporate taxes, it seems appropriate to conclude that it is not exemptions or reduced rates for small firms that drive the non-significance for the category of young-small firms. Instead, the more likely explanation is that start-ups have low or zero profits, even in sectors that are characterised by a high average profitability.

50. The next step is to investigate whether the statutory corporate tax rate has a differential effect on firms that are in the process of catching up towards the frontier (rising firms), as opposed to firms that are falling behind (declining firms). If corporate taxes are indeed "success taxes", as argued previously, then

21 The coefficient on the interaction term relprofs×Tct-1 is identified through variation of relative profitability across sectors and both variation of corporate taxes across countries and within the same country over time. Strictly speaking, the simulation experiment should therefore not only be phrased in terms of within country corporate tax changes but also in terms of corporate tax differences between countries.

22 . One can reject the hypothesis that the tax effects are zero for all groups except for the small and young. Strictly speaking, however, one cannot, show that there are statistically significant differences between the tax effects across categories of firms, due to the large standard errors of the estimated coefficients.

one would expect successful, rising firms to be more negatively affected than unsuccessful, declining firms. In terms of the identification strategy, one would expect a higher profitability for rising firms than for declining firms, which are expected to have a low profitability even in sectors that are, on average, relatively profitable. Given the larger tax base of rising firms and the implicit progressivity of the corporate tax schedule, their TFP growth would then be more negatively affected by the statutory corporate tax than that of declining firms.

Table 2. The effect of corporate taxes on TFP in rising vs. declining firms

The estimated equation is

$$\Delta lnTFP_{icst} = \delta_1 \Delta lnTFP_{Fcst} + \delta_2 ln(TFP_{ics,t-1}/TFP_{Fcs,t-1}) + \lambda_1 *I*Profit_s *TAX_{c,t-1} + \gamma_{sI} *I + \gamma_{ct} + \varepsilon_{icst}$$

Dependent Variable: TFP growth	(1)	(2)	(3)
Basic model			
Leader TFP growth	0.493***	0.501***	0.204***
	(0.021)	(0.022)	(0.019)
TFP relative to leader (t-1)	-0.117***	-0.115***	-0.186***
	(0.010)	(0.010)	(0.015)
Rising	0.184***		
	(0.016)		
Interactions between firm & sector characteristics & tax			
Rising & profitability	0.117***		
	(0.027)		
Declining & profitability & tax	-0.027	-0.038	-0.126
	(0.090)	(0.088)	(0.113)
Rising & profitability & tax	-0.251***	-0.251***	-0.268**
	(0.091)	(0.090)	(0.120)
Observations	287 727	287 727	287 727
Fixed effects:			
Sector	yes	no	no
Sector-catchup	no	yes	yes
Country-year	yes	yes	yes
R^2	0.44	0.44	0.14

(i) In the estimated empirical model $\Delta lnTFP_{icst}$ denotes TFP growth in firm i, country c, sector s and year t, *(ii)* $\Delta lnTFP_{Fcst}$ denotes TFP growth in the technological leader firm, *(iii)* $(TFP_{ics,t-1}/TFP_{Fcs,t-1})$ denotes the inverse of distance to the leader, *(iv)* $Profit_s *TAX_{c,t}$ the interaction between profitability and the corporate tax, *(v)* γ_s and γ_{ct} sector and country-year fixed effects, respectively. The estimation sample contains 12 European OECD countries over the period 1998-2004. TFP is the residual of a Cobb-Douglas production function estimated at the country-sector level. I is an indicator variable that takes a value of 1 if the firm is in the process of catching up with the technological frontier and a value of 0 otherwise. Robust standard errors corrected for clustering at the country-sector level in parentheses. * denotes significant at 10%; ** at 5%; *** at 1%

51. Table 2 reports the results for three variants of the basic estimating equation (2), where the effect of corporate taxes is allowed to vary across rising and declining firms. In Columns (1) and (2) a rising firm is defined as a firm that is contemporaneously reducing the TFP gap with the technological frontier. One problem with this measure is simultaneity since the firm's contemporaneous TFP level enters both the dependent variable and the indicator for rising firms.[23] To address this issue, in Column (3) the more

23. The indicator for rising firms is constructed using only the sign of the first difference of the TFP gap, which limits possible endogeneity problems due to the dependent variable entering the calculation of the first difference of the TFP gap.

restrictive definition of a rising firm includes only firms that are reducing the TFP gap with the technological frontier over the sample period. Since the indicator variable for a rising firm now depends on TFP levels in all sample periods, the potential for simultaneity with the dependent variable is reduced in this specification.

52. Column (1) includes the indicator for rising firms both non-interacted and interacted with the $relprof_s \times T_{ct}$ term. The non-interacted indicator variable controls for average differences in TFP growth between rising and declining firms. Not surprisingly, firms that are catching up have, on average, higher TFP growth, and this is particularly pronounced in sectors that are relatively more profitable, as indicated by the positive coefficient on the interaction between rising and profitability. But more interestingly, the coefficient on the interaction between relative profitability and the statutory corporate tax is only negative and significant for rising firms. The statistically insignificant coefficient on the interaction between declining firms and the $relprof_s \times T_{ct}$ term indicates that declining firms are not affected by corporate taxes. In Column (2), average differences between rising and declining firms in all sectors are controlled for by including sector fixed effects that are differentiated by type of firm. The results from this more demanding specification only confirm the prior findings. To reduce potential simultaneity problems, Column (3) uses a more restrictive definition of rising firms including only firms that have reduced the TFP gap with the technological frontier over the sample period. The difference in the estimated coefficients on leader TFP growth and relative TFP between Columns (1) and (2) and Column (3) confirms that the estimates in Columns (1) and (2) may indeed suffer from simultaneity bias. The estimated coefficients on leader TFP growth and relative TFP in Column (3) are close to the ones in Table 1, supporting this specification. The result that the negative effect of corporate taxes on TFP is fully borne by successful rising firms is confirmed in this specification.

Investment results

53. The analysis of firm level investment follows the approach of Becker and Sivadasan (2006) who derive the following estimating equation from an Euler equation:

$$\left(\frac{I}{K}\right)_{icst} = \beta_1\left(\frac{I}{K}\right)_{ics,t-1} + \beta_2\left(\frac{I}{K}\right)^2_{ics,t-1} + \beta_3\left(\frac{CF}{K}\right)_{ics,t-1} + \beta_4 UC_{cs,t-1} + \gamma_s + \gamma_{ct} + \varepsilon_{icst}, \qquad [6]$$

where I denotes gross investment, K last year's capital stock, CF cash flow, UC the tax adjusted user cost of capital, γ_s and γ_{ct} sector and country-year fixed effects, and ε_{icst} a random error term. The lagged dependent variable and its square capture the dynamics of the investment process. With quadratic adjustment costs, as in Becker and Sivadasan (2006), it is expected that the coefficient on the lagged dependent variable is positive and the coefficient on its square is negative. The cash flow ratio captures the effect of financial market imperfections. It is expected that credit constrained firms' investment increases with their access to internal funds. The user cost of capital combines the real cost of debt and equity financing, the economic rate of depreciation, real capital gains and losses and an adjustment for taxes into a single measure and is expected to reduce investment. The results are reported in Table 3.

54. The specification in Column (1) shows that all the coefficients have the expected sign: The lagged investment-to-capital ratio enters positively, its square negatively, the lagged output and cash flow ratios positively, and the tax adjusted user cost negatively. All of these findings are in line with the results of Becker and Sivadasan (2006). The average long-run user cost elasticity of the investment-to-capital ratio is estimated to be -0.69.[24] A simulation experiment indicates that a reduction of the corporate tax rate from 35% to 30% reduces the user cost by approximately 2.8%. With a long-run elasticity of the investment-to-

24. The average long-run user cost elasticity is obtained as $\sigma=\beta4/(1-\beta1-\beta2(I/K)).(UC/(I/K))$, where I/K and UC denote, respectively, the average investment ratio and user cost in the sample.

capital ratio of -0.69, this implies a long-run increase of the investment-to-capital ratio of approximately 1.9%. At its sample median of 18.4%, this corresponds to a 0.35 percentage points increase in the investment-to-capital ratio. If investment is expressed in terms of its ratio to value added, this corresponds to a 0.14 percentage points increase in the investment-to-value added ratio at its sample median of 7.5%.

Table 3. Investment at the Firm Level

The estimated equation is

$$(I/K)_{icst} = \beta_1 (I/K)_{ics,t-1} + \beta_2 (I/K)^2_{ics,t-1} + \beta_3 (Y/K)_{ics,t-1} + \beta_4 (CF/K)_{ics,t-1} + \beta_5 UCtax_{cs,t-1} + \gamma_s + \gamma_{ct} + e_{icst}$$

Dependent Variable: Investment-to-capital ratio	(1)	(2)	(3)
Basic model			
Investment-to-capital ratio (t-1)	0.532***	0.531***	0.534***
	(0.026)	(0.026)	(0.026)
Investment-to-capital ratio squared (t-1)	-0.415***	-0.414***	-0.418***
	(0.025)	(0.025)	(0.025)
Output-to-capital ratio (t-1)	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)
Cashflow-to-capital ratio (t-1)	0.048***	0.048***	0.047***
	(0.003)	(0.003)	(0.003)
Tax adjusted user cost (t-1)	-0.829**	0.147	
	(0.410)	(0.689)	
Interactions between firm & sector characteristics & tax			
Profitability & tax adjusted user cost		-0.723**	
		(0.351)	
Tax adjusted user cost (Age<6&Empl<30)			-0.339
			(0.497)
Tax adjusted user cost (Age<6&Empl>=30)			-0.401
			(0.476)
Tax adjusted user cost (Age>=6&Empl<30)			-0.832*
			(0.437)
Tax adjusted user cost (Age>=6&Empl>=30)			-1.039**
			(0.430)
Long-run tax adjusted user cost elasticity	-0.69		
Observations	211 599	211 599	211 599
Fixed effects:			
Sector	yes	yes	yes
Size-age	no	no	yes
Country-year	yes	yes	yes
R^2	0.12	0.12	0.12

(i) In the estimated empirical model $(I/K)_{icst}$ denotes the investment-to-capital ratio, (ii) $(I/K)_{ics,t-1}$ its lag, (iii) $(I/K)^2_{ics,t-1}$ its squared lag, (iv) $(Y/K)_{ics,t-1}$ the lag of the output-to-capital ratio, (v) $(CF/K)_{ics,t-1}$ the lag of the cashflow-to-capital ratio, (vi) $UCtax_{cs,t-1}$ the lag of the tax adjusted user cost and (vii) γ_s and γ_{ct} sector and country-year fixed effects, respectively. The estimation sample contains 12 European OECD countries over the period 1998-2004 and only observations with investment ratios beween 0 and 1. Robust standard errors corrected for clustering at the country-sector level in parentheses. * denotes significant at 10%; ** at 5%; *** at 1%

55. There are in principle two potential explanations for the negative effect of the user cost detected in Table 3. The negative effect of the tax adjusted user cost on investment can either be driven by the components of the user cost that are unrelated to taxes (*e.g.* real cost of debt and equity financing, economic rate of depreciation, real capital gains/losses) or by the tax adjustment components (corporate tax corrected for depreciation allowance). It is unlikely that the effect of the components unrelated to taxes

increases systematically with relative profitability. If the negative effect on investment results, at least partly, from the tax adjustment component, it should therefore be stronger in relatively profitable sectors where the tax base is large.[25] This conjecture is tested in Column (2) of Table 3 by interacting the tax adjusted user cost with the relative profitability variable. The estimated coefficient on the interaction term is negative and significant at the 5% level. This suggests that the tax adjustment component is contributing significantly to the negative effect of the user cost of capital on firm level investment.

56. Column (3) of Table 3 allows for different effects of the user cost on firms of different size and age categories. The distinction between firms of different size classes does not seem particularly relevant here. In contrast, the coefficient on the user cost for young firms is closer to zero than the coefficient for old firms and statistically insignificant. If the negative effect of the user cost on firm level investment is partly driven by the tax adjustment component as suggested in Column (2), one possible explanation is that young firms are generally less profitable than older firms and therefore less affected by corporate taxation. The other explanation may again be that among young firms there is a disproportionately high share of small firms that benefit from exemptions or reduced rates.

5. Robustness checks

Productivity

57. Three sets of robustness checks are meant to make sure that the findings obtained for productivity are not dependent on the particular set of estimation specifications chosen. Column (1) of Table 4 reports results for the baseline specification when relative TFP is instrumented with its one period lags to reduce potential simultaneity problems due to A_{icst-1} entering both the left hand side and the right hand side of the estimating equation. A_{icst-1} enters the dependent variable with a negative sign and relative TFP with a positive sign so that unobserved shocks on A_{icst-1} could lead to a negatively biased coefficient on relative TFP. This is confirmed in Column (1) of Table 4: the coefficient on relative TFP increases from -0.19 in the baseline specification in Table 1 to -0.09 in the instrument variables specification. However, the coefficient on the variable of interest, the interaction between relative profitability and corporate taxes remains negative and now even becomes significant at the 1% level.

58. Column (2) reports the results of the baseline specification when TFP is estimated using the Levinsohn and Petrin (2003) method instead of ordinary least squares. The size of the coefficient on the interaction term between relative profitability is reduced by approximately one third but remains negative and significant at the 10% level. Column (2) reports the results of the baseline specification when the superlative TFP index described in Section 3 is used as the dependent variable instead of TFP estimated by OLS. The superlative TFP index has the advantage that it is calculated by pooling firms in the same sector across countries which strongly reduces the possibility that the corporate tax rate in a specific country could influence the leader TFP level. In this specification, the coefficient on the interaction between relative profitability and the corporate tax rate is very close to the one obtained for TFP estimated by OLS, but it is now significant at the 1% level.

59. As a final robustness check for the productivity results, Column (3) shows that the results remain qualitatively unchanged if firms in non-European OECD members are included in the sample. Since data on firms in non-European OECD members are extracted from the Worldscope database, which includes only large listed firms, the sample is restricted to firms with more than 100 employees for both data sources. This reduces sample size by approximately 80%. Nevertheless, the coefficient on the interaction

25 Note that the firm-level cash flow is not a measure of the tax base since it is defined as operating profits before depreciation but after interests and taxes.

term between relative profitability is reduced by only around 15% and remains negative and significant at the 5% level.

Table 4. Robustness checks: productivity

The estimated equation is

$$\Delta lnTFP_{icst} = \delta_1 \Delta lnTFP_{Fcst} + \delta_2 ln(TFP_{ics,t-1}/TFP_{Fcs,t-1}) + \delta_3 Profit_s * TAX_{c,t-1} + \gamma_s + \gamma_{ct} + \varepsilon_{icst}$$

	(1)	(2)	(3)	(4)
Dependent Variable: TFP growth	IV	LP	Index	OLS
Basic Model				
Leader TFP Growth	0.145***	0.133***	0.084***	0.093***
	(0.021)	(0.019)	(0.006)	(0.021)
TFP Relative to Leader (t-1)	-0.098***	-0.158***	-0.144***	-0.106***
	(0.012)	(0.012)	(0.007)	(0.010)
Interactions between firm & sector characteristics & tax				
Profitability & tax	-0.383***	-0.198*	-0.314***	-0.258**
	(0.139)	(0.119)	(0.085)	(0.102)
Fixed effects:				
Sector	yes	yes	yes	yes
Country-year	yes	yes	yes	yes
Observations	214 075	278 984	285 931	52 784
R^2	0.05	0.09	0.07	0.06
Sample	Amadeus	Amadeus	Amadeus	Worldscope-Amadeus

(i) In the estimated empirical model $\Delta lnTFP_{icst}$ denotes TFP growth in firm i, country c, sector s and year t, *(ii)* $\Delta lnTFP_{Fcst}$ denotes TFP growth in the technological leader firm, *(iii)* $(TFP_{ics,t-1}/TFP_{Fcs,t-1})$ denotes the inverse of distance to the leader, *(iv)* $Profit_s * TAX_{c,t}$ the interaction between profitability and the corporate tax, *(v)* γ_s and γ_{ct} sector and country-year fixed effects, respectively. The Amadeus and joint Amadeus-Worldscope estimation samples contain 12 European OECD countries and 14 OECD countries, respectively, over the period 1998-2004. LP denotes TFP estimated using the Levinsohn & Petrin (2003) method, Index the superlative productivity index and OLS TFP estimated using OLS. Robust standard errors corrected for clustering at the country-sector level in parentheses. * denotes significant at 10%; ** at 5%; *** at 1%

Investment

60. The investment equations have been checked for robustness in three different ways. First, the lagged output ratio in the baseline model is replaced by the output growth rate, to allow for potential Samuelson-style accelerator effects. As expected the coefficient on the output growth rate is positive and significant at the 1% level (see Table 5, Column 1). More importantly, the coefficient on the tax adjusted user cost variable becomes more negative than in the baseline specification and remains significant at the 5% level.

61. As a second test, the regression presented in Column (2) of Table 5 tests the robustness of the results against increasing the threshold of investment ratios retained in the estimation sample to 1.5. The coefficient on the tax adjusted user cost variable becomes more negative than in the baseline specification and is significant at the 1% level in this case.

62. Finally, Column (3) of Table 5 includes firms in non-European OECD countries, extracted from the Worldscope database. Again, the sample size is reduced in this case because Worldscope only includes large listed firms with more than 100 employees. As a result, firms below that threshold had to be dropped from the Amadeus sample as well to preserve consistency across countries. For this sample containing firms from both European and non-European OECD countries, the coefficient on the tax adjusted user cost remains negative and significant at the 5% level.

Table 5. Robustness checks: investment

The estimated equation is

$$(I/K)_{icst} = \beta_1 (I/K)_{ics,t-1} + \beta_2 (I/K)^2_{ics,t-1} + \beta_3 (Y/K)_{ics,t-1} + \beta_4 (CF/K)_{ics,t-1} + \beta_5 UCtax_{cs,t-1} + \gamma_s + \gamma_{ct} + \varepsilon_{icst}$$

	(1)	(2)	(3)
Dependent Variable: Investment-to-capital ratio	<1	<1.5	<1
Basic model			
Investment-to-capital ratio (t-1)	0.475***	0.474***	0.674***
	(0.018)	(0.022)	(0.076)
Investment-to-capital ratio squared (t-1)	-0.380***	-0.290***	-0.508***
	(0.023)	(0.016)	(0.094)
Output growth rate (t)	0.137***		
	(0.008)		
Output-to-capital ratio (t-1)		0.000***	0.001***
		(0.000)	(0.000)
Cashflow-to-capital ratio (t-1)	0.052***	0.060***	0.025***
	(0.003)	(0.003)	(0.003)
Tax adjusted user cost (t-1)	-1.463**	-1.521***	-1.252**
	(0.641)	(0.510)	(0.493)
Long-run tax adjusted user cost elasticity	-1.21	-1.27	-1.04
Observations	128,228	232,448	56,086
Fixed effects:			
Sector	yes	yes	yes
Country-year	yes	yes	yes
R^2	0.13	0.12	0.20
Sample	Amadeus	Amadeus	Worldscope-Amadeus

(i) In the estimated empirical model $(I/K)_{icst}$ denotes the investment-to-capital ratio, *(ii)* $(I/K)_{ics,t-1}$ its lag, *(iii)* $(I/K)^2_{ics,t-1}$ its squared lag, *(iv)* $(Y/K)_{ics,t-1}$ the lag of the output-to-capital ratio, *(v)* $(CF/K)_{ics,t-1}$ the lag of the cashflow-to-capital ratio, *(vi)* $UCtax_{cs,t-1}$ the lag of the tax adjusted user cost and *(vii)* γ_s and γ_{ct} sector and country-year fixed effects, respectively. The estimation sample contains 12 European OECD countries for the Amadeus sample and 15 OECD countries for the joint Amadeus-Worldscope sample over the period 1998-2004. It is restricted to observations with investment ratios beween 0 and 1 in columns (1) and (3) and to investment ratios between 0 and 1.5 in column (2). Robust standard errors corrected for clustering at the country-sector level in parentheses. * denotes significant at 10%; ** at 5%; *** at 1%

6. Conclusions

63. The empirical analysis presented here provides evidence of substantial negative effects of corporate taxation on productivity and investment. These conclusions are based on a large and representative dataset of firms from OECD member countries. All firms except those that are both small and young see their productivity growth reduced by high corporate taxes. In particular those firms that are in the process of catching up with the technological frontier are more negatively affected than the remaining firms. This supports the view that corporate taxes are in effect "success taxes" (Gentry and Hubbard, 2004) which fall disproportionately on firms that are contributing positively to aggregate productivity growth. Moreover, the results show that part of the negative effect on productivity may be driven by an increase in the user cost of capital and the associated reduction in firm level investment in physical capital which embodies technological progress. The effect of the user cost is larger in relatively profitable sectors where the tax base is large, indicating that the tax component of the user cost is indeed likely to be responsible for the observed reduction of investment rates.

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