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Do Corporate Taxes harm economic performance?

Explaining distortions in R&D- and Export-Intensive UK Firms *

Ioannis Bournakis¹ and Sushanta Mallick²

Abstract

This paper makes a first attempt to analyse the effects of corporate tax liability on firm level Total Factor Productivity (TFP) – as the key driver of economic performance. This is a new dimension in the UK productivity puzzle that has not attracted attention so far. We use 6559 manufacturing firms over 2004-2011 to investigate whether higher levels of corporate tax affect the productivity catch-up process by reducing after tax earnings that can be alternatively used for productivity enhancing investment. We particularly focus on R&D and export intensive firms. Our key results are summarized as: first, higher levels of corporate taxation impact adversely on TFP and this finding is robust to different tax measures and insensitive to endogeneity bias; second, R&D and export intensive firms tend to have higher rates of TFP growth; finally, higher levels of tax liability as a share of Earnings Before Interest and Tax (EBIT) decelerate TFP growth of these firms.

Keywords: Total Factor Productivity (TFP), Catch-Up, Tax Liability, Effective Tax Rate, Firm-level Data, FAME Data, UK.

JEL Classification: O3, O4.

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¹ Department of Economics, Middlesex University, London, Hendon, NW4 4BT, UK

² School of Business and Management, Queen Mary University of London, Mile End Road, London, E1 4NS, UK.

1. Introduction

The persistent losses in UK productivity since 2007 indicate that understanding the productivity puzzle requires a combination of factors -other than pure cyclical effects- such as: investment in intangible capital formation (Goodridge et al., 2013), impaired resource allocation (Oulton, 2001) and Barnett et al. 2014) and factors proportion (Harris and Moffat, 2016). In this paper we seek to explain this puzzle by investigating any possible unintended effects on productivity arising from higher levels of corporate tax during the 2000s. In particular, our analysis uses firm level data to explore how corporate tax liability affects productivity performance within a firm-level productivity convergence framework.

There is a strand of literature that stresses the role of taxes on various aspects of firm performance. Hall and Van Reenen (2000) argue that there is an equal and proportionate relationship between tax exemptions and R&D investment that largely determine the location of R&D activity. Djankov et al. (2010) have found in a cross-country context how different types of corporate taxation affect FDI and industry dynamics focusing on firms' entry and exit decisions. With the exception of Arnold et al. (2011), evidence on the effect of corporate tax on productivity is scarce. The empirical evidence from Arnold et al. (2011) indicates that higher corporate tax negatively affects productivity growth in more profitable industries. The present study is motivated from findings of the above studies in order to investigate whether changes in corporate taxation can have effects on productivity performance of R&D and exporting firms. Our motivation to investigate the effects of corporate taxation across firms with different R&D and export status relying on corporate finance models (see Keuschnigg and Ribi, 2013) and Brekke et al., 2014) that show how tax liability can impact on investment decisions of firms which are financially constrained. This literature argues that external creditors face asymmetric information when they decide their allocation of funds across firms; so any firm liability that reduces the amount of profit potentially limits the amount of external credit. R&D and exporting firms are heavily dependent on external funding; thus one should identify whether there are tax-induced effects that adversely impact on these activities.³

³ The focus on R&D and exporting in this study represents the weight of these activities on aggregate productivity. It is now a well-established stylized fact with regard to the existence of social returns to innovation (see Griffith et al. (2003, 2004), Cameron (2006), Bourlès et al. (2013) and Bloom et al. (2013) on the role of R&D in productivity catch-up models). Similarly, there is substantial literature (less conclusive though) about the existence of learning effects from exporting. We refer to Melitz (2003) for a theoretical exposition while more recent evidence for the learning by exporting literature can be found in Mallick and Yang (2013).

In this context, our paper contributes to the firm productivity literature investigating the existence of fiscal effects that might matter for the rate of productivity growth at the firm level. More precisely, we address two questions: (i) whether changes in the statutory corporate tax rates affect investment decisions in productivity enhancing projects and (ii) whether tax effects vary for R&D and exporting firms. A novel aspect of our paper is that we do not rely only on how exogenous statutory corporate tax rates affect productivity but we also use firm specific payments of corporate tax to capture all the within-firm manipulations realised when firms comply with tax legislation.

Two main stylized facts justify why evidence from UK firms is well suited to this sort of analysis. First, in recent decades, productivity levels in the UK have substantially fallen behind those of the US (Cameron et al., 2005; Mayhew et al., 2006) while there is also evidence of within industry productivity dispersion (Griffith et al. 2006). Therefore, it becomes important to identify whether there are fiscal aspects of this productivity handicap. Second, the existence of considerable firm-level heterogeneity (Davis et al., 1996; Bartelsman and Doms, 2000; Disney et al., 2003) both across and within industries suggests that UK firms are quite likely to react differently to external shocks, which in turn affect both firms' rate of productivity growth and the speed of convergence towards the national frontier. Understanding how firms respond to changes in tax policy is vital from a macroeconomic perspective when policy makers make choices between different types of taxation and their potential impact on firm-level productivity growth. The empirical part of the paper builds upon recent theoretical model (Keuschnigg and Ribi (2013)) that highlights the importance of post-tax income as an asset for external funding. The theoretical prediction of this model is that higher levels of corporate tax negatively affect investment decisions and thus productivity growth.

The remainder of the paper is organized as follows: section 2 overviews key aspects of the taxation-productivity nexus; section 3 presents the empirical strategy alongside data and key features of the UK corporate tax system; section 4 presents the econometric specification and results from baseline and sensitivity analysis; and section 5 concludes the paper.

2. Analytical Underpinnings for the Taxation-Productivity Link

Corporate finance models (Hubbard (1998), Cullen and Gordon (2007) and Keuschnigg and Ribi (2013)) that analyze how taxation policy can affect investment motivate the empirical framework of the paper. These models propose that corporate tax increases the user cost of capital, and also identify mechanisms through which taxation worsens financial constraints due to moral hazard and asymmetric information between external creditors and the firm. We assume that investment decisions are sensitive to external finance and hence higher levels of corporate tax liability decrease the amount of post-tax working capital that firms can use as collateral for raising external funds. This leads to financial constraints that potentially decrease investment in activities which can promote technical efficiency.⁴ We analyze the adverse tax induced effects on a firm's performance within a productivity convergence framework in the spirit of Aghion and Howitt (1998) allowing for corporate tax liability to drive both firm productivity growth and the catch up process towards the frontier.

Corporate taxation can cause disproportionate effects on R&D and exporting firms as these two groups are relatively more sensitive to external finance. The key objective investigated in the present paper is whether changes in tax policy affect productivity performance of more risk-taking firms. R&D activity is very likely to incur losses in the short-run⁵ as it involves substantial start-up costs that are to a large extent sunk. These costs are paid up-front, which require sufficient cash-flows that are usually derived from external sources. Furthermore, one should not ignore that R&D projects are highly uncertain adding to R&D firms' extra liquidity pressure, which is again covered from external finance (Máñez et al., 2014). In a neoclassical set-up (Hubbard, 1998) with perfect information, taxation affects investment only via an increase in the user cost of capital which is the opportunity cost associated with the alternative uses of firm's income. The model of Keuschnigg and Ribi (2013) proposes another view in which firms operate in an environment of tight credit constraints and imperfect information between the firm and its creditor. Based on these considerations, higher corporate tax lowers the amount of post-tax income and it shrinks the borrowing capacity of the firm. The main implication of this theoretical proposition is that

⁴ Gemmell et al. (2016) show that negative effects induced from higher corporation tax is proportionally higher to small firms. This effect is attributed to the fact that small firms are more likely to be credit constrained in the post-tax period, which also affects their capacity to raise external funding. See Schaller (1993) and Aghion et al. (2007) for an exposition on how asset size influences external finance.

⁵ These losses prevail up to the point that current projects become fertile leading to the appropriation of economic rents (i.e. revenue from patents).

R&D firms encounter difficulties to finance future innovation projects, which in turn lead to efficiency losses and lower productivity growth. The key element tested in this paper is whether higher average tax expenses lead to adverse effects on the financial position and borrowing capacity of R&D firms.

Changes in the corporate tax can also impact firms' commitments in serving international markets. Exporting involves relatively higher levels of business costs,⁶ which require additional financial strength. The corporate tax system can create incentives or disincentives for exporters in a similar fashion as it is with R&D firms. A higher corporate liability reduces firm's working capital as well as it deteriorates chances for external finance. Likewise with R&D firms, the paper investigates whether higher levels of corporate taxation affect investment, which can lower productivity growth and restrict the international commitment of UK exporters.⁷

To sum up the previous considerations, we investigate the distortionary effects of taxation on firm productivity within a convergence framework. The empirical evidence of the paper is taken from FAME data of UK manufacturing firms for the period 2004-2011. For the implementation of the empirical analysis, a well-specified TFP measure is required. We use the semi-parametric approach of Olley and Pakes (1996) (OP, hereafter) to derive TFP that addresses, first, simultaneity bias between inputs and various unobserved productivity shocks and second, selection bias.⁸ OP offers more flexibility than standard OLS and purely non-parametric TFP technique relying on a set of strong assumptions.⁹ We outline the OP methodology and the issues related to FAME data in Appendix 2.

⁶ Costs related to exporting are the establishment of foreign networks, transportation of commodities, post sales services etc.

⁷ Exporting activity can generate substantial learning gains (Bernard and Jensen, 1999; Greenaway and Kneller, 2004; Greenaway and Yu, 2004; Crespi et al., 2008), and thus any obstacle to international expansion can potentially restrict knowledge spillovers related to exporting.

⁸ For a robustness check, we also calculate TFP using the semi-parametric technique of Levinsohn-Petrin (LP) (2003). The econometric results from TFP via LP (2003) are discussed at the end of the econometric analysis section.

⁹ See Blundell and Bond (2000) and Hígon (2004) for an analytical discussion regarding alternative parametric estimation techniques for TFP. OP's advantage is that it controls for selection bias between capital and probability to exit the market. Firms with higher level of capital stock are likely to generate more future profits and thus the probability to exit after a negative productivity shock is smaller.

3. Empirical Strategy

3.1. Model Specification

The empirical model is derived from an autoregressive specification of productivity as per Bernard and Jones (1996a and 1996b) and Griffith et al. (2009) formulation. Parameter A is the measure of technical efficiency, which is assumed to be homogenous of degree 1 and exhibit decreasing returns with reference to each individual production input. Vector γ_{it} includes other firm specific characteristics that literature suggests (Aw et al., 2008) as crucial determinants in the evolution of A . The empirical variant of A is a TFP index:

$$\ln A_{it} = \gamma_{it} + a_1 \ln A_{it-1} + a_2 \ln A_{Ft} + a_3 \ln A_{Ft-1} + u_{it} \quad [3.1]$$

Equation [3.1] can be empirically reformulated into an Error Correction Model (ECM) specifying TFP growth in firm i as:

$$\begin{aligned} \Delta \ln TFP_{it} = & a_2 \Delta \ln TFP_{Ft} + a_3 Tax_{it-1} + a_4 R_i + a_5 E_i + \\ & + \lambda GAP_{it-1} + \delta Y_t + \eta S_j + u_{it} \end{aligned} \quad [3.2]$$

$\Delta \ln TFP_F$ is the growth rate of the frontier F , Tax refers to the tax measure (corporate tax liability or effective tax rate (ETR)), R and E are binary variables referring to the R&D and Export status of the firm, ($R=1$, if i is an R&D active firm during the whole period of our sample and 0 otherwise; a similar definition applies to E). GAP_{it-1} represents the TFP distance between firm i and the frontier firm F , TFP_{it-1} / TFP_{Ft-1} . Our benchmark frontier measure is the firm with the highest TFP in industry j at year t .¹⁰ The specification is also augmented with a set of year (Y) and four-digit NACE (Rev2) sectors (S) dummies to capture common macroeconomic shocks and fixed idiosyncrasies at the industry level. Finally, there is a stochastic error term u_{it} .

¹⁰ We replicate results measuring the frontier unit as the firm with the highest TFP in the whole sample at year t and as a hypothetical firm with TFP at the average TFP of the 5% more productive firms in industry j in year t . Appendix 4 shows summary statistics for alternative definitions of GAP . Indicatively, average firm's TFP is 68.6% of the frontier's TFP; in other words, the distance from the frontier is 32 percentage points ($1-0.68=0.32$). The alternative definitions of the frontier unit provide- as expected- different coefficients for GAP and $\Delta \ln TFP_{Ft}$ in [3.2] and [3.3], but the pattern of results and the level of significance remain unchanged. These results are available from the authors upon request.

A variant of [3.2] is also considered for testing whether the effect of corporate tax on TFP growth varies with firm i 's distance from the frontier using an interaction term of GAP and Tax .

$$\begin{aligned} \Delta \ln TFP_{it} = & a_2 \Delta \ln TFP_{Ft} + a_3 Tax_{it-1} + a_4 R_i + a_5 E_i + \lambda GAP_{it-1} + \\ & + \mu [GAP_{it-1} \times Tax_{it-1}] + \delta Y_t + \eta S_j + u_{it} \end{aligned} \quad [3.3]$$

Parameter μ captures the effect of corporate tax on the catch-up process. Accordingly, we posit a positive sign for the estimated coefficient of μ . We also anticipate that estimated parameters a_2 , a_4 and a_5 will be positive while parameters a_3 and λ will be negative. Finally we consider another variant of [3.2] that uses interchangeably the interaction terms of $[R_i \times Tax_{it-1}]$ and $[E_i \times Tax_{it-1}]$ in order to test whether the effect of tax liability varies with the R&D and export status of the firm.

We use two alternative definitions of Tax seeking to capture two different conceptualisations regarding the impact of tax burden. The first measure is the amount of tax bill that is due using the statutory tax rate that applies for each different profit category.

Based on this, corporate tax liability (Tax) is defined as follows: $Tax_{it} = \sum_{s=1}^5 (EBIT_{it} - h_s) \times \tau_{is}$,

where $EBIT$ are earnings before interest and taxes as reported in FAME, h is the size range (threshold) in which the statutory tax rate changes and τ is the statutory tax rate applied for the size range h_s in year t . Tax_{it} is expressed as a ratio of taxable profit¹¹ to obtain the share of tax liability. The statutory tax rate τ might not change much over time for some group of firms but for small and very large sized firms there have been substantial changes in the period studied. The second tax measure is ETR expressed as the ratio of corporate tax payment over $EBIT$ using only the information available from FAME. ETR takes into account all the ex post within business manipulations that firms do before paying the final tax bill. Appendix 1A outlines some key characteristics of the UK corporate system in the period under review.

Regarding the definitions of R and E , we only include committed R&D and exporting firms implying that R and E are assigned value 1 only if i reports data on R&D expenditure and export sales for all eight years of the period 2004-2011.¹² Based on this definition, the

¹¹ Taxable profit is reported in FAME under the name Profits before Tax (PbT).

¹² A less strict definition of R and E is also applied assigning value one to firms with R&D and export data for at least four years in the sample. Econometric results from alternative measures of R and E are not shown in the paper but they are available from the authors upon request.

number of R&D firms is 945 while the number of exporting firms is 1773. Some preliminary evidence in Figures 1 and 2 show that R&D and exporting firms clearly maintain a higher level of TFP than other counterparts, which gives a signal that the levels of profitability are also likely to be higher, thus the issue worth exploring is whether the distortionary effect of corporate taxation is more severe in these group of firms.

To estimate [3.2] and [3.3] we use FAME database that covers both private and public companies in the UK. Our sample is an unbalanced panel of manufacturing firms (4-digit NACE Rev.2 classification) over the period 2004 to 2011. All data reported in FAME are from unconsolidated accounts derived from Profit-Loss and Balance sheets. We focus on variables that are needed for the computation of TFP; output is measured as total sales adjusted for the cost of materials and firm inventories. Book values from FAME are converted into 2005 constant prices using 4-digit NACE industry production price indices (Office of National Statistics-ONS). Capital is measured from the book value of total fixed assets in FAME after being converted into 2005 constant prices with an industry invariant capital price index from ONS. Labour is measured as the number of employees. Appendix 2A outlines the key steps for the derivation of TFP following the Olley and Pakes (1996) algorithm and Appendix 2B displays summary statistics of all variables used in the analysis.

Figure 1: Average TFP Levels of R&D and Non-R&D Firms, UK Firms 2004-2011

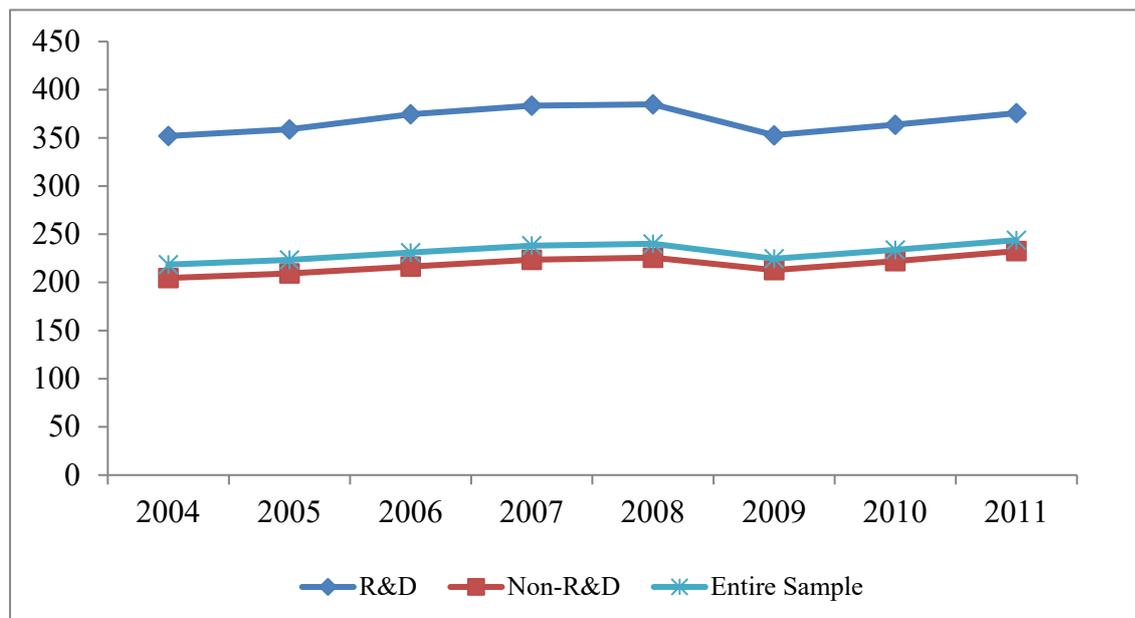
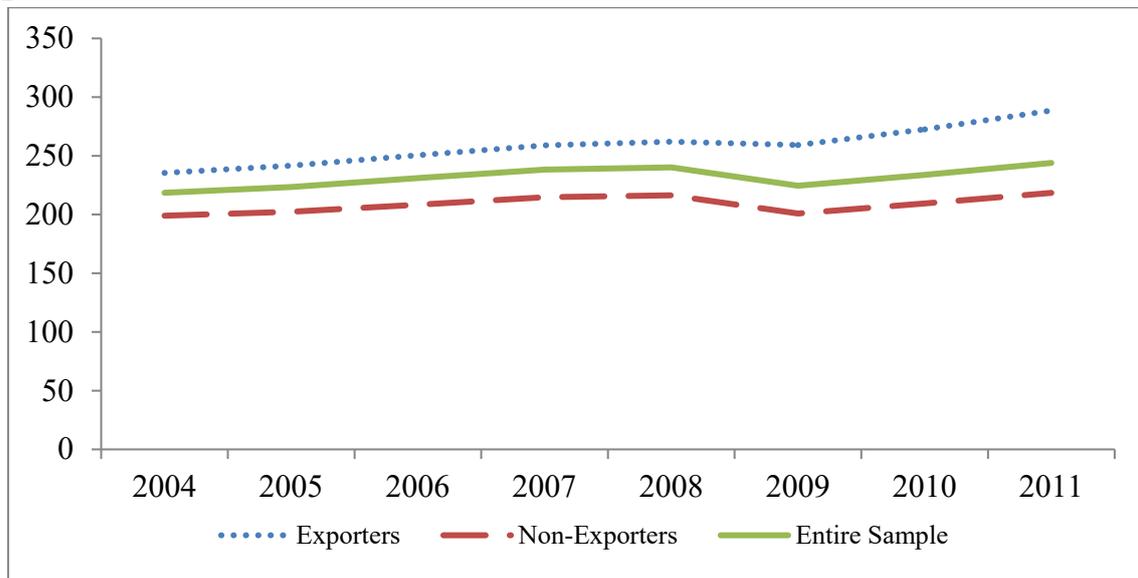


Figure 2: Average TFP Levels of Exporters and Non-Exporters, UK Firms 2004-2011



3.2 Baseline OLS Estimates

We start with OLS baseline estimates for [3.2] and [3.3], which are shown in Table 1. The coefficient of GAP_{it-1} is negative and highly significant, which is in line with the hypothesis that laggard firms tend to grow faster. R&D active firms experience higher TFP growth rates while productivity growth differences between exporters and non-exporters are insignificant in conventional statistical terms. The autonomous effect of TFP growth of the frontier is positive signifying the existence of knowledge spillovers derived from more productive firms in the industry. The magnitude of this effect is strong suggesting that 1% increase in the TFP growth of the frontier increases TFP growth rate in i by 0.21 percentage points. The effect of corporate tax liability (Tax_{it-1}) on TFP growth is negative and statistically significant at the 1% level. Column (2) replicates results from specification [3.3], which augments the original productivity model with the interaction term $[GAP_{it-1} \times Tax_{it-1}]$. The positive coefficient of the multiplicative term suggests that as tax liability increases the rate of productivity catch-up falls, which is compatible to our first hypothesis that corporate taxation restrains resources whose alternative use is in productivity enhancing investments.

The role of corporate tax in driving productivity growth of innovators and exporters is examined in columns (3) and (4) with the interaction terms $[R_i \times Tax_{it-1}]$ and $[E_i \times Tax_{it-1}]$. Coefficients of the multiplicative variables are negative and significant suggesting that the burden of corporate tax causes adverse productivity effects in those two groups. A further investigation is undertaken with a triple interaction term to test whether innovators and exporters grow faster compared to non-innovators and non-exporters, conditional on the distance from the frontier and the level of tax liability. Results are shown in columns (5) and (6) signifying that innovators and exporters typically maintain higher absorptive capacity closing the productivity gap faster with the speed of this process to depend on the level of corporate tax liability.

OLS estimates for [3.2] and [3.3] are supportive of the initial hypotheses that higher tax liability reduces the amount of working capital weakening a firm's position to invest in productivity enhancement assets¹³ and the distortive effect of corporate tax is disproportionately higher on firms that invest in R&D and export activities. Firms that undertake efficiency enhancing activities such as innovation and international market expansion encounter various uncertainties that require higher levels of working capital as a

¹³It will also be valid to point out here that firm i 's opportunity cost of higher tax liability is less market expansion highlighting the alternative uses of existing working capital.

counterweight for likely short-term losses. Working capital is the main collateral that firms can use for obtaining external funding and continue business activities. The use of triple interaction terms $[GAP_{it-1} \times Tax_{it-1} \times R_i]$ and $[GAP_{it-1} \times Tax_{it-1} \times E_i]$ support a similar scenario; the distortive effect of taxation harms disproportionately the catch up process of dynamic firms, which might induce uncompensated international competitiveness losses for UK innovators and exporters. Finally, the diagnostic tests at the bottom of Table 1 report low R-squared values reflecting omitted variables bias. This is to say that there are other equally important TFP growth drivers that are currently excluded from the specifications. Some robustness tests are provided in the following sections to prove whether OLS estimates are robust or results are driven by potential endogeneity and measurement bias between TFP growth and GAP_{it-1} .

Table 1: OLS Regressions of TFP Growth and Tax Liability by UK Firms during 2004-2011

	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta \ln TFP_{Ft}$	0.216*** (14.29)	0.264*** (10.86)	0.189*** (13.82)	0.182*** (13.22)	0.219*** (14.23)	0.227*** (13.71)
GAP_{it-1}	-0.189*** (14.49)	-0.261*** (8.55)	-0.136*** (12.30)	-0.135*** (12.17)	-0.191*** (14.38)	-0.197*** (13.85)
Tax_{it-1}	-0.069*** (6.09)	-0.359*** (3.65)	-0.097*** (6.66)	-0.062*** (3.67)	-0.074*** (6.12)	-0.102*** (4.87)
$[GAP_{it-1} \times Tax_{it-1}]$		0.435*** (3.09)				
R_i	0.005* (1.79)	0.005* (1.69)	0.012** (2.15)	0.004 (1.36)	0.004 (0.70)	0.005* (1.75)
E_i	0.001 (0.35)	0.001 (0.36)	0.001 (0.70)	0.011*** (3.54)	0.001 (0.36)	0.007 (1.55)
$[R_i \times Tax_{it-1}]$			-0.053* (1.71)			
$[E_i \times Tax_{it-1}]$				-0.063*** (4.10)		
$[GAP_{it-1} \times Tax_{it-1} \times R_i]$					0.075* (1.88)	
$[GAP_{it-1} \times Tax_{it-1} \times E_i]$						0.071** (2.07)
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	32178	32178	26861	26861	32178	32178
Adjusted R^2	0.023	0.024	0.017	0.017	0.023	0.023
AIC	-25806	-25830	-25779	-25793	-25807	-25809
RESET	126.750	147.274	25.043	20.915	127.204	130.464
RESET p value	0.000	0.000	0.000	0.000	0.000	0.000

Absolute t-statistics in parentheses are consistent robust standard errors clustered by firm and *indicates $p < 0.10$, **indicates $p < 0.05$, ***indicates $p < 0.01$. RESET test refers to the hypothesis that the model has no omitted variables. AIC is the Akaike information criterion. In relative terms the preferred model is the one that minimizes the AIC value.

3.3 GMM Estimates for Endogeneity and Measurement Bias

The GAP_{it-1} term in specifications [3.2] and [3.3] comprises the levels of TFP_{it-1} , which is also a component of TFP growth rate. Concerning Tax and ETR which enter the regressions in lags, they only satisfy weak exogeneity. The tax and TFP relationship might have been persistent, as previous TFP realizations impact on future tax liabilities. These considerations imply that OLS estimates suffer from endogeneity bias. Another crucial issue

in estimating [3.2] and [3.3] is the impact of “noisy” TFP measure, which is a common characteristic in firm level studies.¹⁴ To provide a more systematic treatment of endogeneity and measurement bias, we replicate results of Table 1 using a Generalized Methods of Moments (GMM) estimator. The challenging task about GMM estimation is to identify appropriately endogenous variables; this is to find valid instruments for Tax_{it-1} , ETR_{it-1} and GAP_{it-1} that will be uncorrelated with the error term in the TFP growth. In our case, industry averages could be valid instruments since errors that are largely idiosyncratic to the firm are very unlikely to be correlated to industry average values (Fisman and Svensson, 2007). We select values in period t-1 up to t-3 of the following industry (4-digit NACE Rev2) average variables: profit rate, equity and TFP¹⁵. We use the orthogonality condition test (Sargan statistic) $E[Z_i | u_i] = 0$, where Z is the set of instruments and the Anderson LM statistic of under-identification, $Cov[Z_i, Tax] \neq 0$. The Anderson LM statistic tests the hypothesis whether the excluded instruments are weak; so they are appropriately excluded from the regression.

Instrument diagnostic tests support our identification strategy with Sargan test being unable to reject the null while LM test clearly rejects the null that excluded instruments are relevant. Turning to GMM estimates, Tax maintains a negative coefficient in four out of six models shown in Table 2 while estimates for the interaction terms between Tax , R and E are also negative in columns (3) and (4). The remaining coefficients remain qualitatively similar to OLS estimates in Table 1, and exceptionally the triple interaction terms are now statistically not different from zero. GMM estimates confirm that a higher level of tax liability has a distortionary nature on productivity growth and it affects the catch up process of firms towards the frontier; these negative effects prevail even after controlling for endogeneity and any other unobserved measurement bias.

¹⁴The OP framework used for the TFP calculation accounts for endogeneity bias between the selection of inputs and output, although a series of other issues still remain unresolved regarding the degree of capital utilization and firm’s monopolistic power in the market. Capital might not always be under full utilization introducing short term rigidities that can cause efficiency losses without necessarily reflecting technical changes. Similarly, the OP methodology does not capture imperfect competition that leads to economies of scale and can be mistakenly attributed to technological progress.

¹⁵ Instruments are computed as mean values across firms in 4-digit NACE Rev2 industries in year t. Profit rate is defined as operational profit over total sales industry; equity is defined as: (Total Assets–Long Term Liabilities)/Total Assets (FAME).

Table 2: GMM Regressions with Industry Level Instruments for TFP Growth and Tax Liability of UK Firms during 2004-2011

	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta \ln TFP_{Ft}$	3.959*** (7.83)	3.858*** (7.61)	3.906*** (7.32)	3.908*** (7.35)	3.578*** (7.02)	3.645*** (7.54)
GAP_{it-1}	-0.01*** (6.53)	-0.013*** (6.31)	-0.08*** (6.13)	-0.08*** (6.15)	-0.015*** (6.09)	-0.014*** (6.34)
Tax_{it-1}	-0.122*** (3.51)	-0.175** (2.14)	-0.355 (1.40)	-0.357 (1.49)	-0.204* (1.66)	-0.187** (2.02)
$[GAP_{it-1} \times Tax_{it-1}]$		-1.170 (0.91)				
R_i	0.294*** (6.31)	0.288*** (5.90)	3.627*** (4.02)	0.304*** (5.97)	2.044 (1.07)	0.289*** (5.79)
E_i	0.078*** (5.57)	0.077*** (5.32)	0.081*** (5.31)	0.635*** (4.11)	0.073*** (5.19)	0.356 (1.30)
$[R_i \times Tax_{it-1}]$			-16.228*** (3.81)			
$[E_i \times Tax_{it-1}]$				-2.703*** (3.79)		
$[GAP_{it-1} \times Tax_{it-1} \times R_i]$					-11.895 (0.94)	
$[GAP_{it-1} \times Tax_{it-1} \times E_i]$						-2.006 (1.04)
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	32390	32137	32136	32136	32137	32137
Adjusted R^2	0.014	0.014	0.014	0.014	0.014	0.014
Anderson LM	52.077	37.236	47.361	48.325	18.597	41.507
Anderson-p value	0.000	0.000	0.000	0.000	0.017	0.000
Sargan	7.083	0.306	10.216	10.852	5.843	5.859
Sargan-p value	0.528	0.989	0.333	0.286	0.558	0.556

Absolute t-statistics in parentheses calculated consistently for robust standard errors clustered by firm and *indicates $p < 0.10$, **indicates $p < 0.05$, ***indicates $p < 0.01$. The instruments in all specifications are the average values of profit rate, equity and TFP at the NACE Rev 2 industry level in periods t-1, t-2 and t-3. The Sargan test refers to the orthogonality condition; under the null the instruments used are valid (i.e. uncorrelated with the error term). The Anderson LM test refers to the relevance of instruments with the endogenous variable; under the null the set of instruments used is weak.

3.4 Further Sensitivity Tests with Alternative Measures of Corporate Taxation

The results shown in Tables 1 and 2 refer to a tax measure that represents what the firm is supposed to pay on different ranges of income assuming that it complies with all rules and laws. In other words, *Tax* measures what is due to the tax office without capturing firm's efforts and facilities to shift or reduce the amount of tax bill based on the pre-tax profits. One can argue that the "true" effect of taxation on TFP is captured only via the actual tax amount paid, which is measured with a variable of effective tax rate (ETR). ETR is essentially a firm

specific variable; so there are severe causal effects with TFP. To interpret correctly the ETR-TFP growth relationship, we only focus on GMM estimates for [3.2] and [3.3]. Instrument identification tests at the bottom of Table 3 show evidence concerning the relevance of industry level averages namely industry profit, equity and TFP as instruments.

Using ETR as a tax variable produces very similar results with Tax_{it-1} in Table 2. The associated interaction terms of ETR_{it-1} with GAP_{it-1} , R_i and E_i are statistically insignificant. Finally, we find again that R&D and export active firms tend to have higher rates of TFP growth. Nonetheless, Table 3 shows neither evidence that ETR affects differently the groups of R&D and exporting firms nor their convergence towards the frontier. Results in Table 3 indicate that the distortionary character of corporate tax on productivity is existent for all firms (not only for the more dynamic ones) and this mechanism takes place via lowering the levels of investment in projects that can boost productivity.

Table 3: GMM Regressions with Industry Level Instruments for TFP Growth and ETR (UK Firms during 2004-2011)

	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta \ln TFP_{Ft}$	2.162*** (2.79)	1.400** (2.22)	1.389** (2.16)	1.397** (2.18)	1.373** (2.14)	1.394** (2.17)
GAP_{it-1}	-0.063*** (2.66)	-0.182** (2.00)	-0.183** (1.97)	-0.18** (2.00)	-0.187* (1.94)	-0.181** (1.98)
ETR_{it-1}	-0.101 (0.78)	-0.217** (2.15)	-0.235** (2.23)	-0.216** (2.13)	-0.235** (2.24)	-0.215** (2.12)
$[GAP_{it-1} \times ETR_{it-1}]$		-0.076 (0.56)				
R_i	0.172** (2.53)	0.100* (1.81)	0.195 (1.26)	0.100* (1.79)	0.192 (1.42)	0.101* (1.80)
E_i	0.045** (2.35)	0.023 (1.48)	0.024 (1.59)	0.035* (1.66)	0.024 (1.57)	0.033* (1.75)
$[R_i \times Tax_{it-1}]$			-0.968 (0.57)			
$[E_i \times Tax_{it-1}]$				-0.086 (0.51)		
$[GAP_{it-1} \times Tax_{it-1} \times R_i]$					-1.322 (0.64)	
$[GAP_{it-1} \times Tax_{it-1} \times E_i]$						-0.110 (0.51)
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	29624	28516	28516	28516	28516	28516
Adjusted R^2	-2.225	-0.834	-0.884	-0.833	-0.877	-0.835
Anderson LM	12.849	12.720	13.008	12.847	12.968	12.537
Anderson-p value	0.000	0.000	0.000	0.000	0.000	0.000
Sargan	6.856	4.203	4.069	4.253	4.005	4.250
Sargan-p value	0.144	0.649	0.667	0.643	0.676	0.643

Absolute t-statistics in parentheses calculated consistently for robust standard errors clustered by firm and *indicates $p < 0.10$, **indicates $p < 0.05$, ***indicates $p < 0.01$. The instruments in all specifications are the average values of profit rate, equity and TFP at the NACE Rev 2 industry level in periods t-1, t-2 and t-3. The Sargan test refers to the orthogonality condition; under the null the instruments used are valid (i.e. uncorrelated with the error term). The Anderson LM test refers to the relevance of instruments with the endogenous variable; under the null the set of instruments used is weak.

A further test for the robustness of estimates in Table 3 is to use another measure for capturing firm i 's manipulations to gain tax reliefs. To do so, we define $\Delta Tax_{it} = ASTR_t - ETR_{it}$, where $ASTR$ (average statutory tax rate) is the mean τ across profit categories in year t . Given that the $ASTR$ is constant for all firms in year t we anticipate that the larger the difference between the two, the stronger the incentive to invest, thus the faster the rate of TFP growth. Estimates in Table 4 confirm this proposition with the coefficient of ΔTax_{it} to be positive and statistically significant both in OLS and GMM specifications. We conclude from these results that the higher the divergence of effective tax rate from the average statutory tax, the faster the growth rate of productivity and the speed of convergence. We remain agnostic about the real sources driving the differences between ETR and $ASTR$ as we have no information about the tax position of the firm (i.e. whether a firm belongs to a particular tax group relief), but we view this finding as evidence that any tax manipulation in the accounting books that results in less tax burden incentivizes productivity enhancing investments.

Finally, we also estimate [3.2] and [3.3] applying the Levinsohn-Petrin (2003) non-parametric technique for the calculation of TFP. Results from Levinsohn-Petrin algorithm are shown in Appendix 3. Our results remain robust with regard to the distortionary effect of tax liability and its associated effect on the catch-up process of laggard firms. Overall, we can say that the negative effect of corporate tax liability on TFP growth is robust to: endogeneity bias, alternative definitions of corporate tax burden and alternative TFP estimation techniques. Table 5 summarizes the empirical findings of the study.

Table 4: Regressions of TFP Growth and the Difference between ASTR and ETR (UK Firms over 2004-2011)

	(1)	(2)	(3)	(4)
	OLS	OLS	GMM	GMM
$\Delta \ln TFP_{Ft}$	0.176*** (12.15)	0.170*** (11.68)	0.157*** (9.27)	0.152*** (6.82)
GAP_{it-1}	-0.145*** (12.31)	-0.137*** (11.25)	-0.124*** (8.32)	-0.119*** (6.20)
ΔTax_{it-1}	0.029*** (3.41)	0.047*** (4.41)	0.075*** (3.07)	0.213* (1.78)
$[GAP_{it-1} \times \Delta Tax_{it-1}]$		-0.047*** (3.23)		-0.145** (2.51)
R_i	0.006** (2.37)	0.006** (2.36)	0.003 (0.89)	0.003 (0.80)
E_i	0.001 (0.23)	0.001 (0.35)	0.004 (1.63)	0.004 (1.51)
Industry dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Observations	22517	22390	12491	12462
Number of Firms	4090	4090	4090	4090
Adjusted R^2	0.016	0.017	0.007	-0.012
Anderson LM			10.992	8.832
Anderson-p value			0.01	0.03
Sargan			0.293	0.000
Sargan-p value			0.864	0.994

Absolute t-statistics in parentheses calculated consistently for robust standard errors clustered by firm and *indicates $p < 0.10$, **indicates $p < 0.05$, ***indicates $p < 0.01$. ΔTax_{it-1} is the difference between $ASTR_t$ and $ETR_{i,t}$. The instruments in the GMM specifications are profit rate, equity and TFP at the NACE Rev 2 industry level in periods t-1, t-2 and t-3.

Table 5: Robustness in Statistical Significance

	(1)		(2)		(3)		(4)		(5)		(6)	
	OLS	GMM										
Olley-Pakes												
$\Delta \ln TFP_{Ft}$	√	√	√	√	√	√	√	√	√	√	√	√
GAP_{it-1}	√	√	√	√	√	√	√	√	√	√	√	√
Tax_{it-1}	√	√	√	√	√	χ	√	χ	√	√	√	√
ETR_{it-1}	√	√	√	√	√	√	√	√	√	√	√	√
ΔTax_{it-1}	√	√	√	◇								
$[GAP_{it-1} \times Tax_{it-1}]$			√	χ								
$[GAP_{it-1} \times ETR_{it-1}]$			√	χ								
R_i	◇	√	◇	√	√	√	χ	√	χ	√	◇	√
E_i	χ	√	χ	√	χ	√	√	√	χ	√	χ	√
$[R_i \times Tax_{it-1}]$					◇	χ						
$[E_i \times Tax_{it-1}]$							√	χ				
$[GAP_{it-1} \times Tax_{it-1} \times R_i]$									◇	χ		
$[GAP_{it-1} \times Tax_{it-1} \times R_i]$											√	χ
Levisohn-Petrin												
$\Delta \ln TFP_{Ft}$		√				√		√		√		√
GAP_{it-1}		√				√		√		√		√
Tax_{it-1}		√		√		√		√		√		√
$[GAP_{it-1} \times Tax_{it-1}]$				√								
R_i		√		√		√		√		√		√
E_i		√		√		√		◇		√		χ
$[R_i \times Tax_{it-1}]$						√						
$[E_i \times Tax_{it-1}]$								◇				
$[GAP_{it-1} \times Tax_{it-1} \times R_i]$										χ		
$[GAP_{it-1} \times Tax_{it-1} \times R_i]$												χ

Notes: Symbols in the Table summarize results across specifications for different estimators and different techniques in the calculation of TFP. Symbols denote the statistical significance of the estimated coefficients as follows: √ at 5% and above; ◇ at 10%; χ lower than 10%.

4. Conclusions

This paper utilizes firm-level data to investigate the impact of corporate taxation on productivity performance in the UK. We analyze the effects of corporate tax liability and effective tax rate within a framework of firm productivity catch-up contributing to the limited body of micro-evidence in the tax-productivity domain. Evidence shown in the paper suggests that higher rates of corporate taxation slow down the rate of TFP growth. There are two explanations for this result; the first one can be found within the neoclassical argument concerning the alternative use of resources, that is higher taxation reduces the resources that

can be alternatively used for capital investment. The second one relies on recent theoretical models of asymmetric information between the lender and the firm and the role of after-tax income in the distributions of external funds. Based on this, increased tax liabilities decrease liquid assets, which decrease the amount of income that firms can promise as collateral for gaining external finance. Our results partly confirm that there are asymmetries in this result with reference to R&D and exporting firms. Using the tax variable as a measure of tax liability, we found that a higher level of tax burden affects disproportionately R&D based firms and exporters. This result points to the direction that higher corporate tax can also affect the positive spillovers derived from the activities of R&D and exporting firms. This scenario becomes less convincing when we apply the effective tax rate as a tax variable as most interaction terms found to be statistically insignificant.

Based on the main message of the present study that national fiscal policy drives firm-specific investment decisions and their productivity catch-up process, the main policy implication is that we need a tax system that promotes dynamic activities. A progressive corporate tax system seems to work towards this direction as it accommodates “a carry forward loss” facility, which is vital to firms that engage in activities with high degree of uncertainty. Finally, a system of tax exemptions would also have been useful for exporting firms that need financial strength before exploiting gains from foreign market expansion.

References

Aghion, P., Fally, T. & Scarpetta, S. 2007, "Credit constraints as a barrier to the entry and post-entry growth of firms", *Economic Policy*, vol. 22, no. 52, pp. 731-779.

Aghion, P., Howitt, P., (1998). *Endogenous Growth Theory*. Cambridge, MA: MIT press.

Alesina, A. & Rodrik, D. 1994, "Distributive politics and economic growth", *The Quarterly Journal of Economics*, vol. 109, no. 2, pp. 465-490.

Arnold, J.M., Brys, B., Heady, C., Johansson, Å., Schweltnus, C. & Vartia, L. 2011, "Tax Policy for Economic Recovery and Growth", *The Economic Journal*, vol. 121, no. 550, pp. F59-F80.

Aw, Bee Yan, Mark J. Roberts, and Daniel Yi Xu. "R&D investments, exporting, and the evolution of firm productivity." *The American Economic Review* 98.2 (2008): 451-456.

Barnett, A., Batten, S., Chiu, A., Franklin, J., & Sebastia-Barriel, M. 2014, "The UK productivity puzzle", Bank of England Quarterly Bulletin, Q2.

Bartelsman, E.J. & Doms, M. 2000, "Understanding productivity: lessons from longitudinal microdata", *Journal of Economic Literature*, vol. 38, no. 3, pp. 569-594.

Bernard, A.B. & Jones, C.I. 1996a, "Comparing apples to oranges: productivity convergence and measurement across industries and countries", *The American Economic Review*, pp. 1216-1238.

Bernard, A.B. & Jones, C.I. 1996b, "Productivity across industries and countries: time series theory and evidence", *The Review of Economics and Statistics*, pp. 135-146.

Bloom, N., Schankerman, M. and Van Reenen, J. (2013), Identifying Technology Spillovers and Product Market Rivalry. *Econometrica*, 81: 1347–1393.

Blundell, R. & Bond, S. 2000, "GMM estimation with persistent panel data: an application to production functions", *Econometric Reviews*, vol. 19, no. 3, pp. 321-340.

Bourlès, R., Cette, G., Lopez, J., Mairesse, J. & Nicoletti, G. 2013, "Do product market regulations in upstream sectors curb productivity growth? Panel data evidence for OECD countries", *Review of Economics and Statistics*, 95 (5): 1750-1768.

Brekke, K.R., Garcia Pires, A.J., Schindler, D. & Schjelderup, G. 2014, "Capital Taxation and Imperfect Competition: ACE vs. CBIT.", *NHH Dept. of Economics Discussion Paper*, , no. 32.

Cameron, G. 2006, "Openness, R&D, and growth at the industry level", *Perspectives in Economic Growth*, pp. 137-158.

Cameron, G., Proudman, J., Redding, S., 2005. Technological convergence, R&D, trade and productivity growth, *European Economic Review*, vol. 49, pp. 775–807.

Crespi, G., Criscuolo, C. & Haskel, J. 2008, "Productivity, exporting, and the learning-by-exporting hypothesis: direct evidence from UK firms", *Canadian Journal of Economics/Revue canadienne d'économique*, vol. 41, no. 2, pp. 619-638.

Cullen, J.B., Gordon, R.H., 2007. Taxes and entrepreneurial risk-taking: Theory and evidence for the U.S., *Journal of Public Economics*, vol. 91, pp. 1479–1505.

Davis, S.J., Haltiwanger, J. & Schuh, S. 1996, "Small business and job creation: Dissecting the myth and reassessing the facts", *Small Business Economics*, vol. 8, no. 4, pp. 297-315.

Devereux, M.P. and Griffith, R., 1999. The Taxation of Discrete Investment Choices. *Institute for Fiscal Studies*.

Devereux, M.P. and Griffith, R., 2003. Evaluating tax policy for location decisions. *International Tax and Public Finance*, 10(2), pp.107-126.

Devereux, M.P., & Loretz S. 2011, "Corporation tax in the United Kingdom", Centre for Business Taxation, Saïd Business School, University of Oxford.

Disney, R., Haskel, J. & Heden, Y. 2003, "Entry, exit and establishment survival in UK manufacturing", *The Journal of Industrial Economics*, vol. 51, no. 1, pp. 91-112.

Djankov, S., Ganser, T., McLiesh, C., Ramalho, R. and Shleifer, A., 2010. The effect of corporate taxes on investment and entrepreneurship. *American Economic Journal: Macroeconomics*, 2(3), pp.31-64.

Fisman, R. and Svensson, J., 2007. "Are corruption and taxation really harmful to growth? Firm level evidence", *Journal of Development Economics*, 83(1), pp.63-75.

Gemmell, N., Kneller, R., McGowan, D., Sanz, I., & Sanz-Sanz, J. F. 2016. "Corporate taxation and productivity catch-up: evidence from European firms", *Scandinavian Journal of Economics*.

Girma, S., Greenaway, A. & Kneller, R. 2004, "Does exporting increase productivity? A Microeconomic analysis of matched firms", *Review of International Economics*, vol. 12, no. 5, pp. 855-866.

Goodridge, P., Haskel, J. & Wallis, G. 2013, "Can intangible investment explain the UK productivity puzzle?." *National Institute Economic Review* 224, no. 1, pp.R48-R58.

Greenaway, D. & Kneller, R. 2004, "Exporting and productivity in the United Kingdom", *Oxford Review of Economic Policy*, vol. 20, no. 3, pp. 358-371.

Greenaway, D. & Yu, Z. 2004, "Firm-level interactions between exporting and productivity: Industry-specific evidence", *Review of World Economics*, vol. 140, no. 3, pp. 376-392.

Griffith, R., Haskel, J. & Neely, A. 2006, "Why is productivity so dispersed?", *Oxford Review of Economic Policy*, vol. 22, no. 4, pp. 513-525.

Griffith, R., Redding, S. & Simpson, H. 2009, "Technological Catch-Up and Geographic Proximity*", *Journal of Regional Science*, vol. 49, no. 4, pp. 689-720.

Griffith, R., Redding, S. & Van Reenen, J. 2003, "R&D and absorptive capacity: Theory and empirical evidence*", *The Scandinavian Journal of Economics*, vol. 105, no. 1, pp. 99-118.

Griffith, R., Redding, S. & Van Reenen, J. 2004, "Mapping the two faces of R&D: Productivity growth in a panel of OECD industries", *Review of Economics and Statistics*, vol. 86, no. 4, pp. 883-895.

Hall, B. & Van Reenen, J. 2000, "How effective are fiscal incentives for R&D? A review of the evidence", *Research Policy*, vol. 29, no. 4, pp. 449-469.

Harris, R. & Li, Q.C. 2009, "Exporting, R&D, and absorptive capacity in UK establishments", *Oxford Economic Papers*, vol. 61, no. 1, pp. 74-103.

Harris, R., & Moffat, J. 2016, "The UK productivity puzzle, 2008–2012: evidence using plant-level estimates of total factor productivity." *Oxford Economic Papers*, gpw057.

Hubbard, R.G. 1998, "Capital-Market Imperfections and Investment", *Journal of Economic Literature*, pp. 193-225.

Keuschnigg, C., & Ribi, E. 2013, "Profit taxes and financing constraints", *International Tax and Public Finance*, 20(5), 808-826.

Levisohn, J. & Petrin, A. 2003, "Estimating production functions using inputs to control for unobservables", *The Review of Economic Studies*, vol. 70, no. 2, pp. 317-341.

Mallick, S. & Yang, Y. 2013, "Productivity Performance of Export Market Entry and Exit: Evidence from Indian Firms", *Review of International Economics*, vol. 21, no. 4, pp. 809-824.

Máñez, J.A., Rochina-Barrachina, M.E., Sanchis-Llopis, J.A. & Vicente, Ó. 2014, "Financial constraints and R&D and exporting strategies for Spanish manufacturing firms", *Industrial and Corporate Change*, vol. 23, no. 6, pp. 1563-1594.

Mayhew, K. & Neely, A. 2006, "Improving productivity—opening the black box", *Oxford Review of Economic Policy*, vol. 22, no. 4, pp. 445-456.

Melitz, M.J. 2003, "The impact of trade on intra-industry reallocations and aggregate industry productivity", *Econometrica*, vol. 71, no. 6, pp. 1695-1725.

Nicoletti, G. & Scarpetta, S. 2005, Product market reforms and employment in OECD countries, OECD.

Olley, S. & Pakes, A. 1996, "The dynamics of productivity in the telecommunications equipment industry", *Econometrica*, vol. 64, pp. 1263-1297.

Oulton, N., 2001. "Must the growth rate decline? Baumol's unbalanced growth revisited", *Oxford Economic Papers*, vol. 53 no.4, pp.605-627.

Schaller, H. 1993, "Asymmetric information, liquidity constraints, and Canadian investment", *Canadian Journal of Economics*, pp. 552-574.

APPENDICES

Appendix 1: Measurement of Corporate Tax

Appendix 1A: Corporation Tax System in the UK

The UK corporation tax system underwent some important changes in the starting tax rate over the period 2001-2011. Table 1A below reports the schedule of corporation tax rate in the UK over the 2000-2011 period (Devereux and Loretz, 2011).

UK Statutory Corporate Tax Rate (τ) for Different Profit Categories

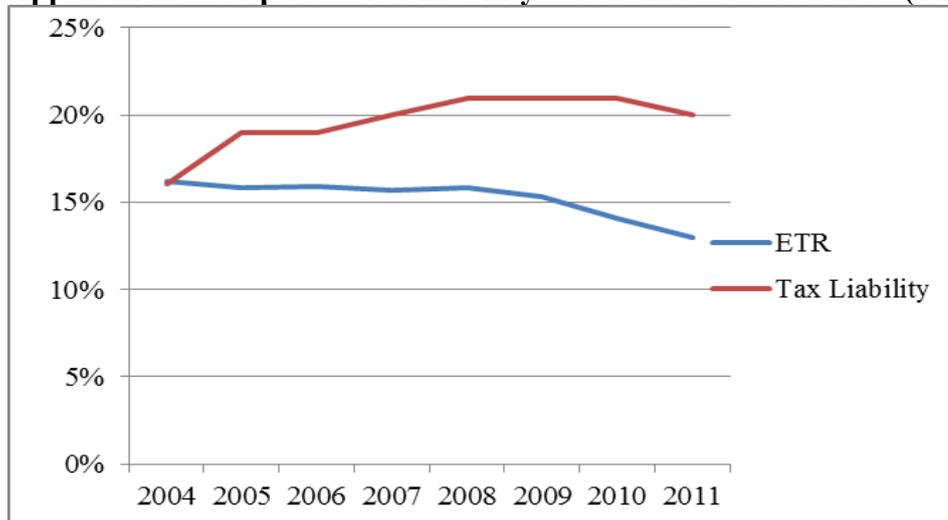
Taxable profit	2000/01- 2001/02	2002/03 - 2005/06	2006/07	2007/08	2008/09 - 2010/11
0 to 10,000	10%	0%	19%	20%	21%
10,001 to 50,000	22.5%	23.75%	19%	20%	21%
50,001 to 300,000	20%	19%	19%	20%	21%
300,000 to 1,500,000	32.5%	32.75%	32.75%	32.5%	29.75%
More than 1,500,001	30%	30%	30%	30%	28%

Another critical change was implemented in July 2009 when overseas dividend income has been largely exempt from UK corporation tax. The tax regime until then was that foreign source dividend income was taxable in the UK with a tax credit for foreign corporation tax paid abroad. Typically, UK raises substantial revenue from corporation tax as a share of GDP, which is higher relative to other G7. However, the burden of tax payments across firms is highly uneven, with 80% of total revenue to come from only 1% of the firms.

Another issue with the calculation of *Tax* and *ETR* is that they become undefined if firms report zero profits (*EBIT*). In the current data set, there are about 16952 observations with zero or negative *EBIT* values. Similarly, there are firms in FAME that report negative corporate tax payment for specific years. Firms usually report negative tax for loss carrying purposes or to benefit from group reliefs. For the purposes of our analysis, a negative *ETR* is meaningless if any of the two (corporate tax or *EBIT*) is negative. Therefore, we are forced to drop observations with either negative corporate tax or negative *EBIT*. Finally, our *ETR* measure is more backward looking as it uses the amount of corporate tax paid in year *t* on projects undertaken in any past history whose returns and profits are reported in year *t*. nevertheless our *ETR* measure is preferred to a more forward looking Devereux and Griffith (1999, 2003) for its simplicity and transparency. This is to say that *ETR* captures more adequately what a profit maximizing entrepreneur considers when making investment decisions. Appendix 1B shows sample means for *ETR* and *Tax*. Both measures follow a

similar trend over time but-as expected- *ETR* is on average 4 percentage points smaller than *Tax*, highlighting within business manipulations for paying lower corporate tax.

Appendix 1B: Corporate Tax Liability versus Effective Tax Rate (ETR)



Appendix 2: Data Features and Productivity Computation

Appendix 2A: The Olley and Pakes TFP Algorithm

The logarithmic form of a standard Cobb-Douglas production function for firm i is written as:

$$y_{it} = a_0 + \alpha k_{it} + \beta l_{it} + \omega_{it} + \varepsilon_{it} \quad [\text{A2.1}]$$

Where k and l are capital stock and labour while ω is an unobserved idiosyncratic term that drives firm i 's individual decisions and ε is an i.i.d error terms common to all firms (i.e. common changes in input prices, other macroeconomic shocks etc.). Estimating parameters α and β using OLS is problematic due to selection bias between unobserved productivity shocks ω_{it} and inputs k and l in period t . Olley and Pakes (1996) suggest an estimation of [A2.1] in three stages. In the first stage, firm decides the amount of investment (I) and labour to be used in the production. Investment is a function of k and ω , $I = I(\omega_{it}, k_{it})$. The inverse function of investment is monotonic, thus ω can be written as: $\omega_{it} = h(k_{it}, I_{it})$. Substituting the productivity function into [A2.1], we get the following:

$$y_{it} = a_0 + \alpha k_{it} + \beta l_{it} + h(k_{it}, I_{it}) + \varepsilon_{it} \quad [\text{A2.2}]$$

In the first stage, a partial linear estimation is used to obtain an estimate for β . For the second stage ω is assumed to follow a first order Markov process: $\omega_{it} = E[\omega_{it} | \omega_{it-1}] + v_{it} = \theta(\omega_{it-1}) + v_{it}$ with v to be a productivity shock term. The Markov-process is plugged into [A2.1] and it is further considered that production of firm i at year t is conditional on a survival probability. Therefore, the conditional form of the production function is written as:

$$\begin{aligned} E[y_{it} | \omega_{it-1}, x=1] &= a_0 + \alpha k_{it} + \beta l_{it} + \theta(\omega_{it-1}, \omega_{it}) + v_{it} + \varepsilon_{it} \\ &= a_0 + \alpha k_{it} + \beta l_{it} + \theta(\omega_{it-1}, \hat{h}(k_{it}, I_{it})) + v_{it} + \varepsilon_{it} \end{aligned} \quad [\text{A2.3}]$$

where $x=1$ if the firm survives at the end of period t . The estimation of the survival probability is implemented at the second stage and unobserved parameter ω_{it} is approximated by first stage's estimate of the inverse investment function. Equation [A2.3] is estimated with a linear probit and the probability of surviving in period t is called P_t . In the third stage, the coefficient of k is recovered using a non-linear least squares (NLLS) estimator for the following specification:

$$y_{it} - \hat{\beta}l_{it} = a_0 + \alpha k_{it} + \theta(\hat{\phi}_{t-1} - \alpha k_{it-1}, \hat{P}_{it}) + v_{it} + \varepsilon_{it} \quad [\text{A2.4}]$$

with $\hat{\phi}_{t-1} = \hat{a}_0 + \alpha \hat{k}_{it-1} + \hat{h}(k_{it-1}, I_{it-1})$.

To implement the Olley and Pakes algorithm (1996), we use a balanced set from FAME of 13062 firms for each year. We had to drop observations with either missing or negative values for y and I . The latter variable is derived from the perpetual inventory method: $I_{it} = k_{it+1} - (1 - \delta)k_{it}$, where k is the real value of fixed assets reported in FAME and δ is the rate of physical depreciation taken at the level of 20%. To obtain I values for 2011, we use linear extrapolation to generate the value of fixed assets for 2012. We also use linear interpolation when FAME reports missing values for the number of employees. The final data set was an unbalanced panel of 6559 firms on average for the period 2004-2011.

Table 2B: Summary Statistics

Variable	N	Mean	Std. Dev.	Min	Max
<i>TFP</i> -Olley and Pakes	52471	5.448	0.924	0.104	10.936
<i>TFP</i> -Levinsohn and Petrin	47416	1.63	0.189	-7.013	6.427
<i>GAP</i>	52471	0.686	0.137	0.010	1.000
<i>Tax</i>	65106	0.162	0.081	0.000	0.210
<i>ETR</i>	70279	0.126	0.144	0.000	0.467
Δ <i>Tax</i>	56176	0.080	0.145	-0.254	0.245

Appendix 3: GMM Regressions of TFP Growth and Tax Liability with Levinsohn-Petrin (LP) (UK Firms over 2004-2011)

	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta \ln TFP_{Ft}$	0.252*** (10.27)	0.155* (1.67)	0.211*** (7.44)	0.190*** (3.94)	0.242*** (9.45)	0.242*** (8.64)
GAP_{it-1}	-0.171*** (5.99)	-0.487 (1.60)	-0.171*** (6.02)	-0.171*** (6.00)	-0.187*** (7.46)	-0.185*** (7.49)
ETR_{it-1}	-1.444*** (11.82)	-0.972** (2.11)	-1.244*** (8.81)	-1.144*** (4.85)	-1.416*** (11.20)	-1.420*** (10.84)
$[GAP_{it-1} \times ETR_{it-1}]$		1.545** (2.01)				
R_i	0.011*** (4.86)	0.011*** (4.90)	0.191*** (3.62)	0.011*** (4.87)	0.034** (2.14)	0.011*** (4.88)
E_i	0.004** (2.37)	0.004** (2.37)	0.004** (2.38)	0.091* (1.65)	0.004** (2.50)	0.011 (1.04)
$[R_i \times Tax_{it-1}]$			-0.881*** (3.40)			
$[E_i \times Tax_{it-1}]$				-0.423* (1.68)		
$[GAP_{it-1} \times Tax_{it-1} \times R_i]$					0.345 (1.34)	
$[GAP_{it-1} \times Tax_{it-1} \times E_i]$						0.102 (0.64)
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	24568	24568	24568	24568	24568	24568
Adjusted R^2	0.041	0.041	0.041	0.041	0.040	0.041
Number of Firms	6026	6026	6026	6026	6026	6026
Anderson LM	25.932	25.531	25.152	26.017	24.924	26.009
Anderson-pvalue	0.000	0.000	0.000	0.000	0.000	0.000
Sargan	0.98	0.700	0.918	0.695	0.106	0.899
p value	0.559	0.893	0.18	0.560	0.264	0.692

Absolute t-statistics in parentheses calculated consistently for robust standard errors clustered by firm and *indicates $p < 0.10$, **indicates $p < 0.05$, ***indicates $p < 0.01$. The table replicates results from Table 2 using Levinsohn-Petrin (2003) approach. The key difference between OP and LP is that the latter uses intermediate inputs as a proxy for unobservable productivity shocks. The reasoning behind this is that intermediate inputs perform better than investment in external shocks hence using them can provide more consistent TFP estimates. The instruments in all specifications are the average values of profit rate, equity and TFP at the NACE Rev 2 industry level in periods t-1, t-2 and t-3. The Sargan test refers to the orthogonality condition; under the null the instruments used are valid (i.e. uncorrelated with the error term). The Anderson LM test refers to the relevance of instruments with the endogenous variable; under the null the set of instruments used is weak.

Appendix 4: GAP Industry and GAP National Frontier Values

Year	GAPIndustry	GAPNational	GAP 95% Percentile
2004	69.04%	51.17%	77.85%
2005	68.92%	51.50%	77.95%
2006	69.00%	51.49%	78.10%
2007	68.93%	51.25%	78.31%
2008	68.92%	50.89%	78.45%
2009	68.38%	49.78%	79.22%
2010	68.18%	49.99%	79.36%
2011	68.28%	50.26%	79.52%
Average	68.65%	50.68%	78.70%

Notes: *GAP* Industry takes as frontier the firm with the highest TFP in the industry in year t , *GAP* National takes as frontier the firm with the highest TFP in the whole sample in year t and *GAP* 95% percentile takes as frontier a hypothetical firm with the average TFP of the five more productive firms in the industry in year t .