CORPORATE TAXATION AND CAPITAL ACCUMULATION: EVIDENCE FROM SECTORAL PANEL DATA FOR 14 OECD COUNTRIES

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Abstract

We present new empirical evidence that aggregate capital accumulation is strongly influenced by the user cost of capital and, in particular, by corporate tax incentives summarised in the tax-adjusted user cost. We use sectoral panel data for the USA, Japan, Australia and eleven EU countries over the period 1982-2007. Our panel combines data on capital stocks, value-added and relative prices from the EU KLEMS database with measures of effective corporate tax rates from the Oxford University Centre for Business Taxation. Our results for equipment investment are particularly robust, and strikingly consistent with the basic economic theory of corporate investment.

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1 Introduction

The impacts of corporate taxation on aggregate investment in the short run and on capital accumulation in the long run are central to any evaluation of the welfare implications of taxes on corporate income. Reliable evidence on the nature and magnitude of these effects is also important for the design of fiscal incentives that are intended to stimulate private sector business investment.

Previous empirical research presents a wide range of conflicting evidence.[1] Studies which rely on aggregate data for individual countries face the problem that significant corporate tax reforms are infrequent, so there may be too few 'experiments' in the data from which to learn about the effects of tax changes. The timing of tax reforms may also confound the analysis, particularly if measures which are intended to stimulate investment tend to be introduced at times when investment is depressed for other reasons. We address these concerns by pooling data from 14 developed countries, and by paying careful attention to the possible endogeneity of our tax measures.[2]

The main innovation in this study is to combine two recently developed cross-country panel datasets to provide the basis for our empirical analysis. These are the

[1] See, for example, Caballero, Engel and Haltiwanger (1995) and Chirinko, Fazzari and Meyer (1999). Hassett and Hubbard (2002) provide a useful survey of this literature.

[2] Studies which consider differential responses of different firms to the same tax reform (depending on how their cost of capital is affected) avoid these problems, but tend to focus on short-run responses. See, for example, Cummins, Hassett and Hubbard (1994, 1996).

EU KLEMS database, which provides comparable data on capital stocks, output and relative prices at the sectoral level for the USA, Japan, Australia and most of the EU countries; and the corporate tax database developed at the Oxford University Centre for Business Taxation, which provides detailed information on corporate tax regimes for these countries. Combining these sources and focusing on countries with data available before 1995 gives us annual observations for up to 27 sectors in 14 OECD countries, over the period 1982-2007.

We consider a standard econometric model of investment, in which the sectoral capital-output ratio depends inversely in the long run on the tax-adjusted user cost of capital, and in which short-run adjustment dynamics as well as the magnitude of the long-run user cost elasticity are estimated from the data. We present empirical estimates using an eclectic range of econometric methods, allowing for heterogeneity in parameters across investment in different types of assets and across investment in different sectors and different countries. Our main findings are strikingly consistent with the basic economic theory of corporate investment, suggesting large effects of tax incentives on long-run capital accumulation. This finding is particularly robust for equipment investment, and less robust for investment in structures. Specifications which allow for cross-sectional parameter heterogeneity also suggest quite rapid adjustment of capital stocks to changes in the user cost of capital.

The remainder of the paper is organised as follows. Section 2 briefly outlines the basic neoclassical investment model. Section 3 presents the data that we use in our empirical analysis. Section 4 describes our econometric specification, and section 5 presents our empirical results. Section 6 concludes.

2 Investment model

Our econometric model is based on the value-maximising investment behaviour of a firm with a Constant Elasticity of Substitution (CES) production technology and an isoelastic demand schedule. We assume that investment in year t adds to the stock of productive capital in the same year, which depreciates at the constant rate δ. In the absence of any adjustment costs, the optimal capital stock in year t (K_t^*) can be expressed as:[3]

$$K_t^* = \alpha Q_t^{\left(\sigma + \frac{1-\sigma}{v}\right)} C_t^{-\sigma} \tag{1}$$

where Q_t is value-added and C_t is the user cost of capital. The parameters σ and ν are respectively the elasticity of substitution between capital and labour and the returns to scale in the production function, and α also depends on the production function parameters.

If we assume that the marginal investment is financed using retained earnings, and that the corporate income tax rate (τ_t), other parameters of the tax system, relative prices and inflation rates are expected to remain constant over time, the user cost of capital can be expressed as:

$$C_t = \frac{P_t^K}{P_t\left(1 - \frac{1}{\eta}\right)} \frac{(1 - A_t)}{(1 - \tau_t)} \frac{(r_t + \delta)}{(1 + r_t)} \tag{2}$$

[3] Appendix A provides details.

where P_t^K is the price of capital goods, P_t is the price of output, A_t is the net present value of current and future tax depreciation allowances associated with a unit of investment in year t, r_t is the real discount rate, and η is the price elasticity of demand.

If we assume instead that the marginal investment is financed by borrowing at the nominal interest rate i_t, and that interest payments are tax-deductible, the user cost of capital can be expressed as:

$$C_t^{Debt} = C_t \left(1 - \frac{J_t}{M_t}\right) \tag{3}$$

where

$$J_t = [\rho_t - i_t(1 - \tau_t)](1 - \tau_t \phi_t) \text{ and } M_t = (1 - A_t)(r_t + \delta)(1 + \pi_t).$$

Here π_t is the expected rate of inflation, $\rho_t = (1 + r_t)(1 + \pi_t) - 1$ is the nominal discount rate, and ϕ_t is the fraction of a unit of investment in year t that can be deducted from the corporate income tax base in the same year.[4] The extra term $\left(1 - \frac{J_t}{M_t}\right)$ reflects the tax advantage of debt finance in a conventional corporate income tax. Conveniently this extra term enters the user cost of capital multiplicatively, so that the impact of this tax advantage for debt on investment behaviour can be investigated by the inclusion of an additional linear term in econometric specifications based on taking logarithms of equation (1).

Before considering further details of our econometric specification, we first present the datasets used in this study, and illustrate the variation over time and across

[4] So that only the fraction $1 - \tau_t \phi_t$ has to be financed by borrowing.

countries in our measures of some of the key variables suggested by this basic theoretical framework.

3 Data

We combine sector-level panel data on production, investment and price variables obtained from the EU KLEMS database with tax variables provided by the Oxford University Centre for Businss Taxation.[5] Our merged dataset includes data for 14 OECD countries covering the period 1982-2007.[6] Our main sample consists of 11 sectors within manufacturing for each of these countries. For comparison, we also present results for a broader sample of 19 sectors, excluding financial intermediation, utilities, and other sectors with substantial public sector influence, as well as results for the complete sample of 27 sectors available in the EU KLEMS database, covering the whole economy. The sectors included in each of these samples are listed in Appendix B.

[5] More information on the EU KLEMS data is provided by O'Mahony and Timmer (2009). More details on the construction of the tax variables can be found in Devereux, Griffith and Klemm (2002) and Loretz (2008). We thank Simon Loretz for providing updated series for use in this study.

[6] These 14 countries are: Australia, Austria, Czech Republic, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, Spain, Sweden, the United Kingdom and the United States. We exclude countries for which data becomes available only after 1995. The time coverage for each country is listed in Appendix B.

3.1 Capital stock and output

A major advantage of the EU KLEMS data is that this provides comparable capital stock measures for 8 different types of assets across sectors and countries, constructed using a common Perpetual Inventory Method (PIM). We exclude residential structures from the total capital stock reported in EU KLEMS, as residential housing is not primarily used as a direct input into production in the business sector. The remaining types of capital assets are aggregated into three broad categories, namely, equipment, structures, and other assets.[7]

The real capital stock ($K_{k,t}$) for asset k is defined as a weighted sum of past real investments (measured in 1995 prices) with weights given by the relative efficiencies of capital goods at different ages according to the formula below (sector and country subscripts are suppressed for convenience):[8]

$$K_{k,t} = \sum_{\tau=0}^{\infty} \theta_{k,\tau} I_{k,t-\tau} = \sum_{\tau=0}^{\infty} (1-\delta_k)^{\tau} I_{k,t-\tau} = (1-\delta_k) K_{k,t-1} + I_{k,t} \tag{4}$$

where $I_{k,t-\tau}$ is real investment in asset k in year $t-\tau$ and $\theta_{k,\tau} = (1-\delta_k)^{\tau}$ is the efficiency of a capital good of age τ relative to the efficiency of a new capital good, assuming a constant rate of depreciation δ_k for each asset type k. The depreciation rates δ_k are obtained from the US Bureau of Economic Analysis (BEA). They differ

[7]Equipment includes transport equipment, computing equipment, communications equipment, and other machinery and equipment. Structures refers to non-residential structures. Other assets include software and others.

[8]For more details on the implementation of the Perpetual Inventory Method to construct the real capital stock series in the EU KLEMS database, see Timmer et al. (2007).

by asset type and sector, but are assumed to be common across countries and constant over time for a particular type of asset in a particular sector.[9]

As a comparison, in Appendix C (Figure C.1), we plot the time series of the total real capital stock for total manufacturing industry over the period 1982-2007 for 11 countries for which this information is available in both the EU KLEMS and the OECD STAN databases. Figure C.1 reveals that these two measures of the real capital stock for the manufacturing sector in these countries are close in magnitude and they also show similar patterns over time.[10]

We use the real value-added measure of output from EU KLEMS, also measured in 1995 prices. Figure 1 plots the time series of the average capital-output ratio in logarithms ($\ln(K/Q)$), separately for equipment and structures, for our sample of manufacturing industries.[11] Over time, there is an upward trend in the capital-output ratio for equipment. In contrast, the capital-output ratio for structures declined towards the end of the sample period.

[9] An advantage of using the BEA depreciation rates is that the depreciation patterns are based on empirical evidence about used asset prices in resale markets wherever possible.

[10] Advantages of the EU KLEMS database over the OECD STAN database for our study are that the former provides real capital stock measures disaggregated by asset type, and covers more countries.

[11] Each series here, and in Figures 2-4 below, is calculated as the unweighted average of the log of the corresponding variable for all 11 manufacturing sectors in all countries for which data is available for that year. The sample covers all 14 countries between 1995 and 2006.

3.2 Relative price of investment goods

EU KLEMS also provides, for each sector in each country, the price index for gross fixed capital formation (by asset type) and the price index for value-added. The ratio of these two indices provides a measure of the price of investment goods relative to the price of output. The base years for these price indices are both 1995.[12] Figure 2 shows the average relative price of investment goods in logarithms ($\ln P^K/P$), separately for equipment and structures, over the sample period.

A striking feature shown in Figure 2 is that, while the relative price of equipment assets declined gradually from the middle of the 1990s, the relative price of structures remained stable until the late 1990s and then began to increase sharply.[13]

3.3 The tax component of the user cost of capital

The tax component of the user cost of capital, $\frac{(1-A)}{(1-\tau)}$, reflects varying tax rules and tax rates in different countries and over time. Data on the statutory corporate income tax rates (τ) and the net present value (NPV) of depreciation allowances

[12] As the base year is 1995 for all price indices, differences in the level of relative prices between countries and sectors are not fully reflected in these measures. This provides one motivation for including country-sector specific fixed effects in our specifications, as the fixed effects can control for price level differences across countries and sectors in the base year.

[13] The declining relative price of equipment is documented in other studies, such as Greenwood, Hercowitz and Krusell (1997) and Hsieh and Klenow (2005). The rapid increase in the relative price of structures is observed in almost every country in our sample since the late 1990s, and is particularly evident in Australia, Czech Republic, Spain, Sweden and the United States.

(A) are provided by the Oxford University Centre for Business Taxation. The NPV of depreciation allowances varies across countries and over time with differences in inflation rates reflected in the nominal discount rate used in the calculation.[14] The NPV of depreciation allowances also varies across different types of assets. Owing to the availability of data, we restrict ourselves to three main categories: equipment, structures, and others.

For total capital, the tax component of the user cost of capital is a weighted average of those for the three different asset types. The weights are the proportions of each asset in the total capital stock. These weights differ across sectors and countries, and also vary over time. The cross-sectional variation relies on different asset structures within each sector (different combinations of equipment, structures and other assets) as well as the cross-country variation in the tax rules (NPV of depreciation allowances and the corporate income tax rate) and the inflation rate in a particular year. The time-series variation comes from the changes in asset structures within each sector over time, and also changes in the tax rules and inflation rates over time. For equipment assets or structures respectively, both the cross-sectional and time-series variation in the tax component of the user cost of capital rely only on the variation in tax rules and inflation rates. Pooling this tax

[14] The one-period nominal discount rate $(1 + \rho_t)$ between year t and year $t + 1$ is constructed as $(1 + r_t)(1 + \pi_t)$, where the real interest rate (r_t) is assumed fixed at 10% and the expected inflation rate (π_t) is assumed to be the actual CPI inflation rate between year $t - 1$ and year t. The s-period nominal discount factor between year t and year $t + s$ is constructed as $(1 + \rho_t)^{-s}$.

data across countries provides rich variation in the tax component of the user cost of capital, which greatly facilitates the identification of the effects of tax incentives on capital accumulation.

Figure 3 shows the time series for the average tax component of the user cost of capital in logarithms ($\ln \frac{1-A}{1-\tau}$), separately for equipment and structures. For both types of assets, developments in tax rates and in tax rules over this period tended to lower the user cost of capital. The average level of the tax component of the user cost for equipment assets remained lower than that for structures throughout the period, which reflects the more generous tax depreciation allowances available for equipment.[15]

In Figure 4 we combine these two components of the user cost of capital and plot both average $\ln(K/Q)$ and average $\ln \frac{P^K}{P} \frac{(1-A)}{(1-\tau)}$ for total capital and for equipment. Similar graphs for each country are provided in Appendix D. In Figure 4, we observe a negative correlation between the capital-output ratio and these components of the user cost of capital, which is broadly consistent with the basic theory of investment outlined in section 2. This pattern is also observed in many individual countries in the sample.

[15] The broad pattern observed in the sample average data also holds for most individual countries.

4 Specification

We assume initially that investment is financed by retained earnings.[16] We also assume that the real discount rate component of the user cost of capital does not vary significantly across sectors and countries, or at least across sectors within each country, so that variation in real interest rates can be controlled for using year dummies, or using a set of year dummies for each country.[17] Combining equations (1) and (2), and taking logarithms of both sides, we then obtain a convenient log-linear relation between the desired level of the capital stock (in the absence of adjustment costs or frictions), output, and the tax-adjusted user cost of capital:

$$\begin{aligned} \ln K_t^* &= \ln \alpha + (\sigma + \frac{1-\sigma}{v}) \ln Q_t - \sigma \ln C_t \\ &= \gamma_t + (\sigma + \frac{1-\sigma}{v}) \ln Q_t - \sigma \ln UC_t \end{aligned} \qquad (5)$$

where

$$\gamma_t = \ln \alpha + \sigma \ln \left(1 - \frac{1}{\eta}\right) - \sigma \ln \frac{(r_t + \delta)}{(1 + r_t)}$$

and

$$\ln UC_t = \ln \left(\frac{P_t^K}{P_t}\right) + \ln \left(\frac{1 - A_t}{1 - \tau_t}\right)$$

combines the measured relative price and tax components of the user cost.

Following Bloom (2000) and Bloom, Bond and Van Reenen (2007), we rely on

[16] Studies of financing patterns suggest that, in aggregate, most corporate investment is financed internally in developed countries. See, for example, Corbett and Jenkinson (1997).

[17] More precisely, our specifications will allow for time-invariant heterogeneity across sectors and countries in this component of the user cost, through country-sector specific fixed effects.

cointegration between the logarithm of the actual capital stock ($\ln K_t$) and the logarithm of this frictionless capital stock, which holds for any finite adjustment costs. The dynamic adjustment of $\ln K_t$ can then be represented by an Error Correction Model (ECM), of the form:

$$a(L) \bigtriangleup \ln K_t = b(L) \bigtriangleup \ln K_t^* - \phi \left(\ln K_{t-k} - \ln K_{t-k}^*\right) + e_t \tag{6}$$

where $a(L)$ and $b(L)$ are polynomials in the lag operator, the order of which will be determined empirically, and e_t is a stationary error term. The parameter ϕ reflects the speed of adjustment of the capital stock towards its long-run target, which is proportional (but not necessarily equal) to the frictionless optimum. The Error Correction Model, which was first used in the empirical investment literature by Bean (1981), nests the partial adjustment and accelerator models as special cases. This specification also has the advantage of separating the long-run determinants of the level of the capital stock from the short-run adjustment dynamics.

After experimenting with different lag lengths, our main specification for the capital stock in sector i in country c in year t has the form:

$$\begin{aligned} \bigtriangleup \ln K_{i,c,t} &= -\phi\left(\ln K_{i,c,t-2} - \alpha_1 \ln Q_{i,c,t-2} - \alpha_2 \ln UC_{i,c,t-2}\right) \\ &\quad + \beta_0 \bigtriangleup \ln K_{i,c,t-1} + \beta_1 \bigtriangleup \ln Q_{i,c,t} + \beta_2 \bigtriangleup \ln Q_{i,c,t-1} \\ &\quad - \beta_3 \bigtriangleup \ln UC_{i,c,t} - \beta_4 \bigtriangleup \ln UC_{i,c,t-1} + d_t + f_{i,c} + \varepsilon_{i,c,t} \end{aligned} \tag{7}$$

where d_t denotes a year dummy and $f_{i,c}$ denotes a time-invariant fixed effect for sector i in country c. The long-run elasticities of the capital stock with respect to output and the user cost are $\alpha_1 = \sigma + \frac{1-\sigma}{v}$ and $\alpha_2 = -\sigma$ respectively. In most specifications we impose the constant returns to scale restriction ($\nu = 1$), in which case we have $\alpha_1 = 1$ and α_2 measures the long-run elasticity of the capital-output ratio with respect to the user cost. In addition to reporting estimates of this baseline specification for total capital, we will present separate models for equipment and structures, consider relaxing the constant returns to scale restriction, allow for possible endogeneity of the user cost of capital, allow the relative price and tax components of the user cost to affect capital accumulation in different ways, explore whether there is additional information in the extra term in the user cost of capital for debt-financed investment,[18] or in other tax measures, and allow for heterogeneity in the estimated parameters across countries and sectors.

5 Results

5.1 Time series properties

We use standard estimation and inference methods for regression models which, given the long time series dimension of our panels, require the variables to be stationary. This is one motivation for imposing the constant returns to scale restriction in our baseline model, and working with the log of the capital-output ratio rather than the logs of the capital stock and output variables individually.

Table E.1 in Appendix E presents the results of formal tests of the null hypothesis

[18] See equation (3).

that these series are non-stationary (integrated of order one). We report results for the Fisher-type panel unit root test proposed by Maddala and Wu (1999), which is suitable for unbalanced panels and allows for heterogeneous slope coefficients across the observations for each country-sector pair.[19] Focusing on the specification which allows for common year effects and country-sector specific linear trends, we find that the logs of the capital stock and output series appear to be non-stationary (I(1)), while the log of the capital-output ratio and the remaining variables used in our model appear to be stationary (I(0)).[20] As always, the results of these formal unit root tests should be interpreted with caution.

5.2 Baseline specifications

Table 1 presents the results of estimating equation (7) using our main sample of 11 manufacturing industries in 14 countries.[21] Columns 1-3 present the results for total capital, equipment and structures, respectively. Panel A reports the basic estimated coefficients and cluster-robust standard errors. Panel B reports the implied long-run elasticities of capital-output ratios with respect to the user cost of capital. Panel

[19] The tests are computed using the command *xtfisher* in Stata. The test procedure is outlined in the note to Table E.1.

[20] An exception is found for the log of the relative price term for structures; although curiously, not for the log of the measured components of the user cost for structures (which includes this relative price term).

[21] In Table 1 and the following tables, the subscripts i and c are suppressed. These results are computed using the fixed effects option of the command *xtreg* in Stata.

C reports tests of the null hypothesis that the long-run elasticity of capital with respect to output is unity (imposed here), and that the long-run user cost elasticity is equal to unity in absolute value (not imposed here). This specification includes a set of year dummies to control for common time effects.

Consistent with the basic neoclassical investment model outlined in section 2, we estimate a negative long-run user cost elasticity (α_2) which is significantly different from zero, but not significantly different from -1, in all three columns. These results are thus consistent with the Cobb-Douglas special case of the CES production function. The short-run effects of changes in the user cost are also found to be significantly different from zero, and in the same direction as the long-run effect.[22] We also find statistically significant but rather slow adjustment of actual capital stocks towards their long-run target levels, as indicated by the low absolute values of the estimated coefficients (-ϕ) on the term $\ln(K/Q)_{t-2}$. Nevertheless, the adjustment process is somewhat faster for equipment than for structures.

Table 2 presents the results of estimating equation (7) using the same sample, without restricting the long-run elasticity of capital with respect to output to be unity. This restriction is formally rejected in all three columns, albeit only marginally in the case of equipment. The long-run elasticity of capital with respect to the user cost remains negative and significantly different from zero in all three

[22] For example, for equipment investment, we estimate that about 10 per cent of the long-run effect of a reduction in the user cost occurs in the first year. The impact effect is much smaller for structures.

cases. The restriction that this long-run user cost elasticity is -1 is now rejected in the case of structures, but not in the case of equipment, and only marginally for the total capital specification.

Table 3 adds a full set of country-sector specific linear trends to the baseline specification from Table 1.[23] Again we estimate highly significant, negative, long-run user cost elasticities in all three cases. The estimated speeds of capital stock adjustment are noticeably faster in this specification.

Tables E.2 and E.3 in Appendix E present estimates of our baseline (Table 1) specification using broader samples of industries. The sample of 19 industries used in Table E.2 excludes financial services and sectors where public sector investment is likely to be important, while the sample used in Table E.3 includes all 27 sectors covered in the EU KLEMS database.[24] In both cases we continue to find highly signficant, negative, long-run elasticities of the capital-output ratio with respect to the user cost; and for equipment investment, we do not reject the hypothesis that this elasticity is unity in absolute value.

5.3 Decomposing the user cost of capital

We are particularly interested in the effects of corporate taxation on capital accumulation, which are summarised in our baseline specification by the tax component of

[23]This specification is thus consistent with the results from our preferred unit root tests in Table E.1, which also included country-sector specific linear trends. The constant returns to scale restriction is imposed here, and in all subsequent tables.

[24]Appendix B provides details of the sectors included in each of these samples.

the user cost of capital. The basic neoclassical investment model outlined in section 2 suggests that the long-run elasticity of capital with respect to different components of the user cost should be the same. We can test this restriction by estimating separate (short-run and long-run) coefficients for our two measured components of the user cost, namely $\ln\left(\frac{P^K}{P}\right)$ and $\ln\left(\frac{1-A}{1-\tau}\right)$.[25]

Table 4 presents results for this extended specification using our main sample of 11 manufacturing industries. For both total capital and for equipment investment, we estimate highly significant, negative, long-run elasticities for both the relative price and tax components of the user cost; these elasticities are close to -1, and we do not reject the restriction of equal long-run elasticities for both components of the user cost. For structures, however, we estimate a significant, negative long-run elasticity (close to -1) only for the relative price component of the user cost, and find no significant effect of the tax component.

At least for equipment investment, these results lend support to the view that using corporate tax incentives to lower the marginal cost of investment can stimulate capital accumulation in the long run. The estimated long-run elasticities for the tax component of the user cost in columns 1 and 2 of Table 4 are considerably larger than those reported in Chirinko, Fazzari and Meyer (1999), and close to the estimates suggested by earlier studies using US firm-level data, such as Cummins, Hassett and Hubbard (1994) and Caballero, Engel and Haltiwanger (1995).

[25]The latter term is labelled $\ln TAX$ in Table 4 and later tables.

5.4 Additional tax variables

The basic neoclassical investment theory also suggests that the effects of corporate taxes on capital accumulation are summarised by this tax component of the user cost of capital.[26] For discrete investment choices, such as the decision by a multinational corporation to locate a plant of fixed size in one country rather than another, the effects of taxation on investment outcomes are likely to be different. Devereux and Griffith (1998, 2003) develop an effective average tax rate (EATR) measure to summarise the impact of corporate taxes on such discrete investment choices, and show that this measure helps to explain the location choices of US multinationals setting up new plants within Europe. The effective average tax rate is a measure of the difference between the net present value of a given, profitable investment project in the presence and in the absence of corporate taxation. This measure could also be important for sector-level investment, if a substantial proportion of sectoral investment takes the form of location decisions or other discrete choices, and such investments add to, rather than displace, other forms of investment.

To investigate this, we add further (short-run and long-run) terms in the effective average tax rate to our previous specification used in Table 4. We also consider adding further terms in the statutory corporate tax rate (τ).[27] Table 5 summarises

[26] The effects of corporate taxation can also be summarised by considering the difference between the user cost in the presence and in the absence of corporate taxation, as in the effective marginal tax rate (EMTR) measures developed by King and Fullerton (1984) and Devereux and Griffith (2003).

[27] Data on statutory corporate tax rates and on EATRs (separately for equipment and structures)

the estimated long-run parameters from these extended specifications. For equipment investment, we continue to find significant negative effects from both the relative price and the tax components of the user cost of capital, and no significant effects from either the effective average tax rate or the statutory corporate tax rate. For total capital, we also find significant, negative effects from both components of the user cost but, perhaps surprisingly, we also find significant, positive long-run effects from both the effective average and statutory tax rates. For structures, we find a similar pattern when the statutory tax rate is included in the specification. These results suggest that the effects of corporate taxes on sectoral equipment investment may well be summarised through their effect on the user cost of capital, although the effects of taxes on sectoral investment in structures may be more complex than the basic theory suggests.

5.5 Debt finance

To explore whether the lower cost of capital for investment financed by borrowing has a significant impact on sectoral investment, we add further (short-run and long-run) terms in the additional component of the tax-adjusted user cost of capital derived for the case in which (marginal) investment is financed by debt ($\ln\left(1-\frac{J}{M}\right)$, defined in equation (3)).[28] Table 6 summarises the estimated long-run elasticities

were also obtained from the Oxford University Centre for Business Taxation. Devereux, Griffith and Klemm (2002) and Loretz (2008) provide further details on the construction of these measures.

[28] Our measure of this term sets the nominal interest rate on borrowing (i_t) equal to the nominal discount rate (ρ_t), which is constructed in the same way described in note 14.

when these additional terms are included in our baseline specification (Panel A), and in the extended specification used in Table 4 (Panel B). If we impose the restriction that the long-run effects of the relative price and tax components of our baseline user cost measure (derived under the assumption that marginal investment is financed only from retained profits) are equal, then there is a suggestion that the tax advantage for debt finance may result in additional investment in structures. However this effect becomes insignificant when we relax the restriction of equal long-run elasticities with respect to the two components of our baseline user cost measure. We also find no significant effect of the additional debt finance term in either of the specifications for total capital or for equipment investment. This may be consistent with evidence suggesting that only a small share of aggregate corporate investment is financed by borrowing.[29]

5.6 Endogeneity of the user cost of capital

5.6.1 Controlling for country-specific business cycles

Our within-groups estimates of the specifications presented above may be inconsistent if any of the explanatory variables are correlated with the error term ($\varepsilon_{i,c,t}$) in equation (7). Of particular concern is the possibility that some changes in tax policy may be endogenous responses to country-specific business cycle fluctuations. For example, governments may tend to introduce more generous investment incentives during economic downturns. It has been documented (Kose, Otrok and Whiteman,

[29] See, for example, Corbett and Jenkinson (1997).

2003) that country-specific factors, although less important in explaining business cycles in developed countries than common world factors, were nevertheless important during some historical episodes. If tax policy responds to country-specific shocks, simply including a single set of year dummies to control for common time effects may be insufficient, and the resulting estimates could be inconsistent.

One solution is to include a full set of country-specific year dummies to control for country-specific factors. This specification also allows for country-specific variation in real discount rates. Identification of the model parameters then relies on differential variation over time in the explanatory variables between different sectors in the same country, given that we continue to control for country-sector specific fixed effects.

Table 7 presents the results when a full set of country-specific year dummies are included in our baseline specification. The results are very similar to those reported in Table 1, suggesting that this source of endogeneity is not a major concern here.

5.6.2 Instrumental Variables (IV) estimation

Another potential concern is that changes in investment demand may affect the relative price of investment goods, in which case the relative price component of the user cost could be endogenous.[30] Moreover, as we use the price index for

[30]Schaller (2006) notes that, at the country level, this source of endogeneity is more likely to be relevant for large economies like the US. For a small open economy, the relative price of investment goods is likely to be determined by world factors and, therefore, more likely to be exogenous. If this is also the case for individual sectors in any country, this source of endogeneity may be less

investment goods to deflate the nominal capital stock and the same price index appears in the numerator of the relative price component of the user cost, there could be a downward division bias if there are measurement errors in this price index (Borjas, 1980).

To address these concerns, we present instrumental variables estimates of our baseline specification. One strategy is to use the tax component of the user cost as an instrument for the composite user cost term, maintaining the assumption that country-level tax policy does not respond (rapidly) to investment demand shocks. Columns 1-3 in Table 8 present 2SLS estimates of our baseline specification, treating $\Delta \ln UC_t$ as an endogenous variable, and using current and lagged values of the tax component of the user cost ($\triangle \ln TAX_t$, $\ln TAX_{t-1}$ and $\ln TAX_{t-2}$) as instrumental variables.[31] As the Hansen test of overidentifying restrictions indicates that some of these instruments may be invalid in the specifications for equipment investment and structures investment, columns 4-6 in Table 8 present 2SLS estimates that use only lagged values of these tax instruments. The main result of interest is that we continue to find highly significant, negative, long-run user cost elasticities in all cases, similar to those reported in Table 1, suggesting that endogeneity of the relative price component of the user cost is not a major concern here.[32]

important for studies using country-sector data, as we do here.

[31] These results are computed using the fixed effects option of the *xtivreg2* command in Stata. Table E.4 in Appendix E reports the corresponding first-stage regression results, which confirm the impression from the formal test statistics that these are informative instruments for $\Delta \ln UC_t$.

[32] We found similar results using longer lags of the user cost term ($\ln UC_{t-3}, \ln UC_{t-4}, \ln UC_{t-5}$

5.7 Heterogeneous parameters

The specifications reported in the previous sections have allowed the intercept term in our Error Correction Model to take different values for each country-sector pair, but have restricted all the slope parameters to be the same for each country-sector pair.[33] These pooled results could be misleading if this restriction is invalid, and there is significant heterogeneity across country-sector pairs in one or more of these slope parameters.

To address this concern, we report estimates using the Mean Group estimator for dynamic, heterogeneous panels proposed by Pesaran and Smith (1995). We first obtain separate OLS estimates of equation (7) for each sector in each country, using only the time series data for that country-sector pair. We then calculate average values of the estimated long-run elasticity parameters, averaging across all sectors in all countries. Pesaran and Smith (1995) show that this approach provides a consistent estimator of the expected value of the cross-section distribution of these parameters, whether they are heterogeneous or common. We report an outlier-robust estimate of the sample means, as suggested by Bond, Leblebicioglu and Schiantarelli (2010). We also report estimates of the long-run elasticity parameters obtained using the Pooled Mean Group estimator of Pesaran, Shin and Smith (1999), which allows the

and $\ln UC_{t-6}$) as instruments for $\Delta \ln UC_t$, although these instruments appear to be weaker, particularly in the specifications for equipment investment and structures investment. These results are reported in Tables E.5 and E.6 in Appendix E.

[33]That is, the parameters $\phi, \alpha_1, \alpha_2, \beta_0, \beta_1, \beta_2, \beta_3$ and β_4 in equation (7).

short-run adjustment parameters (ϕ and the β coefficients) to be heterogeneous but imposes the restriction that the long-run elasticity (α_2) is common.

To implement this approach, we consider a more parsimonious specification of the short-run adjustment dynamics:

$$\begin{aligned}\triangle \ln K_{i,c,t} &= -\phi \left(\ln \frac{K_{i,c,t-2}}{Q_{i,c,t-2}} - \alpha_2 \ln UC_{i,c,t-2} \right) + \beta_0 \triangle \ln K_{i,c,t-1} \\ &\quad + \beta_1 \triangle \ln Q_{i,c,t} - \beta_3 \triangle \ln UC_{i,c,t} + d_t + f_{i,c} + \varepsilon_{i,c,t}\end{aligned} \tag{8}$$

in which the parameters $\phi, \alpha_2, \beta_0, \beta_1$ and β_3 (as well as the intercept) are allowed to take heterogeneous values in the Mean Group approach, while the long-run elasticity α_2 is imposed to be common in the Pooled Mean Group approach.[34] Controlling for the effect of common shocks is less straightforward when we allow for heterogeneous slope parameters. We first consider two simple specifications which achieve this only approximately. One is to estimate the time series models for each country-sector pair using 'demeaned' variables, which are expressed as deviations from year-specific sample means calculated using all the observations available for the same variable in the same year.[35] An extension is to include an additional linear trend term in each of the time series models estimated using this demeaned data.

Table 9 presents outlier-robust Mean Group (MG) and Pooled Mean Group (PMG) estimates of the average speed of adjustment parameter ($-\phi$) and the (av-

[34] Omitting the terms $\Delta \ln Q_{i,c,t-1}$ and $\Delta \ln UC_{i,c,t-1}$ from equation (7) has little effect on the estimates of the long-run user cost elasticity (α_2) reported in the preceding sections.

[35] This approach is equivalent to including a set of year dummies in models with common slope parameters, but not in models with heterogeneous slope parameters.

erage) long-run user cost elasticity (α_2) for our sample of manufacturing industries.[36] The average speed of adjustment for a 'typical' country-industry pair is estimated to be much faster than that suggested by our previous specifications with common slope parameters. The (average) long-run user cost elasticity is estimated to be somewhat lower in absolute value than that suggested by our previous specifications, particularly for investment in structures. Nevertheless these estimates remain significantly different from zero in all specifications.

An alternative to expressing each variable as the deviation from its year-specific sample mean is to include the year-specific means of the dependent variable and each of the explanatory variables in equation (8) as additional explanatory variables in the time series models estimated for each of the country-sector pairs. This approach gives the 'common correlated effects' (CCE) versions of the Mean Group and Pooled Mean Group estimators, proposed by Pesaran (2006), which also allow for a form of cross-section dependence in the error term ($\varepsilon_{i,c,t}$). While more general, this specification requires a longer time series to be available for each of the country-sector pairs, and even using the more parsimonious dynamic specification introduced

[36] The PMG results are computed using the *xtpmg* command in Stata. Code to obtain the outlier-robust MG results was adapted from that given in Bond et al. (2010). Robust estimates of the mean value are obtained using the Stata command *rreg*, giving a weighted mean with lower weights ($w_{i,c}$) on individual estimates with more extreme values. Standard errors for these weighted means are calculated as $\sigma = \sqrt{\sum_{i,c} w_{i,c}^2 \widehat{\sigma}_{i,c}^2}$, where $\widehat{\sigma}_{i,c}$ is the heteroskedasticity-consistent standard error for the parameter in the time series model for sector i in country c.

in equation (8) is feasible for only 11 of our 14 sample countries.[37]

Table 10 presents outlier-robust Mean Group (MG) and Pooled Mean Group (PMG) estimates of the average speed of adjustment parameter ($-\phi$) and the (average) long-run user cost elasticity (α_2) for this more general specification, with and without additional linear trend terms. For total capital and equipment investment, the (average) long-run user cost elasticity for a typical country-sector pair remains negative and significantly different from zero, although these estimates suggest a distribution of elasticities centred around -0.5, rather than -1. For structures, the Pooled Mean Group estimate of the long-run user cost elasticity remains statistically significant but small, while the Mean Group estimate of the average elasticity becomes insignificantly different from zero in this specification.

5.8 An illustrative simulation

The effect of standard corporate income taxes is to raise the user cost of capital, at least for corporate investment financed from equity sources (retained earnings or new share issues). We conclude our analysis with a brief illustration of the estimated effects of eliminating this tax effect on the user cost. This could be achieved by the introduction of an Allowance for Corporate Equity (ACE) in an otherwise standard corporate income tax, or by the replacement of a standard corporate income tax

[37] The countries omitted from the sample here are Denmark, Finland and the Czech Republic. For this reason the results in Table 10 are not strictly comparable with those reported in the previous tables.

with a form of cash flow tax.[38]

Averaged across all 11 manufacturing sectors in all 14 of our sample countries, the effect of eliminating this tax effect in the last year of our sample period in 2007 would have reduced the user cost for equipment investment by 10%. Using the Pooled Mean Group elasticity estimate in column 3 of Table 9, this reduction in the user cost would increase the capital-output ratio for equipment assets by 9% in the long run. Figure 5 shows the estimated adjustment path for the average country-sector pair, based on the same specification. More than half of the adjustment occurs within 2 years, and most of the adjustment is complete after 5 years. Slower adjustment would be suggested by pooled specifications, reported in earlier Tables, which restrict all slope parameters to be homogeneous, but this restriction appears not to be supported by the data.

6 Conclusions

This paper presents new empirical estimates of the effects of the tax-adjusted user cost of capital on capital-output ratios, using sectoral panel data covering 14 OECD countries during the period 1982-2007. For equipment investment, we find very robust evidence that aggregate capital accumulation is strongly influenced by the

[38] A cash flow tax with expensing of investment sets $A_t = \tau_t$ and hence $(1 - A_t)/(1 - \tau_t) = 1$. The ACE allowance is equivalent to the expensing treatment in present value terms; see, for example, Bond and Devereux (2003). Belgium and Italy have recently introduced a form of the ACE allowance, in 2008 and in 2011 respectively.

user cost of capital, and specifically by the component of the user cost that depends on corporate taxation through the net present value of tax depreciation allowances and the statutory corporate tax rate. Our results also suggest that the effects of corporate taxation on equipment investment are summarised through this tax component of the user cost of capital. These findings are strikingly consistent with the basic economic theory of corporate investment, and support the view that tax policy can influence capital accumulation.

For investment in structures, our empirical results are less clear cut. Although our baseline model suggests a large and significant long-run user cost elasticity, this result relies on variation in the relative price component of the user cost, and even this estimate is less robust than our results for equipment investment. Another intriguing finding is that we find no effect on investment of the tax advantage for debt finance associated with the deductibility of interest payments.

References

[1] Bean, Charles R.,"An Econometric Model of Manufacturing Investment in the UK," *Economic Journal* 91 (1981), 106–121.

[2] Bloom, Nicholas, "The Real Options Effect of Uncertainty on Investment and Labour Demand," Institute for Fiscal Studies working paper no. 00/15 (2000).

[3] Bloom, Nicholas, Stephen R. Bond, and John Van Reenen, "Uncertainty and Investment Dynamics," *Review of Economic Studies* 74:2 (2007), 391-415.

[4] Bond, Stephen R., Asli Leblebicioglu , and Fabio Schiantarelli, "Capital Accumulation and Growth: A New Look at the Empirical Evidence," *Journal of Applied Econometrics* 25:7 (2010), 1073-1099.

[5] Bond, Stephen R., and Michael P. Devereux, "Generalised R-based and S-based Taxes under Uncertainty", *Journal of Public Economics* 87 (2003), 1291-1311.

[6] Borjas, George J., "The Relationship Between Wages and Weekly Hours of Work: the Role of Division Bias," *Journal of Human Resources* 15:3 (1980), 409-423.

[7] Caballero, Ricardo J., Eduardo M. A. Engel, and John C. Haltiwanger, "Plant-level Adjustment and Aggregate Investment Dynamics," *Brookings Papers on Economic Activity* 2 (1995), 1–39.

[8] Chirinko, Robert S., Steven M. Fazzari, and Andrew P. Meyer, "How Responsive is Business Capital Formation to Its User Cost? An Exploration with Micro Data," *Journal of Public Economics* 74:1 (1999), 53-80.

[9] Corbett, Jenny, and Tim Jenkinson, "How is Investment Financed? A Study of Germany, Japan, UK and US," *The Manchester School* 65 (1997), 69-93.

[10] Cummins, Jason G., Kevin A. Hassett, and R. Glenn Hubbard, "A Reconsideration of Investment Behavior Using Tax Reforms as Natural Experiments," *Brookings Papers on Economic Activity* 2 (1994), 1-74.

[11] Cummins, Jason G., Kevin A. Hassett, and R. Glenn Hubbard, "Tax Reforms and Investment: A Cross-country Comparison," *Journal of Public Economics* 62:2 (1996), 237-273.

[12] Devereux, Michael P., and Rachel Griffith, "Taxes and the Location of Production: Evidence from a Pandel of US Multinationals," *Journal of Public Economics* 68:3 (1998), 335-367.

[13] Devereux, Michael P., Rachel Griffith, and Alexander Klemm, "Corporate Income Tax Reforms and International Tax Competition," *Economic Policy* 35 (2002), 451-495.

[14] Devereux, Michael P., and Rachel Griffith, "Evaluating Tax Policy for Location Decisions," *International Tax and Public Finance* 10:2 (2003), 107-26.

[15] Greenwood, Jeremy, Zvi Hercowitz, and Per Krusell, "Long-run Implications of Investment-specific Technological Change," *The American Economic Review* 87:3 (1997), 342-362.

[16] Hall, Robert E., and Dale W. Jorgenson, "Tax Policy and Investment Behavior," *The American Economic Review* 57 (1967), 391-414.

[17] Hassett, Kevin A., and R. Glenn Hubbard, "Tax Policy and Business Investment" (pp.1293-1343), in A. J Auerbach and M. Feldstein (Eds.), *Handbook of Public Economics*, vol. 3 (North-Holland, 2002).

[18] Hsieh, Chang-Tai, and Peter J. Klenow, "Relative Prices and Relative Prosperity," *The American Economic Review* 97:3 (2005), 562-585.

[19] Jorgenson, Dale W., "Capital Theory and Investment Behavior," *The American Economic Review* 53:2 (1963), 247-259.

[20] Kose, M. Ayhan, Christopher Otrok, and Charles H. Whiteman, "International Business Cycles: World, Region, and Country-specific Factors," *The American Economic Review* 93:4 (2003), 1216-1239.

[21] King, Mervyn A., and Don Fullerton, "The Taxation of Income from Capital: A Comparative Study of the United States, the United Kingdom, Sweden, and Germany," *NBER Books* (National Bureau of Economic Research, Inc, 1984).

[22] Loretz, Simon, "Corporate Taxation in the OECD in a Wider Context," *Oxford Review of Economic Policy* 24:4 (2008), 639–660.

[23] Maddala, G.S. and Shaowen, Wu, "A Comparative Study of Unit Root Tests with Panel Data and A New Simple Test," *Oxford Bulletin of Economics and Statistics* 61 (1999), 631-652.

[24] O'Mahony, Mary, and Marcel P. Timmer, "Output, Input and Productivity Measures at the Industry Level: the EU KLEMS Database," *The Economic Journal* 119:538 (2009), 374-403.

[25] Pesaran, M. Hashem, and Ron Smith, "Estimating Long-run Relationships from Dynamic Heterogeneous Panels," *Journal of Econometrics* 68:1 (1995), 79-113.

[26] Pesaran, M. Hashem, Yongcheol Shin, and Ron Smith, "Pooled Mean Group Estimation of Dynamic Heterogeneous Panels," *Journal of the American Statistical Association* 94 (1999), 289-326.

[27] Pesaran, M. Hashem, "Estimation and Inference in Large Heterogeneous Panels with a Multifactor Error Structure," *Econometrica* 74:4 (2006), 967-1012.

[28] Schaller, Huntley, "Estimating the Long-run User Cost Elasticity," *Journal of Monetary Economics* 53 (2006), 725–736.

[29] Timmer, Marcel P., Mary O'Mahony, and Bart van Ark, "The EU KLEMS Growth and Productivity Accounts: An Overview," *EU KLEMS Productivity Reports* (2007).

Figure 1: Average capital-output ratio (in logs): manufacturing industries

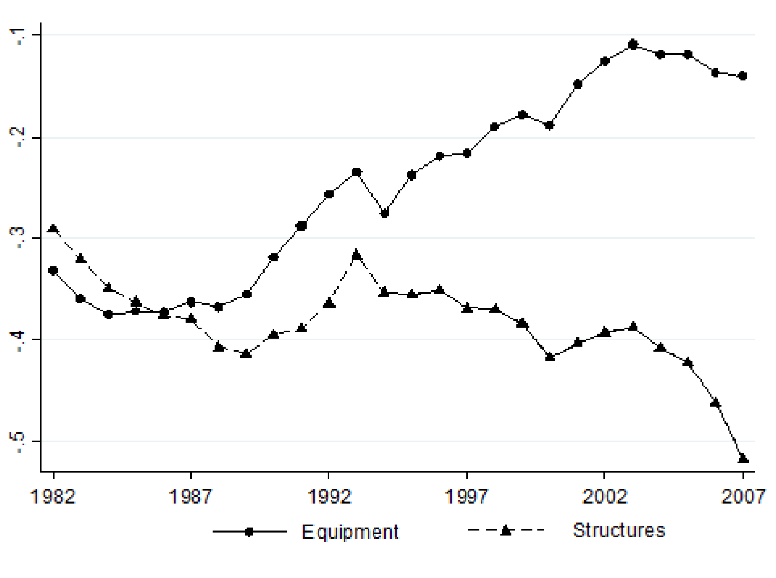


Figure 2: Average relative price of assets (in logs): manufacturing industries

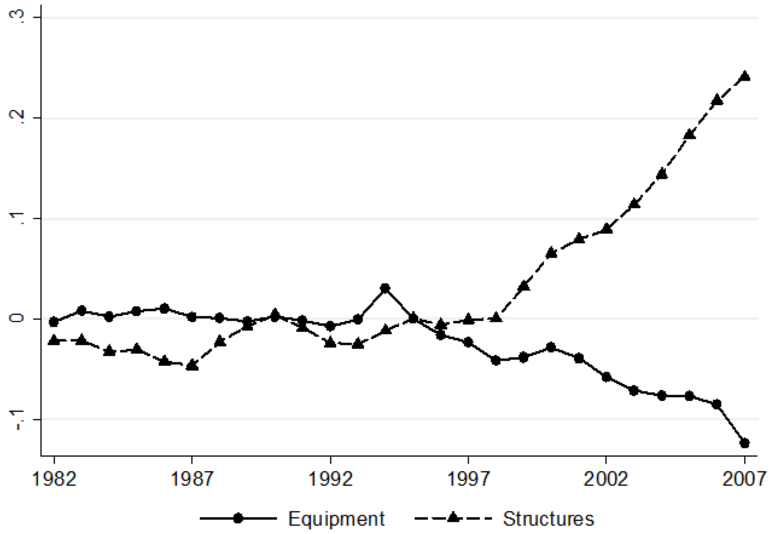


Figure 3: Average tax component of the user cost of capital (in logs): manufacturing industries

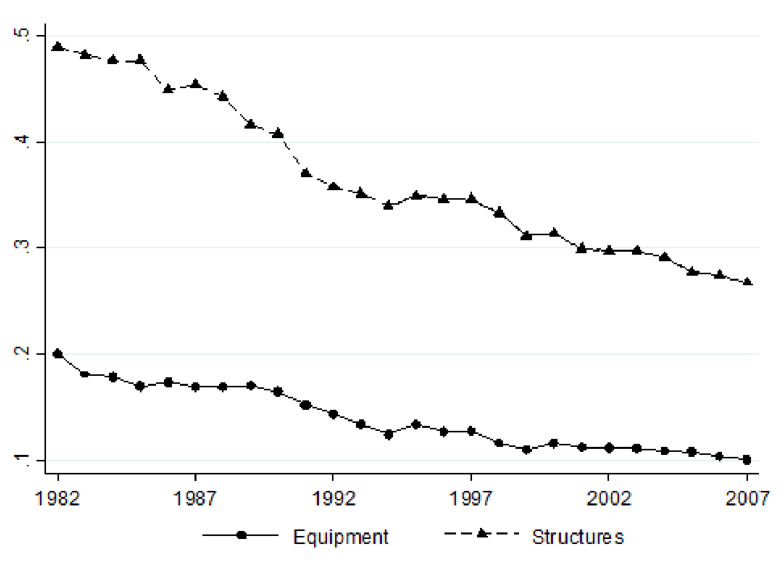
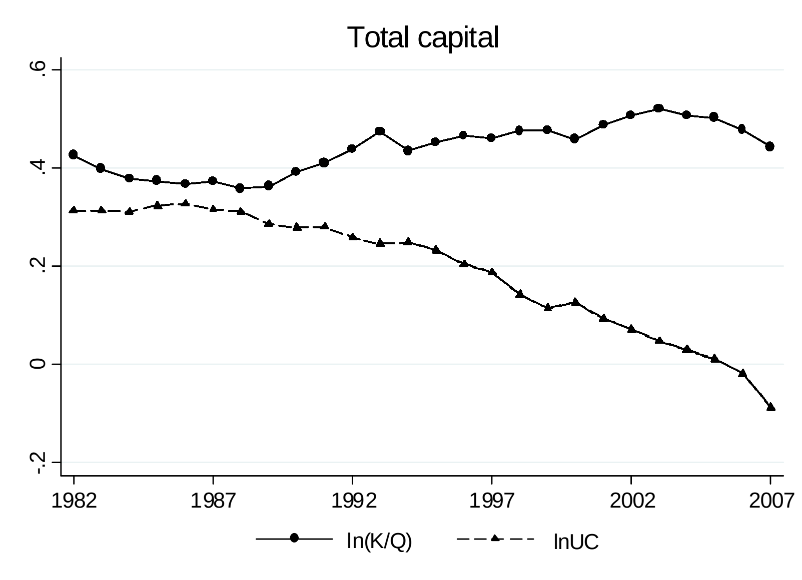


Figure 4: Average capital-output ratio and the measured components of the user cost of capital (in logs): manufacturing industries



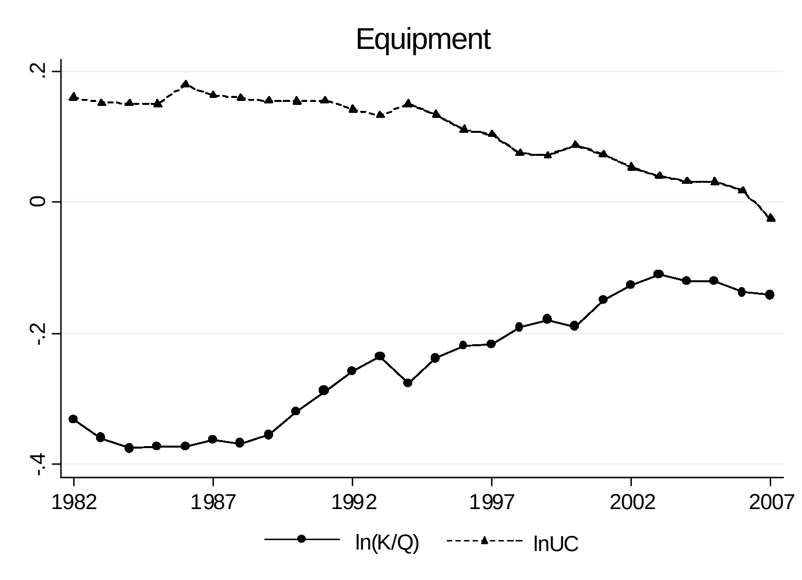
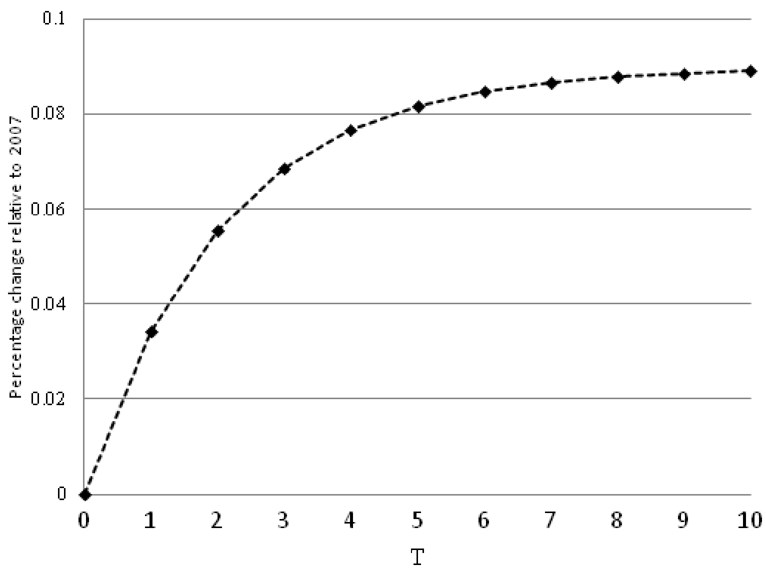


Figure 5: Simulated effects of a 10 percent reduction in the user cost on the capital-output ratio: equipment



Note: The simulated path is shown for an average country-sector pair, based on the Pooled Mean Group results summarised in Column 3 of Table 9.

Table 1: Within-groups estimations: baseline specification with CRS restriction

VARIABLES	(1) Total capital	(2) Equipment	(3) Structures
Panel A			
$\ln(K/Q)_{t-2}$	-0.027***	-0.056***	-0.013***
	(0.004)	(0.008)	(0.002)
$\ln UC_{t-2}$	-0.028***	-0.065***	-0.013***
	(0.004)	(0.009)	(0.002)
$\Delta \ln K_{t-1}$	0.484***	0.393***	0.549***
	(0.033)	(0.064)	(0.030)
$\Delta \ln Q_t$	0.067***	0.114***	0.021***
	(0.009)	(0.016)	(0.006)
$\Delta \ln Q_{t-1}$	0.054***	0.089***	0.026***
	(0.007)	(0.011)	(0.005)
$\Delta \ln UC_t$	-0.071***	-0.126***	-0.013***
	(0.008)	(0.018)	(0.004)
$\Delta \ln UC_{t-1}$	-0.049***	-0.092***	-0.018***
	(0.007)	(0.011)	(0.004)
Panel B: LR coefficient			
$\ln UC\ (\alpha_2)$	-1.053***	-1.153***	-0.988***
	(0.118)	(0.096)	(0.174)
Panel C: Tests (p-value)			
$\alpha_1 = 1$	0.000	0.035	0.000
$\alpha_2 = -1$	0.648	0.116	0.947
Year dummies	Yes	Yes	Yes
No. of groups	154	154	154
Observations	3146	3143	3141
R^2	0.471	0.396	0.448

[1] Standard errors in brackets are robust and clustered over time within country-industry pairs

[2] *** p<0.01, **p<0.05, * p<0.1

Table 2: Within-groups estimations without the CRS restriction

	(1)	(2)	(3)
VARIABLES	Total capital	Equipment	Structures
Panel A			
$\ln K_{t-2}$	-0.034***	-0.061***	-0.022***
	(0.005)	(0.009)	(0.003)
$\ln Q_{t-2}$	0.024***	0.050***	0.009***
	(0.004)	(0.008)	(0.002)
$\ln UC_{t-2}$	-0.027***	-0.062***	-0.009***
	(0.004)	(0.010)	(0.002)
$\Delta \ln K_{t-1}$	0.484***	0.393***	0.548***
	(0.034)	(0.065)	(0.030)
$\Delta \ln Q_t$	0.066***	0.111***	0.020***
	(0.009)	(0.016)	(0.006)
$\Delta \ln Q_{t-1}$	0.052***	0.085***	0.024***
	(0.007)	(0.011)	(0.005)
$\Delta \ln UC_t$	-0.070***	-0.124***	-0.011***
	(0.009)	(0.018)	(0.004)
$\Delta \ln UC_{t-1}$	-0.047***	-0.088***	-0.016***
	(0.007)	(0.012)	(0.004)
Panel B: LR coefficients			
$\ln Q\ (\alpha_1)$	0.702***	0.828***	0.400***
	(0.088)	(0.081)	(0.112)
$\ln UC\ (\alpha_2)$	-0.788***	-1.012***	-0.414***
	(0.117)	(0.112)	(0.116)
Panel C: Tests (p-value)			
$\alpha_1 = 1$	0.000	0.035	0.000
$\alpha_2 = -1$	0.076	0.909	0.000
Year dummies	Yes	Yes	Yes
No. of groups	154	154	154
Observations	3146	3143	3141
R^2	0.473	0.397	0.452

[1] Standard errors in brackets are robust and clustered over time within country-industry pairs

[2] *** p<0.01, **p<0.05, * p<0.1

Table 3: Within-groups estimations with country-sector specific trends

	(1)	(2)	(3)
VARIABLES	Total capital	Equipment	Structures
Panel A			
$\ln(K/Q)_{t-2}$	-0.091***	-0.160***	-0.047***
	(0.013)	(0.016)	(0.010)
$\ln UC_{t-2}$	-0.060***	-0.133***	-0.021***
	(0.008)	(0.018)	(0.005)
$\Delta \ln K_{t-1}$	0.351***	0.226***	0.427***
	(0.039)	(0.071)	(0.035)
$\Delta \ln Q_t$	0.100***	0.159***	0.039***
	(0.011)	(0.017)	(0.007)
$\Delta \ln Q_{t-1}$	0.102***	0.162***	0.050***
	(0.009)	(0.014)	(0.007)
$\Delta \ln UC_t$	-0.078***	-0.130***	-0.012***
	(0.009)	(0.017)	(0.004)
$\Delta \ln UC_{t-1}$	-0.064***	-0.114***	-0.017***
	(0.008)	(0.015)	(0.004)
Panel B: LR coefficient			
$\ln UC$ (α_2)	-0.654***	-0.832***	-0.444***
	(0.092)	(0.067)	(0.141)
Panel C: Test (p-value)			
$\alpha_2 = -1$	0.000	0.012	0.000
Year dummies	Yes	Yes	Yes
Country-sector linear trends	Yes	Yes	Yes
No. of groups	154	154	154
Observations	3146	3143	3141
R^2	0.520	0.475	0.492

[1] Standard errors in brackets are robust and clustered over time within country-industry pairs

[2] *** p<0.01, **p<0.05, * p<0.1

Table 4: Within-groups estimations: decomposing the user cost of capital

VARIABLES	(1) Total capital	(2) Equipment	(3) Structures
Panel A			
$\ln(K/Q)_{t-2}$	-0.026***	-0.055***	-0.014***
	(0.004)	(0.008)	(0.002)
$\ln(P^K/P)_{t-2}$	-0.027***	-0.062***	-0.016***
	(0.004)	(0.009)	(0.002)
$\ln TAX_{t-2}$	-0.023***	-0.095***	0.001
	(0.008)	(0.020)	(0.004)
$\Delta \ln K_{t-1}$	0.484***	0.387***	0.544***
	(0.033)	(0.064)	(0.030)
$\Delta \ln Q_t$	0.070***	0.118***	0.024***
	(0.010)	(0.016)	(0.006)
$\Delta \ln Q_{t-1}$	0.054***	0.089***	0.028***
	(0.007)	(0.011)	(0.006)
$\Delta \ln(P^K/P)_t$	-0.080***	-0.142***	-0.017***
	(0.009)	(0.020)	(0.005)
$\Delta \ln(P^K/P)_{t-1}$	-0.051***	-0.097***	-0.024***
	(0.008)	(0.013)	(0.005)
$\Delta \ln TAX_t$	-0.029**	-0.045*	0.004
	(0.012)	(0.024)	(0.006)
$\Delta \ln TAX_{t-1}$	-0.032**	-0.059*	-0.000
	(0.014)	(0.030)	(0.006)
Panel B: LR coefficients			
$\ln(P^K/P)$	-1.049***	-1.111***	-1.143***
	(0.129)	(0.096)	(0.184)
$\ln TAX$	-0.917***	-1.709***	0.107
	(0.312)	(0.357)	(0.317)
Panel C: Test (p-value)			
Equal LR coefficients	0.698	0.101	0.002
Year dummies	Yes	Yes	Yes
No. of groups	154	154	154
Observations	3146	3143	3141
R^2	0.473	0.400	0.450

[1] Standard errors in brackets are robust and clustered over time within country-industry pairs

[2] *** p<0.01, **p<0.05, * p<0.1

Table 5: Within-groups estimations: additional tax variables

	Total capital		Equipment		Structures	
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
LR coefficients						
$\ln(P^K/P)$	-1.034***	-1.007***	-1.105***	-1.097***	-1.151***	-1.162***
	(0.128)	(0.132)	(0.097)	(0.097)	(0.185)	(0.174)
$\ln TAX$	-4.529***	-2.456***	-2.281***	-2.109***	-0.843	-1.435***
	(1.187)	(0.512)	(0.775)	(0.456)	(1.690)	(0.480)
EATR	4.557***		0.674		1.467	
	(1.532)		(0.738)		(2.672)	
τ		1.838***		0.380		2.690***
		(0.490)		(0.293)		(0.614)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
No. of groups	154	154	154	154	154	154
Observations	3143	3143	3143	3143	3141	3141
R^2	0.476	0.476	0.401	0.401	0.451	0.453

[1] Standard errors in brackets are robust and clustered over time within country-industry pairs

[2] *** p<0.01, **p<0.05, * p<0.1

[3] Short-run dynamics are included in the specifications.

Table 6: Within-groups estimations: debt finance

LR coefficients	(1) Total capital	(2) Equipment	(3) Structures
Panel A			
$\ln\ UC$	-1.062***	-1.171***	-1.076***
	(0.125)	(0.099)	(0.176)
$\ln(1-\frac{J}{M})$	-0.096	-0.090	-0.304***
	(0.095)	(0.075)	(0.090)
Panel B			
$\ln(P^K/P)$	-1.041***	-1.120***	-1.147***
	(0.136)	(0.099)	(0.184)
$\ln TAX$	-1.528***	-1.855***	-0.212
	(0.533)	(0.422)	(0.463)
$\ln(1-\frac{J}{M})$	-0.189	-0.010	-0.129
	(0.149)	(0.088)	(0.113)

[1] Standard errors in brackets are robust and clustered over time within country-industry pairs

[2] *** p<0.01, **p<0.05, * p<0.1

[3] Year dummies and short-run dynamics are included in the specifications.

Table 7: Within-groups estimations: with country-specific year dummies

VARIABLES	(1) Total capital	(2) Equipment	(3) Structures
Panel A			
$\ln(K/Q)_{t-2}$	-0.039***	-0.061***	-0.018***
	(0.005)	(0.010)	(0.003)
$\ln UC_{t-2}$	-0.039***	-0.068***	-0.019***
	(0.005)	(0.012)	(0.003)
$\Delta \ln K_{t-1}$	0.399***	0.317***	0.487***
	(0.040)	(0.074)	(0.029)
$\Delta \ln Q_t$	0.055***	0.084***	0.020***
	(0.010)	(0.018)	(0.006)
$\Delta \ln Q_{t-1}$	0.051***	0.079***	0.022***
	(0.008)	(0.013)	(0.006)
$\Delta \ln UC_t$	-0.066***	-0.108***	-0.023***
	(0.010)	(0.019)	(0.005)
$\Delta \ln UC_{t-1}$	-0.050***	-0.097***	-0.032***
	(0.009)	(0.013)	(0.005)
Panel B: LR coefficient			
$\ln UC$ (α_2)	-0.994***	-1.129***	-1.028***
	(0.094)	(0.100)	(0.128)
Panel C: Test (p-value)			
$\alpha_2 = -1$	0.947	0.201	0.825
Country-specific year dummies	Yes	Yes	Yes
No. of groups	154	154	154
Observations	3146	3143	3141
R^2	0.590	0.518	0.566

[1] Standard errors in brackets are robust and clustered over time within country-industry pairs

[2] *** p<0.01, **p<0.05, * p<0.1

Table 8: IV within-groups estimations, using tax components as instruments

VARIABLES	(1) Total capital	(2) Equipment	(3) Structures	(4) Total capital	(5) Equipment	(6) Structures
IVs	$\Delta \ln TAX_t$, $\ln TAX_{t-1}$, $\ln TAX_{t-2}$			$\ln TAX_{t-1}$, $\ln TAX_{t-2}$		
Panel A						
$\ln(K/Q)_{t-2}$	-0.026***	-0.053***	-0.013***	-0.026***	-0.045***	-0.018***
	(0.004)	(0.008)	(0.002)	(0.004)	(0.009)	(0.003)
$\ln UC_{t-2}$	-0.026***	-0.058***	-0.012***	-0.027***	-0.042***	-0.021***
	(0.004)	(0.009)	(0.002)	(0.005)	(0.012)	(0.004)
$\Delta \ln K_{t-1}$	0.487***	0.402***	0.548***	0.486***	0.423***	0.552***
	(0.034)	(0.066)	(0.030)	(0.035)	(0.073)	(0.030)
$\Delta \ln Q_t$	0.058***	0.091***	0.019***	0.059***	0.037	0.038***
	(0.009)	(0.014)	(0.006)	(0.012)	(0.027)	(0.009)
$\Delta \ln Q_{t-1}$	0.054***	0.089***	0.026***	0.054***	0.090***	0.031***
	(0.007)	(0.011)	(0.005)	(0.007)	(0.013)	(0.006)
$\Delta \ln UC_t$	-0.033***	-0.034	-0.003	-0.039	0.177*	-0.084***
	(0.011)	(0.022)	(0.006)	(0.034)	(0.094)	(0.030)
$\Delta \ln UC_{t-1}$	-0.051***	-0.097***	-0.017***	-0.050***	-0.109***	-0.026***
	(0.007)	(0.012)	(0.004)	(0.007)	(0.015)	(0.005)
Panel B: LR coefficient						
$\ln UC$ (α_2)	-1.022***	-1.096***	-0.952***	-1.027***	-0.934***	-1.174***
	(0.129)	(0.103)	(0.182)	(0.136)	(0.177)	(0.154)
Panel C: Tests (p-value)						
$\alpha_2 = -1$	0.865	0.353	0.794	0.844	0.709	0.259
Hansen test	0.788	0.013	0.004	0.496	0.151	0.285
Under-identification	0	0	0	0	0	0
Weak identification (F-statistic)	309.060	130.440	777.640	31.980	15.569	15.372
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
No. of groups	154	154	154	154	154	154
Observations	3146	3143	3141	3146	3143	3141

[1] Standard errors in brackets are robust and clustered over time within country-industry pairs.

[2] *** p<0.01, **p<0.05, * p<0.1.

[3] In Panel C, we report the p-values of the first-stage Kleibergen-Paap rank LM test of underidentification. We also report the F-statistics of the Cragg-Donald Wald test of weak identification of parameters for individual endogenous regressors.

Table 9: PMG and outlier-robust MG estimations: 14 countries

	Demeaned		Demeaned+T	
	(1)	(2)	(3)	(4)
(Average) coefficients	PMG	MG	PMG	MG
Total capital				
-ϕ	-0.212***	-0.258***	-0.392***	-0.437***
	(0.019)	(0.014)	(0.024)	(0.022)
ln UC	-0.571***	-0.765***	-0.413***	-0.472***
	(0.022)	(0.111)	(0.019)	(0.183)
Equipment				
-ϕ	-0.222***	-0.258***	-0.382***	-0.431***
	(0.019)	(0.014)	(0.024)	(0.019)
ln UC	-0.900***	-0.765***	-0.889***	-0.628***
	(0.025)	(0.111)	(0.026)	(0.116)
Structures				
-ϕ	-0.139***	-0.177***	-0.334***	-0.364***
	(0.019)	(0.014)	(0.026)	(0.021)
ln UC	-0.445***	-0.367***	-0.040***	-0.288***
	(0.026)	(0.145)	(0.017)	(0.080)

[1] We estimate the parsimonious model $\Delta \ln K_{i,c,t} = -\phi_{i,c}[\ln(K/Q)_{i,c,t-2} - \alpha_{2i,c} \ln UC_{i,c,t-2}]$ $+\beta_{0i,c} \Delta\ln K_{i,c,t-1} + \beta_{1i,c} \Delta\ln Q_{i,c,t} - \beta_{3i,c} \Delta\ln UC_{i,c,t} + f_{i,c} + \varepsilon_{i,c,t}$ using demeaned data, with and without linear trends (T).

[2] For the Pooled Mean Group (PMG) estimators, we report the common long-run elasticity of the capital-output ratio with respect to the user cost of capital (α_2), and the mean estimate of the convergence rate (-ϕ) across country-industry pairs.

[3] For the Mean Group (MG) estimators, we report outlier-robust estimates of the mean for each of these parameters across country-industry pairs.

[4] Robust standard errors in parentheses.

[5] *** p<0.01, ** p<0.05, * p<0.1.

[6] Short-run dynamics are included in the specifications.

Table 10: Common correlated effects PMG and outlier-robust MG estimations: 11 countries

	CCE		CCE+T	
	(1)	(2)	(3)	(4)
(Average) coefficients	PMG	MG	PMG	MG
Total capital				
-ϕ	-0.124***	-0.144***	-0.126***	-0.159***
	(0.014)	(0.012)	(0.014)	(0.011)
$\ln UC$	-0.431***	-0.494***	-0.731***	-0.441***
	(0.024)	(0.256)	(0.000)	(0.159)
Equipment				
-ϕ	-0.176***	-0.194***	-0.274***	-0.234***
	(0.017)	(0.014)	(0.038)	(0.015)
$\ln UC$	-0.148***	-0.638***	-0.542***	-0.613***
	(0.004)	(0.243)	(0.000)	(0.241)
Structures				
-ϕ	-0.057***	-0.058***	-0.110***	-0.102***
	(0.015)	(0.006)	(0.013)	(0.009)
$\ln UC$	-0.046***	-0.098	-0.246***	-0.237
	(0.016)	(0.179)	(0.002)	(0.425)

[1] We estimate the parsimonious model $\Delta \ln K_{i,c,t} = -\phi_{i,c}[\ln(K/Q)_{i,c,t-2} - \alpha_{2i,c} \ln UC_{i,c,t-2}] + \beta_{0i,c} \Delta\ln K_{i,c,t-1} + \beta_{1i,c} \Delta\ln Q_{i,c,t} - \beta_{3i,c} \Delta\ln UC_{i,c,t} + \gamma' Z_t + f_{i,c} + \varepsilon_{i,c,t}$ with and without linear trends (T), where the vector Z_t includes the year-specific sample means of the dependent variable and each of the explanatory variables

[2] For the Pooled Mean Group (PMG) estimators, we report the common long-run elasticity of the capital-output ratio with respect to the user cost of capital (α_2), and the mean estimate of the convergence rate (-ϕ) across country-industry pairs.

[3] For the Mean Group (MG) estimators, we report outlier-robust estimates of the mean for each of these parameters across country-industry pairs.

[4] Robust standard errors in parentheses.

[5] *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

[6] Short-run dynamics are included in the specifications.

Appendix A: Derivation of the user cost of capital

A.1. Equity finance

In this Appendix, we derive the tax-adjusted user cost of capital for the case in which investment is financed by equity (retained profits or new share issues), as in equation (2).

Allowing for corporate taxation, we write the net revenue (Π_t) generated by the firm in period t as

$$\Pi_t = (1 - \tau_t) P_t F(K_t, L_t) - (1 - \tau_t \phi_t) P_t^K I_t - (1 - \tau_t) W_t L_t + \widetilde{A}_t \qquad (A.9)$$

where $F(K_t, L_t)$ denotes output (value-added) produced using capital (K_t) and labour (L_t), P_t is the output price, I_t denotes real gross investment, P_t^K is the price of capital goods, and W_t is the wage rate. Among the tax parameters, τ_t is the statutory corporate income tax rate, ϕ_t is the fraction of a unit of investment spending that can be deducted from taxable profits in the same year, so that $\tau_t \phi_t$ is the value of the first year allowance on a unit of investment in period t, and $\widetilde{A}_t$ is the value of writing-down allowances on past investments that can be claimed in period t.

With no debt finance, we have

$$\Pi_t = D_t - N_t \qquad (A.10)$$

where D_t denotes dividends paid in period t and N_t denotes revenue raised from new share issues, so that Π_t is also the net cash distribution to shareholders.

Abstracting from personal taxation, this gives the value of the firm as

$$V_t = E_t \left[\sum_{j=0}^{\infty} \beta_{t+j} \Pi_{t+j} \right] \tag{A.11}$$

where $E_t\left[.\right]$ denotes the conditional expectation based on information available in period t, and β_{t+j} is the discount factor which gives the value in period t of an expected payoff in period $t+j$. Letting r_t denote the *ex ante* real discount rate between period t and period $t+1$, and π_t denote the expected inflation rate between period t and period $t+1$, the nominal discount rate (ρ_t) satisfies $(1+\rho_t) = (1+r_t)(1+\pi_t)$, and the nominal discount factors are given by

$$\beta_t = 1; \quad \beta_{t+1} = \frac{1}{1+\rho_t}; \quad \beta_{t+j} = \prod_{i=0}^{j-1} (1+\rho_{t+i})^{-1} \text{ for } j = 2, 3, ... \tag{A.12}$$

Following Hayashi (1982), we can also express the value of the firm as

$$\begin{aligned} V_t &= E_t \left[\sum_{j=0}^{\infty} \beta_{t+j} \Pi^*_{t+j} \right] + E_t \left[\sum_{j=0}^{\infty} \beta_{t+j} A^*_{t+j} \right] \\ &= V^*_t + E_t \left[\sum_{j=0}^{\infty} \beta_{t+j} A^*_{t+j} \right] \end{aligned} \tag{A.13}$$

where

$$\Pi^*_{t+j} = (1-\tau_{t+j}) P_{t+j} F(K_{t+j}, L_{t+j}) - (1-A_{t+j}) P^K_{t+j} I_{t+j} - (1-\tau_{t+j}) W_{t+j} L_{t+j}, \tag{A.14}$$

A_{t+j} is the present value in period $t+j$ of current and future tax allowances associated with a unit of new investment in period $t+j$, and A^*_{t+j} is the component of $\widetilde{A}_{t+j}$ associated with investments made before period t.

Choosing investment (I_t) in period t to maximise V_t is then equivalent to maximising V^*_t, as the final term in (A.13) does not depend on I_t. Here the optimisation problem can be written recursively as

$$V_t^*\left(K_{t-1}\right)=\left\{\max_{I_t}\ \Pi_t^*(K_t,\ I_t)+\beta_{t+1}E_t\left[V_{t+1}^*\left(K_t\right)\right]\right\} \tag{A.15}$$

subject to the capital accumulation constraint

$$K_t=(1-\delta)K_{t-1}+I_t \tag{A.16}$$

where δ is the rate of depreciation. To ensure that the firm's value maximisation problem has a solution in the absence of adjustment costs, we assume that there is some degree of monopolistic competition in the product market and the firm faces a downward sloping demand curve for its output of the isoelastic form

$$P_t\left(Q_t\right)=Q_t^{-\frac{1}{\eta}} \tag{A.17}$$

where $\eta>1$ is the price elasticity of demand. This gives

$$\frac{\partial\Pi_t^*}{\partial K_t}=\left(1-\tau_t\right)P_t\left(1-\frac{1}{\eta}\right)\frac{\partial F_t}{\partial K_t}. \tag{A.18}$$

Treating input prices as given, we also have

$$\frac{\partial\Pi_t^*}{\partial I_t}=-(1-A_t)P_t^K. \tag{A.19}$$

Differentiating equation (A.15) with respect to I_t yields

$$\frac{\partial V_t^*}{\partial I_t}=\frac{\partial\Pi_t^*}{\partial K_t}+\frac{\partial\Pi_t^*}{\partial I_t}+\beta_{t+1}E_t\left[\frac{\partial V_{t+1}^*}{\partial K_t}\right]=0 \tag{A.20}$$

and differentiating equation (A.15) with respect to K_{t-1} yields

$$\frac{\partial V_t^*}{\partial K_{t-1}}=(1-\delta)\frac{\partial\Pi_t^*}{\partial K_t}+(1-\delta)\beta_{t+1}E_t\left[\frac{\partial V_{t+1}^*}{\partial K_t}\right]. \tag{A.21}$$

Combining equations (A.20) and (A.21), we obtain

$$\frac{\partial V_t^*}{\partial K_{t-1}} = -\left(1-\delta\right)\frac{\partial \Pi_t^*}{\partial I_t} \tag{A.22}$$

and hence

$$\beta_{t+1}E_t\left[\frac{\partial V_{t+1}^*}{\partial K_t}\right] = -\left(1-\delta\right)\beta_{t+1}E_t\left[\frac{\partial \Pi_{t+1}^*}{\partial I_{t+1}}\right]. \tag{A.23}$$

Substituting (A.18), (A.19), and (A.23) into equation (A.20), we can rearrange the first-order condition for optimal investment to obtain

$$\frac{\partial F_t}{\partial K_t} = \frac{P_t^K\left(1-A_t\right)}{P_t(1-\frac{1}{\eta})\left(1-\tau_t\right)}\left(1-(1-\delta)\beta_{t+1}E_t\left[\frac{P_{t+1}^K(1-A_{t+1})}{P_t^K(1-A_t)}\right]\right). \tag{A.24}$$

Assuming that relative prices, inflation rates, tax rates and tax depreciation schedules are expected to remain constant, we have $E_t[P_{t+1}^K(1-A_{t+1})/P_t^K(1-A_t)] = 1+\pi_t$. In this case equation (A.24) simplifies to give a familiar expression for the tax-adjusted user cost of capital, similar to Jorgenson (1963), Hall and Jorgenson (1967) and Devereux and Griffith (2003), as:[39]

$$\frac{\partial F_t}{\partial K_t} = \frac{P_t^K}{P_t\left(1-\frac{1}{\eta}\right)}\frac{\left(1-A_t\right)}{\left(1-\tau_t\right)}\frac{\left(r_t+\delta\right)}{\left(1+r_t\right)} = C_t, \tag{A.25}$$

which is equation (2) in the text.

Finally for the CES production function

$$Q_t = F(K_t, L_t) = \left(a_K K_t^\rho + a_L L_t^\rho\right)^{\frac{\nu}{\rho}},$$

[39] Jorgenson (1963), Hall and Jorgenson (1967) and Devereux and Griffith (2003) assume that firms take output prices as given, so they have $\left(1-\frac{1}{\eta}\right) = 1$. We assume that investment in period t generates additional output in period t, while Devereux and Griffith (2003) assume that investment in period t generates additional output only in period $t+1$. This timing difference accounts for the additional term $(1+r_t)$ in the denominator of equation (A.25).

where $\sigma = 1/(1-\rho)$ is the elasticity of substitution and ν is the returns to scale, we have

$$\frac{\partial F_t}{\partial K_t} = a_K \nu Q_t^{\frac{1}{\sigma}\left(\sigma+\frac{1-\sigma}{\nu}\right)} K_t^{\frac{-1}{\sigma}}. \tag{A.26}$$

Combining equations (A.25) and (A.26) then gives an expression for the optimal capital stock in this case as:

$$K_t = (a_K \nu)^{\sigma} Q_t^{\left(\sigma+\frac{1-\sigma}{\nu}\right)} C_t^{-\sigma},$$

which has the form of equation (1) in the text.

A.2. Debt finance

In this Appendix, we derive the tax-adjusted user cost of capital for the case in which investment is financed by borrowing, as in equation (3).

Following Devereux and Griffith (2003), we assume that investment spending in period t, net of tax allowances claimed in period t, is completely financed by borrowing the amount $(1-\tau_t\phi_t)P_t^K I_t$ in period t, at a nominal interest rate i_t. This borrowing is repaid in period $t+1$, with the interest payment deductible against the corporate tax, giving a cash outflow of $(1-\tau_t\phi_t)P_t^K I_t[1+i_t(1-\tau_{t+1})]$ in period $t+1$. Either no borrowing occurs in later periods or, if it does, the amounts borrowed in later periods do not depend on the choice of I_t.[40] With these assumptions, we have

$$\Pi_t^* = (1-\tau_t) P_t F(K_t, L_t) - (1-A_t)P_t^K I_t - (1-\tau_t) W_t L_t + (1-\tau_t\phi_t)P_t^K I_t$$

[40] In particular, the change in investment that is required in period $t+1$ to hold K_{t+1} constant, when considering a change in I_t and hence in K_t, is assumed not to be financed by borrowing.

$$\Pi^*_{t+1} = (1-\tau_{t+1}) P_{t+1} F(K_{t+1}, L_{t+1}) - (1-A_{t+1}) P^K_{t+1} I_{t+1} - (1-\tau_{t+1}) W_{t+1} L_{t+1}$$
$$-(1-\tau_t\phi_t) P^K_t I_t [1 + i_t(1-\tau_{t+1})]$$

and Π^*_{t+j} unchanged from that given in equation (A.14) above from period $t+2$ onwards.

Using the same simplifying assumptions noted in Appendix A.1 above, the first-order condition for optimal investment can then be rearranged to give:

$$\begin{aligned}
\frac{\partial F_t}{\partial K_t} &= \frac{P^K_t}{P_t\left(1-\frac{1}{\eta}\right)}\left[\frac{(1-A_t)}{(1-\tau_t)}\frac{(r_t+\delta)}{(1+r_t)} - \frac{[\rho_t - i_t(1-\tau_t)](1-\tau_t\phi_t)}{(1-\tau_t)(1+\rho_t)}\right] \\
&= \frac{P^K_t}{P_t\left(1-\frac{1}{\eta}\right)}\frac{(1-A_t)}{(1-\tau_t)}\frac{(r_t+\delta)}{(1+r_t)}\left(1-\frac{J_t}{M_t}\right) \\
&= C_t\left(1-\frac{J_t}{M_t}\right) = C^{Debt}_t
\end{aligned}$$

as in equation (3) in the text, where

$$J_t = [\rho_t - i_t(1-\tau_t)](1-\tau_t\phi_t) \quad \text{and} \quad M_t = (1-A_t)(r_t+\delta)(1+\pi_t).$$

Appendix B: List of industries and countries

- Sample 1: 11 manufacturing industries

This sample includes the following manufacturing industries: 1) Basic metals and fabricated metal; 2) chemicals, rubber, plastics and fuel; 3) electrical and optical equipment; 4) food, beverages and tobacco; 5) machinery not elsewhere classified; 6) manufacturing not elsewhere classified and recycling; 7) other non-metallic minerals; 8) pulp, paper and printing; 9) textiles, leather and footwear; 10) transport equipment; 11) wood and cork.

- Sample 2: 19 industries

This sample includes the 11 manufacturing industries in sample 1, plus the following sectors: 12) agriculture, hunting, forestry and fish; 13) mining and quarrying; 14) construction; 15) wholesale and retail trade; 16) hotels and restaurants; 17) transport and storage; 18) real estate; 19) post and telecommunications.

- Sample 3: 27 industries.

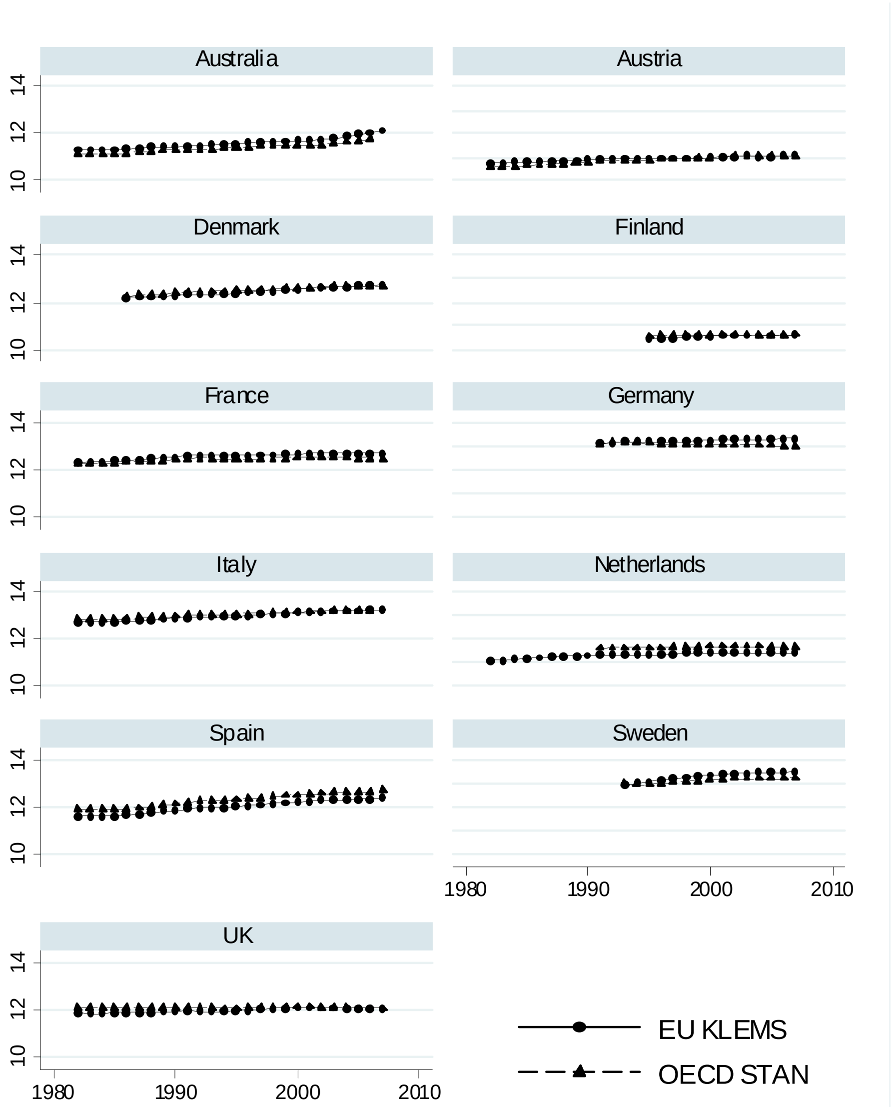
In addition to the 19 industries included in sample 2, we include the following sectors: 20) electricity, gas and water supply; 21) financial intermediation; 22) education; 23) public administration, defence and compulsory social security; 24) health and social work; 25) other community, social and personal services; 26) private households with employed persons; 27) extra-territorial organisations and bodies.

- Country coverage

Country	Coverage	Country	Coverage
Australia	1982-2007	Italy	1982-2007
Austria	1982-2007	Japan	1982-2006
Czech Republic	1995-2007	Netherlands	1982-2007
Denmark	1986-2007	Spain	1982-2007
Finland	1995-2007	Sweden	1993-2007
France	1982-2007	UK	1982-2007
Germany	1991-2007	US	1982-2007

Appendix C: EU KLEMS and OECD STAN

Figure C.1: Total real capital stock (in logs): total manufacturing industry



Appendix D: Time-series plots for individual countries

Figure D.1: Average K/Q ratio and user cost of capital (in logs): total capital

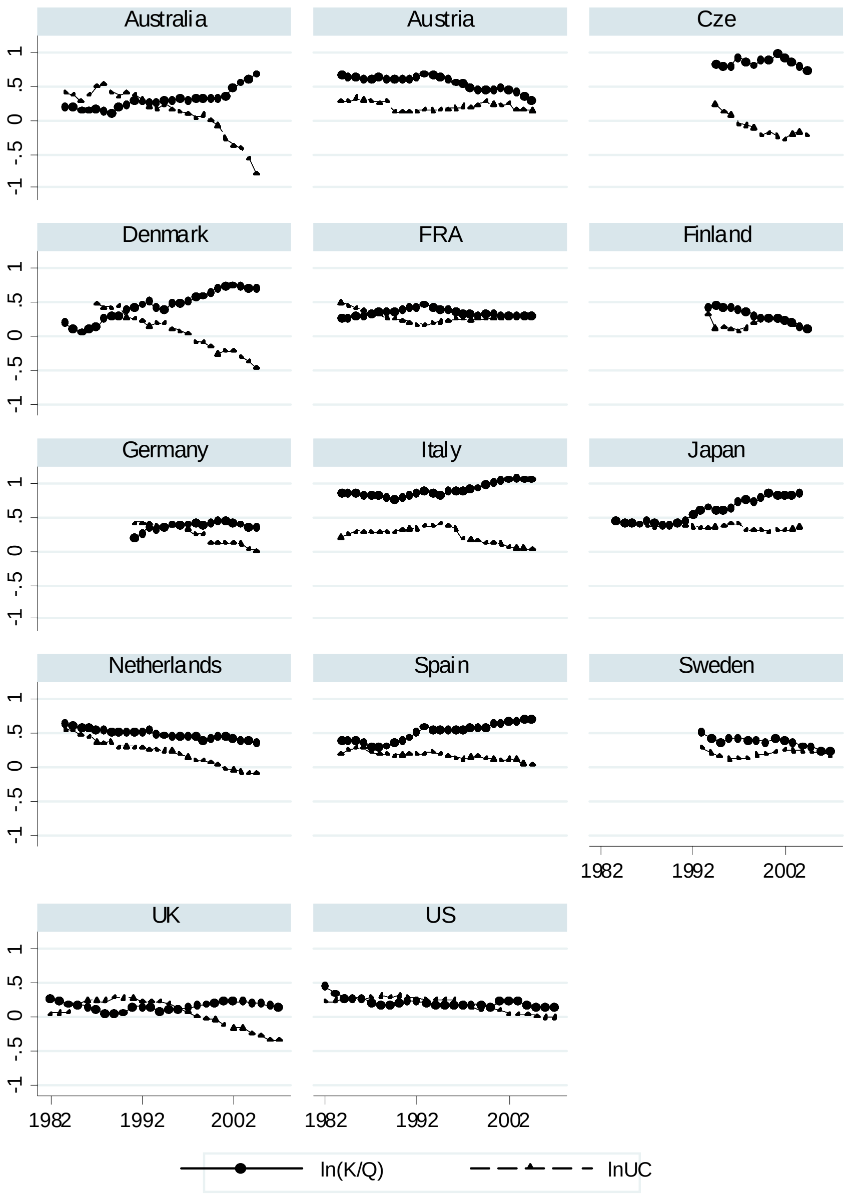


Figure D.2: Average K/Q ratio and user cost of capital (in logs): equipment

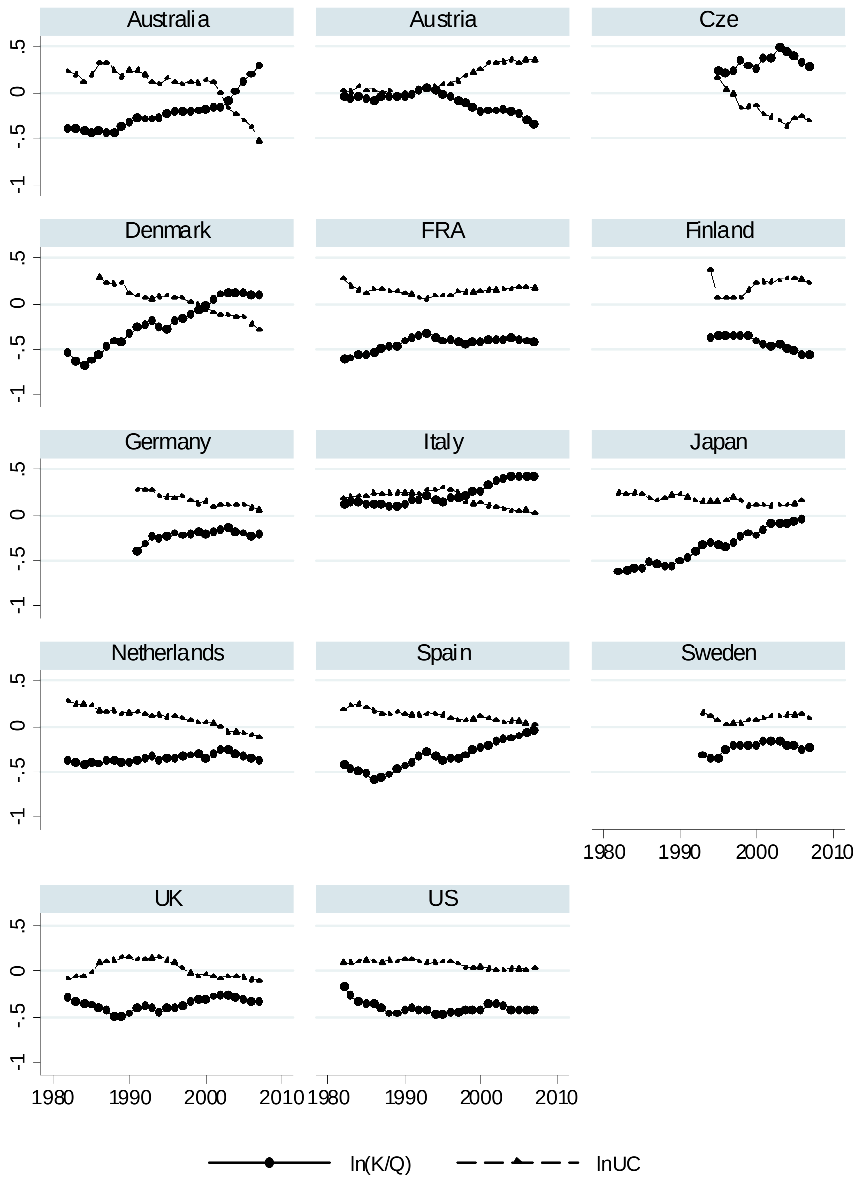


Table E.1: Panel unit-root test results (p-values): 14 countries, 11 manufacturing industries

	Total capital	Equipment	Structures
Raw data			
$\ln K$	0.000	0.000	0.000
$\ln Q$	0.011	0.011	0.011
$\ln(K/Q)$	0.008	0.002	0.007
$\ln UC$	0.150	0.000	0.382
$\ln(P^K/P)$	0.044	0.000	0.999
$\ln TAX$	0.000	0.000	0.048
With linear trends			
$\ln K$	0.539	0.998	0.135
$\ln Q$	0.266	0.266	0.266
$\ln(K/Q)$	0.008	0.058	0.016
$\ln UC$	0.258	0.000	0.124
$\ln(P^K/P)$	0.021	0.000	0.920
$\ln TAX$	0.000	0.000	0.000
Demeaned data			
$\ln K$	1.000	1.000	1.000
$\ln Q$	1.000	1.000	1.000
$\ln(K/Q)$	0.000	0.025	0.000
$\ln UC$	0.555	0.000	0.002
$\ln(P^K/P)$	0.891	0.000	0.003
$\ln TAX$	0.000	0.000	0.000
Demeaned data with linear trends			
$\ln K$	1.000	1.000	1.000
$\ln Q$	1.000	1.000	1.000
$\ln(K/Q)$	0.000	0.000	0.001
$\ln UC$	0.056	0.000	0.002
$\ln(P^K/P)$	0.035	0.000	0.308
$\ln TAX$	0.005	0.000	0.000

Note: This table presents p-values from the Fisher-type test for unit roots in heterogeneous panels (Maddala and Wu, 1999). Suppose the stochastic process, $y_{i,t}$, is generated by an autoregressive process:

$$\Delta y_{i,t} = \alpha_i + \beta_i y_{i,t-1} + \delta_i t + \sum_{j=1}^{p} \gamma_{i,j} \Delta y_{i,t-j} + \varepsilon_{i,t}$$

where t is a linear trend. The null hypothesis is H_0: $\beta_i=0$ for all i, and the alternative is H_1: $\beta_i<0, i=1,2,...N_1$, $\beta_i=0$, $i=N_1+1,N_1+2,...N$, $0<lim_{N\to\infty}(N_1/N)\leq 1$. The Fisher test first computes the p-value π_i for each group using the Phillips-Perron unit-root test. Then it computes the statistic $-2\sum \log\pi_i$, which follows a χ^2 distribution with 2N degrees of freedom under the null. We report the p-values of the χ^2 statistics in this table. Results are reported for the lag length p=3, but are not highly sensitive to this choice. 'Demeaned' series are expressed as deviations from year-specific sample means, where these means are calculated using observations for all available groups in that year. These tests are computed using the command *xtfisher* in Stata.

Table E.2: Within-groups estimations: baseline specification, 19 industries

VARIABLES	(1) Total capital	(2) Equipment	(3) Structures
Panel A			
$\ln(K/Q)_{t-2}$	-0.019***	-0.046***	-0.013***
	(0.003)	(0.005)	(0.002)
$\ln UC_{t-2}$	-0.010***	-0.048***	-0.009***
	(0.003)	(0.006)	(0.002)
$\Delta \ln K_{t-1}$	0.591***	0.487***	0.587***
	(0.022)	(0.038)	(0.025)
$\Delta \ln Q_t$	0.058***	0.108***	0.023***
	(0.007)	(0.012)	(0.004)
$\Delta \ln Q_{t-1}$	0.042***	0.075***	0.030***
	(0.005)	(0.008)	(0.004)
$\Delta \ln UC_t$	-0.031***	-0.109***	-0.006
	(0.007)	(0.015)	(0.005)
$\Delta \ln UC_{t-1}$	-0.020***	-0.068***	-0.020***
	(0.005)	(0.009)	(0.004)
Panel B: LR coefficient			
$\ln UC$ (α_2)	-0.524***	-1.041***	-0.657***
	(0.131)	(0.102)	(0.145)
Panel C: Test (p-value)			
$\alpha_2 = -1$	0.000	0.690	0.019
Year dummies	Yes	Yes	Yes
No. of groups	266	265	266
Observations	5608	5609	5657
R^2	0.494	0.447	0.450

[1] Standard errors in brackets are robust and clustered over time within country-industry pairs

[2] *** p<0.01, **p<0.05, * p<0.1

Table E.3: Within-groups estimations: baseline specification, 27 industries

VARIABLES	(1) Total capital	(2) Equipment	(3) Structures
Panel A			
$\ln(K/Q)_{t-2}$	-0.020***	-0.050***	-0.010***
	(0.002)	(0.004)	(0.003)
$\ln UC_{t-2}$	-0.010***	-0.055***	-0.004
	(0.002)	(0.005)	(0.003)
$\Delta \ln K_{t-1}$	0.575***	0.470***	0.587***
	(0.024)	(0.034)	(0.053)
$\Delta \ln Q_t$	0.056***	0.111***	0.020***
	(0.006)	(0.012)	(0.005)
$\Delta \ln Q_{t-1}$	0.048***	0.077***	0.037***
	(0.006)	(0.009)	(0.009)
$\Delta \ln UC_t$	-0.027***	-0.119***	-0.000
	(0.006)	(0.013)	(0.007)
$\Delta \ln UC_{t-1}$	-0.026***	-0.069***	-0.025***
	(0.007)	(0.009)	(0.008)
Panel B: LR coefficient			
$\ln UC\ (\alpha_2)$	-0.513***	-1.102***	-0.396***
	(0.104)	(0.076)	(0.255)
Panel C: Test (p-value)			
$\alpha_2 = -1$	0.000	0.180	0.019
Year dummies	Yes	Yes	Yes
No. of groups	351	349	351
Observations	7417	7345	7469
R^2	0.473	0.439	0.426

[1] Standard errors in brackets are robust and clustered over time within country-industry pairs

[2] *** p<0.01, **p<0.05, * p<0.1

Table E.4: First-stage regression results for Table 8: dependent variable $\Delta \ln UC_t$

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Total capital	Equipment	Structures	Total capital	Equipment	Structures
Instruments						
$\Delta \ln TAX_t$	1.078***	1.078***	1.104***			
	(0.046)	(0.061)	(0.030)			
$\ln TAX_{t-1}$	0.150***	0.114**	0.343***	-0.214***	-0.129**	-0.119**
	(0.054)	(0.056)	(0.086)	(0.055)	(0.056)	(0.047)
$\ln TAX_{t-2}$	-0.091**	0.004	-0.131***	-0.019	-0.056	-0.026
	(0.045)	(0.040)	(0.046)	(0.046)	(0.041)	(0.051)
$\ln(K/Q)_{t-2}$	-0.001	-0.025	-0.039***	-0.022	-0.036***	-0.055***
	(0.013)	(0.012)	(0.011)	(0.014)	(0.012)	(0.012)
$\ln UC_{t-2}$	-0.016	-0.058***	-0.085***	-0.029**	-0.064***	-0.079***
	(0.014)	(0.015)	(0.019)	(0.015)	(0.016)	(0.019)
$\Delta \ln K_{t-1}$	-0.043	-0.114**	0.061	-0.045	-0.097*	0.112
	(0.083)	(0.049)	(0.083)	(0.089)	(0.049)	(0.089)
$\Delta \ln Q_t$	0.264***	0.261***	0.245	0.249***	0.253***	0.226***
	(0.031)	(0.032)	(0.032)	(0.033)	(0.034)	(0.035)
$\Delta \ln Q_{t-1}$	-0.005	-0.019	0.067	-0.005	-0.006	0.048
	(0.024)	(0.021)	(0.032)	(0.026)	(0.023)	(0.037)
$\Delta \ln UC_{t-1}$	0.043	0.053*	-0.147**	0.063*	0.068**	-0.079***
	(0.030)	(0.031)	(0.063)	(0.033)	(0.032)	(0.073)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
No. of groups	154	154	154	154	154	154
Observations	3146	3143	3141	3146	3143	3141

[1] Standard errors in brackets are robust and clustered over time within country-industry pairs
[2] *** p<0.01, **p<0.05, * p<0.1

Table E.5: IV within-groups estimations, using lagged user cost as instruments

VARIABLES	(1) Total capital	(2) Equipment	(3) Structures
IVs	$\ln UC_{t-3}$, $\ln UC_{t-4}$, $\ln UC_{t-5}$, $\ln UC_{t-6}$		
Panel A			
$\ln(K/Q)_{t-2}$	-0.035***	-0.064***	-0.039***
	(0.005)	(0.012)	(0.013)
$\ln UC_{t-2}$	-0.036***	-0.072***	-0.060***
	(0.006)	(0.015)	(0.021)
$\Delta \ln K_{t-1}$	0.451***	0.348***	0.515***
	(0.036)	(0.074)	(0.048)
$\Delta \ln Q_t$	0.096***	0.126***	0.089**
	(0.017)	(0.039)	(0.043)
$\Delta \ln Q_{t-1}$	0.060***	0.085***	0.061**
	(0.009)	(0.012)	(0.025)
$\Delta \ln UC_t$	-0.191***	-0.185	-0.314*
	(0.062)	(0.182)	(0.173)
$\Delta \ln UC_{t-1}$	-0.047***	-0.092***	-0.062*
	(0.009)	(0.022)	(0.032)
Panel B: LR coefficient			
$\ln UC$ (α_2)	-1.046***	-1.129***	-1.521***
	(0.131)	(0.122)	(0.295)
Panel C: Test (p-value)			
$\alpha_2 = 1$	0.727	0.290	0.077
Hansen test	0.315	0.095	0.255
Under-identification	0	0	0
Weak identification (F-statistic)	8.907	4.218	1.518
Year dummies	Yes	Yes	Yes
No. of groups	154	154	154
Observations	2530	2523	2524

[1] Standard errors in brackets are robust and clustered over time within country-industry pairs

[2] *** p<0.01, **p<0.05, * p<0.1

[3] In Panel C, we report the p-values of the first-stage Kleibergen-Paap rank LM test of underidentification. We also report the F statistics of the Cragg-Donald Wald test of weak identification of parameters for individual endogenous regressors.

Table E.6: First-stage regression results for Table E.5: dependent variable $\Delta \ln UC_t$

VARIABLES	(1) Total capital	(2) Equipment	(3) Structures
Instruments			
$\ln UC_{t-3}$	0.151***	0.092***	0.028
	(0.035)	(0.031)	(0.027)
$\ln UC_{t-4}$	-0.082**	-0.019	0.001
	(0.033)	(0.034)	(0.025)
$\ln UC_{t-5}$	0.055	0.019	-0.013
	(0.034)	(0.037)	(0.024)
$\ln UC_{t-6}$	-0.062**	-0.034	-0.020
	(0.026)	(0.027)	(0.019)
$\ln(K/Q)_{t-2}$	-0.018	-0.036***	-0.068***
	(0.015)	(0.014)	(0.015)
$\ln UC_{t-2}$	-0.107***	-0.126***	-0.140***
	(0.026)	(0.026)	(0.029)
$\Delta \ln K_{t-1}$	-0.040	-0.048	0.003
	(0.103)	(0.055)	(0.089)
$\Delta \ln Q_t$	0.238***	0.230***	0.217***
	(0.037)	(0.035)	(0.037)
$\Delta \ln Q_{t-1}$	0.052*	0.010	0.114***
	(0.029)	(0.024)	(0.036)
$\Delta \ln UC_{t-1}$	0.023	0.091***	-0.153***
	(0.031)	(0.032)	(0.060)
Year dummies	Yes	Yes	Yes
No. of groups	154	154	154
Observations	2530	2523	2524

[1] Standard errors in brackets are robust and clustered over time within country-industry pairs

[2] *** p<0.01, **p<0.05, * p<0.1

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