



Corporate Taxation and Productivity Catch-Up: Evidence from European firms

Norman Gemmell, Richard Kneller, Danny McGowan,
Ismael Sanz and José F. Sanz-Sanz

WORKING PAPER 1/2013
March 2013

The Working Papers in Public Finance series is published by the Victoria Business School to disseminate initial research on public finance topics, from economists, accountants, finance, law and tax specialists, to a wider audience. Any opinions and views expressed in these papers are those of the author(s). They should not be attributed to Victoria University of Wellington or the sponsors of the Chair in Public Finance.

Further enquiries to:
The Administrator
Chair in Public Finance
Victoria University of Wellington
PO Box 600
Wellington 6041
New Zealand

Phone: +64-4-463-9656
Email: cpf-info@vuw.ac.nz

Papers in the series can be downloaded from the following website:
<http://www.victoria.ac.nz/cpf/working-papers>

Corporate Taxation and Productivity Catch-Up: Evidence from European Firms

Norman Gemmell^a, Richard Kneller^b, Danny McGowan^c,
Ismael Sanz^d and José F. Sanz-Sanz^e

Abstract

Firms that lie far behind the technological frontier have the most to gain from imitating the technology or management practices of others. That some firms converge relatively slowly to the productivity frontier suggests the existence of factors that cause them to underinvest in their productivity. In this paper we explore how far higher rates of corporate taxation affect firm productivity convergence by reducing the after tax returns to productivity enhancing investments for small firms. Using data for 11 European countries we find evidence for such an effect; productivity growth in small firms is slower the higher are corporate tax rates. Our results are robust to the use of instrumental variable and panel data techniques with quantitatively similar effects found from a natural experiment following the German tax reforms in 2001.

Keywords: Productivity, taxation, convergence

JEL Codes: D24, H25, L11, O31

^a Gemmell: Victoria University of Wellington, New Zealand; ^b Kneller: (corresponding author), University of Nottingham, UK, Email: richard.kneller@nottingham.ac.uk; ^c McGowan: Bangor University, UK; ^d Sanz: Universidad Rey Juan Carlos, Spain. ^e Sanz-Sanz: . Kneller and McGowan gratefully acknowledge financial support from the ESRC under project no. RES-194-23-0003. Sanz-Sanz would like to acknowledge support from project ECO2012-35572.

1. Introduction

Large differences in the level of productivity between firms within the same industry have stimulated a significant body of research into the drivers of productivity change, and in particular the factors that encourage firms to imitate the superior technologies and management practices of those on the productivity frontier.¹ For example, numerous studies have examined evidence that non-frontier firms invest to improve their productivity in response to the presence of foreign multinational firms (see Gorg and Greenaway, 2004, for a review), or intra-market (Foster, Haltiwanger and Krizan, 2001) and import competition (Schmitz, 2005; Disney, Haskel and Heden, 2003; Nicoletti and Scarpetta, 2005).

We contribute to the literature on firm productivity growth in this paper by testing whether aspects of the domestic policy environment - in our case corporate taxation - affect the productivity catch-up of firms. All else being equal, those firms that lie the furthest from the technological frontier can be expected to have the most to gain from imitating others and therefore be the most likely to make productivity enhancing investments (PEIs). These PEIs may include investment in physical capital or in the creation of new knowledge through R&D. Increasingly they may also include complementary investments in intangible assets, such as management and organisation (reference).

Our approach to studying the impact of corporate tax on firm productivity most closely follows that of Arnold et al (2011) but taking a different methodological approach based on the insights of Keuschnig and Ribi (forthcoming) and the 'technology catch-up' model of Griffith et al (2009). Arnold et al (2011) argue that corporate taxation affects the incentive to make PEIs by reducing their post-tax return and thus the share of any increased profit appropriated by the firm. Keuschnig and Ribi (forthcoming) show how taxation may affect the investment choice of firms of different types.

In the following section we outline the previous literature that motivates our analysis, and the rationale for the methods we choose. Section 3 then outlines the econometric model that we adopt to estimate the effects of corporate taxation. Section 4 describes some key characteristics of the data. Section 5 details the main results of the paper. Section 5.1 describes the baseline estimates and we use sections 5.2 to 5.4 to test their robustness. Finally, we draw some conclusions from the study in Section 6.

¹ Syverson (2004) shows that in the US firms near the top of the productivity distribution (the 90th percentile) produce close to twice as much output from an identical amount of inputs compared to firms that are near the bottom of the productivity distribution (the 10th percentile). In other countries these differences are even larger (Syverson, 2011).

2. Previous Literature and our Approach

In recent years a wide variety of studies have begun to examine sources of productivity differences at the firm level, with insights for the role of tax and other policy settings in particular.² The productivity effects of taxation on firm behaviour had largely been inferred through indirect channels such as R&D and capital investment. The relationship between tax policy (mostly R&D tax credits) and the volume, or the location, of R&D across countries/US states is reviewed in Hall and van Reenen (2000), while Auerbach (2002), Gordon and Hines (2002), Hasset and Hubbard (2002), and Hines (2005) examine the relationship between taxation and investment.³

Investments in physical capital may affect productivity where new technology is embodied in capital. The effects of taxation can be further amplified because the tax system does not typically allow for the costs associated with complementary investments in organisational capital to be offset against the firm's tax liability (unlike for machinery and equipment or patents/copyrights) through depreciation allowances. Nerlove et al (1993) make a similar point with regard to taxation of physical and human capital in a model of long run economic growth as do Henrekson and Sanandaji (2011) with regard to the investments made by entrepreneurs to reduce uncertainty. That is, taxation is essentially levied on both the investment and its return. More recently a broader set of determinants of productivity have been examined. Bloom and van Reenen (2007) provide strong evidence that higher-quality management practices, which they label organisational capital, are positively correlated with measures of firm productivity performance. Corporate taxation affects the incentive to make investments of this type by reducing their post-tax return and thus the share of any increased profit appropriated by the firm (Arnold et al, 2011).

The literature on capital investment provides a motivation to search for differences in the effects from corporate tax on productivity across firms of different sizes. Keuschnig and Ribi (forthcoming) develop a model which draws upon the corporate finance literature to show how profit taxation affects the capital investment decisions of firms that are financially constrained. In their model profit

² In studying the effects of tax policy on firm-level productivity change we build on a literature that has examined the productivity effects of policy changes intended to stimulate greater competition or investment within an industry. This literature includes the effects of policy changes related to market regulation (Nicoletti and Scarpetta, 2005; Arnold, Nicoletti and Scarpetta, 2008), labour market flexibility (Petrin and Sivadasan, 2010) and trade liberalisation (Pavcnik, 2002; Bloom, Draca and Van Reenen, 2011). The evidence from this paper might be used to suggest that a wider range of aspects of the domestic policy environment are also relevant.

³ Similar evidence has examined other aspects of firm performance such as entry and exit decisions, firm growth and reallocation across firms. See for example Rajan and Zinglaes (1998), Klapper et al (2006), Griffith et al. (2007) and Batelsman et al (2010). See Djankov (2009) for an excellent survey of the evidence on the effects of regulation on firm entry. On the effects of taxation on industry entry and exit rates, See Da Rin et al (2011), Djankov et al (2010) and Kneller and McGowan (2012). Carroll et al (2000a,b) examine the effects of US tax reforms in the 1980s on the investment and hiring decisions of small businesses, finding significant effects.

taxes impair investment, not by raising the user cost of capital, although the work of Hubbard (1998) may suggest additional effects there, but by reducing 'pledgeable income'. They argue that the relationship between the firm and outside investors is subject to information problems, which limits the amount of external funds firms can raise. A firm's capacity to raise credit depends on the amount of pledgeable income it can credibly promise as a repayment to banks. They show that for firms for which it is difficult or too expensive to obtain external finance, profit taxes reduce cash flow, and therefore pledgeable income, tightening financial constraints and reducing capital investment levels.

Keuschnig and Ribi (forthcoming) also show that efficiency costs are particularly severe when credit constraints are very tight, for example because the firm has few assets of its own. As small firms are more likely to be asset constrained and therefore credit constrained (Schaller, 1993; Aghion, Fally and Scarpetta, 2007), this would suggest that small firms are likely to have slower productivity catch-up as a consequence of higher taxation.⁴ Evidence is consistent with the idea that the constraints on small firms may also lead to underinvestment of other types of capital, including organisational capital. Bloom et al (2011), for example, have shown that small firms on average have lower quality management practices than larger firms, where these management practices include the collection and analysis of performance information, rewards for high performing workers and the retraining or firing of low performing ones. If small firms are more constrained by managerial capacity and time compared to large firms, they therefore require higher returns from adopting these new work practices.

Not all models yield the same predictions for the effects of taxation on small firms however. According to Haufler et al (2011) small firms are characterised by a desire to pursue more radical innovation projects than larger incumbents. Further, sectors in which rates of innovation are high are characterised as having substantially more mergers and acquisition of small firms. Consistent with these stylised facts they develop a model in which entrepreneurs chose between different types of innovation, where these investments differ in their risk and return, and can either sell their innovation to an incumbent or bring it to market themselves. Taxation affects the choice between entry and selling the innovation to an incumbent firm, but also the types of projects that are initially chosen.

From their analysis Haufler et al (2011) show that lower corporate tax rates encourage entrepreneurs to establish independent enterprises rather than selling their innovations, but

⁴ In a recent review of the literature on entrepreneurship and tax theory Henrekson and Sanandaji (2011) argue with regard to the modelling the effects of tax that "issues of secondary importance in analyses of large, established firms may prove crucial when analysing small entrepreneurial businesses" (p168-169). Whilst we do not explicitly study entrepreneurs it should be obvious that their general argument mirrors the main point made in this paper.

because of the inability to offset losses in the event of failure of the innovation they are more likely to choose low-risk innovation projects. Lower taxation may therefore reduce innovation but increase the number of firms and competition in the market. This result differs from the reasoning in Arnold et al (2011) that limited loss offset provisions result in low-risk, low-return projects being taxed at lower effective tax rates than projects that may yield higher returns in some states of the world. Our empirical evidence can therefore be seen as evidence on the relative merits of these different models, although we do not claim to test the predictions of any particular model.

Finally, motivation for the idea that taxation may discourage productivity enhancing investments also comes from the work of Bridgman et al (2009), who examine the productivity effects of regulations in the US sugar market. Whilst the industry regulation they study extends beyond taxation to include restrictions on the entry of new sugar beet refiners and imports, one aspect of the policy environment they consider is the application of an income tax on sugar beet refiners (to pay for a subsidy for sugar beet farmers). They find that the productivity of sugar refiners fell as a result of the regulation of this market. This occurred in part because the share of industry revenues that went to the refiners fell because of the tax. As a result, the authors argue, refiners had little incentive to invest to maintain their equipment which lowered their productivity. We follow Bridgman et al (2009) in studying the effects that higher taxation has on the incentive for firms to invest in their productivity, although here this incentive depends on the productivity gap rather than from regulation of an up-stream sector.

By studying the productivity effects of corporate taxation we also build on the work of Arnold et al (2011), who find that corporate taxation has a direct effect on firm productivity growth, lowering the growth of firms in more profitable industries. Like Arnold et al (2011) we study the direct productivity effects of corporate taxation, but make a number of methodological changes. The choice by Arnold et al (2011) to study the between-industry differences in the effects of corporate taxation on firm productivity growth arose out of a concern for the possible effects of endogeneity bias on their estimation results; namely that the effects of corporate taxation may reflect non-corporate tax policy factors or economic shocks omitted from the estimating equation. To deal with this they include country-time dummies in their regression equations.⁵

However, this approach faces the conceptual challenge posed by Keuschnigg and Ribi (forthcoming) of explaining why all firms within an industry are similarly affected by corporate taxation and also why cross-industry differences are best captured by the profitability of the industry rather than some other characteristic. It might also be argued that this methodology reduces the usefulness of

⁵ The country-time dummies are perfectly collinear with the corporate tax variable of interest, hence they follow the approach of Rajan and Zingales (1998) in using industry interaction terms.

their results for policy. Whilst Arnold et al (2011) provide strong evidence that firms in less profitable industries are affected differently to those in more profitable ones, they are unable to assess whether the net effect of corporate taxation on productivity growth is negative or not (because this effect is captured, along with all other time varying country factors, by the country-time dummies).

We take an alternative approach and explore differences in the effects of taxation across firms within the same industry using the reduced form model of firm productivity convergence due to Griffith et al (2009). In addition we use exogenous changes in taxation to identify its effects, considering the robustness of our findings to the use of both an instrumental variable approach and using a 'natural experiment' in the data. Drawing on the tax competition literature to identify exogenous components of taxation, we follow Brett and Pinkse (2000) and Egger et al (2005a, b) and create instruments based on the underlying characteristics of other European countries, their size, demographic structure etc.

We find that these instruments strongly predict a country's tax rate and lead to an increase in the estimated effect of corporate taxation. The exogenous tax event that we examine is the 13 percentage points reduction in corporate tax rates in Germany between 2000 and 2001, and used previously by Becker et al (2006) to identify the effects of tax reform on capital investment by foreign affiliates. Becker et al (2006) describe the motives behind this tax reform as attracting FDI, encouraging investment and to adapt the German tax system to the rules of the EC Common Market.⁶ We also show that our results remain similar if we take the approach of Arnold et al (2011) – adding numerous control variables to regressions, including country-time dummies and firm fixed effects.

Using an unbalanced panel of manufacturing and service sector firms from 11 European countries over the period 1996 to 2005, we find evidence that corporate taxation has significant effects on the productivity growth of small firms that are furthest from the productivity frontier. The ability of small firms to catch-up with the best firms in their industry and country is slowed by higher rates of corporate tax. Hence taxation exacerbates the managerial and financial constraints faced by small firms. Consistent with a view that large firms are relatively unconstrained, we also show that our these effects do not apply to large firms, even those with low productivity.

Our results are robust to the use of a measure of small business taxation (as used by France, Spain and the UK); measures of the forward looking effective marginal corporate tax rate for machinery and equipment investment due to Devereux and Griffith (1998, 2003); as well as the introduction of

⁶ In this regard, the paper complements the evidence of the effects of changes to corporate taxation and depreciation allowances on investment using a natural experiment approach by Cummins et al (1994, 1996) and House and Shapiro (2008).

various country, industry, time and dummy variables; the introduction of firm fixed effects, to control for time-invariant firm-specific differences such as managerial ability. Further, our results are robust to allowing for country-industry differences in the rate at which firms catch-up with the productivity frontier, to the use of IV methods or when we focus on the 2001 German tax reforms.

In these latter regressions we again show that there are no similar effects for large firms and are robust to the inclusion of firm fixed effects, but also that they are unaffected by the choice of counterfactual. We find similar outcomes for the productivity growth of small German firms irrespective of whether we use other German firms, or small firms in other countries where there was no tax change (Sweden, Spain and the UK), as a counterfactual. We conclude from the robustness of our findings to the array of empirical methodologies that we use, that the results are consistent with a causal relationship from corporate taxation to productivity catch-up by small firms. Higher corporate tax rates reduce the returns from PEIs, lowering productivity growth.

Finally, we note that the effects we find for corporate tax are economically significant. Our results suggest that compared to a counterfactual of no-change in the corporate tax rate, the effect of German tax reforms was to raise the productivity growth rate for a small firm with a productivity level 75% of the frontier firm by 2.2 percentage points. Similar sized effects are found from the other estimations we undertake. To provide some context for that figure, Lileeva and Trefler (2010) report that Canada's entry into NAFTA increased the productivity of Canadian manufacturing firms by 3.5%.

3. Model and Econometric Strategy

In order to motivate the empirical section of the paper we begin by developing a reduced form model of productivity convergence. This draws closely on the work of Griffith et al (2009) and Lileeva and Trefler (2010) and we make the modest extension to add corporate taxation. We assume that output in firm i in industry j in county c at time t is a function of the production technology set out in equation (1), where the A term measures total factor productivity (TFP) of the firm and K and L measure the factor inputs physical capital and labour. Equation (1) is assumed to exhibit diminishing marginal returns in each of the factor inputs and is allowed to differ across industries and countries.

$$Y_{ijct} = A_{ijct} f_{jc}(K_{ijct}, L_{ijct}) \quad (1)$$

Based on the evidence presented in Coe and Helpman (1995), Eaton and Kortum (1999), Keller (2001a, 2002) and others, the TFP of a firm is assumed to be a function of new knowledge that pushes forward the technical frontier, labelled TF_{jct} , as well as efforts to improve productivity by increasing efficiency or imitation, D_{ijct} . Formally, $A_{ijct} = g(D_{ijct}, TF_{jct})$. Firms that undertake

product and process innovation through R&D as well as intangible forms of innovation, such as those in management or product design, are assumed to help push forward the technical frontier.

Our focus in this paper is on the determinants of D_{ijct} . We assume that these imitative productivity efforts are an increasing function of the size of the productivity gap. Those firms furthest from the technological frontier have the greatest scope for imitation of the superior technologies used by others and would be expected to grow more quickly than firms for which there is less scope for imitation. Following evidence from Bartelsman et al(2008) we assume that firms converge upon the productivity level of the domestic leader in their industry.⁷

As in Lileeva and Trefler (2010) we assume the process of productivity convergence does not occur automatically, but rather firms must invest to raise their productivity. These might be large investments, where the firm takes a substantial leap-forward in its choice of technology, or small changes at the margin. To capture this we assume PEIs include those in intangible assets such as organisational capital (Bloom and Van Reenen, 2007, 2010) and improvements in the quality of human or physical capital such as IT (Ilmakunnas et al, 2004; Jogensen et al, 2005, 2008; Oliner et al, 2007). In all cases we assume that these PEI's are costly to the firm, although they might be thought of as an increasing function of the size of the investment. These costs might include the disruption costs a firms incurs from new technologies or work practices, such as installation problems, fine-tuning the new technology and retraining workers (Holmes, Levine and Schmitz, 2008). They may also reflect the credit constraints faced by firms when trying to raise external funds (Keuschnigg and Ribi, forthcoming).

We bring together these ideas by assuming that the firm can raise its productivity from A_0 (its initial productivity level) to A_1 (where $A_1 > A_0$) but to do so must pay a fixed cost F .⁸ It follows that the returns to productivity enhancing investments differ for each firm according to the size of their initial productivity gap and that they will only choose to invest if the productivity gains are above some critical threshold level, given by the fixed cost. Those firms with little to gain from the investment, that is, the gap between A_0 and A_1 is small relative to the fixed cost, will not invest and will operate below the productivity frontier. If the scope and range of investments are increasing in the range of

⁷ Bartelsman et al (2008) find that firms converge more quickly to the domestic-industry frontier than the global-industry frontier, suggesting that the former may be the more important source for imitation. This assumption has the convenient property that it does not require us to transform the cross-country data to a common currency in order to compare the productivity of firms. Such comparisons are sensitive to the choice of exchange rate. We test the robustness of our results to this assumption by including in some regressions (see Table 9) industry-time dummies, which will capture movements of the global-industry frontier.

⁸ Motivation to model these costs in this way can also be found in Henrekson and Sanandaji (2011) who argue that in many ventures the profitability of investments are influenced by costly activities such as *ex ante* search costs or *ex post* entrepreneurial effort and that these are better expressed as fixed amounts.

technologies that can be imitated, then firms with a large knowledge gap will be more likely to make the investment.

Whilst convergence of productivity levels from below is a feature that we find in our cross-country firm-level data, and has been found in other micro datasets by Bartelsman et al (2008), Griffith, et al (2009) and others, a number of papers also find evidence that the rate of convergence differs across firms. This suggests that there are further factors that constrain the ability of some firms to make imitative investments. In this paper we explore whether this occurs because the constraints on finance and management for small firms are higher, so that small firms require higher returns from their investments compared to large firms. For these firms, managing the adjustment costs associated with productivity improvements takes a greater relative share of available managerial time.

As Arnold et al (2011) 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 corporate tax rates that are most relevant. The share of additional profits appropriated by the firm is therefore lower in high tax settings, in much the same way that the literature on physical capital investment suggests that higher corporate taxes will depress capital investment. We anticipate that these constrained and highly taxed firms will make fewer, smaller and less-risky investments to improve their productivity, so that the speed of convergence to the productivity frontier will be slower. If capital investment is reduced they are also less likely to be associated with fewer complementary investments in organisational capital, magnifying the effects of taxation. To summarise, the internal sources of productivity improvement are therefore an increasing function of the initial TFP gap, but a negative function of the corporate tax rate (T_{ct}).

To account for the fact that productivity enhancing investments, such as those in organisational capital, cannot be observed in the data available to us, we estimate a reduced form model of productivity convergence and taxation with an error correction structure set of out in equation (2). Aside from the addition of the terms capturing the effects of taxation this equation is identical to that estimated by Griffith et al (2009).

$$\Delta \ln A_{ijct} = \alpha + \alpha_0 \Delta \ln A_{Fjct} + \alpha_1 \ln \left(\frac{A_{ijct-1}}{A_{Fjct-1}} \right) + \alpha_2 \ln \left(\frac{A_{ijct-1}}{A_{Fjct-1}} \right) * T_{ct-1} * D_{SIZE_i} + \varepsilon_{ijct} \quad (2)$$

The parameter α_0 in equation (2) captures the instantaneous effect on all firms of changes in the productivity frontier where, as mentioned already, this is the domestic-industry frontier. The productivity gap for a firm is measured by the ratio of firm productivity to the domestic-industry frontier at time t , such that the parameter α_1 measures the speed at which firms can close this gap. We anticipate that α_1 will be negative, the greater the size of the initial productivity gap the faster a firm would otherwise be expected to grow. It follows that the parameter α_2 , which captures the effects of taxation for small firms will be positive, as these factors are expected to slow the rate at which this convergence occurs. The variable D_{SIZE_i} is a dummy variable equal to one when the firm has fewer than 20 employees. We test the robustness to that definition of small firms in section 5.

As we describe in more detail below, the data on taxation we use is measured at the country-time level. An important concern in the estimation of equation (2) is the effect of endogeneity bias on our tax variables, explained by the omission of important variables that are correlated with these country-time factors and the error term in the regression. We test for the possible effects of this bias in the main estimation results, by adding various combinations of country, industry, year variables, time-varying country factors, country-time dummies, an instrumental variable approach and an exogenous tax event in Germany. We discuss the effects of these different strategies as well as any additional control variables in more detail in Section 5.

4. Data Description and Summary

Our firm-level data is taken from the Amadeus database (Bureau van Dijk) and covers 11 European countries for the years 1996-2005. To reduce the number of observations available in the dataset to a level manageable for estimation, we follow Schwellnus et al (2009) and apply retrospective sampling. To perform this sampling we use population weights for each size-sector-country strata from the OECD's Structural and Demographic Business Statistics database for 2003. As in Arnold et al (2011) we restrict the analysis to firms in manufacturing and service sectors (Nace 15-93) and exclude firms with missing data and obvious key punch errors prior to the re-sampling. We also exclude observations from the agricultural, forestry and mining sectors as well as service sectors such as education and health services where public provision is more likely and corporate taxation is usually not applicable. The final sample is both smaller in size than the original Amadeus database and does not suffer from the same size-bias towards large firms.

The loss of firms without the necessary information on inputs when constructing our measure of TFP results in a final sample that is unbalanced across countries and time. In order to concentrate on the determinants of productivity catch-up, we further restrict the analysis to non-frontier firms. The

sample used in the estimation covers around 226,000 observations on 54,787 firms. The country coverage differs, depending upon the coverage within the Amadeus database, and within the final sample ranges from just 100 observations for Austria, to close to 88,000 for Italy. The larger European countries are particularly well represented. In addition to the 88,000 observations for Italy, there are around 8,000 observations for France, 23,000 for Germany, 48,000 for Spain and 32,000 for the UK. Around 88% of all observations are therefore from these 5 countries. The data are also unbalanced across time. The loss of firm information is greater the further we move away from the base year of 2003. There are over 40,000 observations in each of the years 2003, 2004 and 2005 but less than a thousand observations in 1996 and 1997. The number of observations per year is displayed in Table 1, while the number of observations per country can be found in Table 3.

To construct measures of productivity for each firm and the productivity frontier we estimate a production function at the country-industry level, such that firms' technologies can differ by country and industry. We then estimate TFP applying the semi-parametric method proposed by Levinsohn and Petrin (2003). This method allows the production function input parameters to be estimated while allowing for the possibility of an endogenous response of productivity to unobserved shocks.⁹ The productivity frontier in each country-industry-time period is approximated by the average productivity of firms that lie above the 95th percentile of the TFP distribution. The frontier is constructed in this way to reduce the possibility that extreme data points caused by measurement error affect the results and that movements of the frontier do not solely reflect the behaviour of a single firm. The TFP of each firm is then constructed as a ratio to the relevant country-industry productivity frontier in each time period.

In Table 2 we report basic summary statistics for the rate of TFP growth across firms and countries, along with the growth rate of the productivity frontier. To ease the comparison across countries we report the TFP of the average firm expressed as a percentage of the productivity frontier rather than the TFP-gap variable, as well as further detail on the distribution of TFP and the average TFP of firms with less than 20 employees. The average rate of TFP growth in the sample is 2.7 per cent per annum. This is faster than the growth rate of the productivity frontier (average rate of growth 1 per cent per annum), which suggests that the average firm converges towards the frontier over time.

The average TFP of a firm compared to its domestic-industry productivity frontier is 79 per cent (the average TFP gap is 21 per cent). Table 3 suggests there is considerable heterogeneity in the size of this gap across countries. For example, firms in Germany operate consistently closer to the domestic

⁹ The Levinsohn and Petrin (2003) estimator uses intermediate inputs as investment 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.

technological frontier than say firms in France or the UK.¹⁰ The average firm in Germany has an estimated TFP that is 89 per cent of the best firms there, whereas for France the average firm has a TFP that is 66 per cent of the best firms in France. For the UK the figure is 80 per cent. The average TFP of small firms is below the average TFP across all firms in every country except Italy and Portugal. In some cases the difference between the TFP for small firms and the average across all firms is large. In Germany for example, the average TFP is 89 per cent of the frontier firm, but 83 per cent for small firms.

Table 3 also provides information on the dispersion of TFP across firms in each country. More generally it would appear that countries such as France, Italy and the UK have a longer tail to the distribution of TFP compared to Germany. The firm at the 25th percentile of TFP has a TFP level that is 85 per cent of the most productive firms in Germany, whereas in France it is 60 per cent, 65 per cent in Italy and 69 per cent in the UK. According to Table 3 the weakest TFP performance would appear to occur in Czech Republic and Denmark, although these are also amongst the countries for which we have least information. Here the TFP of the average firm compared to the productivity frontier in these countries is 58 and 61 per cent respectively, while the TFP of the firm at the 25th percentile is 39 and 43 per cent respectively of the best firms.

[Insert Table 1]

[Insert Table 2]

[Insert Table 3]

The data for statutory corporate tax rates we use are obtained from EUROSTAT, *Taxation Trends in the EU*. In Table 4 we report the statutory corporate tax rate for each country averaged between 1996 and 2005, along with the change in the tax rate over that time period. We use the statutory tax rates because of their comparability across countries. As we use data only for incorporated firms, statutory corporate tax rates are also likely to be used as the benchmark by which to determine the returns to PEIs (Djankov et al., 2010). They are also the relevant marginal tax rate for investments in assets, such as many intangibles, for which there is no provision in the tax system for the costs of depreciation. In Section 5.2, we test the robustness of our results to this measure of corporate taxation by also considering the forward looking effective marginal and average tax rates constructed by Devereux et al (2002). These effective rates are hypothetical forward looking tax rates applicable to a specified investment in plant and machinery undertaken under alternative assumptions regarding, for example, the relevant rate of interest, inflation rate, method of financing

¹⁰ As the production function is estimated separately for each country and industry the estimates of TFP do not provide information on the level of TFP across countries or industries. The results cannot therefore be used to determine whether firms in Germany are more or less productive than those in France for example.

(debt, equity) etc. They therefore provide an example of effective tax rates assuming that the productivity enhancing investment made by the firm is in machinery equipment.

According to the information presented in the table, the highest average corporate tax rates are in Germany, 45.5 per cent, and Italy, 43.3 per cent. The corporate tax rates in the remaining countries range between 28 per cent (Sweden, Finland) and 37 per cent (France). Also important for the effects we identify are the changes in taxation across years. The corporate tax rate has fallen over time in most countries in the sample, with the largest falls in Germany (18 percentage points), Czech Republic and Italy (15 percentage points), Portugal (12 percentage points) and Austria (9 percentage points). In contrast in Spain and Sweden the corporate tax rate in 2005 was the same as in 1996, and in Finland it was 1 percentage point higher. Of the countries for which we have most data, the majority of changes in the rate of corporate taxation are relatively modest, of the order of 2-4 percentage points per year. An exception is Germany where the tax rate was reduced by 13 percentage points to 38 per cent between 2000 and 2001. We focus on the effects of the tax reform in Germany as a test of the robustness of our findings in Section 5.4.

[Insert Table 4]

5. Empirical Evidence

In this section we report the results from the estimation of equation (2) and provide some discussion of the magnitude of the effects that we estimate. Some general issues of robustness are explored in section 5.2, while the results from the IV regressions and 2001 tax reform in Germany can be found in Sections 5.3 and 5.4 respectively.

5.1 Baseline Estimates

Regression 1 of Table 5 represents the most parsimonious regression that we estimate. The regression includes a measure of the growth of the technological frontier, the firm-specific gap with this frontier (denoted TFP gap in the table), and a set of time-dummies. These time-dummies control for shocks common across the European countries, for example the point in the business cycle. Following evidence from Arnold et al (2011) that profitability matters for productivity growth, we also include in the regression a variable which considers whether the rate of convergence is affected by the profitability of the industry, and whether this rate of convergence is faster or slower for small

firms.¹¹ Here we hypothesise that profitability might either act as a spur to make productivity enhancing investments or, if these investments are paid for out of retained earnings, rather act to slow the rate of convergence by firms. To ensure that we capture the inherent profitability of an industry rather than any effect that higher corporate tax rates in a country might have on this variable, we follow Arnold et al (2011) and use (time invariant) industry-level data on profitability for the US to proxy for this.¹²

The results for the variables measuring the effects of the TFP gap and the growth of the frontier compare favourably with those from elsewhere in the literature. Growth of the productivity domestic-industry frontier is found to have positive spillover effects on the growth of firms operating behind the frontier (see Griffith et al 2001, 2003 for similar evidence). The magnitude of the coefficient indicates this effect is relatively strong. When the frontier grows by 1 per cent, productivity in non-frontier firms grows by 0.335 percentage points. The results from regression 1 also show that the rate of productivity growth is higher the greater is the distance between the firm's productivity and that of the (domestic-industry) frontier. As expected firms that are far behind the productivity frontier have greater scope to imitate the technology of others and therefore catch-up with the best firms over time.¹³ The rate of growth the firm experiences depends of course on the size of its initial productivity gap. According to the summary statistics in Table 3 the average productivity of non-frontier firms relative to the productivity frontier is 79 per cent. For this average firm, the rate of productivity growth would be 1.7 percentage points per annum faster than a firm with a productivity level 85 per cent of the frontier firm, and around 4.3 percentage points per annum faster than a firm with a productivity level 90 per cent of the frontier firm.¹⁴ The evidence in regression 1 also indicates that small firms in industries with low-profitability actually appear to converge more, and not less, quickly to the technological frontier, although there is no significant effect from this variable on the rate of convergence for larger firms.

[Insert Table 5]

Regression 1 also examines the role of taxation in shaping the rate of productivity catch-up for small firms (defined according to whether employment is more or less than 20). By including the

¹¹ The significance of the tax-TFP gap variable is insensitive to the inclusion of these profitability variables, although the estimated effect is somewhat smaller in regression 2 (our preferred specification). The coefficient estimate on the tax-TFP gap for small firms is 0.116 with a t-statistic of 8.93.

¹² The US is chosen as the country from which to derive this industry variable as its firms are subject to lower tax rates and fewer policy restrictions compared those in Europe and because it is not included in the sample. 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). 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, 1998-2005.

¹³ Similar evidence exists at the aggregate (Bond et al., 2001), industry (Griffith et al., 2001) and firm level (Griffith et al., 2003).

¹⁴ These results are unchanged when we use an Olley and Pakes (1996) based estimate of firm TFP.

interaction between taxation and a measure of the distance to the productivity frontier, we consider a more general model of the effects of taxation than the existing literature on productivity convergence. From regression 1 we find no evidence for such an effect, the corporate tax-TFP interaction term is insignificant for small firms. Corporate taxation does not significantly change the rate at which small firms invest to close the productivity gap, with weak evidence that it might actually increase this rate. Whilst, this is consistent with a view that higher corporate taxation encourages firms to work-harder to improve their productivity, the remaining regressions in Table 5 indicate that this conclusion is driven by omitted variables.

According to the tax competition literature, countries that are large typically have higher corporate tax rates than small countries because firms are attracted to large markets and this outweighs the negative effects of taxation on their location choices. If higher corporate tax rates lead to the weeding out of weak firms, such that only the best firms can survive in the industry, and these better firms have faster rates of productivity growth, then this might explain the negative sign on the interaction term between corporate tax rates and the TFP-gap variable in regression 1. Alternatively, higher corporate tax rates may be correlated with some other omitted aspect of the business environment of a country, such as infrastructure expenditure, which again would increase the rate of convergence. In regression 2 we assume that these omitted country and industry factors are time invariant in nature and test the sensitivity of the results in regression 1 to the inclusion of country and industry dummies.¹⁵ The inclusion of country effects has an important impact on the results for the TFP gap-corporate tax interaction term for small firms. The significant positive coefficient on this interaction variable indicates that higher corporate taxation slows the rate at which these firms converge to the productivity frontier. This result is consistent with an interpretation that higher taxation reduces the net present value (NPV) of future investments for small firms, such that they invest less in productive technologies.

How large are the tax effects we find? In Table 6 we use the coefficient estimates from regression 2 to compare the rate of productivity growth of small firms in different tax settings. In the table we compare the growth rate of a small firm with a productivity level equal to 75%, 85% and 95% of the frontier in their country at different rates of corporate taxation (25%, 30%, 35%, 40% and 45%) compared to a firm that faces a corporate tax rate of just 20%. These tax rates are chosen as representative of the corporate tax rates across the countries that make up our sample. The tax rate of 40% is close to that for Germany and Italy at the end of the sample period, France had a tax rate of 35% by the end of the period, the UK around 30% and Austria 25%. No country in our sample had

¹⁵ We also add fixed industry effects to control for any time-invariant industry-specific factors.

a statutory corporate tax rate of 20%, but this figure is an upper bound on the tax rates found in low-tax European countries not in the sample, such as Ireland and Switzerland.

The table shows that for a small firm in a country with corporate tax rates of 25% and with a productivity level 75% of a frontier firm, productivity growth is 0.3 percentage points per annum slower compared to that estimated for the same firm facing a corporate tax rate of 20%. In a high tax country, the corporate tax rate is 40%, productivity growth is 1.2 percentage points slower than the firm facing a corporate tax rate of 20%. The effects of taxation become quantitatively less important the closer the small firm is to the productivity frontier. For firms with a productivity level equal to 95% of the frontier, operating in low tax environments (the corporate tax rate is 25% compared to 20%) the difference is only 0.11 percentage points. As the difference in corporate tax rates increases (the corporate tax rate is 40% compared to 20%) growth is reduced by 0.5 percentage points.

5.2 Robustness Issues

Before moving on to consider the effects of endogeneity bias on our results for the corporate tax-TFP gap variable, in this section we examine the implications for assumptions made about firm size; make an allowance for the use of small business tax rates in some countries; and use measures of effective rather than statutory tax rates.

Two questions that might be raised about the robustness of the effects of corporate taxation in regression 2 are a) whether they in fact capture the effects of corporate taxation on all firms rather than just small firms, and b) whether they are driven by differences in the rate of convergence between small and large firms but with taxation playing no role. We consider the answers to those questions in regressions 3 and 4 in Table 5. To test for the former, in regression 3 we add alongside the corporate tax-TFP gap interaction for small firms, the same variable for all firms (TFP gap*Corp. Tax.). In this regression the coefficient on the tax-gap variable captures the effect of taxation on convergence of firms irrespective of their size, while the tax-gap-size interaction (TFP gap*Corp. Tax.*D_{SIZE}) tests whether the effect for small firms is different from this general effect. Regression 4 tests whether the rate of convergence differs for small firms, independent of any effect that corporate tax rates might have, by including an interaction between the small firm dummy (D_{SIZE_i}) and the TFP-gap variable.

In both regressions we find that the main results in regression 2 are robust to this change. In regression 3 we find no significant effects of taxation on all firms, the tax-TFP gap variable is insignificant, but that taxation continues to affect the convergence of small firms. It would appear

from this result that only small firms are constrained in their ability to make productivity enhancing investments and are therefore sensitive to corporate tax rates, whereas large firms are unaffected.¹⁶ In regression 4 the results indicate that the rate of convergence is faster for small firms compared to large firms, conditional on the tax-gap variable for small firms. This is consistent with a view that small firms are highly innovative and enjoy, in the absence of credit constraints, fast rates of productivity growth.

[Insert Table 6]

In regression 5 of Table 7 we test whether the results from regression 4 are sensitive to how we classify small firms, by using an alternative cut-off of 50 employees. We find that the coefficient on the TFP gap-tax interaction term remains significant in this regression and as expected the point estimate falls in size relative to that estimated in regression 4. When we test whether the effect of corporate taxation on firms with 20-50 employees is significantly different from that found for firms with an employment level less than 20, we cannot reject the null hypothesis that they are similar though.¹⁷ We conclude from this that the effects of corporate taxation on the productivity catch-up of firms with between 20 and 50 employees is statistically similar to that for firms with employment less than 20 and therefore the effects of corporate taxation are broader than first thought.

The constraints on small firms, for example in their access to finance compared to large firms, have long been recognised by policy makers and as a consequence some countries, such as the UK, France, Spain and Portugal, have attempted to alleviate the effects of these constraints by lowering the corporate tax rate for small firms (Nam and Radulescu, 2007). In some cases these differences can be large. For example, in the UK the small business corporate tax rate in 2003 was 19% compared to the standard rate of 30%. In regression 6 we replace the standard corporate tax rate for that applied to small firms in France, Spain, Portugal and UK. Interestingly, this has little effect on the coefficient magnitude for corporate taxation and the variable remains statistically significant.¹⁸

[Insert Table 7]

In our use of the statutory corporate tax rate we have both ignored the possibility that the ranking of productivity enhancing investment opportunities will change because of different depreciation allowances for different types of capital (Devereux and Griffith, 2003) as well as progressivity in the

¹⁶ Further investigation shows that the tax-TFP gap variable for all firms becomes insignificant once country dummies are added to the regression (as in regression 2).

¹⁷ To perform this test we create a new tax-TFP gap variable for firms with employment between 20 and 50 employees and then test for the significance variable when the tax-TFP for firms with between 1 and 50 employees is also included in the regression. The coefficient on tax-TFP gap variable for 20-50 employees is equal to 0.15 with a t-statistic (p-value) of 1.24 (0.214).

¹⁸ The results for taxation are also robust to dropping from the regression sample those countries (France, Spain, Portugal and the UK) where the small business tax rate differs from the standard tax rate.

corporate tax rate schedule across time introduced by loss offset provisions (Arnold and Schwellnus, 2008). We have also ignored the role played by taxation of other forms of income, such as personal taxes on interest income and capital gains, which may be relevant when determining the method of financing for investments for incorporated firms (Devereux and Griffith, 2003). To model this in regression 7 we replace our measures of the statutory corporate tax rate with forward looking effective rates from IFS/Devereux et al (2002). These effective rates are hypothetical forward looking tax rates applicable to specified investment in plant and machinery undertaken under alternative assumptions regarding, for example, the relevant rate of interest, inflation rate, method of financing (debt, equity) etc. These are available as both average and marginal rates for each year for all of the countries in our sample except for Denmark and the Czech Republic. As well as arguably reflecting more closely the actual tax rates faced by firms, albeit based on a particular set of assumptions about the type of investment, method of financing etc., the forward looking nature of these tax rates have the additional advantage that they might reasonably be regarded as exogenous to economic shocks.

The average rate is the tax rate relevant for discrete investment choices of the type we examine: whether to make an investment or not (Devereux and Griffith, 1998, 2003) so we anticipate this will slow the rate of productivity convergence for small firms. For the marginal tax rate the relationships are potentially more complicated. Given the high correlation between the two measures of effective tax rates in the data (the raw correlation is over 85%) we cannot separately capture the effect of a higher average tax rate from that of a higher marginal rate. We use instead the difference between the effective average and marginal rates. It might be expected that this measure of taxation will pick up several effects. Firstly, it may capture the effects of changes in depreciation allowances. As depreciation allowances are reduced, the average and marginal tax rates become more similar which discourages investments. We might therefore expect an increase in the difference in the average and marginal rates to increase the rate of catch-up. Alternatively, higher marginal tax rates can also reflect an absence of loss offset provisions and affect the risk taking by firms (Arnold and Schwellnus, 2008). Risky innovative projects, which have a probability of yielding large productivity gains, have a higher effective marginal tax rate when no provision for possible losses is allowed for in the tax system. Here we anticipate that the closer the average becomes to the marginal tax rate, their difference falls towards zero, the greater are loss offset provisions, and the more likely it is that firms will undertake risky innovative projects.¹⁹ We would therefore expect that the coefficient on the difference in tax rates will be positive in this case.

¹⁹ To give the example used in Arnold et al (2011), consider two projects yielding the same expected return r . The first project yields this with certainty, while the second project yields either $3r$ or $-r$ with equal probabilities. With no loss offset

The results for these additional tax variables are shown as regression 7 and suggest that the latter effect dominates for small firms. We find that an increase in the interacted effective average tax rate slows the rate of productivity catch-up for small firms, as does the difference between the average and the marginal rates. We conclude from these results that higher average tax rates slow the rate of productivity catch-up by small firms, as does greater progressivity in the corporate tax schedule.

5.3 Endogeneity Bias

In the results presented from regression 2 (Table 5) onwards we control for time-invariant features of a country that may affect the rate of productivity growth of firms, so that the effects of taxation are identified by their effects within countries. But, what if there are time-varying omitted country factors that are correlated with corporate taxation and productivity contained within the error term? It might be the case for example, that governments which choose high corporate tax rates have higher expenditures on infrastructure (including road, rail and ICT), which would tend to increase the productivity of firms in that country. If these expenditures affect firms that are furthest from the technological frontier then this would tend to bias the effects of taxation that we capture towards zero. Alternatively, high corporate tax rates may indicate a more general tendency by some governments to regulate businesses, which may reduce the rate of productivity growth of firms within a country (Tybout, 2003). If these anti-business policies are difficult to measure, then this would tend to reduce the rate of productivity growth and may increase the size of the estimated coefficient on the corporate tax variable. Whichever is the most relevant explanation, it is worth noting that because we find no effect from corporate taxation on convergence by large firms, this omitted variable bias can only occur because of an effect on convergence by small firms. Our first approach to dealing with this potential issue is to add a series of political and additional fiscal controls.

In regression 8 (Table 7) we consider whether the results found so far are explained by the omission of difficult-to-observe policy variables by adding control variables that capture various time varying aspects of the political make-up of a country. Here we assume that governments in different political environments will affect the business environment of a country in different ways, and that tax policy may be affected by the point in the political cycle. The political variables we include are the number of years the chief executive has spent in office, the number of years left in the current term, the vote share of the largest political party and whether the party of the executive controls all houses. We also control for whether the country has a proportional representation system as well as a measure

provisions and a corporate tax rate of 30% the after tax return is $0.7r$ for the safe project and $0.55r$ for the risky project. The return is therefore greater for the safe project, despite the fact the tax rate is identical.

of political decentralisation (whether there are autonomous regions), the mean district size of the House and Senate and the checks and balances in place.

Lastly we add a measure of total government expenditures and government revenues as a ratio to GDP. Here we assume that the omitted policy variables that might contaminate our results are reflected in the level of fiscal expenditures or tax and non-tax revenues within the country. In this regression we continue to include country, industry and time-dummies and, given the results in regression 4, allow the rate of convergence to differ between small and large firms. To conserve space we report only the main variables of interest and indicate in the table which other variables have been included. The data on the political variables are from the World Bank's Database of Political Institutions database and data for government expenditures are from the IMF Government Financial Statistics data set.

The results suggest that omitted policy variables were of modest concern. A number of these political controls are statistically significant as are the government expenditure and revenue variables, but the main findings are robust to the inclusion of the political and fiscal variables in regression 8.²⁰ We continue to find evidence that productivity catch-up is slower for small firms in high corporate tax settings. Moreover the addition of these controls changes the magnitude of the coefficient by very little.

During the recent global macroeconomic crisis countries adopted a variety of fiscal responses in an attempt to stimulate growth in the economy. These included temporary tax-cuts early on in the crisis and then emergency tax rises in response to growing fiscal deficits. This reveals that tax rates are often adjusted in response to the macroeconomic shocks faced by a country, where these shocks are also likely to have a productivity impact. If these external shocks have different effects on small and large firms, or according to the size of their productivity gap, then it follows that it may be the effect of these shocks that we capture in the regression rather than corporate taxes. It also seems likely that the political and fiscal variables do not properly control for this source of bias. Our previous findings may therefore not be free of endogeneity bias.

One solution to this problem requires the identification of a variable (an instrument) that affects the timing and the size of any tax changes, but not the rate of productivity growth by firms within a country. In regression 9 in Table 7 we draw on a number of papers from the tax competition

²⁰ The coefficients (t-statistics) on the number of years spent in office 0.0001(0.62), years left in office -0.004 (0.70) and a dummy for whether there is proportional representation -0.008 (0.18) are all statistically insignificant, while those for the vote threshold 0.00007 (5.74), if party of executive controls all houses -0.014 (4.90), mean district size of house 0.00003 (5.62), checks-and-balances (0.09 (2.21), vote share of the largest government party 0.001 (1.63) and a dummy for autonomous regions -0.014 (4.90) are all significantly related to the rate of firm productivity change. The coefficient (t-statistics) on the share of government expenditure expressed as a total of GDP is statistically significant and negative -0.013(16.96) as is government revenues -0.006 (9.57).

literature, namely Brett and Pinkse (2000) and Egger, Pfaffermayr, and Winner (2005a,b), and use a weighted measure of GDP growth, population, urbanisation, working age population and unemployment of neighbour countries as instruments. Devereux et al (2008) outline a model in which multinational firms choose their capital stock based upon the effective marginal tax rate they face and simultaneously decide upon location of their profits in response to differences in statutory tax rates between countries. They find evidence that OECD countries compete over effective marginal tax rates for capital and over statutory rates for profit but that these effects are only present between open countries. Moreover, the reductions in equilibrium tax rates they observe can be explained almost entirely by more intense competition between countries due to the relaxation of capital controls. We use the inverse of distance between each country and the each of the 24 members of the OECD as weights. Foreign countries that are geographically close therefore take on greater importance for the relevant variable in this measure.

A complication of the current set-up is that we are interested in instrumenting for the interaction between corporate taxation, initial TFP and a dummy for small firms. Initial TFP cannot be viewed as an exogenous instrument. Instead we follow advice from Ozer-Balli and Sørensen (2010)²¹ and first construct the predicted values of corporate taxation from a regression using the instruments (the weighted values of neighbour countries population, urban population, working age population, GDP growth and unemployment) and other exogenous covariates. We then construct a new interaction term using these predicted values and the TFP gap for small firms. This new variable is then used as an instrument for the tax-gap variable for small firms in the original regression in a standard IV command.

The instruments are plausibly exogenous and tests show that they are relevant, they are highly significant in the first stage are highly significant (F-test 31666.32).²² The results for the IV regressions indicate a significant downward bias on the tax-gap variable in earlier regressions. The coefficient on the tax-gap variable for small firm increases from 0.4 in regression 4 up to 1.2 in regression 9. Of interest the coefficient from these IV regressions is close to what we find when we use German tax reforms further below (see tables 9 and 10).

Before moving to our final attempt to tackle the issue of endogeneity through the use of a natural experiment, we follow Arnold et al (2011) and take an agnostic view on what the endogenous variable might be. In regressions 10, 11 and 12 we flood the regression with dummy variables. In

²¹ Jeffrey Wooldridge offers similar advice on the issue on the stalist (<http://www.stata.com/stalist/archive/2011-03/msg00188.html>)

²² Devereux et al (2008) use as an alternative instrument a distance-weighted measure of the 24 OECD countries' corporate tax rates (excluding the country itself). We have constructed a similar measure and find that it also performs well in an IV estimation.

regression 10 (Table 8) we control for the possibility that rate of convergence differs for each country-industry combination by interacting the TFP gap variable with a full set of country-industry dummies. In this regression we assume that the omitted variable is country-industry specific and affects the rate of convergence, but is time-invariant in nature. These cross-country and industry differences in the rate of convergence might occur because convergence is affected by other aspects of the policy environment. Arnold, Nicoletti and Scarpetta (2008) find for example that product market regulations affect productivity catch-up. As there is now a convergence parameter for each country-industry combination we do not report the results for this variable in the table. In regression 11 we extend the specification to include a full set of country-time and industry-time effects.²³ The inclusion of the country-time dummies ensures that the effects of taxation are identified only through their interaction with the productivity gap for small firms. This has the advantage that the coefficient on the corporate tax-TFP gap-size variable can be affected by endogeneity bias only if the omitted variable differs in its effects according to the size of the productivity gap of small firms. This would could also be used to indicate that parameter heterogeneity across countries are not a strong feature of our results. The likelihood that any omitted variable bias explains the results that we find is thus also reduced. The industry-time dummies capture factors such as differences in the underlying rate of growth of the global technical frontier, industry profitability or external financial dependence.

[Insert Table 8]

Allowance for either country-industry differences in the rate of productivity convergence or the inclusion of country-time and industry-time effects has no effect on the main conclusions of the paper. We continue to find evidence consistent with the view that high corporate tax rates slow convergence of small firms by reducing the returns to productivity enhancing investments.

Thus far we have assumed that the investments a firm makes in its productivity will move it closer to the domestic-industry frontier. As a final exercise in this section we relax this assumption and allow for the possibility that the returns to productivity enhancing investments may be constrained by difficult-to-observe, firm-specific characteristics such as the managerial ability of the firm (Bloom and Van Reenen, 2007, 2010). Deficiencies in management capabilities within a firm might mean that it is not capable of ever reaching the productivity of the best firms resulting in a permanent deficit in the steady state productivity level. In regression 12 we control for these time-invariant firm characteristics through the inclusion of firm fixed effects alongside the country-time and industry-time effects.

²³ We cannot use country-time dummies in conjunction with an instrumental variable approach because the instruments also vary by country and time and are thus perfectly collinear with the country-time effects in the first stage regression.

We continue to find that corporate taxation significantly slows productivity convergence when we control for firm fixed effects. The effects of corporate taxation appear relatively strong in this regression, even for firms that are close to the productivity frontier. According to the results reported in regression 12, for a small firm with a productivity level 85% of the frontier firm and in a country with corporate tax rates of 25% compared to 20%, productivity growth is an estimated 1.95 percentage points lower. When the firm faces a corporate tax rate of 40% rather than 20%, productivity growth is an estimated 7.8 percentage points lower.

5.4 The 2001 German Tax Reforms as a Natural Experiment

As noted in the summary statistics in Section 4, for most of the countries that make up our sample the rate of corporate taxation is reduced occasionally and in relatively small steps, such that it displays a general downward trend over the sample period. The exception to this is Germany where there was a large single reduction of just over 13 percentage points between 2000 and 2001. This was the only corporate tax change between 1999 and 2002 in Germany. The key features of the reforms were the replacement of the different tax rates on retained earnings (40%) and distributed profits (30%) with a single lower tax on all profits (25%). When combined with local trading taxes, the statutory tax rate fell from 51.6% to 38.3% (Spengel, 2001). Becker et al (2006) use this tax change as a 'natural experiment' to identify the effects of tax reform on the investment of foreign affiliates in Germany, finding significant and large effects. Becker et al (2006) describe the motives behind this tax reform as aimed at attracting FDI, encouraging investment and to adapt the German tax system to the rules of the EC Common Market. The motives behind the tax change therefore appear to be consistent with the view that the change in corporate tax rates was exogenous to firm productivity.

In the regressions reported in Table 9 we consider whether these reforms affected the productivity growth of small German firms using the change in the tax rate in 2001 to identify the effect of corporate taxation on productivity convergence. As we now switch to the use of changes in the tax rate in regression 13 we report for completeness the results from a regression on the full sample of countries using only changes in taxation to identify any effect on the pace of productivity convergence for small firms. We find that our results are robust to this change, indeed the coefficient on the change in corporate taxation is well within the range of estimates we have derived elsewhere in the paper.

In regressions 14 to 16 we use data only for Germany. In these regressions the effect of corporate taxation on productivity convergence is identified from differences in the effect of the change in the

corporate tax rate between 2000 and 2001 for small firms with different productivity gaps relative to the domestic-industry productivity frontier. In all other time periods this variable has a value of zero.²⁴ As in previous regressions we also control for the initial TFP gap of a firm, and the interaction of this variable with a dummy for small firms. In regression 15 we test whether the tax change had any effect on productivity growth on all German firms, or whether it was specific to small firms. This regression might be thought of as a triple-difference regression. We anticipate that the effects of taxation affected small firms only. Finally, in regression 16 we also include firm fixed effects to control for unobservable time-invariant, firm-specific factors, such that we now rely only on the within-firm, cross-time information in the data to identify the effects of taxation.

The results reported in Table 9 are robust to the use of this natural experiment for corporate taxation in Germany; we continue to find strong evidence that the rate of convergence by small firms is slowed by corporate taxation or rather the change in corporate tax rates in this case. The decrease in German corporate tax rates increased the rate of productivity convergence, where the estimated effect is quite similar to that reported in Table 7 when using an IV approach (regression 9), but somewhat below that reported when including firm fixed effects (regression 12) and about 3 times that when we include various country and industry dummy variables. Moreover, in regression 15 we find that the same tax change had no effect on the rate of productivity growth for large firms (given by the $\text{TFP gap} * \Delta \text{Corp. Tax}$ variable). For this group we find no evidence of TFP catch-up; both the TFP gap variable and the TFP gap variable interacted with corporate taxation are insignificantly different from zero. Again this supports the conclusions we drew earlier in the paper about the productivity effects of taxation on large firms. This might be viewed as consistent with the summary statistics in Table 3, where the average German firm was found to operate relatively close to the domestic-industry frontier. The inclusion of firm fixed effects in regression 16 does not affect the relationship between corporate taxation and productivity catch-up found elsewhere in the table but it does reduce the estimated magnitude of this effect. From this table we conclude there is strong evidence that the German tax reform of 2001 affected the productivity catch-up of small firms, and only small firms.

Using the 13 percentage point reduction in corporate tax rates and the coefficient estimates from regression 16, our results suggest for a firm with productivity equal to 75% of the frontier firm implies TFP growth would have been 2.2 percentage points faster compared to a counterfactual of no-change in the corporate tax rate. The average TFP even of small firms tends to be higher than this in Germany, in which case the effects are somewhat smaller. For a small firm with a TFP level 85%

²⁴ Tax changes also occurred in a number of other years in Germany, although on a smaller scale. These are ignored in producing the results in regression 15 but the results we report in the Table are robust to the inclusion of these other tax changes.

(90%) of the frontier firm our estimates suggest that TFP growth increased by 1.2 (0.8) percentage point compared to that predicted if corporate tax rates were left at 51 per cent.

[Insert Table 9]

In Table 10 we consider the effect of the natural experiment in a different manner. Thus far we have used large German firms as the counterfactual group to that of small firms. If there was a European-wide shock to the productivity of small firms over this time period then large German firms do not provide an appropriate counterfactual, whereas small firms from other European countries would. In regressions 17 to 19 we consider the robustness of our results to the use of small firms from Spain, Sweden and the UK as a counterfactual. Firms from these countries are chosen because the corporate tax rates remained unchanged over the years 1999 to 2002, but would still be affected by any European-wide productivity shocks to small firms. In all other non-German countries in the sample the corporate tax rate changed across these years. Using the results from regressions 17-19 in conjunction with those in reported as regressions 13-16 rules out the possibility that German-specific, or small firm-specific events, which might include policy change or random shocks, explain the changes in productivity growth we find for small German firms following the 2001 tax reforms.

In regression 17 we include country-year dummies as before, but now interact the German tax event dummy (equal to 1 for Germany in 2001; zero otherwise) with the small firm TFP gap-corporate tax term.²⁵ Based on our earlier findings we anticipate that the coefficient on the TFP gap* D_{SIZE} *Corp.Tax variable is positive; higher corporate taxation slows productivity catch-up in small firms in Germany, Spain, Sweden and the UK, but that the 2001 tax reforms in Germany, given by the TFP gap* D_{SIZE} *Corp.Tax* D_{GERM01} variable has a negative effect. The tax change in Germany increased the rate of productivity convergence of small firms. We continue to find that high corporate tax rates reduce the rate of productivity growth within small firms in regression 17, as shown by the small firm's TFP gap-corporate tax interaction, but that the reduction in corporate tax rates led to significantly faster productivity growth within the treatment group, shown by the small firm TFP gap*corp tax*Germany 2001 variable. Moreover, our results are unchanged when we exclude small UK firms from the control group (regression 19) on the basis that UK corporate tax rates were reduced in 1998 and this may have affected subsequent productivity growth.²⁶

[Insert Table 10]

Finally, Bertrand et al (2004) note that many difference-in-difference studies use data spanning more than just a before and after period. A consequence of this is that where outcomes are serially

²⁵ The German tax event dummy is, of course, perfectly collinear with the country-year dummies meaning that it is omitted from the regression.

²⁶ The results are in fact robust to all possible permutations of the control group.

correlated, standard errors will be inconsistent resulting in artificially small standard errors and spurious inference. One solution suggested by Bertrand et al (2004) is to collapse the data into a single pre- and post-treatment group. We conduct this robustness test in regression 19 of Table 9. The pre-treatment period is defined as the years 1999 and 2000 while the post-treatment period is 2002. We therefore calculate the mean of each variable by firm-period and re-estimate the equation. In order that this is comparable with the results in regression 17 country-period and industry-period dummies are included in the model. Although the standard errors are somewhat larger when we use this approach relative to those reported in regression 17, our results remain robust and highly significant. In fact the coefficient on the treatment interaction (-0.6075) is almost identical to that found when the model is estimated using multiple years of data.

6. Conclusions

The role that government plays in encouraging increased productivity growth in firms has always attracted considerable academic interest. Much of this interest has however, been focused on those policy changes that foster changes in the extent of competition in an industry, either from foreign or other domestic firms. In this paper we consider a more basic aspect of the policy environment of a country, the role of corporate taxation. That taxation might affect productivity is not new, but its effects have typically only been examined as indirect consequences of changes in the desire by firms to invest in physical capital or R&D. In this paper we instead provide evidence on whether it affects the returns to productivity enhancing investments, slowing the rate at which small firms catch-up with the best firms in their industry and country. We find evidence consistent with this view. Higher rates of corporate taxation slow the rate of convergence for small firms, who are likely to be the most constrained from making productivity enhancing investments. These results appear very robust to the addition of covariates to the regression, including those which account for differences in the steady state level of productivity of firms, or the rate of convergence by firms in the same industry-frontier. They are also robust to attempts to instrument for taxation using other OECD country tax rates, flooding the regression with various country, industry and firm dummy variables and using the 2001 tax reform in Germany as a natural experiment. The results are therefore consistent with a causal interpretation from corporate taxation on the rate of convergence and suggest heterogeneity in the effects of taxation across firms. Small firms are affected, whereas large firms are not, and firms with a large productivity gap are more affected than firms with a small productivity gap compared to the best firms in their country and industry.

Tables

Table 1: Number of Observations by Year

<u>Year</u>	<u>Observations</u>
1996	617
1997	837
1998	2,176
1999	15,497
2000	20,800
2001	23,556
2002	31,268
2003	44,124
2004	46,495
2005	41,098
Total	226,468

Table 2: Population Summary Statistics

	Observations	Mean	Std. Dev.
<i>Firm productivity growth</i> _{ijct}	226,468	2.7%	68.6
<i>TFP growth of frontier</i> _{jct}		1.0%	13.1
<i>TFP gap with frontier firms</i> _{jct}		0.789	18.4

Notes: TFP gap is measured as the ratio of productivity of firm i over the productivity frontier in industry j in country c .

Table 3: TFP Gap with Frontier by Country

	Mean TFP (all firms)	Mean TFP (Emp. <20)	All firms				Obs. (all firms)	Obs. (Emp. <20)
			p25	p50	p75	sd		
<i>Austria</i>	0.743	0.339	0.646	0.988	0.999	0.356	98	96
<i>Czech Republic</i>	0.583	0.512	0.393	0.532	0.795	0.256	8,684	7,722
<i>Denmark</i>	0.610	0.489	0.432	0.625	0.811	0.252	1,021	946
<i>Finland</i>	0.814	0.794	0.750	0.808	0.879	0.101	5,305	4,175
<i>France</i>	0.664	0.598	0.602	0.667	0.737	0.135	8,299	6,208
<i>Germany</i>	0.892	0.831	0.843	0.994	0.999	0.173	22,857	12,663
<i>Italy</i>	0.772	0.781	0.654	0.788	0.923	0.180	88,016	68,264
<i>Portugal</i>	0.873	0.913	0.761	0.834	0.991	0.114	410	275
<i>Spain</i>	0.709	0.687	0.622	0.713	0.791	0.130	47,915	42,328
<i>Sweden</i>	0.683	0.646	0.594	0.682	0.775	0.145	11,698	11,430
<i>United Kingdom</i>	0.804	0.803	0.687	0.842	0.990	0.187	32,165	29,462
<i>Total</i>							226468	183569

Notes: TFP is measured as the ratio of productivity of firm i over the productivity frontier in industry j in country c .

Table 4: Corporate Tax Rates and Changes

	Average Tax Rate (%)	Change between 1995 and 2005 (change in percentage points)
<i>Austria</i>	33.18	-9
<i>Czech Republic</i>	33.36	-15
<i>Denmark</i>	32.00	-6
<i>Finland</i>	28.00	1
<i>France</i>	37.14	-6.7
<i>Germany</i>	45.46	-18
<i>Italy</i>	43.27	-14.9
<i>Portugal</i>	35.00	-12.1
<i>Spain</i>	35.00	0
<i>Sweden</i>	28.00	0
<i>United Kingdom</i>	31.00	-3

Notes: Statutory corporate tax rates are from the Eurostat Taxation Trends in the EU. The years of tax reform are those that occur during the sample window of each country in Table 1. No tax reforms are found for Spain and Sweden during these time periods.

Table 5: Corporate Taxation and Productivity Convergence

Regression No. Estimator	1 OLS	2 OLS	3 OLS	4 OLS
<i>TFP growth of frontier</i> _{ict}	0.335 (57.36)**	0.347 (64.92)**	0.347 (63.78)**	0.347 (65.31)**
<i>TFP gap</i>	-0.235 (15.17)**	-0.333 (15.51)**	-0.338 (6.95)**	-0.303 (19.23)**
<i>[TFP gap * D_{SIZE}]</i> * <i>Corp. Tax</i> _{ct}	-0.048 (1.41)	0.215 (5.77)**	0.210 (4.30)**	0.411 (4.60)**
<i>TFP gap</i> * <i>Corporate Tax Rate</i> _{ct}			-0.019 (0.16)	
<i>TFP gap</i> * <i>D_{SIZE}</i>				-0.103 (2.36)*
<i>TFP gap</i> * <i>Profitability</i> _j	-0.001 (1.22)	0.001 (1.66)+	0.001 (1.90)+	0.000 (0.50)
<i>[TFP gap * D_{SIZE}]</i> * <i>Profitability</i> _j	-0.002 (5.09)**	-0.001 (2.78)**	-0.001 (2.11)*	-0.000 (0.33)
<i>Additional Control Variables</i>				
<i>Country dummies</i>		√	√	√
<i>Time dummies</i>	√	√	√	√
<i>Industry dummies</i>		√	√	√
<i>No. of firms</i>	54,787	54,787	54,787	54,787
<i>Observations</i>	226,468	226,468	226,468	226,468

Notes: +, * and ** indicate significance at the 10%, 5% and 1% levels of significance. Standard errors are clustered at the firm level and reported in parentheses. TFP gap is measured as the ratio of productivity of firm *i* over the productivity frontier in industry *j* in country *c*. The dependent variable is the rate of productivity growth in firm *i*. *D_{SIZE}* is a dummy equal to one for firms with less than 20 employees.

Table 6: Estimated Effects of Taxation on the Productivity Growth of Small Firms

<i>TFP (% of frontier)</i>	Corporate Tax Rate				
	25%	30%	35%	40%	45%
75%	-0.31	-0.62	-0.93	-1.24	-1.55
85%	-0.17	-0.35	-0.52	-0.70	-0.87
95%	-0.11	-0.23	-0.34	-0.45	-0.57

Notes: In this table we report how much slower firm productivity would be expected to grow relative to a firm that pays a 20% corporate tax rate and has the same TFP gap relative to the frontier. This table is based on the coefficient estimates from regression 2 (Table 5).

Table 7: Corporate Taxation and Productivity Convergence

Regression No.	5	6	7	8	9
Estimator	<50 emps	Small firm tax	Effective tax rates	OLS	IV
<i>TFP growth of frontier_{ict}</i>	0.345 (65.82)**	0.349 (64.30)**	0.374 (86.65)**	0.328 (52.85)**	0.361 (93.71)**
<i>TFP gap</i>	-0.321 (20.50)**	-0.302 (19.05)**	-0.300 (17.74)**	-0.385 (26.62)**	-0.385 (59.13)
<i>[TFP gap*D_{SIZE}]*Corp. Tax_{ct}</i>	0.295 (12.71)**	0.395 (5.87)**		0.454 (5.04)**	1.258 (38.54)**
<i>[TFP gap*D_{SIZE}]*Eff. Ave Tax_{ct}</i>			1.224 (6.27)**		
<i>[TFP gap*D_{SIZE}] * Eff. Ave. - Marg. Tax</i>			1.511 (13.64)**		
<i>TFP gap*D_{SIZE}</i>	-0.047 (2.02)*	-0.090 (2.78)**	-0.374 (5.61)**	-0.181 (4.52)**	-0.469 (35.65)**
<i>TFP gap*Profitability_j</i>	0.000 (0.30)	0.000 (0.35)	0.000 (0.33)	0.003 (5.30)**	0.002 (10.50)**
<i>[TFP gap*D_{SIZE}]*Profitability_j</i>	0.000 (0.03)	0.000 (0.04)	0.001 (1.21)	0.002 (2.78)**	0.001 (4.74)**
<i>Additional Control Variables</i>					
<i>Country dummies</i>	√	√	√	√	√
<i>Time dummies</i>	√	√	√	√	√
<i>Industry dummies</i>	√	√	√	√	√
<i>Political controls_{ct}</i>				√	√
<i>Fiscal controls_{ct}</i>				√	√
<i>F-test on excluded instruments (p-value)</i>					31,666 (0.00)
<i>No. of firms</i>	54,787	54,787	50,311	48,733	44,837
<i>Observations</i>	226,468	226,468	216,713	198,875	190,191

Notes: +, * and ** indicate significance at the 10%, 5% and 1% levels of significance. Standard errors are clustered at the firm level and reported in parentheses. TFP gap is measured as the ratio of productivity of firm *i* over the productivity frontier in industry *j* in country *c*. The dependent variable is the rate of productivity growth in firm *i*. D_{SIZE} is a dummy equal to one for firms with less than 20 employees, except in column 1 where they are defined as having less than 50 employees. In regression 9 the instruments used as distance weighted values of population, working age population, urbanisation, GDP growth and unemployment. 24 OECD countries are used as the relevant neighbour countries.

Table 8: Corporate Taxation and Productivity Convergence: Testing for endogeneity bias

Regression No.	10	11	12
Estimator	Country- Industry TFP gap	OLS	FE
<i>TFP growth of frontier</i> _{ict}	0.334 (52.31)**	0.318 (45.69)**	0.616 (83.50)**
<i>TFP gap</i>	- -	-0.364 (25.17)**	-1.008 (53.53)**
<i>[TFP gap * D_{SIZE}]</i> * Corp. Tax _{ct}	0.374 (4.19)**	0.372 (4.01)**	2.405 (24.33)**
<i>[TFP gap * D_{SIZE}]</i>	-0.100 (2.90)**	-0.173 (4.23)**	-0.651 (16.70)**
<i>TFP gap * Profitability_j</i>	-13.685 (1.06)	0.002 (4.52)**	0.004 (5.09)**
<i>[TFP gap * D_{SIZE}]</i> * Profitability _j	-0.000 (0.65)	0.002 (3.63)**	-0.004 (7.62)**
<i>Additional Control Variables</i>			
<i>Country dummies</i>	√	-	-
<i>Time dummies</i>	√	-	-
<i>Industry dummies</i>	√	-	-
<i>Political controls</i> _{ct}	√	√	√
<i>Fiscal controls</i> _{ct}	√	√	√
<i>Country-industry * TFP gap</i>	√		
<i>Country-Time dummies</i>		√	√
<i>Industry-Time dummies</i>		√	√
<i>Firm effects</i>			√
<i>No. of firms</i>	48,733	48,733	48,733
<i>Observations</i>	198,875	198,875	198,875

Notes: +, * and ** indicate significance at the 10%, 5% and 1% levels of significance. Standard errors are clustered at the firm level and reported in parentheses. TFP gap is measured as the ratio of productivity of firm *i* over the productivity frontier in industry *j* in country *c*. The dependent variable is the rate of productivity growth in firm *i*. D_{SIZE} is a dummy equal to one for firms with less than 20 employees.

Table 9: Corporate Taxation and Productivity Convergence: Sub-Sample of German Firms

Regression No.	13	14	15	16
Treatment Group	All firms	Small German firms	Small German firms	Small German firms
Control Group	-	Large German firms	Large German firms	Large German firms
<i>TFP growth of frontier_{jct}</i>	0.344 (64.95)**	0.202 (4.11)**	0.200 (4.09)**	1.426 (33.86)**
<i>TFP gap</i>	-0.306 (19.04)**	0.037 (0.76)	0.031 (0.63)	-0.847 (33.86)**
<i>TFP gap*Δ Corp. Tax_{ct}</i>			-0.167 (0.65)	
<i>[TFP gap*D_{SIZE}]*ΔCorp. Tax_{ct}</i>	0.885 (4.18)**	0.922 (4.75)**	1.082 (3.39)**	0.461 (9.04)**
<i>[TFP gap*D_{SIZE}]</i>	-0.044 (2.09)*	-0.360 (6.18)**	-0.355 (6.02)**	0.046 (2.30)*
<i>Additional Control Variables</i>				
<i>Country dummies</i>	√			
<i>Time dummies</i>	√			
<i>Industry dummies</i>	√			
<i>Industry-year dummies</i>		√	√	√
<i>Fiscal controls_{ct}</i>		√	√	√
<i>Firm fixed effects</i>				√
<i>No. of firms</i>	54,787	5,852	5,852	5,852
<i>Observations</i>	226,468	22,857	22,857	22,857

Notes: +, * and ** indicate significance at the 10%, 5% and 1% levels of significance. Standard errors are clustered at the firm level and reported in parentheses. TFP gap is measured as the ratio of productivity of firm *i* over the productivity frontier in industry *j* in country *c*. The dependent variable is the rate of productivity growth in firm *i*. D_{SIZE} is a dummy equal to one for firms with less than 20 employees.

Table 10: Corporate Taxation and Productivity Convergence: Sub-Sample of German Firms

Regression No.	17	18	19
Treatment Group	Small German firms	Small German firms	Small German firms
Control Group	Small ESP, SWE, UK firms	Small ESP & SWE firms	Small ESP, SWE, UK firms
<i>TFP growth of frontier_{jct}</i>	0.9855 (404.53)**	0.9626 (170.82)**	1.0370 (76.03)**
$[TFP\ gap * D_{SIZE}] * Corp. Tax_{ct}$	3.1754 (168.69)**	3.0672 (91.89)**	3.1730 (89.43)**
$[TFP\ gap * D_{SIZE}] * Corp. Tax_{ct} * D_{GERM01}$	-0.6288 (-19.70)**	-0.4685 (-15.37)**	-0.6075 (-14.51)**
$[TFP\ gap * D_{SIZE}]$	-1.0103 (-468.08)**	-1.0176 (-242.31)**	-1.1476 (-71.83)**
<i>Additional Control Variables</i>			
<i>Country-year dummies</i>	√	√	
<i>Industry-year dummies</i>	√	√	
<i>Country-period dummies</i>			√
<i>Industry-period dummies</i>			√
<i>Firm fixed effects</i>	√	√	√
<i>No. of firms</i>	15,516	10,524	
<i>Observations</i>	36,844	24,515	20,814

Notes: +, * and ** indicate significance at the 10%, 5% and 1% levels of significance. Standard errors are clustered at the firm level and reported in parentheses. TFP gap is measured as the ratio of productivity of firm *i* over the productivity frontier in industry *j* in country *c*. The dependent variable is the rate of productivity growth in firm *i*. D_{SIZE} is a dummy equal to one for firms with less than 20 employees.

References

- Aghion, P., Fally, T., and Scarpetta, S. (2007). 'Credit constraints as a barrier to the entry and post-entry growth of firms' *Economic Policy*, pp. 731-779.
- Aghion, P., Blundell, R., Griffith, R., Howitt, P. and Prantl, S. (2009). 'The Effects of Entry on Incumbent Innovation and Productivity', *Review of Economics and Statistics*, Vol. 91(1), pp. 20-32.
- Arnold, J. Brys, B., Heady, C., Johansson, A. Schwellnus, C. and Vartia, L. (2011). 'Tax policy for economic recovery and growth', *The Economic Journal*, Vol. 121, pp.F59-F80.
- Arnold, J. and Schwellnus, C (2008). 'Do corporate taxes reduce productivity and investment at the firm level? Cross-country evidence from the Amadeus dataset' CEPII Working Paper 2008-19.
- Arnold, J. Nicoletti, G. and Scarpetta, S. (2008). 'Regulation, allocative efficiency and productivity in OECD countries', OECD Working Papers No. 616.
- Auerbach, A. (2002). 'Taxation and corporate financial policy' in Auerbach and M. Feldstein (eds.) *Handbook of Public Economics* Vol. 3. Amsterdam: north-Holland, 1251-1292.
- Bartelsman, E. J., Haskel, J. and Martin, R. (2008). 'Distance to Which Frontier? Evidence on Productivity Convergence from International Firm-Level Data' Centre for Economic Policy Research Discussion Paper 7032.
- Becker, J., Fuest, C. and Hemmelgarn, T. (2006). 'Corporate Tax Reform and Foreign Direct Investment in Germany – Evidence from Firm-Level Data,' CESifo Working Paper Series 1722.
- Bertrand, M., Duflo, E. and Mullainathan, S. (2004) 'How Much Should We Trust Differences-in-Differences Estimates?', *Quarterly Review of Economics*, 119(1), p. 249-275.
- Bloom, N., and Van Reenen, J. (2007). 'Measuring and Explaining Management Practices across Firms and Countries.' *Quarterly Journal of Economics*, 122(4): 1351–1408.
- Bloom, N., and Van Reenen, J. (2010). 'Why Do Management Practices Differ across Firms and Countries?' *Journal of Economic Perspectives*, 24(1): 203–24.
- Bloom, N., Draca, M., and Van Reenen, J. (2011). 'Trade Induced Technical Change? The Impact of Chinese Imports on Innovation, IT and Productivity.' National Bureau of Economic Research Working Paper 16717.
- Bloom, N., Sadun, R., and Van Reenen. J. (2009). 'The Organization of Firms across Countries.' National Bureau of Economic Research Working Paper 15129.
- Bloom, N., Sadun, R., and Van Reenen, J. Forthcoming. 'Americans Do I.T. Better: US Multinationals and the Productivity Miracle.' *American Economic Review*.
- Bond S., Hoeffler, A. and Temple, J. (2001). 'GMM Estimation of Empirical Growth Models,' Economics Papers 2001-W21, Economics Group, Nuffield College, University of Oxford.
- Brett, C. and Pinkse, J. (2000). 'The determinants of municipal tax rates in British Columbia,' *Canadian Journal of Economics*, Vol. 33:3, pp. 695-714>
- Bridgman, B., Qi, S. and Schmitz, J.A. (2009). 'The Economic Performance of Cartels: Evidence from the New Deal U.S. Sugar Manufacturing Cartel, 1934–74.' Federal Reserve Bank of Minneapolis Staff Report 437.
- Carroll, R., Holtz-Eakin, D. Rider, M. and Rosen, H, (2000a). 'Entrepreneurs, Income Taxes, and Investment.' in Joel Slemrod, ed., *Does Atlas Shrug? The Economic Consequences of Taxing the Rich*. Cambridge: Harvard University Press.
- Carroll, R., Holtz-Eakin, D. Rider, M. and Rosen, H, (2000b). 'Income Taxes and Entrepreneurs' Use of Labor.' *Journal of Labor Economics*, Vol. 18:2, pp. 324-351.
- Coe, D. and Helpman, E. (1995). 'International R&D spillovers', *European Economic Review*, Vol. 39, pp. 859-887.
- Cummins, J. G., Hassett, K. A., & Hubbard, G. R. (1994). A reconsideration of investment behavior using tax reforms as natural experiments. *Brookings Papers on Economic Activity*, 2, 1–59.
- Cummins, J. G., Hassett, K. A., & Hubbard, G. R. (1994). 'Tax reforms and investment: A cross-country comparison, *Journal of Public Economics*, Vol. 62, pp. 1479-1505.

- Da Rin, M., Di Giacomo, M., and Sembenelli, A. (2011). 'Entrepreneurship, Firm Entry, and the Taxation of Corporate Income: Evidence from Europe', *Journal of Public Economics*, Vol. 95(9-10), pp. 1048-1066.
- Devereux, M.P., Griffith, R. and Klemm, A. (2002). Corporate income tax reforms and international tax competition. *Economic Policy*, Vol.35, pp.451-495.
- Devereux, M. and Griffith, R. (2003). 'Evaluating tax policy for location decisions' *International tax and Public Finance*,
- Devereux, M.P. and Griffith, R. (1998). 'Taxes and the Location of Production: Evidence from a Panel of US Multinationals', *Journal of Public Economics*, Vol. 68(3), pp. 335-367
- Devereux, M.P. Lockwood, B., Redoano, M., (2008). 'Do countries compete over corporate tax rates?' *Journal of Public Economics*, Vol. 92(5-6), pp. 1210-1235.
- Disney, R., Haskel, J. and Heden, Y. (2003). 'Restructuring and Productivity Growth in UK Manufacturing', *Economic Journal*, Vol. 113, pp. 666–94.
- Djankov, S. (2009). 'The regulation of entry: A survey', *The World Bank Research Observer*, Vol. 24, pp. 183-203.
- Djankov, S., Ganser, T., McLiesh, C., Ramalho, R. and Schleifer, A. (2010). 'The Effect of Corporate Taxes on Investment and Entrepreneurship', *American Economic Journal: Macroeconomics*, Vol. 2, pp. 31-64.
- Eaton, J. and Kortum, S. (1999). 'International patenting and technology diffusion', *International Economic Review*, Vol. 40, pp. 537-570.
- Egger, P., Pfaffermayer, M. and Winner, H. (2005a). 'An unbalanced spatial panel data approach to US state tax competition,' *Economics Letters*, Vol. 88(3), pp.329-335.
- Egger, P., Pfaffermayer, M. and Winner, H. (2005b). 'Commodity taxation in a 'linear' world: a spatial panel data approach,' *Regional Science and Urban Economics*, Vol. 35(5), pp. 527-541.
- Foster, Lucia, John Haltiwanger, and C. J. Krizan. (2001). 'Aggregate Productivity Growth: Lessons from Microeconomic Evidence.' In *New Developments in Productivity Analysis*, ed. Charles R. Hulten, Edwin R. Dean, and Michael J. Harper, 303–63. Chicago and London: University of Chicago Press.
- Gordon, R. and Hines, J. (2002). 'International Taxation' in Auerbach, A. and Feldstein, M. (eds.), *Handbook in Public Economics*, Vol. IV, pp. 1935-1995.
- Görg, H. and Greenaway, D. (2004). 'Much Ado About Nothing? Do Domestic Firms Really Benefit from Foreign Direct Investment?' *World Bank Research Observer*, Vol. 19, pp. 171-197.
- Griffith, R., Redding, S. and Van Reenen, J. (2001). 'Measuring the cost-effectiveness of an R&D tax credit for the UK.' *Fiscal Studies*, Vol. 22(3), pp.375-399.
- Griffith, R., Redding, S. and Van Reenen, J. (2003). 'R&D and Absorptive Capacity: Theory and Empirical Evidence.' *Scandinavian Journal of Economics*, Vol. 105(1), pp.99-118.
- Griffith, R., Redding, S. Simpson, H. (2009). 'Technological Catch-Up And Geographic Proximity,' *Journal of Regional Science*, Vol. 49(4), pp. 689-720.
- Hall, B. and Van Reenen, J., (2000). 'How effective are fiscal incentives for R&D? A review of the evidence,' *Research Policy*, Vol. 29(4-5), pp. 449-469.
- Hassett, K. and Hubbard, G. (2002). 'Tax policy and business investment', in A.J. Auerbach and M. Feldstein (eds.) *Handbook of Public Economics* Vol. 3. Amsterdam: north-Holland, 1293-1343.
- Haufler, A. Nörback, P-J, Persson, L. (2011). 'Entrepreneurial innovations and taxation', CESifo Working Paper No. 3473.
- Henrekson, M. and Sanandaji, T. (2011). 'Entrepreneurship and the theory of taxation', *Small Business Economics*, Vol. 37, pp. 167-185.
- Hines J.R.Jr., (2005). 'Do Tax Havens Flourish?,' NBER Chapters, in: Tax Policy and the Economy, Volume 19, pages 65-100 National Bureau of Economic Research, Inc.

- Holmes, T. J., Levine, D., and Schmitz, J.A. (2008). 'Monopoly and the Incentive to Innovate When Adoption Involves Switchover Disruptions.' National Bureau of Economic Research Working Paper 13864.
- House, C. and Shapiro, M. (2008). 'Temporary investment tax incentives: theory with evidence from bonus depreciation', *American Economic Review*.
- Ilmakunnas, P., Maliranta, M. and Vainiomäki, J. (2004). 'The Roles of Employer and Employee Characteristics for Plant Productivity.' *Journal of Productivity Analysis*, Vol.21(3), pp.249–76.
- Jorgenson, D.W., Ho, M. and Stiroh, K. (2005). Productivity. Volume 3. Information Technology and the American Growth Resurgence. Cambridge and London: MIT Press.
- Jorgenson, D.W., Ho, M. and Stiroh, K. (2008). 'A Retrospective Look at the U.S. Productivity Growth Resurgence.' *Journal of Economic Perspectives*, Vol.22(1), pp. 3–24.
- Keller, W. (2001). 'The geography and channels of diffusion at the worlds technology frontier', NBER Working Paper Series No. 8150.
- Keller, W. (2002). 'Geographic localisation of international technology diffusion', *American Economic Review*, Vol. 92, pp. 120-142.
- Keuschnigg, C. and Ribí, E. (forthcoming). 'Profit taxation and financial constraints', *International Tax and Public Finance*.
- Klapper, L., Laeven, L. and Rajan, R. (2006). 'Entry regulation as a barrier to entrepreneurship', *Journal of Financial Economics*, Vol. 82, pp. 591-629.
- Kneller and McGowan (2012), 'Tax Policy and firm entry and exit dynamics: Evidence from OECD countries', University of Nottingham Working Paper No.2012/01.
- Levinsohn, J. and Petrin, A. (2003). 'estimating production functions using inputs to control for unobservable' *Review of Economics and Statistics*, Vol. 70, pp. 317-342.
- Lileeva, A. and Trefler, D. (2010) 'Improved access to foreign markets raises plant-level productivity.... For some plants', *Quarterly Journal of Economics*, pp. 1051-1099.
- Nam, C.W. and Radulescu, D.M (2007). 'Effects of Corporate Tax Reforms on SMEs' Investment Decisions under the Particular Consideration of Inflation', *Small Business Economics*, Vol. 29, pp. 101-118.
- Nerlove, M. Razin, A., Sadka, E. and von Weizsäcker, R. (1993). 'Comprehensive income taxation, investments in human and physical capital, and productivity', *Journal of Public Economics*, Vol. 50, pp. 397-406.
- Nicoletti, G., and Scarpetta, S. (2005). 'Regulation and Economic Performance: Product Market Reforms and Productivity in the OECD.' Organisation for Economic Co-operation and Development Economics Department Working Paper 460.
- Oliner, S., Sichel, D., and Stiroh, K. (2007). 'Explaining a Productive Decade.' Brookings Papers on Economic Activity, Vol. 1, pp.81–137.
- Olley, G. S., and Pakes, A. (1996). 'The Dynamics of Productivity in the Telecommunications Equipment Industry.' *Econometrica*, Vol. 64(6), pp.1263–97.
- Ozer-Bali, H. and Sørensen, B. (2010). 'Interaction effects in econometrics', mimeo. Massey University, New Zealand.
- Pavcnik, N. 2002. 'Trade Liberalization, Exit, and Productivity Improvement: Evidence from Chilean Plants.' *Review of Economic Studies*, Vol. 69(1), pp. 245–76.
- Petrin, A., and Sivadasan, J. (2010). 'Estimating Lost Output from Allocative Inefficiency, with Application to Chile and Firing Costs.' Unpublished.
- Rajan, R. and Zingales, L. (1998). 'Financial dependence and growth'. *American Economic Review*, Vol. 88, pp. 559-586.
- Schaller, H. (1993). 'Asymmetric information, liquidity constraints, and Canadian investment' *Canadian Journal of Economics*, Vol. 26, pp. 552-574.
- Schmitz, J. A. (2005). 'What Determines Productivity? Lessons from the Dramatic Recovery of the U.S. and Canadian Iron Ore Industries following Their Early 1980s Crisis.' *Journal of Political Economy*, 113(3): 582–625.

- Spengel, C. (2001). 'Der Steuerstandort Deutschland im Internationalen Vergleich, Eine Analyse Vor Dem Hintergrund Des Steuersenkungsgesetzes 2001, Expertise Für Den Sachverständigenrat Zur Begutachtung der Gesamtwirtschaftlichen Entwicklung, Universität Mannheim.
- Syverson, C. (2004). 'Market Structure and Productivity: A Concrete Example.' *Journal of Political Economy*, Vol. 112 (6), pp. 1181–1222.
- Syverson, C. (2011). 'What Determines Productivity?' *Journal of Economic Literature*, Vol. 49 (2): pp.326–65.

About the Authors

Norman Gemmell is Professor of Public Finance at Victoria Business School, Victoria University of Wellington, New Zealand.
Email: norman.gemmell@vuw.ac.nz

Richard Kneller is Research Fellow in the Centre for Globalisation and Economic Policy and a professor of Economics at the University of Nottingham.
Email: richard.kneller@nottingham.ac.uk

Danny McGowan is a lecturer in Economics at Bangor Business School, Bangor University, U.K.
Email: d.mcgowan@bangor.ac.uk

Ismael Sanz is Professor of the Department of Applied Economics I at Universidad Rey Juan Carlos.
Email: ismael.sanz@urjc.es

José F. Sanz-Sanz is Professor of Applied Economics at Universidad Complutense de Madrid.
Email: jfelizs@ccee.ucm.es