CORPORATE TAXATION AND THE PRODUCTIVITY AND INVESTMENT PERFORMANCE OF HETEROGENEOUS FIRMS: EVIDENCE FROM OECD FIRM-LEVEL DATA

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Corporate Taxation and the Productivity and Investment Performance of Heterogeneous Firms: Evidence from OECD Firm-Level Data

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Abstract

This paper adds to the recent literature use micro-level data to examine the response of firms' productivity levels or growth rates to various policy settings. Our particular interest is to investigate how far corporate tax settings might affect firms' innovation and risk-taking activity. Previous investigations of this issue have examined the link between higher corporate taxes and firm-level total factor productivity (TFP) as mediated through higher profitability. That is, firms with higher corporate profits but in regimes involving higher corporate tax rates are expected to have lower TFP than equivalent firms in low corporate tax regimes. In this paper we re-examine this evidence – which has suggested apparently large and persistent impacts of corporate tax on firm-level TFP, as mediated through profits. We then consider how far alternative indicators of firm-level innovation/technology can provide better proxies for the impact of taxes on productivity via innovation effects than those based on firm profits.

Using an econometric model of innovation and productivity similar to that proposed by Griffith et al. (2006) and Schwellnus and Arnold (S&A, 2008), we show that:

- Using a similar sized sample to S&A (2008) but which does *not* exclude small (<20 employee) firms, the estimated impact of higher corporate tax rates on TFP *when interacted with firm profit levels* is no longer implausibly large and occurs relatively quickly (within 4-5 years rather than over decades).
- Using alternative measures of industries' innovative characteristics such as research intensity, the extent of intra-industry trade and firm entry-exit rates, we find stronger evidence that firms in those 'innovation intensive' industries are more adversely affected by high corporate tax rates than those in low 'innovation intensive' industries.
- Higher corporate tax rates, via their effect on the post-tax user cost of capital have significant adverse effects on firm's investment levels.

Keywords: corporate taxation, productivity, investment

JEL classification: D21, E22, H25, H32

1. Introduction

Macro-dynamic modelling in recent years has made great strides in analysing the potential impact of changes in tax policy on a variety of macro variables including output and productivity levels and the transitional/long-run rates of output or productivity growth (e.g. Barro et al., 1995; Turnovsky, 2004). While some of these models have been 'tested' by calibrating them to specific country (usually US) characteristics, in general empirical tests of such models have relied on aggregate level regressions for panels of different country samples, (see, for example, Kneller et al., 1999; Bleaney, et al 2001; Lee and Gordon, 2005; Angelopoulos et al., 2007; Myles, 2007; Romer and Romer, 2007; Arnold, 2008; Romero-Avila and Strauch, 2008). While these studies increasingly find evidence consistent with significant adverse impacts on long-run GDP growth rates from increases in various 'distortionary' taxes, the reliability of these high-level reduced form estimates has proved hard to pin down.

Micro-level evidence – at the firm, industry or sector levels – is comparatively scarce; what there is tends to focus on tax impacts on investment in particular or factors expected to contribute to overall investment or productivity performance – such as research and development expenditures, human capital formation or inter-industry and inter-country re-allocations of investment or profit. [references to tax-investment & MNC investment/profit-shifting studies]. Much of this literature confirms that various types of investment activity or the location of corporate investments and profits are responsive to particular aspects of countries' tax regimes. Whether *factor productivity* is affected at the micro level by those same tax regimes is less clear with only one study, to our knowledge, addressing this aspect directly – Schwellnus and Arnold (2008).

Schwellnus and Arnold (2008) use a sample of firm-level data for OECD countries over 1996-2004 to investigate whether firms facing higher corporate tax rates on their profits exhibit lower total factor productivity (TFP) and investment levels compared to firms facing lower corporate tax rates. Based on the identifying assumption that "firm level TFP growth in very profitable sectors should be lower relative to sectors with low profitability in countries with high corporate taxes" they find that firm-level productivity appears to be lower in high tax country-year combinations. This may partly reflect companion evidence that investment is also lower in high tax contexts (in response to a higher user cost of capital) and if technological advances are at least partly embodied in this investment.

The Schwellnus and Arnold (S&A) analysis is an innovative and helpful advance in the methodologies applied to the study of the productivity effects of corporate tax changes but is limited by two aspects (methodological issues are discussed in more detail below). Firstly, because differences in corporate tax rates (across countries and/or time) affect firms differentially to the extent that their taxable profits differ, in the S&A estimation model a corporate profit-tax rate interaction term is the sole tax variable used to identify corporate tax effects. It might be expected that other corporate tax parameters (in addition to statutory rates) and variables other than profit could mediate corporate tax effects to TFP. More importantly, the key hypothesis is that corporate taxes reduce innovation and risk-taking and hence adversely affect TFP. However, while a measure of corporate profitability proxies the relevant tax base, it is unclear whether, or how far, this reflects the innovative or risk-taking characteristics of firms.

Secondly the estimated TFP impact of a corporate tax change is surprisingly large: TFP growth for a 'median firm' is around 0.4 percentage points higher when the statutory corporate rate is reduced from 35% to 30% and since "*trend TFP growth of OECD countries averaged 1.1% over the period 2000-2005 … this is actually a large number*" (S&A, 2008, p.16). Arguably this estimate puts it in the 'implausibly large' category, in the same way that previous estimates based on aggregate level data have been described as implausibly large.

In this paper, we examine a firm-level dataset for OECD countries very similar to that used by S&A to re-test for the tax-profitability effects on TFP measured by S&A. We further argue that, to the extent that corporate tax can be expected to impact on firms' innovation or risk-taking characteristics that are hypothesised to generate different TFP growth across firms, this may be captured by a number of firm characteristics, not just firms' overall profit levels. In particular we argue that corporate tax may impact on productivity via interactions with inter-firm differences in 'research intensity', the degree of intra-industry trade, and firms' entry/exit/survival characteristics.

The remainder of the paper is structured as follows. In section 2 we discuss the relevant hypotheses linking corporate tax and firm productivity within an overall model of firm productivity. Section 3 then describes the data and methodology we use and section 4 discusses our econometric results. Section 5 draws some conclusions.

2. Corporate Tax, Technology and Total Factor Productivity

A model of the impact of tax on firm-level productivity requires a model of the various factors driving that productivity and the ways in which they are, or are not, likely to be susceptible to tax policy. Recent models of firm productivity, in turn, have focused on technological innovation as a key force driving firms' TFP levels. Successful innovations by firms, whether technological, managerial or whatever, can be expected to yield an economic return (profit) *inter alia* through their ability to raise the firm's TFP. Griffith *et al* (2006) for example, argue that the notion of an expanding 'frontier technology' and firms' heterogeneous abilities to catch-up on the frontier, can help explain simultaneous but counter-veiling tendencies toward convergence and divergence in firms' productivity levels.[1] As they emphasise (p.4) for the UK case: the "*aggregate picture hides substantial heterogeneity across establishments and a Darwinian process of selection as poor performers exited and were replaced by new cohorts of establishments*". That is, understanding how technology affects firm-level productivity needs to recognise the heterogeneous circumstances, and turnover, of firms. We discuss this further below.

How might firm-level taxation affect innovation/productivity processes? As S&A (2008) note, if successful innovations are measured by the net-of-tax rate of return, then to the extent that tax parameters drive a wedge between a firm's gross and net returns, they can be expected to discourage that innovative activity, that in turn impacts negatively on a firm's ability to improve its productivity levels, other things equal. In principle this applies to both incorporated and unincorporated enterprises – such that the relevant tax parameters will differ in each case depending on these enterprises' liabilities under personal, corporate and other tax schedules. In our empirical work we focus on incorporated firms so that it is the impact of effective rates of corporate tax that are most relevant.

Standard features of corporate tax in OECD countries typically include (i) the use of one or more statutory rates (e.g. some countries set lower rates at low profit levels); (ii) limitations on the extent of tax rebates for negative profits (losses) generating asymmetric treatment of profits and losses (e.g. Auerbach, 1986; Altschuler and Auerbach, 1990; Cooper and Knittel, 2006; Creedy and Gemmell, 2009); (iii) various deductions offsetting tax liabilities on gross profits such as capital allowances, credits for R&D expenditures etc.

[1] Where technological improvements are embodied in new capital, and the measurement of this capital is unable to fully capture 'quality' improvements, some of this innovative improvement may appear to be attributable to firms' investment rather than TFP. This raises important issues for the measurement and interpretation of changes in capital stock and TFP.

These have the effect of generating firm-specific ETRs that can be quite different from statutory rates of tax and also contributing some progressivity to most corporate tax regimes.

This latter effect is especially associated with loss-making, and its tax treatment. As Auerbach (2007) has shown for the US for example, limitations on the use of losses for tax purposes is the major factor that has reduced effective average tax rates (EATRs) and changes in EATRs over time. In addition, as S&A (2008) and Gentry and Hubbard (2004a,b) point out, corporate taxes can be characterised as 'success taxes' since effective marginal rates are typically higher at higher profit levels, via the asymmetric treatment of losses, and because this feature also ensures the government taxes risky investments that are successful (yield higher profit) more than risky investments that fail (make a loss). To model the impact of corporate taxes on TFP we use the Griffiths *et al* (2006) model of firm technology (which ignores taxation), augmented by the insights of S&A (2008) to allow us to test for tax-specific impacts on firm TFP.

The model proposed by Griffith *et al* (2006) allows for a distribution of productivity across firms that changes over time and where each firm has the potential to catch-up on best-practice technology in 'frontier' firms. Their formulation captures productivity convergence, but can also accommodate some persistence in firms' productivity levels over time. Their starting point is equation (1) below where lnA_{it}, is an index of technology or TFP (in firm i, at time¸ t). It is a function of previous TFP levels, lnA_{it-1}, allowing some persistence, a (heterogeneous) component reflecting the individual firms' abilities to generate TFP improvements, γ_i, and the frontier technology currently available in firm j, $lnA_{Fj\,t-1}$, capturing convergence or 'catch-up' possibilities. Hence, represented in ADL (1,1) form:

$$lnA_{it} = \gamma_i + a_1 lnA_{i\,t-1} + \beta_0 A_{F_j\,t} + \beta_1 A_{F_j\,t-1} + u_{it} \tag{1}$$

where u_{it} is a white noise error terms representing stochastic shocks to TFP[2]; or in error correction form as:

$$\Delta lnA_{it} = \gamma_i + \beta_0 \Delta A_{F_j\,t} + \phi\left\{lnA_{i\,t-1} + \beta' A_{F_j\,t-1}\right\} + u_{it} \tag{1'}$$

[2] Note that (1) can be re-arranged to be expressed in terms of the *change* in TFP, and Griffith *et al* allow for it to be applied only to firms whose TFP remains high enough to remain in the industry, with implications for methods of testing (see below).

where $\beta^{c} = \frac{\beta_{1}+\beta_{2}}{1-\alpha_{1}}$ is the long-run growth rate of frontier technology and $\phi = 1 - \alpha_1$ is the error correction parameter.

Equation (1′) captures heterogeneity in firm productivity across industries (and countries). It allows for endogenous productivity catch-up but the presence of γ_i ensures that firms may converge towards their own equilibrium productivity path relative to that of the frontier firm(s). In the long-run, even if all firms' TFPs grow at the same rate, they are not necessarily converging to the same *level*. In addition, stochastic shocks to TFP together with the speed of correction to the steady-state mean that firms observed TFP may be 'transitional' for many periods. With the addition of a homogeneity assumption (that in the long-run all firms TFPs will grow at the rate of the frontier TFP), equation (1′) can be rewritten in terms of firm's TFP *relative to* frontier levels, as:

$$\Delta \ln A_{i\,t} = \gamma_i + \beta \Delta A_{F_j\,t} + \phi \left(\frac{A_i}{A_{F_j}}\right)_{t-1} + u_{i\,t} \qquad (2)$$

Equation (2) forms the basis of our TFP model (with the addition of suitable industry, country and time fixed effects) prior to consideration of corporate tax impacts. Tax effects may be short-run and/or long-run (we focus on the latter in reporting our empirical estimates), and can be thought of as impacting on the firm-specific rates of TFP growth, γ_i.[3] Conceptually this operates via the tax-wedge driven between the pre- and post-tax rates of return on innovations that drive each firm's productivity improvements (or declines - where tax affects declining firms or induces that decline). How we capture those tax impacts in our empirical model, we turn to next.

An interesting question concerns what country-, industry- of firm-specific characteristics might drive firm-level productivity and which are also susceptible to corporate tax settings? Information of firms' individual corporate tax liabilities would allow us to explore this question directly; for example, is a higher tax liability via effective marginal tax rate associated with lower TFP? Unfortunately *firm*-level corporate tax data is unavailable. Statutory corporate tax rate data by country and time period is however available, and we can

[3] Griffith *et al* (2006) include a firm-specific fixed effect to pick up those firm-level sources of innovation. Doing so in our case would effectively remove the firm-specific sources of variation that may be due to corporate tax effects and that it is desired to identify here. We therefore include country, industry and time fixed effects but exclude firm fixed effects.

examine how far this affects industry-specific factors expected to be impacted by corporate tax – such as profitability.

The key insight of S&A (2008) is to recognise that firm-level corporate tax liability is a function of each firm's taxable profit levels in addition to the relevant tax rate. Though this profit data is also not available at the firm level, S&A (2008) construct *industry-level* information of firm profitability. However, this is based on *accounting* profit data rather than the *taxable* profit, net of relevant deductions, to which corporate tax rates are directly applicable, and hence at best proxies the relevant tax base. When combined with country-time-specific data on corporate tax rates, this allows S&A (2008) to apply to difference-in-difference estimation framework proposed by Rajan and Zingales (1998) to examine whether greater financial development assists firm growth.

The rationale is as follows. Ragan and Zingales (1998) argue that, if the level of financial development of an economy is important for its growth then, within a country, firms that have better access to sources of finance external to the firm should be less constrained, other things equal, than firms relying on internal finance. This suggests an empirical testing strategy that exploits the difference-in-difference approach recognising that firms within sectors that are inherently less dependent on internal finance should be observed to growth faster in countries that are more financially developed compared to firms in the same sectors in countries that are less financially developed. For present purposes, in effect S&A (2008) replace the country- and time-specific 'financial development' element of Rajan & Zingales with the 'statutory corporate tax rate', and replace the industry-specific element of 'external finance dependence' with industry-specific profitability. Since profit represents (at least in principle; more on this in section 3) the tax base to which the corporate tax rate is applied, then firms observed in inherently more profitable industries might be expected to have lower productivity in countries and/or years where corporate tax rates are higher, compared to firms in the same industries in low tax countries/years.

It is also worth noting that, since firm-level TFP might be expected to be positively, and endogenously, correlated with the firm's profitability (the tax base), the predicted negative impact on TFP of higher corporate tax rates arises despite this positive, endogenous relationship. That is, to the extent that profitability is thought to be determined simultaneously with TFP, this endogeneity should *reduce*, not increase, our likelihood of finding a negative observed association between corporate tax liabilities and TFP. In addition, the use of *industry*-level profitability mitigates this possible endogeneity at firm level.

The values of a firm's profits as reflected in company accounts (the S&A data source, and the one used in this paper) are often very different from profits liable to corporate tax (at the host country rate). Nevertheless, as a 'tax base' proxy, accounting profit might be expected to broadly capture the potential for more profitable industries to face higher tax liabilities. With profit measured relative to value added, a measure of industry 'profitability' interacted with the corporate tax rate represents a form of industry-level effective average tax rate.

However, two important elements of the potential impact of corporate tax on TFP are the particular effects on innovation and risk-taking, with successful ventures (as evidenced, for example, in greater profitability) typically penalised disproportionately by corporate tax regimes. Various aspects of corporate tax regimes, other than the statutory rate, such as R&D tax credits or deductions for some or all types of investment, are aimed at reducing the adverse impact of corporation tax on firm's 'success'. These may not be observed through levels of firms' accounting profits, but rather through choices over types of investment or the extent of activities that give rise to reductions in *taxable* profits via increased deductions. To the extent that these aspects, stimulated by the corporate tax regime, generate productivity improvements (as opposed to corporate tax minimising strategies with no 'real' economic benefits) they should be evident in firm-level TFP.

Of course, even where *taxable* profits are available, these will allow tests of the influence of corporate tax on TFP via profitability which cannot specifically test the hypothesis that it is the impact of tax on firms' innovation and risk-taking activities that acts as the mechanism by which higher corporate tax rates reduce productivity. *Any* firm with a higher level of profitability but where these profits are taxed more highly could expect to experience lower TFP levels of growth. For example, the availability of internal sources of finance may be the binding constraint on firms' investment that would enhance productivity. In this case corporate tax will adversely affect productivity but it may be unrelated to firms' willingness or ability to innovate or make risky investment choices.

While measures of innovation or risk-taking are necessarily imprecise and difficult to pin down, we propose to test how far indictors that are more likely to be closely associated with innovation/risk-taking (than is profitability) are associated with lower TFP when combined with higher corporate tax rates. In particular, innovation is often argued to be associated with research-intensity, with Research & Development (R&D) argued to be a pre-requisite for successful innovative products and processes (Griffith et al, 2004). Along similar lines, it has been argued that common characteristics of innovative industries include heightened levels of intra-industry trade (Melitz, 2003; Abraham and Van Hove, 2005; Balboni, 2005) and high rates of entry and exit of firms (Samaniego, 2009; Aghion, 2006; Aghion et al, 2006)

To examine these potential corporate tax impacts we construct industry-level measures of R&D intensity, intra-industry trade and firm entry-exit rates. A rational for these measures is that, like profitability, they are commonly argued to be positively correlated with TFP. Hence, if firms in similar industries (for example, in terms of R&D intensity) are located in different countries (*x* and *z*), and hence face different corporate tax rates, this should generate *lower* TFP in the higher-tax equivalent firms in country *x* compared to those in lower-tax country *z*. We discuss these issues further below.

3. Data and Methodology

Our firm-level data comes from the Amadeus database (Bureau van Dijk). In general we follow the approach of S&A (2008) in order to allow comparisons of their results with ours. In specific case we choose to define our firm sample differently in order to test parameter sensitivities etc. The database covers 16 European Union countries over the time period 1995-2008, though the sample for the first and final years of 1995 and 2008 is much smaller (S&A use 1996-2004). Following S&A (2008) we exclude Central and Eastern European Countries from the sample to preserve greater homogeneity across the EU sample. Unlike S&A (2008) we include in our sample all types of firms, including small firms with less than 20 employees. These small firms tend to have less satisfactory coverage leading to more missing values. However, since up to 95% of firms in our database have less than 20 employees, focusing only on large firms would risk drawing false conclusions for economy-wide firms based on an analysis of a particular and relatively minor set of firms with special characteristics.

3.1 Sampling Procedures

Our procedures for randomly selecting a sample of firms is described in detail in Appendix 1. We follow S&A (2008) in omitting certain outliers from our samples, where the nature of the data suggests possible errors or difficulties of interpretation. For example, in calculating TFP (see below) we remove all variables with negative values from the dataset; in calculating firm investment, those reporting investment greater than their capital stock, or with extremely large decreases in capital stock (but not exiting the market) were also removed from the database. We further restrict the analysis to firms in manufacturing and services sectors (Nace 15-93).[4]

The Amadeus database covers 30 European OECD member countries over the time period 1995-2008. To ensure that the final sample is representative of the underlying population of firms we combine this with information on the distribution of firms by size class and industry from the OECD's much larger Structural and Demographic Business Statistics Database (yielding an overlapping set of 16 countries across the two databases). We use a random sampling procedure to select around 200,000 firms from the Amadeus dataset that match those in the OECD SDBS in terms of the employment size/industry/country composition (see Appendix 1). This yields a 'full sample' of 197,017 firms and a total of 1,034,933 observations. The sample we use for testing is further limited by available firm-level data on all relevant variables. This leads to final samples up to 242,000 observations for the various regression equations tested.

Important differences from our sample and that constructed by S&A (2008), in addition to our longer time span, are: (i) we begin by including all firms, not just those with more than 20 employees; and (ii) we select our stratified random sample before constructing firm TFP measures rather than after. (iii) S&A exclude multinational corporations (MNCs) from their sample, due to possible impacts of international tax rules on their effective tax rates. We prefer to retain MNCs in our sample since otherwise this seems likely to exclude many of the most tax-sensitive firms both in terms of international investment responses and profit-shifting. In addition, recent conceptual work and evidence at the aggregate level suggests that MNCs profit location choices are driven by statutory corporate tax rates (Devereux et al, 2008; Huizinga and Laeven, 2008).

For our R&D intensity variable, data come from the OECD's *Science, Technology and Industry Outlook*. We have computed average values for the period 1995-2007 by industrial

[4] To assist comparability with S&A (2008) we also dropped the following sectors: recycling (Nace 37), refuse disposal (Nace 90), utilities (Nace 40, 41), financial services (Nace 65-67), real estate (Nace 70), holding companies (Nace 7415), public administration (Nace 75), education (Nace 80), health (Nace 85) and 'membership organisations' (Nace 91); see S&A (2008, p.10) for discussion.

sector. When using R&D intensity data we lose firms from service sector industries, focusing only on manufacturing industries.

3.2 *Estimating Productivity Measures*

To estimate total factor productivity, we take residuals from the estimated log-linear (Cobb-Douglas) production function in which value added (for firm *i* in year, *t*) is regressed on labour and capital stock inputs, where value added has been calculated as operating revenue minus material inputs. Labour inputs are measured by the firm's total wage bill, with capital stocks defined as tangible fixed assets. Sector-specific price indices from the EUKLEMS database have been used to transform nominal into real values, except for capital stocks for which we use a gross fixed capital formation deflator (from EUROSTAT National Accounts).

In line with S&A (2008) we estimate the production function at the country-industry level, such that firms' technologies can differ by country and industry. S&A propose two regression methods to estimate TFP: OLS and the semi-parametric method proposed by Levinsohn and Petrin (2003). We follow the latter method because this allows the production function input parameters to be estimated while allowing for the possibility of an endogenous response of productivity to unobserved shocks.[5]

3.3 *Estimating Corporate Tax Effects*

Following Griffith et al. (2006), Rajan and Zingales (1998) and S&A (2008) we add country (*c*), industry (*s*) and time (*t*) dummies to equation (2) together with interaction terms involving industry profitability (measured relative to mean profitability) and country-time specific tax rates, $\Pi_s \tau_{c\ t-1}$.

$$[\Delta \ln A]_{(i\,t)} = (_{i} + \beta_{0}\, \Delta A_{(F(j\,t))}) + ((A_{(F\,j)}/A_{i})_{(t-1)}\; \alpha(_{s}\, \tau_{(c\,t-1)}) + u_{c} + u_{s} + u_{t} + \varepsilon \quad (3)$$

where terms are as defined in equation (2) and Π_s is profitability in industry *s*, $\tau_{c,t-1}$ is the statutory corporate tax rate in country *c* at time *t-1*[6], u_s, u_c and u_t are industry, country and year fixed effects[7] and ε_{it} is a random firm-specific error term.

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[5] The Levinsohn and Petrin (2003) estimator uses intermediate inputs as proxies, arguing that these may proxy for the unobservable productivity shock. However, the method requires additional information on firms' use of material inputs, thus reducing the sample.

[6] Note that the long-run impact in this ADL (1, 1) specification is captured by the parameter on the lagged (t-1) tax term, α, modified by the convergence parameter ϕ.

Equation (3) allows for both a 'frontier effect' on firms' TFP levels as well as 'convergence or catch-up effect' and some persistence in TFP levels over time[8]. The interaction term $\Pi_s \tau_{c\ t-1}$ captures the differences-in-differences impact of corporate taxes whereby firms in the more profitable industries are expected to have lower TFP when they are also in countries and/or years with high corporate tax rates. Note that the interaction component terms Π_s and $\tau_{c,t-1}$ cannot be introduced separately while industry (*s*) and interactive country-year (*ct*) fixed effects are also included. However, as a robustness check we can investigate whether, omitting these fixed effects, the two interactive components display the expected signs (positive for profitability; negative for corporate tax rates).

To estimate the impact of corporate taxes on productivity therefore requires data on industry-level profitability and country-time specific statutory corporate tax rates, as described above. Data for statutory corporate tax rates are obtained from EUROSTAT, *Taxation Trends in the EU*. Information on the profitability of industries is calculated from the 2002 U.S. Benchmark Input-Output Data Table (*U.S. Bureau of Economic Analysis*, 2002).[9] For each industry at the 2 digit ISIC level a profitability ratio is calculated from data on gross operating surplus divided by value added; this is applied to the whole period of our analysis, 1995-2008. We follow Rajan and Zingales (1998) in assuming that profitability differences observed across 2-digit industries in the United States apply similarly to the same industries in other sample countries. By making this assumption we reduce potential endogeneity between firm-level productivity and profitability across industries, and avoid simultaneity between the country- and time-specific corporate tax rate and the country-and time-*in*dependent industry profitability measure.

Furthermore, if we were to use an industry profitability measure differentiated by country there is increased risk that such a measure would reflect biases in reported profit. As S&A (2008) argue, in countries with high statutory corporate tax rates firms may under-

[7] In addition we add interacted country-time or industry-time fixed effect (both cannot be added simultaneously). These allow for the possibility of common TFP shocks can affect all firms in the same industry in a given year (but different for firms in the same industry but a different country) or affecting all firms in the same country in a given year (but differing across firms in the same country but a different industry). Such shocks can arise, for example, where time fixed effects have an asynchronous component across countries such that in some years there can be a delayed country-specific time effect. Alternatively there may be TFP time shocks that, as well as having a common component across all industries, also affect some industries with different lags.

[8] 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.

[9] S&A (2008) use the 1997 version.

report their profits (and/or over-report their deductions). This can be compounded if high statutory corporate taxes are positively related to other conditions that adversely affect firm profitability (e.g. where corporate tax regimes with high rates occur simultaneously with government regulatory or similar interventions that harm profitability), this would further bias any country-specific profitability measures.

3.4 Taxes, the User Cost of Capital and Investment

Since Jorgenson (1963) introduced the concept of the *user cost of capital*, C, the relationship between this tax adjusted rental price and the dynamics of investment demand remains central in the empirical literature. Therefore, in the analysis of investment behaviour we have computed this concept as captured in equation (4).

$$C = \frac{(1-S)}{(1-\tau)}(\rho + \delta - \pi) - \delta \tag{4}$$

where δ stands for the economic depreciation, τ denotes the statutory corporate tax rate, π indicates the existing inflation rate, ρ represents the investor's discount rate and S quantifies the present value of all the tax savings due to the existing fiscal incentives received by a given investment project in any specific form. In particular, in determining the specific value for S we have followed the proposal by King and Fullerton (1984), who identified three alternative ways for a new investment to become fiscally enhanced: standard depreciation allowances (Z), immediate expensing (including free depreciation) and up-front tax credits (k). As a consequence, if f_1, f_2 and f_3 represent the proportion of the cost of a given asset which is entitled to each of these forms of tax incentives, then S is given by:

$$S = f_1 \tau Z + f_2 \tau + f_3 k \tag{5}$$

The value of the standard depreciation allowance is given by the legal method provided by the tax system, normally one of the following: straight-line depreciation, constant declining balance depreciation or the method of the 'sum-of-the-years'-digits – see Appendix 2. In determining the value of the firm's discount rate we also follow King and Fullerton (1984). However, since our interest is restricted to the impact of the corporate tax, in determining the magnitude of this discount rate we discard the tax treatment of savings under personal income taxation. Therefore, for the case of debt finance we assume $\rho = i(1-\tau)$ whereas if the investment is financed using own resources the nominal discount rate coincides with the market interest rate, i.e. $\rho = i$.[10]

In generating the user cost of capital as a *country-specific* regressor in our estimations, equation (4) has been computed for 6 different investment types in each of the 16 countries included in the study for the period 1996-2008. By an investment type we mean the combination of two forms of finance – debt and equity - and three alternative general asset types – buildings, machinery and technology. As a result, for each year every country has six basic measures of the user cost of capital (3 assets $\times$ 2 financial instruments). These basic measures of the cost of capital are weighted to be included in our estimations.

The weighting procedure for the assets uses the shares of the real fixed capital stocks of buildings, machinery (the sum of transport equipment, other machinery and equipment, and other non-residential investment) and technology (Information and Communications Technologies, ICTs) based on the information provided in EU KLEMS growth and productivity accounts. The weighting procedure for forms of finance is based on the information from Morningstars on the market debt-to-capital ratio for more than 8.000 companies traded in US stock exchanges. This information has then been averaged by industry. Both the asset and form-of-financing weighting procedures are based on information for the US; that is, we assume again that industry-level technologies are similar across countries. In this way we also reduce the potential endogeneity between productivity and the user cost of capital, since more productive firms may have more access to loans and be more intensive in ICT use. By using US assets and form of financing shares, we also reduce the correlation between the user cost of capital and corporate tax rates if firms using more debt than equity tend to be found in countries with higher corporate tax rates.

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[10] In doing this we avoid our results being contaminated by the tax treatment of savings in the personal income tax. Originally, King and Fullerton (1984) determined the nominal discount rates for three alternative forms of finance: debt, retained earnings and equity. In quantifying these discount rates they took into account the tax treatment in personal income taxation. Specifically, $\rho = i(1-\tau)$ for debt finance, $\rho = i(1-m)/(1-z)$ for retained earnings and $\rho = i/\theta$ for new share issues, where m is marginal tax rates for interest income, z is the effective tax rate for capital gains and θ is the imputation rate in the case of dividend payments. The assumption of different discount rates depending on the form of finance has been subject to some criticisms however; see Scott (1987).

In computing equation (4), it is worth noting that since our concern is to isolate the impact of the corporate tax, it is preferable to use common values for non-tax variables regardless of the year under examination. The table below shows the assumed values for these non-tax variables which are consistent with other studies for the same time period (e.g. Lammersen and Schwager, 2005).

Summary of values for non-tax variables	
Economic depreciation rates (δ)	Buildings (3.80%); Machinery (18.04%); Technology (43.10%)
Nominal interest rate (i)	10%
Inflation rate (π)	2%

The main advantage of this *cost-of-capital* approach stems from its transparency in taking into account otherwise complex tax provisions. However, it is important to bear in mind the following underlying assumptions. Firstly, the computation of equation (4) rests on the assumption that all the tax allowances and tax incentives can be claimed. In other words, companies' taxable incomes are large enough to absorb the full amount of potential fiscal incentives. Secondly, the modelling of incentives replicates the general setting for new investment; that is, special incentives schemes are not considered. Thirdly, due to the assumption of fixed equal values for common non-tax variables, the computed cost of capital cannot capture the impact of uncertainty.

Appendix 3 shows the user cost of capital for each of the six basic measures. We show the average for the period 1996-2007 in the nine countries included in the database (1995 and 2008 have very few observations in the Amadeus database). Scandinavian countries – Finland and Sweden – have the lowest corporate tax rates on average during these years, whereas Germany and Italy have the highest. The general trend has been a decrease in the corporate tax rate from a simple average of 39.6% to 31.3%. The user cost of capital corroborates that the best way to finance assets its debt. There is a different of more than 4 percentage points in each of the cases. As for the type of assets, the user cost of capital is on average highest for buildings, followed by technology and machinery. Nevertheless there are some countries for which the user cost of capital of buildings is lower than for technology: Finland, Spain and especially Sweden and France. In contrast, investing in technology in Italy is profitable even with very low rates of returns.

In addition to the use of the user cost of capital, in the investment analysis we have computed gross investment as the first difference between capital stocks. Following, S&A (2008) and Becker and Sivadasan (2006), we exclude from the analysis firms with investment higher than their capital stock and firms that are less than five years old. We also follow those authors in dropping firms with negative investment: such firms may be exiting the market or substantially down-sizing, therefore potentially biasing results. To test sensitivity to this restriction, in later robustness checks we include all firms in some estimations.

4. Results

4.1 Some Descriptive Statistics

Some descriptive statistics are shown in Appendix IV. The first one is on TFP growth by countries.

In Appendix IVa, average annual growth in TFP for the firms included in our sample during the period 1996-2007 is 0.9%. However this ranges from the -8.8% of the Czech Republic to 3.4% of Portugal. Some comments on these figures are worth making. Firstly they might be explained by country specific factors. The transition of the Czech Republic from a communist economic regime to a market economy in this period, for example, while Portugal, a relatively low productivity EU country, appears to be catching up. In contrast, Spain is perhaps benefitting less from frontier countries' technology, with TFP growth below the nine-country average. This in line with the OECD Productivity Database indicating multi-factor productivity growth for Spain of 0.0% during the period 1995-2007. Secondly, for some countries there are a relatively small number of observations, such that these averages can be driven by extreme values. This is indicated by the large standard deviations in the table.

In Appendix IVb, we show the TFP growth by industry, along with the right-hand-side variables: profitability, R&D intensity (as a share of value added and production), intra-industry trade and entry-exit rates. Note that all these RHS variables are values for the US. Annual TFP growth for manufactures during the period 1996-2007 is estimated at 1.1%, close to the 0.8% estimated by EUKLEMS for the Euro Area for the period 1995-2004. Air transport and telecommunications appear to be the worst performing, with negative TFP growth rates. Again this would appear to be driven extreme values for a single firm in that industry.[11]

Finally, Appendix IVc shows the structure of firms by employment and age. Only 5.5% of the firms have more than 20 employees, which is the sample used in S&A. Almost one third of the firms are relatively new, between 0 and 6 years, whereas a quarter are more than 18 years old.

4.2 Corporate Tax and Productivity

In this section we report results for firm-level TFP estimated by the Levinsohn and Petrin (2003) procedure discussed above. Table 1 shows results from estimating equation (3); the left-hand column headed "S&A (2008)" reports the equivalent S&A result for comparison; our results are in columns 1-7.

Column 1 reports the results for the two technology variables ('frontier TFP growth' and the gap between each firm and the frontier TFP), in addition to the relevant dummies and difference-in-difference effect associated with the impact of corporate tax rates and profit levels. We find a positive and significant impact on firms' TFP levels from the TFP growth of frontier firms in the same industry. In line with expectations, we also find a negative effect associated with a firm's distance from the frontier TFP level, indicating that *ceteris paribus* there is convergence among firm's efficiency levels.

Our sample includes almost 241,500 observations, similar in overall size to the S&A sample of 287,000 observations. However, since their sample is constructed to exclude firms of less than 20 employees, in column (2) we similarly restrict our sample to permit more direct comparisons. This radically reduces our sample size to around 11,000 firms and yields a smaller effect from frontier TFP growth (0.09 versus 0.17 for S&A) but a similar convergence effect (-0.21 versus -0.19). The 'frontier' effects on TFP growth are larger than either the S&A results or those in column 3 suggesting that small firms rely more on technology spillovers developed by others than internally developed R&D.

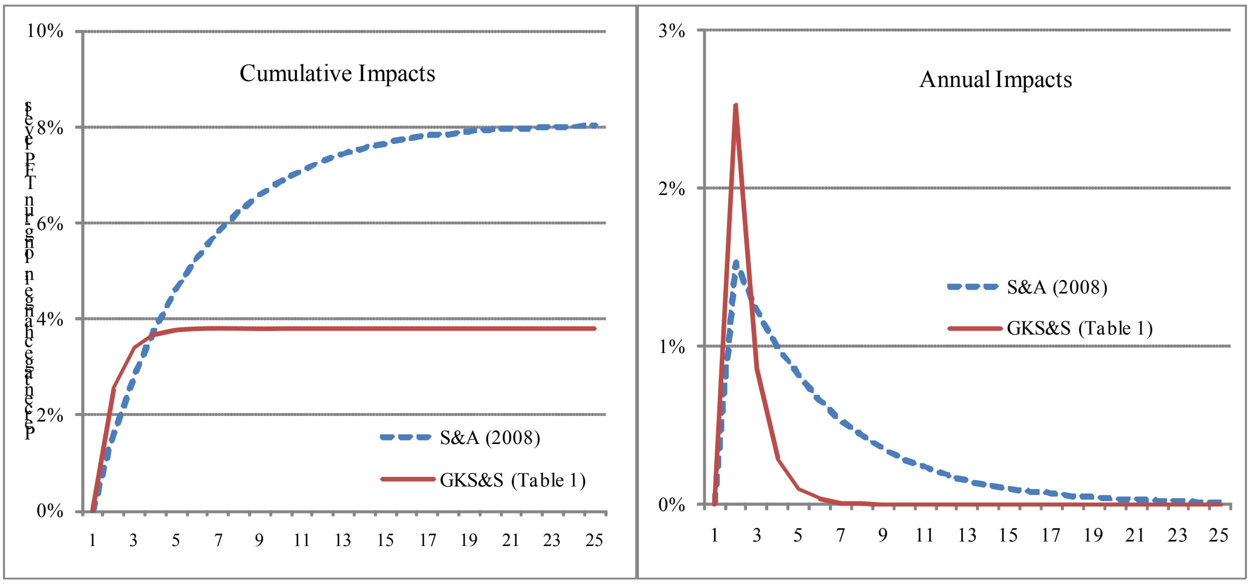
Our variable of interest, profitability interacted with the corporate tax rate, shows a negative and significant impact on growth in columns (1) and (2). This is similar to the S&A (2008) result. That is, firms in more profitable industries appear to have lower TFP when this

[11] It is also worth noting that this negative figure does not imply negative aggregate productivity growth, where that will be determined by additionally by the reallocation of market share across firms and the relative productivity of those firms that enter the industry versus those that exit.

occurs in high tax country-year combinations compared to low tax countries/years. Compared to the S&A parameter of -0.31 we find a larger direct effect (α in equation (3) above) for the larger sample including all firm sizes (-0.51) but a similar or smaller effect (-0.28) when <20 employee firms are omitted. These results would suggest that the adverse productivity impacts of corporate taxes are especially pronounced for small firms, perhaps because their limited size makes them more likely to be vulnerable when subject to profit failures. We note at this point however, that this result is sensitive to the exclusion of interactions between industry-and firm size in column (4). Once we control for the different in the rate of TFP growth between firms of different sizes within an industry we find that small firms are in fact less sensitive to higher corporate tax rates.

The parameters above do not measure the long-run impact of corporate taxes on TFP, which requires inclusion of the convergence parameter in the calculation. This is estimated at -0.662 in column (1) indicating that the impact decays relatively quickly: for example, changing the corporate tax rate by 5 percentage points (ppts) would have an impact on TFP growth over five years then largely disappear. The long-run impact on the TFP level would be to increase this by 3.8% in firms in the sector with median TFP. In contrast, S&A (2008) estimates (from Table 1) suggest much slower convergence with impacts lasting around 20 years, and increasing TFP level in the long-run by 8% (see Figure 1). So, in the short run the tax-related TFP impact we estimate is somewhat higher, but from 4 years onwards the S&A estimated impact is higher. Over 20 years, we estimate that a firm in a median profitability sector will increase its TFP by a 0.2% annually approximately half of the S&A estimate of 0.4%. Given trend TFP growth of OECD countries of around 1% per year in recent years (OECD, 2007), we consider our estimated impact to be more plausible, especially when recognising that our sample includes a wider range of both large and small firms. Figure 1 also highlights the potential for differences in taxation to help to explain differences in productivity levels, and therefore income levels, between countries.

Figure 1 Long-run impact of a 5 p.pts. cut in corporate tax rates on TFP levels



In column (3) of Table 1 we replace year-*country* interacted dummies with year-*industry* dummies to allow for the possibility that time-dependent shocks are common across firms in an industry rather than in a country. By doing this the R^2 increases from 0.05 to 0.06. Otherwise, results are very similar to those of column (1), suggesting that parameter estimates are robust and not driven by the evolution of technology affecting different industries or countries.

Column (4) interacts profitability and corporate tax rates with firms' employment size.[12] As already noted, we also introduce size-industry interacted dummies to this regression. We find that the estimated corporate tax impact is both quantitatively smaller (less negative) and not significantly different from zero for very small firms – those with 5 employees or less. For the three categories of firm with more than 5 employees however (6-19, 20-30, 31+) the effect of corporate taxes on TFP is significantly negative and of similar orders of magnitude – the parameter estimate for 20-30 employee firms is slightly larger (less negative) but not significantly different from the others. It seems likely that especially small firms are less research-intensive, such that their productivity is less affected by a "success tax" such as the corporate tax rate. Such small firms, perhaps especially where they represent young firms, may also benefit more from tax exemptions than other firms, making them less sensitive to the corporate tax rate.

[12] Column (5) confirms the results in column (4) when introducing sector-year interacted dummies instead of country-year dummies.

Column 6 and 7 show, however, that a firm's age does not significantly affect the impact of the tax-profitability interaction on TFP. All firm age impacts are in the range -0.47 to -0.60 (-0.42 to -0.54) and are not significantly different. This is in contrast to S&A who found that older firms (6+ years) are more affected by taxes than younger firms. This may be due to the fact that our sample includes a much larger fraction of small- and medium-sized firms that are affected in a similar same way by corporate taxes, independently of their age.

Research Intensity

Table 2 tests research intensity variables interacted with corporate tax rates. By introducing R&D we are able to analyse if firms in sectors more intensive in technology are more affected by corporate tax rates than firms in the same country or year but in a industry that is less technology-intensive. Similarly a firm from a technology intensive industry in a country with a high corporate tax rate will be affected more than a firm from the same industry but in a country with a lower corporate tax rate. Furthermore, if our hypothesis that corporate tax rates reduce the incentive to take risks is correct, then a firm in a highly technology intensive industry *and* facing a high corporate tax rate will invest less in risky, TFP-enhancing activities. Of course, if some R&D activities are financed from profits, firms in countries with higher corporate profit taxes will be less able to finance this type of investment. In this case, firms that are also in more profitable industries (for given R&D intensity) will have lower TFP when corporate tax rates are higher due to this 'tax base' effect. It is also worth remembering that these regressions control for the general tendency for some industries and countries to have higher underlying rates of TFP growth.

To measure R&D intensity, we use US 23 2-digit industry-level R&D spending from OECD ANBERD Database as a ratio of either total production or value added (from the OECD STAN Database). We use the mean value of the ratio over the period 1995-2007. We choose to employ the US values for all countries to reduce the potential endogeneity arising from the possibility that, in a heterogeneous firm setting, within a given country, firms with higher productivity may be capable of investing more in R&D, thus biasing any estimated relationship from R&D to productivity.

To examine the role of R&D we are forced to focus on manufacturing sector firms since there is less information available on R&D spending in service sectors. We first re-estimate the same equation as in column 1 of Table 1 but restricted to manufacturing firms. We find similar results, with a convergence parameter somewhat lower of -0.607 instead of -

0.662 and a higher associated impact to tax interacted with profitability (-0.600 instead of -0.505). We also find some indication that manufacturing firms are more affected and for a longer period of time by taxes than combined industry-plus-service sector firms (a long-run impact of -1.0 instead of -0.8). The 'frontier effect' seems to be very similar in both estimations, and the R-squared increases to 0.08, suggesting that the model explains manufacturing firms' TFP better than for service sector firms.

Column 1 shows that introducing the interacted term of research intensity with the corporate tax rate does not affect the parameters associated with the 'frontier' effect and convergence. Research intensity (as a share of value added) interacted with corporate tax rate is however negative and highly significant, as predicted. Firms in high technology sectors in countries with high corporate tax rates tend to have reduced TFP growth compared with firms in the same sector but in lower corporate tax rate countries or firms in the same country but in low R&D-intensity industries. If we again simulate a reduction of the corporate tax rate by 5 percentage points (ppts), TFP would increase at a higher rate for four years before returning to its previous growth rate. The impact on the *level* of TFP would be a permanent rise of 3.9%.

To test the relevance of R&D versus profitability as transmission mechanisms from corporate taxes to TFP, column 2 introduces both R&D intensity interacted with the corporate tax rate *and* profitability interacted with the corporate tax rate. Results from nesting both hypotheses show that the research intensity interaction 'wins the race', indicating that the technology intensity of the sector is more relevant that sector profitability to account for the impact of corporate taxes on TFP growth. Put another way, recognising the role of R&D intensity to mediate corporate tax effects onto TFP, a firm's profitability adds no significant additional information.

This, analysis therefore suggests a more obviously *technology-related* channel by which corporate taxes impact on TFP growth. That is, higher corporate tax rates induce firms in technology sectors especially to reduce their engagement in TFP-enhancing facilities because the rate of return, if they succeed, will be lowered. By contrast, firms in low technology-intensive sectors are less affected by corporate tax rates, because their opportunities to benefit from R&D activities are commensurately lower. We find similar results when computing research intensity as a share of production rather than value added (columns 3 & 4). In this case the permanent impact on TFP of reducing the corporate tax rate by 5 ppts levels appears somewhat larger at 5.5%. When we introduce industry-year dummies instead of country-year dummies (columns 5-8), we reach the same conclusion: research intensity is more relevant than profitability for determining the TFP impact of corporate tax rates. In fact we find somewhat larger TFP impacts of reducing the corporate tax rate by 5 ppts: 4.2% for the interaction with research intensity measured as a share of value added and 5.9% when computed as a share of production. Again, industry-year dummies capture a bit more of the variance than country-year dummies.

Table 3 analyses whether the impact of the corporate tax rate interacted with sector research intensity differs by the size and age of firms. Column 1 shows that parameters for the three 'fundamental variables' (the frontier effect, the convergence parameter and the interaction between corporate tax rate and research intensity) are highly stable across specifications. The estimated corporate tax rate impact on TFP growth by firm size is inconclusive, however, except that again, very small firms (up to 5 employees) appear to be least affected by corporate tax rates. Greater negative effects are found for all three larger categories (6-19, 20-30, 31+). To the extent that these categories differ, the 20-30 employee group appears to be less affected. These differences may reflect the typical sizes of the more research intensive, and less research intensive, firms but we are unable to confirm this from our data. Columns 2-4 show that this aspect of the results is consistently found for the alternative R&D intensity measure (as a share of production) and use of industry dummy variables.

Columns 5-8 shows the interacted effect of corporate tax rates and R&D intensity *by firm age*. These results suggest some tendency for especially young firms to be more responsive (more negative) to higher corporate tax rates, but otherwise different age groups display similar orders of magnitude – around -0.5 or -0.7 depending on specification. This evidence is in contrast to S&A (2008) who find a larger negative effect of corporate tax rates (when interacted with *profitability*) for older firms. Without further investigation it is hard to know the reasons behind this difference. It may be, for example, that by excluding firms of less than 20 employees, the 'young' firms in S&A's sample are more likely to be part of broader consolidated groups, making it easier to these firms to access group-related financial support and hence less vulnerable to corporate tax impacts. Our results would seem to be more in line with intuition that, other things equal, young innovating firms are especially vulnerable to higher corporate taxes compared to older innovating firms.

Intra-Industry Trade

We focus now on the role of intra-industry trade. As noted earlier, industries/sectors with more intra-industry trade are expected to be more competitive and are those in which creativeness, service and product innovations (or differentiation from other firms' goods) are more relevant to firm success and survival. In these sectors, arguably investments in these intangible assets, rather than inputs such as capital stock and employment, become critical for firms' performance. As in the case of interactions between profitability or R&D intensity and corporate tax rates, we test here whether firms in industries where intra-industry trade is greater are more affected by corporate tax rates than firms in the same country but in industries with less intra-industry trade. Of most relevance in this case are differences between firms in the same *industries* but in different *countries*. Intra-industry trade is often symptomatic of the presence of international firms producing similar, but differentiated, goods. Hence, for firms in the same industry with substantial pressure from international competition, international differences in corporate tax rates become more important.

Our data on intra-industry trade are again taken from the OECD STAN Database, and we use US values in order to reduce any potential endogeneity of those more productive sectors being also the sectors with more intra-industry trade. This reduces the number of observations to 26,128 because this information is available only for a limited number and range of industrial sectors (Nace 15-33).

Table 4 shows that the interaction of intra-industry trade with corporate tax rates impacts negatively and significantly on firms' TFP. Column 1 indicates that a 5 ppts reduction in the corporate tax rate would increase TFP levels by 6.3% over four years and then disappear (in a sector with a median intra-industry trade). Introducing year-*industry* dummies instead of year-*country* yields a similar result with a slightly higher impact of 6.8%. Of interest the effect of the corporate tax variable is better identified (the standard error is smaller) when we include industry-year rather than country-year effects. This would tend to reinforce the view that for the intra-industry trade measure it is the within industry-between country variation that is of greatest interest.

Columns 3 and 4 show that for small firms (<5 employees) the interaction between intra-industry trade and corporate tax rates is not significant. Tax exemptions to small firms may protect them from the impact of corporate tax rates or there may simply be limited numbers of such small firms engaged in intra-industry trade intensive industries. By contrast, larger firms may have to, or be more able to, differentiate their products more from those of other firms via innovations – and that are discouraged by corporate tax.

In contrast to the results from Table 2 for R&D, the interaction of corporate tax rates with intra-industry trade *and age* yields different results: now older firms (>10 years) appear to be associated with bigger impacts. This may reflect a tendency for younger innovating firms to be able to withstand short-term losses or low profitability (worsened by corporate tax rates) compared to older firms. That is, older high technology firms in loss or low profit situations are more likely to be vulnerable to failure since they have moved beyond their early gestation period when low returns might be expected. That is, if a high technology firm is still making losses or low returns after 10 years, high tax rates may force such firms under more readily.

Industry Entry-Exit Rates

Another potential indicator of the effect of corporate tax rates to TFP growth may be the entry-exit rate of firms in an industry. Industries with relatively high turnover rates might generally be expected to have lower sunk costs (entry+exit rates are low in basic metals, chemicals, and retail and wholesale and high in textiles) but this is an industry characteristic also associated with innovative technologies (industry churn is also high in machinery and equipment, telecommunications and computer services). Whilst, perhaps a noisy measure of technology related aspects of an industry it has the advantage that it also covers the service sector. As with previous measures capturing technology-related aspects of an industry, so we might expect the negative impacts of higher corporate taxes in high entry-exit industries, ceteris paribus, to reduce TFP. Column 1 of Table 5 shows some evidence of a negative effect from the interaction term between the entry-exit rate of firms and corporate tax rates, though not to a statistically significant level when year-*country* dummies are included. When introducing year-*industry* dummies instead, the evidence of effects on TFP growth is stronger, with generally more precise estimates: column 2 shows a negative and significant effect of the interacted term. As discussed before, the introduction of these industry-year effects relies more on the cross time and country variation in the data to indentify the effects of corporate taxation.

We therefore find some evidence of corporate tax rates being associated with higher entry-exit rates perhaps inducing firms to die prematurely before realising their productivity potential such that those industries have lower TFP when corporate tax is higher. This evidence reinforces the conclusion of the Sapir Report (2004), who stresses that higher productivity levels and growth in the US compared to Europe, could be due to the fact that entry, as well as exit and turnover of firms, are more prominent in North American. In addition, as Aghion (2006) points out: 'Half of new pharmaceutical products are introduced by firms that are less than 10 years old in the United States, versus only 10% in Europe. Similarly, 12% of the largest US firms by market capitalisation at the end of the 1990s had been founded less than twenty years before, against only 4% in Europe.'

Columns 3-4 again suggest that particularly small firms, (<5 employees), are less affected by corporate tax rates even in the relatively high turnover industries, with a smaller, non-significant estimated impact. Larger firm size categories reveal similarly negative impacts from corporate taxes though the precision of these estimates is more variable. Columns 5 show insignificant effects from the interaction between corporate tax rates and turnover by industry and firm *age*. The introduction of year-*industry* dummies, however, improves the precision of the estimated effects yielding statistically significant negative effects, similar across firm ages. Year–industry dummies seem likely to capture technology differences better since these might be expected to differ more by sector than country.

The User Cost of Capital

Turning to estimates of the impact of corporate taxes on investment rather than TFP, Table 6 shows the results of estimating the impact of the user cost of capital on investment based on equation (4). We follow Becker and Sivadasan (2006), controlling for lagged investment, squared lagged investment, the output-to-capital ratio and cashflow-to-capital ratio. Using cashflow leads to a reduced sample of 138,318 firms. Becker and Sivadasan (2006) argue that quadratic adjustment costs means that we should expect a positive impact from lagged investment and a negative effect from squared lagged investment. Also firms with more access to internal funds will have more opportunity to finance new investment in the presence of financial market imperfections such as credit constraints. Thus, we follow these authors by introducing cashflow and output-to-capital ratios.

Column 1 shows that lagged investment and squared lagged investment have the expected significant signs. Cashflow and output-to-capital ratios also have the expected signs but are not significantly positive. Since our sample includes firms of all sizes (whereas S&A (2008) restrict their sample to firms with 20+ employees), it may be that for especially small firms output-to-capital ratios and cashflows are not decisive for marginal investment decisions. If so, it is unclear why this might be. The next column shows that, indeed, when restricting our sample to firms with 20+ employees we also find a significant positive impact from output-to-capital ratio (and the R-squared improves substantially suggesting that it is more difficult to explain small firms' investment). Cashflows seem to have a high correlation with output-to-capital ratios. When we drop this latter variable in the restricted sample, we find a positive and significant impact for the cashflow-to-capital ratio (not shown).

Estimates of the impact of the user cost of capital on investment are negative and significant. (Our estimates appear to be even higher, in absolute terms, than those obtained by S&A, 2008). The estimated coefficient associated with the user cost of capital appears to *decrease* (in absolute value) when introducing year-*industry* dummies (column 2). Similarly, especially large firms (>30 employees) reveal smaller and less robust estimates of the impact of the user cost of capital on investment (columns 3-4). This may reflect a greater use of loan finance for investment which is less affected by corporate taxes (via debt deductibility) compared with financing with retained profits or equity. We also find no significantly different effects on firms' investment when disaggregated by *age* (columns 5-6).

Table 7 shows that industry-profitability or industry-research intensity (whether measured as a share of value added and production) do not appear to affect the impact of the user cost of capital on investment. That is, in contrast to TFP growth, profitability and R&D appear not to be relevant in this context. This evidence therefore suggests that firms in industries with high R&D intensity are more discouraged by corporate tax rates in their TFP-enhancing activities than firms in less R&D-intensive industries. However, firms in both types of industries are equally discouraged in their investment decisions. Similar evidence applies to profitability. This is in contrast to S&A (2008) who find that the user cost of capital reduces investment for firms in more profitable industries. Finally, regarding intra-industry trade (columns 7-8) we find that investment by firms in industries with more intra-industry trade are less affected by the user cost of capital than firms in industries with less intra-industry trade.

5. Conclusions

This paper has sought to add to the recent literature that has begun to use micro-level data to examine the response of firms to various conditions affecting their productivity levels or growth rates. Our particular interest has been to investigate how far corporate tax settings might affect firms' innovation and risk-taking activity: both of these activities can be linked to the known characteristics of corporate tax regimes in European countries via their treatment of corporate profits and losses.

Previous investigation of this issue, by Schwellnus and Arnold (2008), examined the link between higher corporate taxes and firm-level TFP as mediated through higher profitability; that is, firms with higher corporate profits but in regimes involving higher corporate tax rates are expected to have lower TFP than equivalent firms in low corporate tax regimes. The mechanism hypothesised to be at work here is the higher tax liability (or effective average tax rates) associated with higher profits acts as a disincentive towards undertaking those innovations that raise TFP.

Our contribution has been to re-examine the evidence of S&A (2008) of apparently large and persistent impacts of corporate tax on firm-level TFP, as mediated through profits, and to consider alternative indicators of firm-level innovation/technology that we argue provide better proxies for the impact of taxes on productivity via innovation effects than using firm profits.

Based on an economteric model of innovation and productivity proposed by Griffith et al. (2006) and Schwellnus and Arnold (2008), we show that:

- Using a similar sized sample to S&A (2008) but which does *not* exclude small (<20 employee) firms, the estimated impact of higher corporate tax rates on TFP *when interacted with firm profit levels* is no longer implausibly large and occurs relatively quickly (within 4-5, rather than 20+ years).
- However, using alternative measures of industries' innovative characteristics such as research intensity, the extent of intra-industry trade and firm entry-exit rates, we find stronger evidence that firms in those 'innovation intensive' industries are more adversely affected by high corporate tax rates than those in low 'innovation intensive' industries.
- Higher corporate tax rates, via their effect on the post-tax user cost of capital have adverse effects on firm's investment levels.

We have adopted approaches here that we believe largely deal with potential endogeneity concerns with such tests and our evidence seems to be supportive of adverse TFP impacts of higher corporate tax rates. In addition our evidence is consistent with these impacts being mediated substantially through their effect on industries that are intensive in R&D, intra-industry trade etc – all characteristics of innovative firms/industries.

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Table 1 The Effect of Corporate Taxes and TFP Growth at the Firm Level

	S&A (2008)	1	2 (Emp > 19)	3	4	5	6	7
TFP growth frontier firms in the same industry	0.173 9.10	0.217 4.70	0.090 1.83	0.247 5.23	0.216 4.12	0.245 5.03	0.2221 4.62	0.234 5.04
TFP gap with frontier firms	-0.190 12.67	-0.662 10.25	-0.212 2.13	-0.668 10.20	-0.678 10.09	-0.683 10.08	-0.678 10.30	-0.684 10.19
Profitability *x* corporate tax	-0.307 2.40	-0.505 2.42	-0.282 1.13	-0.497 2.66				
Profitability *x* corporate tax (employment 1-5)					-0.167 0.91	-0.172 1.09		
Profitability *x* corporate tax (employment 6-19)					-0.799 3.33	-0.791 3.52		
Profitability *x* corporate tax (employment 20-30)					-0.516 2.08	-0.506 1.99		
Profitability *x* corporate tax (employment 31+)					-0.810 2.97	-0.827 2.89		
Profitability *x* corporate tax (firm age 7-10)							-0.572 2.28	-0.547 2.70
Profitability *x* corporate tax (firm age 7-10)							-0.476 1.65	-0.429 1.69
Profitability *x* corporate tax (firm age 11-17)							-0.523 2.31	-0.486 2.51
Profitability *x* corporate tax (firm age 18+)							-0.596 2.63	-0.548 2.85
Year, Country & Industry dummies	YES	YES	YES	YES	YES	YES	YES	YES
Country *x* year dummies	YES	YES	YES	**NO**	YES	**NO**	YES	**NO**
Industry *x* year dummies	**NO**	**NO**	**NO**	YES	**NO**	YES	**NO**	YES
Industry * size dummies	**NO**	**NO**	**NO**	**NO**	YES	YES	**NO**	**NO**
Industry * age dummies	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	YES	YES
Observations	287,727	241,476	11,408	241,476	241,476	241,476	201,541	201,541
R-squared	0.10	0.05	0.05	0.06	0.06	0.06	0.06	0.06

Table 2 Testing Research Intensity Variables (as shares of value added or production)

	S&A model (small sample)	1	2	3	4	5	6	7	8
TFP growth frontier firms in the same industry	0.205 3.40	0.210 3.31	0.211 3.31	0.211 3.32	0.211 3.32	0.231 4.04	0.232 4.03	0.231 4.04	0.232 4.03
TFP gap with frontier firms	-0.607 6.62	-0.619 6.73	-0.620 6.69	-0.619 6.73	-0.619 6.73	-0.634 6.49	-0.635 6.47	-0.634 6.49	-0.635 6.47
Research intensity *x* corporate tax (value added)		-0.487 6.27	-0.456 7.38			-0.531 6.50	-0.485 7.20		
Research intensity *x* corporate tax (production)				-0.684 6.28	-0.640 7.39			-0.746 6.47	-0.681 7.06
Profitability *x* corporate tax	-0.006 1.69		-0.001 0.70		-0.001 0.71		-0.001 0.94		-0.002 0.96
Year, Country & Industry dummies	YES	YES	YES	YES	YES	YES	YES	YES	YES
Country *x* year dummies	YES	YES	YES	YES	YES	**NO**	**NO**	**NO**	**NO**
Industry *x* year dummies	**NO**	**NO**	**NO**	**NO**	**NO**	YES	YES	YES	YES
Observations	86,745	86,745	86,745	86,745	86,745	86,745	86,745	86,745	86,745
R-squared	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09

Table 3 Testing Research Intensity Interacted with Firm Employment and Age

	1 R&D share of *Value added*	2 R&D share of *Production*	3 R&D share of *Value added*	4 R&D share of *Production*	5 R&D share of *Value added*	6 R&D share of *Production*	7 R&D share of *Value added*	8 R&D share of *Production*
TFP growth frontier firms in the same industry	0.207 3.01	0.208 3.01	0.229 3.88	0.229 3.88	0.206 2.97	0.206 2.98	0.220 3.49	0.220 3.49
TFP gap with frontier firms	-0.627 6.59	-0.627 6.58	-0.639 6.43	-0.639 6.42	-0.622 5.41	-0.622 5.41	-0.636 5.16	-0.636 5.15
Research intensity *x* corporate tax (employment 1-5)	-0.213 3.67	-0.302 3.70	-0.258 3.96	-0.364 3.94				
Research intensity *x* corporate tax (employment 6-19)	-0.718 7.21	-1.010 7.25	-0.778 8.33	-1.090 8.29				
Research intensity *x* corporate tax (employment 20-30)	-0.267 2.97	-0.372 2.96	-0.333 2.69	-0.461 2.68				
Research intensity *x* corporate tax (employment 31+)	-0.481 4.37	-0.668 4.48	-0.623 4.07	-0.866 4.13				
Research intensity *x* corporate tax (firm age 1-6)					-0.586 5.78	-0.828 5.85	-0.601 6.20	-0.847 6.21
Research intensity *x* corporate tax (firm age 7-10)					-0.499 5.13	-0.700 5.11	-0.542 5.26	-0.760 5.26
Research intensity *x* corporate tax (firm age 11-17)					-0.483 5.44	-0.676 5.39	-0.512 5.17	-0.717 5.13
Research intensity *x* corporate tax (firm age 18+)					-0.502 5.60	-0.704 5.57	-0.528 5.01	-0.739 4.99
Year, Country & Industry dummies	YES	YES	YES	YES	YES	YES	YES	YES
Country *x* year dummies	YES	YES	**NO**	**NO**	YES	YES	**NO**	**NO**
Industry *x* year dummies	**NO**	**NO**	YES	YES	**NO**	**NO**	YES	YES
Industry * size (or age) dummies	YES	YES	YES	YES	YES	YES	YES	YES
Observations	86,745	86,745	86,745	86,745	72,022	72,022	72,022	72,022
R-squared	0.08	0.08	0.09	0.09	0.12	0.12	0.13	0.13

Table 4 Testing Intra-industry Trade Interacted with Corporate Tax

TFP growth frontier firms in the same industry	0.205 3.88	0.156 2.83	0.220 4.18	0.173 3.09	0.230 4.38	0.167 2.39
TFP gap with frontier firms	-0.630 5.16	-0.657 5.27	-0.682 5.31	-0.706 5.44	-0.687 5.13	-0.714 5.15
Intra-industry trade *x* corporate tax	-0.008 1.98	-0.009 2.83				
Intra-industry *x* corporate tax *x* emp 1-5			-0.003 0.69	-0.003 0.91		
Intra-industry *x* corporate tax *x* emp 6-19			-0.012 2.39	-0.013 3.26		
Intra-industry *x* corporate tax *x* emp 20-30			-0.007 1.79	-0.008 2.34		
Intra-industry *x* corporate tax *x* emp 31+			-0.012 2.39	-0.013 2.69		
Intra-industry *x* corporate tax *x* age 1-6					-0.008 1.35	-0.008 1.74
Intra-industry *x* corporate tax *x* age 7-10					-0.006 1.90	-0.007 2.33
Intra-industry *x* corporate tax *x* age 11-17					-0.012 2.32	-0.011 2.88
Intra-industry *x* corporate tax *x* age 18+					-0.012 2.26	-0.012 2.82
Year, Country & Industry dummies	YES	YES	YES	YES	YES	YES
Country *x* year dummies	YES	**NO**	YES	**NO**	YES	**NO**
Industry *x* year dummies	**NO**	YES	**NO**	YES	**NO**	YES
Industry * size (or age) dummies	NO	NO	YES	YES	YES	YES
Observations	26,128	26,128	26,128	26,128	22,479	26,128
R-squared	0.06	0.06	0.07	0.07	0.07	0.08

Table 5 Entry and Exit Rates of Firms Interacted with Corporate Tax

TFP growth frontier firms in the same industry	0.224 4.89	0.251 5.48	0.215 4.09	0.244 5.26	0.223 4.75	0.228 5.45
TFP gap with frontier firms	-0.694 10.35	-0.700 10.26	-0.708 10.07	-0.712 10.07	-0.702 10.16	-0.710 10.06
Entry-exit rate of firms *x* corporate tax	-0.008 1.29	-0.005 2.15				
Entry-exit *x* corporate tax *x* emp 1-5			-0.007 1.08	-0.003 1.11		
Entry-exit *x* corporate tax *x* emp 6-19			-0.012 1.62	-0.007 2.77		
Entry-exit *x* corporate tax *x* emp 20-30			-0.010 1.34	-0.005 1.29		
Entry-exit *x* corporate tax *x* emp 31+			-0.011 1.95	-0.007 1.58		
Entry-exit *x* corporate tax *x* age 1-6					-0.007 1.14	-0.005 2.28
Entry-exit *x* corporate tax *x* age 7-10					-0.008 1.27	-0.005 2.39
Entry-exit *x* corporate tax *x* age 11-17					-0.007 1.08	-0.004 1.85
Entry-exit *x* corporate tax *x* age 18+					-0.008 1.27	-0.005 2.12
Year, Country & Industry dummies	YES	YES	YES	YES	YES	YES
Country *x* year dummies	YES	**NO**	YES	**NO**	YES	**NO**
Industry *x* year dummies	**NO**	YES	**NO**	YES	**NO**	YES
Observations	206,877	206,877	206,877	206,877	174,500	174,500
R-squared	0.06	0.06	0.06	0.06	0.07	0.07

Table 6 User cost of capital and investment

	1	S&A	Emp >19	2	3	4	5	6
Lagged tangible investment to capital stock ratio	0.135 4.84	0.532 20.46	0.162 3.94	0.139 5.44	0.136 5.34	0.138 5.50	0.134 5.19	0.133 5.25
Squared lagged tangible investment to capital stock ratio	-0.117 2.59	-0.415 16.60	-0.120 1.95	-0.126 2.89	-0.122 2.87	-0.125 2.91	-0.123 2.88	-0.123 2.89
Lagged output to capital ratio	0.000003 0.37	0.000*** 0.000	0.0004 1.98	0.000008 0.86	0.000003 0.29	0.000007 0.76	0.000006 0.65	0.00008 0.96
Lagged cash-flow to capital ratio	0.000039 0.57	0.048 16.00	-0.0003 0.56	0.000018 0.22	0.000037 0.46	0.000019 0.22	0.000044 0.48	0.000027 0.26
Lagged user cost of capital	-1.062 2.60	-0.829 2.02	-2.91 1.99	-0.404 1.84				
Lagged user cost of capital *x* employment 1-5					-0.935 1.96	-0.325 1.34		
Lagged user cost of capital *x* employment 6-19					-0.958 2.15	-0.361 1.55		
Lagged user cost of capital *x* employment 20-30					-1.383 2.33	-0.677 1.68		
Lagged user cost of capital *x* employment 31 or more					-0.596 1.28	0.074 0.29		
Lagged user cost of capital *x* age 0-6							0.220 1.24	0.247 1.34
Lagged user cost of capital *x* age 7-10							-0.122 0.52	-0.022 0.11
Lagged user cost of capital *x* age 11-17							-0.120 0.91	-0.150 1.20
Lagged user cost of capital *x* age 18+							-0.002 0.91	-0.002 1.33
Year, Country & Industry dummies	YES	YES	YES	YES	YES	YES	YES	YES
Country *x* year dummies	YES	YES	YES	**NO**	YES	**NO**	YES	**NO**
Industry *x* year dummies	**NO**	**NO**	**NO**	YES	**NO**	YES	**NO**	YES
Industry* size (age) dummies	**NO**	**NO**	**NO**	**NO**	YES	YES	YES	YES
Observations	138,318	211,599	10,472	138,318	138,318	138,318	138,318	138,318
R-squared	0.03	0.12	0.10	0.04	0.04	0.05	0.04	0.05

Table 7 User cost of capital and investment (Continuation)

	1	2	3	4	5	6	7	8
Lagged tangible investment to capital stock ratio	0.134 4.86	0.139 5.46	0.123 3.46	0.121 3.37	0.124 3.46	0.121 3.37	0.153 4.03	0.153 4.33
Squared lagged tangible investment to capital stock ratio	-0.116 2.60	-0.124 2.89	-0.071 1.31	-0.072 1.25	-0.071 1.31	-0.072 1.25	-0.092 2.31	-0.087 2.34
Lagged output to capital ratio	0.000004 0.47	0.000009 1.01	-0.000002 0.30	0.000002 0.43	-0.000002 0.31	0.000002 0.43	-0.00001 0.61	0.000007 0.29
Lagged cashflow to capital ratio	0.000037 0.54	0.000016 0.19	0.000299 0.94	0.000250 0.82	0.000299 0.94	0.000250 0.82	0.001345 2.67	0.001173 0.82
Lagged user cost of capital	-0.974 2.28	-0.265 1.24	-1.011 1.57	-0.166 0.74	-0.998 1.55	-0.167 0.74	-6.785 6.37	-0.332 0.76
Lagged user cost of capital interacted with profitability	-0.108 0.76	-0.167 1.05						
Lagged user cost of capital *x* R&D intensity (% value added)			-0.000037 0.69	0.000010 0.16				
Lagged user cost of capital * R&D intensity (% production)					-0.000043 0.60	0.000017 0.20		
Lagged user cost of capital *x* Intra-industry trade							0.625 3.43	0.222 0.80
Year, Country & Industry dummies	YES	YES	YES	YES	YES	YES	YES	YES
Country *x* year dummies	YES	**NO**	YES	**NO**	YES	**NO**	**NO**	**NO**
Industry *x* year dummies	**NO**	YES	**NO**	YES	**NO**	YES	YES	YES
Observations	138,318	138,318	53,471	53,471	53,471	53,471	18,991	18,991
R-squared	0.03	0.04	0.03	0.05	0.03	0.05	0.04	0.05

Appendix 1: Construction of the Dataset

Countries

Firm data is taken from the Amadeus database (from Bureau van Dijk). This database covers 30 European OECD member countries over the time period 1995-2008. To ensure that the final sample is representative of the underlying population of firms we combine this with information on the distribution of firms by size class and industry from the OECD's Structural and Demographic Business Statistics Database. More detail on this process is provided below. Data on 18 of the 30 countries is available within the OECD SDBS database. As is evident from the table the excluded countries are mostly Central and Eastern European Countries. Given their transition from central planning to a market economy over the sample period other motivations for the exclusion of these countries might also be found. There are many missing observations for Switzerland and Luxembourg in the OECD SDBS database; we therefore also choose to exclude these two countries from the analysis. This leaves a final sample of 16 countries.

Table A1: Countries available in Amadeus, OECD SDBS and Final Sample

Available in Amadeus	**Available in OECD SDBS**	Final Sample	**Available in Amadeus**	**Available in OECD SDBS**	Final Sample
Austria	X	X	Italy	X	X
Belarus			Latvia		
Belgium	X	X	Luxembourg	X	
Bosnia			Netherlands	X	X
Bulgaria			Norway	X	X
Croatia			Portugal	X	X
Czech Republic	X	X	Romania		
Denmark	X	X	Serbia		
Estonia			Slovak Republic		
Finland	X	X	Slovakia		
France	X	X	Slovenia		
Germany	X	X	Spain	X	X
Greece			Sweden	X	X
Iceland	X	X	Switzerland	X	
Ireland	X	X	UK	X	X

Industries

Firms within Amadeus are classified according to the 4-digit ISIC industry classification. We focus the analysis on firms in both the manufacturing and services sectors (Nace 15-93). We however exclude the sectors of recycling (Nace 37), refuse disposal (Nace 90) and utilities (Nace 40, 41), because of the high share of public ownership in some countries over the sample period. In addition financial services (Nace 65-67), real estate (Nace 70) and holding companies (Nace 7415) are excluded due to different reporting standards in these sectors. Finally, due to the presence of many non-profit organisations in the public administration (Nace 75), education (Nace 80), health (Nace 85) and activities of membership organisations (Nace 91), these four sectors have been also excluded from the sample. The (2-digit) industries covered within the analysis are listed in Table A2.

Table A2: Industries Used in the Analysis (ISIC 2-digit)

ISIC Code	MANUFACTURING
	Food products, beverages and tobacco
15	Manuf. of food products and beverages
16	Manuf. of tobacco products
	Textiles and textile products
17	Manuf. of textiles
18	Manuf. of wearing apparel, dressing and dyeing of fur
19	Tanning and dressing of leather, luggage, handbags, saddlery, harness and footwear
20	Manuf. of wood and of products of wood and cork, except furniture, straw and plaiting
	Paper, paper products, printing and publishing
21	Manuf. of paper and paper products
22	Publishing, printing and reProd. of recorded media
	Energy products, chemicals and plastic products
23	Manuf. of coke, refined petroleum products and nuclear fuel
24	Manuf. of chemicals and chemical products
25	Manuf. of rubber and plastics products
26	Manuf. of other non-metallic mineral products
	Basic metals and fabricated metal products
27	Manuf. of basic metals
28	Manuf. of fabricated metal products, except machinery and equipment
29	Manuf. of machinery and equipment n.e.c.
	Electrical and optical equipment
30	Manuf. of office, accounting and computing machinery
31	Manuf. of electrical machinery and apparatus n.e.c.
32	Manuf. of radio, television and communication equipment and apparatus
33	Manuf. of medical, precision and optical instruments, watches and clocks
	Transport equipment
34	Manuf. of motor vehicles, trailers and semi-trailers
35	Manuf. of other transport equipment
	Manufacturing nec, recycling
36	Manuf. of furniture, manufacturing n.e.c.
37	Recycling

45	CONSTRUCTION
	WHOLE SALE AND RETAIL TRADE
50	Sale, maint. and repair of motor vehicles/cycles, retail sale of fuel
51	Wholesale trade and commission trade, except of motor vehicles and motorcycles
52	Retail trade, except of motor vehicles and motorcycles, repair of personal and household goods
55	HOTELS AND RESTAUTANTS
	TRANSPORT, STORAGE AND COMMUNICATIONS
60	Land transport, transport via pipelines
61	Water transport
62	Air transport
63	Supporting and auxiliary transport activities, travel agencies
64	Post and telecommunications
	REAL ESTATE, RENTING , BUSINESS ACTIVITIES
70	Real estate activities
71	Renting of machinery without operator and of household goods
72	Computer and related activities
73	Research and development
74	Other business activities

Firms

Two important limitations on the use of cross-country data drawn from the Amadeus database are (1) that the data is a non-representative sample of firms within each country; and (2) pooling the data across countries exceeds the limits of available computer power. To generate a useable database we therefore attempt to address both of these issues by randomly sampling from each country such that the final sample matches the size distribution within an industry within a given country reported within the OECD Structural and Business Demographic Database. This is done in such a way such that the final database can be thought of as representative within a country, but also across the database as a whole. Large countries have greater number of firms than small countries within the final dataset.

In more detail, the sample selection process involved first deleting any outliers and obvious data entry errors from the Amadeus data. All variables with negative values were eliminated from the sample. Firms reporting a higher value of investment than their capital stock, or with extreme decreases in capital stock (and not exiting the market) were dropped from the database, as were firms whose employment growth was above 200% (the top 1 per cent of observations) in a single period or sales growth above 500%.

The second step was to determine the number and type of firms to randomly sample. The OECD SDBS database reports the number of firms within one of 5 employment size bands (<10, 10-19, 20-49, 50-249, >250), by each ISIC (2-digit) industry according to the census of production within each country. From here we calculate the ratio of the number of firms within each of these size/industry/country cells relative to the total number of firms across the 16 countries that make up the sample. This is a data demanding process and so we perform this sampling based on Amadeus and OECD SDBS data for 2003 only (the exception to this is Ireland which is based on data for 2007). This represents the middle of our sample period. Our sample will therefore remain representative of the population of firms within our 16 countries to the extent that there is no net drift between size bands within an industry, and that the overall distribution of firms did not change markedly over time. The confidence with which we might make this assumption might be reasonably thought to diminish as we move further forward or backward from 2003.

Using the ratio of the number of firms in each size/industry/country cell to the total number of firms we then calculated the number of observations from that cell that would be needed to generate a final sample of 200,000 firms in 2003, a number chosen so that the final dataset would include around 1 million firm-year observations. The number of firms in each cell was rounded to the nearest integer. The final step was to randomly sample with replacement from an equivalent size/industry/country cell within the Amadeus database such that the number of observations drawn for 2003 was equal to that suggested by the OECD SDBS database necessary to generate a total figure of 200,000 firms in that year.

Further detail on the data by size class for country totals are provided in Tables A3 and A4. In Table A3 we report the number of firms within each size class suggested by the OECD SDBS dataset, and that available in Amadeus before and after (labelled Final Sample) randomly sampling. In Table A4 we present information on the distribution of firm size within the OECD SDBS, Amadeus and the Final Sample. A number of points can be made using these two tables. Firstly, the number that the OECD SDBS database suggests should be available from these 16 countries is far greater than can be obtained from Amadeus (14.4 million versus 585,017). The size bias in Amadeus is also clear. According to the OECD SDBS 91.4 per cent of firms have less than 10 employees, whereas the raw Amadeus data suggests that this figure is only around 50 per cent. Similarly according to the OECD SDBS 0.2 per cent of firms have more than 250 employees, whereas in the Amadeus data these firms make up 3 per cent of the total number of observations. As Table A4 makes clear, the extent of this size bias differs markedly across country datasets.

Also evident from the tables are clear differences in the number and distribution of firms that are not evident when using the Amadeus database. Perhaps most obviously Italy has by far the largest number of firms according to the OECD SDBS, a result that in part at least reflects the greater proportion of small firms in that country. At the other end Austria, Denmark and the UK tend to have more large firms than the average. In the case of the UK at least this translates into more large firms within the final database than is the case for other countries.

Finally, according to Table A4 the stratified random sampling would appear to have been successful in controlling for this. Within Table A4 it also becomes obvious however that this has occurred in part because the same firms have been repeatedly sampled. Perhaps most stark within this is the repeated sampling of the 130 Danish firms in the Amadeus dataset that have less than 10 employees.

After completing the sampling exercise across all years of the sample we are left with a final sample of 1,034,933 firm-year observations (Table A5). As suggested by comparing this figure with the 200,000 firms collected in 2003 this is not a balanced panel with a noticeable reduction in the number of observations towards the beginning and the end of the period. On average there are 6 observations per firm (inter-quartile range is 5-8 years per firm).

Table A3: Number of Firms by Employment and Country in OECD SDBS Database, Amadeus and the Random Sample

	Employment: Sample:	<10	10-19	20-49	50-249	>250	Total
Austria	OECD SDBS	224816	19532	9657	4298	875	259178
	Amadeus	2453	636	313	124	17	3543
	Random Sample	3089	255	117	44	0	3505
Belgium	OECD SDBS	345212	16066	9756	3772	828	375634
	Amadeus	17866	3569	4021	2780	735	28971
	Random Sample	4759	210	119	38	0	5126
Czech Republic	OECD SDBS	706858	21802	11278	6197	1289	747424
	Amadeus	4934	2070	1832	2773	857	12466
	Random Sample	9767	288	142	71	0	10268
Denmark	OECD SDBS	159217	12571	6633	3537	628	182586
	Amadeus	130	16	19	30	12	207
	Random Sample	2063	131	52	23	0	2269
Finland	OECD SDBS	161890	6817	4228	2173	534	175642
	Amadeus	12152	2964	2189	1180	422	18907
	Random Sample	2224	77	40	16	0	2357
France	OECD SDBS	1997753	83454	57022	23026	4942	2166197
	Amadeus	33965	23675	23181	11236	2922	94979
	Random Sample	27642	1138	772	301	5	29858
Germany	OECD SDBS	1508161	143280	72866	30083	5901	1760291
	Amadeus	18170	5613	3579	2752	1806	31920
	Random Sample	20861	1965	988	398	3	24215
Iceland	OECD SDBS	4183	231	115	29	4	4562
	Amadeus	146	17	8	1	0	172
	Random Sample	57	2	0	0	0	59
Ireland	OECD SDBS	62116	6432	3562	1347	265	73722
	Amadeus	4864	1751	1388	594	85	8682
	Random Sample	850	77	41	12	0	980
Italy	OECD SDBS	3497540	129151	49543	18784	2834	3697852
	Amadeus	4404	4368	9143	8814	1450	28179
	Random Sample	48409	1771	668	243	3	51094
Netherland	OECD SDBS	417510	29275	17305	8295	1540	473925
	Amadeus	476	187	309	404	73	1449
	Random Sample	5668	379	205	98	0	6350
Norway	OECD SDBS	199763	10949	5267	2279	465	218723
	Amadeus	34461	6312	2993	1019	141	44926
	Random Sample	2748	139	58	16	0	2961
Portugal	OECD SDBS	523530	23557	12189	4946	684	564906
	Amadeus	13317	9085	8700	4327	685	36114
	Random Sample	6196	280	151	51	0	6678
Spain	OECD SDBS	1588125	65374	37431	13422	2328	1706680
	Amadeus	66370	39188	29103	11031	2086	147778
	Random Sample	21972	889	500	170	1	23532
Sweden	OECD SDBS	475876	13702	7977	3758	833	502146

	Amadeus	79270	10255	6625	3430	908	100488
	Random Sample	6571	172	94	37	0	6874
United Kingdom	OECD SDBS	1314004	120449	52358	25940	5602	1518353
	Amadeus	3276	2716	5114	9976	5154	26236
	Random Sample	18175	1650	708	338	20	20891
Total	**OECD SDBS**	**13186554**	**702642**	**357187**	**151886**	**29552**	**14427821**
	Amadeus	**296254**	**112422**	**98517**	**60471**	**17353**	**585017**
	Random Sample	**181051**	**9423**	**4655**	**1856**	**32**	**197017**

Table A4: Distribution of Firm by Employment Size, Country and Database

	Employment: Sample:	<10	10-19	20-49	50-249	>250	% of observations of country in total for all countries
Austria	OECD SDBS	86.74	7.54	3.73	1.66	0.34	1.80
	Amadeus	69.24	17.95	8.83	3.50	0.48	0.61
	Random Sample	88.13	7.28	3.34	1.26	0.00	1.78
Belgium	OECD SDBS	91.90	4.28	2.60	1.00	0.22	2.60
	Amadeus	61.67	12.32	13.88	9.60	2.54	4.95
	Random Sample	92.84	4.10	2.32	0.74	0.00	2.60
Czech Republic	OECD SDBS	94.57	2.92	1.51	0.83	0.17	5.18
	Amadeus	39.58	16.61	14.70	22.24	6.87	2.13
	Random Sample	95.12	2.80	1.38	0.69	0.00	5.21
Denmark	OECD SDBS	87.20	6.88	3.63	1.94	0.34	1.27
	Amadeus	62.80	7.73	9.18	14.49	5.80	0.04
	Random Sample	90.92	5.77	2.29	1.01	0.00	1.15
Finland	OECD SDBS	92.17	3.88	2.41	1.24	0.30	1.22
	Amadeus	64.27	15.68	11.58	6.24	2.23	3.23
	Random Sample	94.36	3.27	1.70	0.68	0.00	1.20
France	OECD SDBS	92.22	3.85	2.63	1.06	0.23	15.01
	Amadeus	35.76	24.93	24.41	11.83	3.08	16.24
	Random Sample	92.58	3.81	2.59	1.01	0.02	15.16
Germany	OECD SDBS	85.68	8.14	4.14	1.71	0.34	12.20
	Amadeus	56.92	17.58	11.21	8.62	5.66	5.46
	Random Sample	86.15	8.11	4.08	1.64	0.01	12.29
Iceland	OECD SDBS	91.69	5.06	2.52	0.64	0.09	0.03
	Amadeus	84.88	9.88	4.65	0.58	0.00	0.03
	Random Sample	96.61	3.39	0.00	0.00	0.00	0.03
Ireland	OECD SDBS	84.26	8.72	4.83	1.83	0.36	0.51
	Amadeus	56.02	20.17	15.99	6.84	0.98	1.48
	Random Sample	86.73	7.86	4.18	1.22	0.00	0.50
Italy	OECD SDBS	94.58	3.49	1.34	0.51	0.08	25.63
	Amadeus	15.63	15.50	32.45	31.28	5.15	4.82
	Random Sample	94.74	3.47	1.31	0.48	0.01	25.93
Netherland	OECD SDBS	88.10	6.18	3.65	1.75	0.32	3.28
	Amadeus	32.85	12.91	21.33	27.88	5.04	0.25

	Random Sample	89.26	5.97	3.23	1.54	0.00	3.22
Norway	OECD SDBS	91.33	5.01	2.41	1.04	0.21	1.52
	Amadeus	76.71	14.05	6.66	2.27	0.31	7.68
	Random Sample	92.81	4.69	1.96	0.54	0.00	1.50
Portugal	OECD SDBS	92.68	4.17	2.16	0.88	0.12	3.92
	Amadeus	36.87	25.16	24.09	11.98	1.90	6.17
	Random Sample	92.78	4.19	2.26	0.76	0.00	3.39
Spain	OECD SDBS	93.05	3.83	2.19	0.79	0.14	11.83
	Amadeus	44.91	26.52	19.69	7.46	1.41	25.26
	Random Sample	93.37	3.78	2.12	0.72	0.00	11.94
Sweden	OECD SDBS	94.77	2.73	1.59	0.75	0.17	3.48
	Amadeus	78.89	10.21	6.59	3.41	0.90	17.18
	Random Sample	95.59	2.50	1.37	0.54	0.00	3.49
United Kingdom	OECD SDBS	86.54	7.93	3.45	1.71	0.37	10.52
	Amadeus	12.49	10.35	19.49	38.02	19.64	4.48
	Random Sample	87.00	7.90	3.39	1.62	0.10	10.60
Total	**OECD SDBS**	**91.40**	**4.87**	**2.48**	**1.05**	**0.20**	**100.00**
	Amadeus	**50.64**	**19.22**	**16.84**	**10.34**	**2.97**	**100.00**
	Random Sample	**91.90**	**4.78**	**2.36**	**0.94**	**0.02**	**100.00**

Table A5: Observations by Year

Year	Random Sample
1995	291
1996	588
1997	2,347
1998	7,932
1999	56,189
2000	73,644
2001	88,264
2002	125,238
2003	196,037
2004	133,392
2005	121,690
2006	116,503
2007	112,661
2008	157
Total	1,034,933

Final Sample

The focus on total factor productivity as the firm performance variable of interest also leads to the loss of observations from the dataset. A lack of information on materials in particular leads to the loss of Austria, Denmark, Ireland, Iceland, Netherlands, Norway and the UK. The final sample is therefore restricted to 9 countries. It also leads to the loss of observations within countries. To understand the implications of this we re-present information from Table A4 for the final set of firms. In practice the effect is relatively small. The distribution for the total remains very similar to that suggested by the OECD SDBS data. This occurs in part because the countries where the loss of observations was the greatest and the effect on the distribution most marked, Belgium and Germany, now account for a very small proportion of the total sample. There are for example, only 78 firms left for Germany for 2003.

	Employment: Sample:	<10	10-19	20-49	50-249	>250
Belgium	OECD SDBS	91.90	4.28	2.60	1.00	0.22
	Random sample	92.84	4.10	2.32	0.74	0.00
	Final Sample	67.19	11.20	15.36	6.25	0.00
Czech Republic	OECD SDBS	94.57	2.92	1.51	0.83	0.17
	Random sample	95.12	2.80	1.38	0.69	0.00
	Final Sample	91.36	4.56	2.84	1.23	0.00
Finland	OECD SDBS	92.17	3.88	2.41	1.24	0.30
	Random sample	94.36	3.27	1.70	0.68	0.00
	Final Sample	93.98	3.28	1.09	1.64	0.00
France	OECD SDBS	92.22	3.85	2.63	1.06	0.23
	Random sample	92.58	3.81	2.59	1.01	0.02
	Final Sample	92.58	4.18	2.54	0.70	0.00
Germany	OECD SDBS	85.68	8.14	4.14	1.71	0.34
	Random sample	86.15	8.11	4.08	1.64	0.01
	Final Sample	17.95	7.69	14.10	60.26	0.00
Italy	OECD SDBS	94.58	3.49	1.34	0.51	0.08
	Random sample	94.74	3.47	1.31	0.48	0.01
	Final Sample	93.66	4.15	1.62	0.57	0.01
Portugal	OECD SDBS	92.68	4.17	2.16	0.88	0.12
	Random sample	92.78	4.19	2.26	0.76	0.00
	Final Sample	90.60	4.82	3.13	1.45	0.00
Spain	OECD SDBS	93.05	3.83	2.19	0.79	0.14
	Random sample	93.37	3.78	2.12	0.72	0.00
	Final Sample	93.57	4.01	2.00	0.43	0.00
Sweden	OECD SDBS	94.77	2.73	1.59	0.75	0.17
	Random	95.59	2.50	1.37	0.54	0.00

	sample					
	Final Sample	96.21	2.61	1.02	0.17	0.00
Total	**OECD SDBS**	**92.38**	**4.30**	**2.24**	**0.91**	**0.17**
	Random sample	**92.75**	**4.24**	**2.17**	**0.83**	**0.01**
	Final Sample	**93.16**	**4.09**	**2.05**	**0.69**	**0.00**

Appendix 2: Present Value of Tax Depreciation.

This appendix summarizes some analytical expressions used in the computation of the user cost of capital.

The countries considered in this paper distinguish three basic tax methods to account for economic depreciation: straight-line depreciation, constant declining balance depreciation or the method of the sum-of-the-years'-digits. The basic expressions in continuous time used in computing the user cost of capital are shown below:

Straight-line depreciation:

$$Z_{SL} = \int_0^{\infty} \frac{1}{l} \cdot e^{-i \cdot t} dt = \frac{1}{l \cdot i}$$

where l represents the tax lifetime, which is specific for each asset in each country.

Constant declining balance:

$$Z_{PC} = \int_0^{\infty} V \cdot e^{-(i+V) \cdot t} dt = \frac{V}{i+V}$$

where V indicates the *country-specific* exponential rate at which each year the depreciation of a given asset is granted.

The 'sum-of-the-years'-digits method:

$$Z_{SD} = \int_0^{\infty} (l-t) \cdot \frac{2}{l^2} e^{-i \cdot t} dt = \frac{2}{l^2} \cdot \left[\frac{l}{i} - \frac{1}{i^2} \right]$$

Appendix III: User cost of capital by country (1996-2007)

Country	Top marginal corporate tax rate	User cost of capital					
		Debt & Buildings	Equity & Buildings	Debt & Machinery	Equity & Machinery	Debt &Technology	Equity &Technology
Belgium	37.6	6.9	12.7	7.7	9.2	4.4	6.1
Czech Republic	31.2	7.3	11.8	7.1	11.7	5.4	9.7
Finland	27.9	8.5	12.4	6.9	10.5	8.8	12.9
France	37.0	6.6	11.9	6.2	11.3	8.5	14.7
Germany	45.3	6.5	14.0	5.4	11.4	6.7	9.5
Italy	41.5	4.6	10.2	1.1	5.8	-2.0	3.6
Portugal	33.3	6.6	11.4	5.7	10.1	6.2	11.2
Spain	34.8	7.4	12.8	6.9	11.8	8.0	13.4
Sweden	28.0	6.9	10.5	6.9	10.5	8.8	13.0
Average	**35.2**	**6.8**	**12.0**	**6.0**	**10.3**	**6.1**	**10.5**

Appendix IV Descriptive statistics

a) TFP growth by country

	Observations	Mean	Standard deviation
Growth in TFP	262,294	0.90	54.1
Growth in TFP Belgium	1,891	2.81	69.4
Growth in TFP Czech Republic	4,343	-8.82	354.9
Growth in TFP Finland	6,168	0.27	34.5
Growth in TFP France	75,261	0.57	14.9
Growth in TFP Germany	133	0.78	6.5
Growth in TFP Italy	86,167	1.94	31.6
Growth in TFP Portugal	440	3.42	13.1
Growth in TFP Spain	71,283	0.66	35.3
Growth in TFP Sweden	16,508	0.53	27.1

b) Descriptive statistics by industry

	Obs.	TFP growth	s.d.	Profit.	R&D (value added)	R&D (production)	Intra-trade	Entry-exit rate
15. Manufacture of leather and related products	1640	0.3	6.3	25.7	0.2	0.1	18.8	17.7
16. Manufacture of wood and of products of wood and cork. except furniture	4045	0.0	23.1	19.2	0.4	0.1	42.6	17.3
17. Manufacture of paper and paper products	399	0.7	4.9	46.5	0.3	0.1	89.0	-
18. Printing and reproduction of recorded media	1195	-2.0	31.4	35.6	0.1	0.0	80.8	-
20. Manufacture of chemicals and chemical products	1128	-0.5	21.8	50.2	9.5	3.5	93.3	15.7
21. Manufacture of basic pharmaceutical products and pharmaceutical prep.	80	1.1	7.9	50.2	9.5	3.5	93.3	15.7
22. Manufacture of rubber and plastic products	2089	1.2	7.1	31.4	0.9	0.3	87.3	14.0
23. Manufacture of other non-metallic mineral products	2479	5.0	51.5	39.9	1.1	0.5	61.5	14.7
24. Manufacture of basic metals	327	0.6	14.2	24.3	1.2	0.4	65.4	-
25. Manufacture of fabricated metal products	8781	2.7	51.1	29.5	4.5	2.0	77.4	-
26. Manufacture of computer. electronic and optical products	1514	1.9	19.6	36.6	16.8	6.3	85.3	-
27. Manufacture of electrical equipment	648	3.8	57.5	44.1	3.5	1.6	79.6	-
28. Manufacture of machinery and equipment n.e.c.	3462	1.2	13.8	31.9	6.2	2.4	94.8	22.5
29. Manufacture of motor vehicles. trailers and semi-trailers	375	0.2	33.6	41.0	16.0	3.8	61.7	-
30. Manufacture of other transport equipment	378	0.9	18.3	28.2	6.5	2.6	66.2	-
31. Manufacture of furniture	1427	0.5	6.6	30.2	-	-	44.3	-
32. Other manufacturing	2058	0.8	37.2	30.2	-	-	44.3	-
33. Repair and installation of machinery and equipment	813	1.8	23.1	31.9	6.2	2.4	94.8	22.5
35. Electricity. gas. steam and air conditioning supply	87	-4.5	37.0	53.1	-	-	-	-
38. Waste collection. treatment and disposal activities	255	-1.5	22.1	43.4	-	-	-	-
42. Civil engineering	1186	-13.2	56.9	23.6	-	-	-	-
43. Specialised construction activities	19464	0.7	10.4	23.6	-	-	-	-
45. Wholesale and retail trade and repair of motor vehicles and motorcycles	13662	1.3	45.6	25.4	-	-	-	18.9

46. Wholesale trade. except of motor vehicles and motorcycles	39912	1.1	46.6	22.3	-	-	-	17.4
47. Retail trade. except of motor vehicles and motorcycles	74275	1.0	23.8	23.2	-	-	-	-
49. Land transport and transport via pipelines	17039	0.5	7.4	36.7	0.2	0.1	-	23.1
50. Water transport	60	0.0	14.2	38.9	0.4	0.1	-	17.5
51. Air transport	11	-5.0	26.9	-0.6	0.2	0.1	-	23.2
52. Warehousing and support activities for transportation	1794	1.0	25.9	22.8	0.0	0.0	-	20.2
53. Postal and courier activities	378	1.2	10.4	33.6	0.1	0.1	-	33.1
55. Accommodation	11119	3.6	17.8	21.8	0.0	0.0	-	25.9
56. Food and beverage service activities	5257	0.0	8.0	21.8	0.0	0.0	-	25.9
58. Publishing activities	3303	2.0	64.2	27.1	3.3	2.1	-	29.0
59. Motion picture. video and television programme production. sound...	203	-0.7	11.3	44.8	-	-	-	-
61. Telecommunications	63	-21.0	39.9	33.6	0.1	0.1	-	33.1
62. Computer programming. consultancy and related activities	2767	1.5	26.9	27.1	3.3	2.1	-	29.0
63. Information service activities	603	-1.8	21.6	27.1	3.3	2.1	-	29.0
68. Real estate activities	7745	-1.5	24.6	33.1	-	-	-	19.6
69. Legal and accounting activities	3202	0.9	9.6	30.7	0.0	0.0	-	20.8
71. Architectural and engineering activities	7084	0.2	39.9	30.7	0.0	0.0	-	20.8
72. Scientific research and development	263	2.3	35.1	6.0	-	-	-	22.6
73. Advertising and market research	8081	-4.2	250.2	30.7	0.0	0.0	-	20.8
74. Other professional. scientific and technical activities	1051	1.7	76.5	30.7	0.0	0.0	-	20.8
77. Rental and leasing activities	2421	1.5	34.1	45.6	10.0	5.1	-	22.3
78. Employment activities	160	0.0	11.4	30.7	0.0	0.0	-	20.8
79. Travel agency. tour operator and other reservation service	885	-0.3	12.2	44.8	-	-	-	-
81. Services to buildings and landscape activities	1911	-1.2	11.2	30.7	0.0	0.0	-	20.8
82. Office administrative. office support and other business support activities	5215	5.4	41.4	30.7	0.0	0.0	-	20.8

Note: Data for profitability. R&D intensity, intra-industry trade and entry-exit rates are for the US.

c) Structure of firms by employment and age

Employment	Share	Age	Share
Firms with less than 5 employees	45.1	Firms aged 0 to 6 years	30.7
Firms with 6 to 19 employees	49.4	Firms aged 7 to 10 years	19.8
Firms with 20 to 30 employees	1.9	Firms aged 11 to 17 years	25.2
Firms with 31 or more employees	3.6	Firms aged 18 or more years	24.3
Total	100.0	Total	100.0

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