

An Alternative Estimation Framework for Firm-Level Capital Investment

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1 Introduction

There are several competing models for the estimation of investment at the firm-level, and their application to economies of transition introduces a further layer of complexity. The accelerator remains the simplest method and, for data reasons, the most commonly applied in the transition literature. It has been superseded elsewhere by more rigorous approaches, notably the q and Euler equation models, which are based on the same problem of intertemporal maximisation under convex costs of adjustment. However the evidence for convex costs of adjustment is controversial, which is significant because neither of these approaches can incorporate non-convexities. Furthermore the data requirements of both approaches are demanding, limiting their applicability to transition economies where the data from financial markets required for q models, and the large samples required for estimation of Euler equations, are rare.

Abel and Eberly [1] show that for a model of intertemporal profit maximisation with non-convex costs of adjustment capacity utilisation is a sufficient

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statistic for the presence of investment opportunities. We derive and implement a variety of Tobit estimation frameworks based on this model and find evidence to suggest that it outperforms a conventional accelerator model. We also test whether problems of access to external finance are depressing levels of investment in Poland and Romania, using Spain as a benchmark for performance. This is done through the estimation of investment-cash flow sensitivity, where there is debate as to the tenability of the standard approach of sample separation. We identify theoretical flaws in the critique and also question its validity with respect to transition economies, and therefore proceed in a conventional manner. We find evidence to suggest that capital markets are constraining the investment decisions of firms in all sub-samples with the exception of privatised firms in Romania. We interpret this as a failure to impose hard budget constraints on these firms, but the existence of alternative explanations for this result highlights the need for further analysis.

2 Theoretical considerations

The flexible accelerator model was developed in response to evidence that the firm may not fully adjust to the new optimal level of capital stock, K_t^* , due to reasons of excess capacity or incomplete adjustment through delivery lags on capital goods or uncertainty on the future level of demand. Chenery [2] and Koyck [3] derived more complex processes for how the firm may proceed along a path described by a single parameter of adjustment. These processes did not, however, explain the determination of the adjustment parameter, leaving it instead as a closed box. The crucial flaw in this approach is that variables that are postulated to influence the new optimal level of the capital stock are themselves a function of the adjustment mechanism, and as such should be included within the parametrisation of the adjustment process.

The Jorgenson extension to the flexible accelerator made some progress in addressing the neoclassical criticisms of the framework by introducing the user cost of capital but the questions of delivery lags and adjustment costs are omitted, allowing the multiperiod optimisation problem to become a static one. The most prevalent methods in current research, the q and Euler equation approaches, stem from the same base model of intertemporal profit maximisation as the neoclassical accelerator, but make assumptions about the dynamics resulting from expectations, and are therefore less subject to the Lucas critique.

The q -model uses information from financial markets to construct the ratio of the market value of the firm to the book value of its capital stock as a

proxy for the true (unobservable) variable describing investment expenditure; the ratio of the discounted future income stream from an additional unit of capital to its purchase price¹. Hayashi [4] derives the conditions under which this approximation can be made², and yet the empirical estimates have generally been unsatisfactory, where they have had low explanatory power and have yielded implausibly high estimates of adjustment cost parameters. A problem with the application of q -models is that many firms are not publicly traded and therefore marginal q is unobservable, compounded in the transition context by trading being too thin to provide reliable estimates in the small proportion of firms for which a market does exist.

The Euler equation approach avoids the problems inherent in the use of financial information by formulating the model in terms of the path of optimal investment. Using the first-order conditions of the same maximisation problem as moment conditions, and lagged variables as instruments, the model can be estimated by GMM. This method has provided more reasonable parameter estimates than have q -models, but its application remains fraught partially due to the poor small-sample properties of GMM and sensitivity to misspecification. A particular difficulty with the identification of differing financial regimes using Euler equations is that they impose only a period-to-period restriction, and therefore fail to detect restrictions that are approximately constant over time. Therefore if the firm is no more financially constrained at the current time than it expects to be in the future it will not be identified as financially constrained, although if a sample is large enough for reliable estimation by GMM this problem is likely to be mitigated.

The assumption of convex adjustment costs is critical within this class of models. Caballero and Leahy [6] show that, once non-convex costs are introduced into the model, q is no longer a positive monotonic function of investment, and is therefore not a sufficient statistic for investment³. In the Euler equation framework the introduction of non-convex adjustment costs results in the first-order conditions no longer being expressed in terms of observables, reducing the ease of estimation. In the next section we review the literature on convex versus non-convex adjustment costs, and introduce an alternative model, developed by Abel and Eberly.

¹Commonly referred to as average and marginal q respectively.

²These conditions are product and factor market competition, linearly homogeneous production and installation functions, homogeneous capital and independence of investment and financing decisions. The effect of relaxation of these assumptions has been documented in Chirinko[5].

³Under certain assumptions average q can be used under non-convex costs, although these same assumptions suggest the use of sales or profits.

2.1 The nature of adjustment costs

2.1.1 Convex adjustment costs

Eisner and Strotz [7] introduced the idea that partial adjustment may not be a result of the relative fixity of factors but rather that the firm experiences some cost of adjustment, which is increasing in the speed of the expansion or contraction undertaken. When the firm is a major buyer of the product of its capital-supplying industry it faces an upwards-sloping supply curve in the short-run, where this effect is reinforced by internal costs of adjustment as a result of lost production, reorganisation, training and suchlike. Gould [8] disagrees with this form on the basis that the purchasing price of capital goods would be independent of whether the investment was for purposes of expansion or replacing depreciated capital, such that the adjustment cost should be a function of gross rather than net investment. Although this is less so the case for internal adjustment costs, the paper argues that this formulation is superior because it imposes some cost of investment even if the firm is not expanding its capital stock⁴. As Lucas [9] points out the implication of convex adjustment costs for expansionary investment is that the firm will stagger investment over periods, similar to the predictions of incomplete adjustment in the flexible accelerator formulation.

2.1.2 Irreversibility and fixed costs

The cost function need not be symmetric and convex as postulated by Eisner and Strotz, but characterised by significant non-convexities as a result of irreversibilities or fixed costs of investment. As Chirinko argues [5, p. 1885]

”(w)ith linear or concave adjustment costs, the firm would have an all-or-nothing investment policy. Convexity forces the firm to think seriously about the future, as too rapid accumulation of capital will prove costly.”

However, the combination of non-zero costs at zero investment with asymmetry around that point removes the ”all-or-nothing” option and introduces friction into the model, where the time path of investment is no longer smooth but exhibits periods of activity and inactivity.

It is evident that some contraction in the capital stock is costless, namely that resulting from depreciation, but contraction over and above this value may be subject to high costs. This may occur where no secondary market is

⁴Chirinko [5] also notes that the external adjustment cost provides the more plausible explanation for the assumption of convexity.

existent, such as under asset specificity to a particular supply linkage, or in a weaker form through a 'lemons' effect resulting from asymmetric information, such that the value of the capital good is significantly discounted in the secondary market⁵.

There may also be costs associated with investment that are independent of the size and speed of the adjustment undertaken, creating some fixed cost of adjustment. These costs, which are internal to the firm, will be generated by the same processes such as lost production or the costs of reorganisation that create the convex costs internal to the firm, where it is arguably too strong an assumption that these costs should be strictly convex to the rate of investment undertaken.

2.1.3 Empirical evidence

There is a considerable body of evidence on the nature of adjustment costs, the majority of which has evaluated the fit between observed behaviour and that predicted by a particular cost function. The difficulty remains that these costs are unobservable and therefore their study can only be undertaken indirectly through the dynamics of the investment process. As addressed previously, a major result of convex adjustment costs is that firms will undertake 'investment smoothing' behaviour, but the evidence for this is debatable. Doms and Dunne [10] found, using a balanced panel of plants, periods of high investment activity directly followed by periods of zero investment, a result at odds with the prediction of smoothing behaviour. They show that, of total plant investment in a fourteen year period, over half of plants sampled adjusted their capital stock by at least 37% of this total in one single year, and by over 50% in two consecutive years. This should be contrasted with the finding that 45% of total investment in the sample is as a result of some 80% of firms undertaking capital adjustments of less than 10% of capital stock.

The absence of smoothing behaviour indicated by this study is further confirmed by Nilsen and Schiantarelli [11], who use an unbalanced panel of Norwegian firms and plants to examine the 'lumpiness' of investment and the incidence of periods of zero investment. They find that the distribution is best characterised by a high peak at zero, with a long, fat tail to the right. This is inconsistent with investment smoothing behaviour not only due to the mode at zero but also due to the presence of high levels of capital adjustment represented by the tail of the distribution. Their estimates of a hazard function for investment show that investment is most likely in the

⁵The failure of the neo-classical assumption of efficient secondary markets is all the more likely in the transition context.

period subsequent to another investment (probability of 39.7%), but that it declines rapidly in the following period, rising steadily to a peak at duration period 9 (39.9%). The interpretation of these results, with which they advise caution, is that there is some persistence of investment over periods as a result of convex adjustment costs, but that the swift decline of the hazard function and subsequent 'J' form indicate the importance of fixed costs in the sample observations.

Industry-wide studies cited in Cooper and Haltiwanger [12] found mixed evidence, where quadratic adjustment costs were a suitable approximation for some costs such as hiring and layoff, inventory, overtime and machine setup costs. In this paper, the authors specify a model of capital adjustment in which both convex and non-convex costs are nested, and then using indirect inference procedures on a large, plant-level panel they estimate the underlying structural parameters of the adjustment cost function. They too find that the convex adjustment cost model cannot replicate the periods of inactivity present in their sample, and that it is also unable to explain the observed non-linear, asymmetric relationship between investment and profitability⁶. Evidence is found in favour of the non-convex models which replicate the 'zeroes and lumps' nature of investment activity, and that irreversibilities can explain the asymmetry of the investment-profit linkage. They conclude that at plant-level the convex adjustment cost model performs poorly⁷, although they find that at the aggregate level non-convexities are less important.

2.2 Capacity utilisation

Although the inclusion of capacity utilisation is ubiquitous in macroeconomic models of investment, at the firm level it is a variable that has largely been ignored. This may be a result of the difficulty of interpreting utilisation rates, where the question of what the boundary case of 100% actually represents is complex, such that significant measurement error may be present in the variable. It will also be influenced by the infrequent reporting of actual capacity utilisation rates, where often a KLEM model is used to estimate the utilisation rate on the assumption that it is proportional to the consumption of a factor input, commonly electricity usage.

Chenery, in order to explain the observed occurrence of partial adjustment in the accelerator model, developed a model using the informational content of capacity utilisation rates. He assumes that there are two types of fixed

⁶This non-linearity is also found by Barnett and Sakellaris [13] who identify three regimes in the responsiveness of investment to changes in average q .

⁷Koeva [14] finds that at plant-level the omission of time-to-build considerations will lead to overestimation of the convexity of adjustment costs.

capital; one of which is large and indivisible with respect to the production process, the other not. Under this assumption it is optimal for a firm to operate at some level of overcapacity in the indivisible type of capital in order to be able to vary the other in response to fluctuations in demand, thereby minimising costs and avoiding being constrained by delivery lags and time-to-build factors. If the level of current output is produced at a higher than optimal level of utilisation the firm will invest, where the rate at which it does so is determined by a parameter describing the expectations on the change in output that created the increase in the utilisation rate. He found that the model of 'optimal overcapacity', had greatest explanatory power in those industries where the accelerator model had least, suggesting a linkage between capacity utilisation and investment rates.

2.2.1 A model of investment incorporating capacity utilisation rates

Abel and Eberly [1] derive a model of investment where the firm optimally chooses the timing and rate of investment, where doing so incurs adjustment costs in the form of fixed costs and irreversibilities. In between these periods of investment activity the firm is able to costlessly adjust the utilisation rate of the factors in response to underlying stochastic state variables, and is also able to adjust the level of the flexible factor, labour. As a result the length of the Marshallian short run, where the firm does not alter its capital stock except through depreciation, is endogenous and a function of the state variables and capital adjustment costs, and may not exhibit the persistence of the convex adjustment cost models⁸.

We assume a profit-maximising firm, operating a market with a downwards-sloping, isoelastic, demand curve, with finite elasticity of demand $\epsilon > 1$.

$$Q^d = \left(\frac{P}{X_1} \right)^{-\epsilon}$$

This demand curve is subject to a shock, X_1 , which evolves according to geometric Brownian motion. The firm produces output, Q , using two factors of production, capital, K , and labour, L , where it chooses how much of each to employ, as well as a common utilisation rate, u . We assume a Cobb-Douglas production function, subject to a productivity shock, X_2 , that also evolves according to geometric Brownian motion (gBm)

$$Q = X_2 u^\nu K^\beta L^\alpha, \quad 0 < \nu \leq \alpha + \beta \leq 1$$

⁸We only give an outline of the model because the full model is too complex to report here, and therefore refer the reader to the original article.

This implies the profit function for the firm

$$\pi(X, u, K, L) = X (u^\nu K^\beta L^\alpha)^{1-\frac{1}{\epsilon}} - \omega u^\eta L - m u^\rho K, \quad \frac{\nu}{\alpha} > \eta \geq 1, \rho \geq 1$$

where X is a composite shock to the revenue function, $X \equiv X_1 X_2^{1-\frac{1}{\epsilon}}$. ω and m are the standardised unit operating costs of labour and capital respectively, where both evolve according to geometric Brownian motion. To determine profit maximisation we combine these shocks and costs into a single variable, which being a product of variables evolving according to gBm does too, Z , defined as

$$Z \equiv \left[\omega^{-\alpha\rho(1-\frac{1}{\epsilon})} m^{-(\nu-\alpha\eta)(1-\frac{1}{\epsilon})} X^\rho \right]^{\frac{1}{(1-\theta)\Delta}}$$

where $\Delta \equiv \rho - [\nu + \alpha(\rho - \eta)](1 - \frac{1}{\epsilon})$ and $\theta \equiv \frac{1}{\Delta}(1 - \frac{1}{\epsilon})[\beta\rho - (\nu - \alpha\eta)]$. We can express profit maximisation by the firm as

$$\pi(Z, K) = A_\pi Z^{1-\theta} K^\theta$$

$$\text{where } A_\pi \equiv \frac{\Delta}{\rho} \left[\left(1 - \frac{1}{\epsilon}\right)^{\frac{1}{\Delta}(1-\frac{1}{\epsilon})[\nu+\alpha(\rho-\eta)]} \left(\frac{\nu-\alpha\eta}{\rho}\right)^{\frac{1}{\Delta}(1-\frac{1}{\epsilon})(\nu-\alpha\eta)} \alpha^{\frac{\rho\alpha}{\Delta}(1-\frac{1}{\epsilon})} \right].$$

Therefore the value of the firm is given by

$$\max_{\{t_i, \Delta K_{t_i} \geq 0\}} E_t \left(\int_0^\infty A_\pi Z_{t+s}^{1-\theta} K_{t+s}^\theta e^{-rs} ds - \sum_{t=1}^\infty e^{-r(t_i-t)} (p\Delta K_{t_i} + Z_{t_i} F) \right)$$

where r is the discount rate, p the price of capital goods and $Z_{t_i} F$ the fixed cost of adjustment that the firm pays for installing capital, where the proportionality to the compound cost variable, Z , prevents this cost from becoming either trivial or too large as K_t rises and falls. The value function of the firm is homogeneous of degree one in Z and K , so the value function can be written as

$$V(K, Z) = K v(y), \quad y \equiv \frac{Z}{K}$$

where y is a sufficient statistic for the firm's investment decision. The firm does not undertake investment unless, through shocks in the system, this state variable rises above a trigger value, b , when it returns the state variable to a target value, c , where these values are determined by the costs of adjustment that the firm faces when it does invest. It can be shown that capacity utilisation

$$\frac{Q}{Q^*} = \left(\frac{y}{b}\right)^{\frac{\nu+\alpha(\rho-\eta)}{\rho}(1-\theta)}$$

where Q^* is capacity output⁹ and b the trigger value, is a positive monotonic function of the state variable, y , and therefore must also be a sufficient statistic for the investment decision. The implication of this result is that we can formulate an investment equation where capacity utilisation is included as an explanatory variable based on a model with explicit adjustment dynamics in the optimisation problem, rather than the Chenery model which assumes an unexplained adjustment parameter.

2.3 Financing constraints

A major and consistent result of studies into firms in transition economies is the importance of finance for restructuring and subsequent performance. Recent surveys have shown that the availability of external finance continues to constrain firms, dampening investment levels and suppressing performance [15]. EBRD indicators suggest that the development of the financial sector in both transition countries included in the dataset used in this paper is above average for transition countries as a whole, although we expect some level of constraint to exist, with differentials both intranationally and internationally.

The importance of internal cash flow for determining investment behaviour was already identified by Tinbergen [16], although he found little evidence to support his intuition. This was later taken on by Kuh [17], who developed a liquidity accelerator model, and later variations on this theme were more successful¹⁰. Much of this strand of theory was based on intuition, without the formulation of a base model. However a link can be made between these early forays and the hierarchy of finance models, e.g. Myers and Majluf¹¹. Kuh's model illustrates one of the difficulties in the assessment of the presence of financing constraints, because he shows that an accelerator where cash flow is the only independent variable included has power in explaining the level of investment undertaken, and is therefore an indicator of the existence of an investment opportunity for firms. As a result, for differ-

⁹The definition of capacity output in this model requires clarification in that it is the greatest level of output that can be produced with the current capital stock without triggering investment.

¹⁰Eisner [18] found that the level of internal funds was strongly significant for the timing of investment, but not its magnitude.

¹¹If the Modigliani-Miller result does not hold (commonly used reasons are taxation or the presence of capital market imperfections such as transaction costs) then there will be a differential between the cost of internal and external finance, and also between the cost of debt and equity finance through the presence of information asymmetries. It is argued therefore that there should be a link between the financial structure of a firm and its investment decision, where the cheaper the finance available the more investment will be undertaken due to the lower required rate of return.

ences in coefficients on the cash flow variable to accurately identify varying access to external finance the variable intended must control for the effect of investment opportunities, and with minimal variance in its explanatory power across firms¹².

There is considerable debate currently on the question of investment-cash flow sensitivity, and the article by Fazzari, Hubbard and Petersen [21] is generally considered to be the root of current microeconomic research. They introduced the approach of separating the sample into groups based on *a priori* beliefs on the level of constraints. They based their priors on the level of the dividend payment, where they argue that the payment of low dividends (in 67% of the sub-sample zero dividends) indicates a high rate of retained earnings so as to finance investment, where this cannot be done by other sources. This approach is problematic, in that it contradicts the results of Lintner [22] who found considerable 'stickiness' in the level of dividends paid, such that this separation would be a result of historic preferences, and may be country-specific [23] or time-specific¹³. However, they find evidence that those firms paying low dividends experience substantially greater sensitivity of investment to cash flow, where this result is robust across all investment function specifications which they estimated¹⁴.

This result is, however, disputed by Kaplan and Zingales [24], who use the same sample of firms but different separation criteria to reverse the previously reported result. The crux of the Kaplan-Zingales critique is that the assessment of financing constraints through the estimation of investment-cash flow sensitivities makes the assumption that this sensitivity should increase monotonically with the level of constraint. They originally showed in their 1997 paper how exceptions to this may exist, basing their argument on the strong, and in our view unrealistic, assumption that the gradient of the marginal cost schedule for external finance is common across all firms. Their 2000 paper [25] goes further to hypothesize that the marginal cost is decreasing in the volume of external financing, citing evidence from Stafford [26]. This result contrasts strongly with the hierarchy of finance literature (in which finance raised externally is minimised because of the increasing marginal cost)

¹²Furthermore the cash-flow variable must be lagged so as to avoid possible problems of endogeneity. See Schiantarelli [19] and Chirinko and Schaller [20] for a comprehensive review of articles and associated difficulties.

¹³In the recent U.S. bull market, rather than semi-permanent increases in dividends, firms generally opted for share buybacks or mergers and acquisitions to transfer wealth to shareholders.

¹⁴They estimated across the triumvirate of investment functions: accelerator, neoclassical and q functions. It should be noted that the t-statistic is consistently higher for estimation of q-models, suggesting that the control for investment opportunities is superior in this class of models to the other two.

and is described by the target-adjustment theory, in which firms, once they overcome the fixed transaction costs of raising external finance, use it as a means to increase working capital to a specific target, as opposed to minimising the volume raised. The implication of this decreasing marginal cost of external finance is that investment activity will be constrained by the value of internal cash flow only up to the point at which external funds must be sought, such that investment and cash flow sensitivity could be either positively or negatively related. However the evidence from Stafford in favour of the target-adjustment model is based on a particular sub-sample of investing firms; those Value Line firms undertaking extraordinary investments. As Stafford himself concludes "to the extent that Value Line firms are relatively free of informational asymmetries, it seems unlikely that these can be the driving force of their financial policies". Therefore the applicability of this result to the study of differential financing constraints generated through asymmetry is debatable because Stafford selects his sample so as to minimise this possibility.

This result may also be less applicable to the transition economies where the lower stage of development of capital markets would be expected to have an effect. In the sample used by Stafford 89.2% of external finance was raised through debt issuance and 10.8% through equity issuance. This result cannot be replicated in transition economies where corporate debt markets are too thin to raise significant capital, such that the major component of external finance continues to be bank-based. In this case the standard result of a rising marginal cost of external finance, due to increasing risk of bankruptcy and moral hazard problems, would provide a more realistic model. Furthermore, within the context of Stafford's rationale, the level of informational asymmetries and structural impediments would be significantly greater

In this paper we expect firstly that the availability of external finance will vary across countries, where Spain will have the lowest cost access. The greater development of financial markets in Poland than in Romania [27] would be expected to result in a lower investment-cash flow sensitivity in Poland as a result of lesser informational asymmetries, although it is clear that the possible extension of preferential rates in the less developed market may reverse this result. We also hypothesize that ownership of the firm will be a determining factor in access to external finance¹⁵, where we expect state-owned firms to experience a lower or flatter cost schedule as a result of reduced risk of bankruptcy or lesser information asymmetries¹⁶. Privatised

¹⁵This approach has been common in the study of investment in transition countries, applied amongst others by Lizal and Svejnar [28] and Anderson and Kegels [29].

¹⁶This may result either from size effects of the extension of soft budget constraints.

firms may be able to raise external finance at a lower cost than ab initio firms as a result of reduced information asymmetries through having a longer period of incorporation and relations with banks, but this benefit may be counteracted by doubts about the political independence of decision-making by the privatised enterprise.

2.4 Model choice

The estimation of an accelerator model remains common in transition literature because of the previously described difficulties associated with q and Euler equation models. Not all attempts to identify an accelerator mechanism in transition have been successful however, where Anderson and Kegels [29] only find evidence to support a Kuh-type cash flow-accelerator. As Bratkowski, Grosfeld and Rostowski [30] argue past production may not be a good indicator of the future profitability of investment under volatile demand conditions such as those of transition, and therefore a sales accelerator may not control with any precision for the presence of investment opportunities.

The Abel and Eberly model does however provide an alternative, and one which both explicitly models the adjustment mechanism and the taking of expectations, and as such is a model more in keeping with current trends in the modelling of investment behaviour. It also has certain departures from the accelerator, which we show with two simple examples¹⁷. If we assume that the environment described by the Abel and Eberly model is representative of the "true" world:

- For a firm experiencing positive demand shocks, both the rate of capacity utilisation and the value of sales variable will increase. Under the accelerator formulation investment will occur because of the positive change in sales, whereas in the "true" world the magnitude of the positive demand shock may not be sufficient to induce the firm to undertake investment because the trigger value is not exceeded.
- If in a particular period the firm is not subject to any exogenous demand shocks the capital stock reduces through depreciation. To provide the same flow of capital services the utilisation rate of the capital stock must rise, but since the cost of capital services is an increasing function of the utilisation rate, the cost of this capital flow rises. The shift in the cost schedule for a profit-maximising firm in a market with a downwards sloping demand curve results in a fall in the level of output, where since

¹⁷For expositional simplicity we ignore the presence of productivity shocks.

$\varepsilon > 1$ the value of sales will fall. Therefore the neoclassical accelerator will predict disinvestment, but actually inactivity will result until the capital stock has depreciated to the point that capacity utilisation is equal to the trigger value, at which point investment occurs.

In the first example the accelerator does not account for the hysteresis of investment that is generated through the presence of non-convex costs of adjustment, but in the second the two models imply, at the point when adjustment does occur, opposite effects on the level of investment expenditure. The inclusion of capacity utilisation as a regressor in investment estimations should therefore provide more information than an accelerator term.

3 Methodology

3.1 Distributional assumptions

We have shown above that the state variable, y , is a linear function of the aggregate price and shock variable, Z , which evolves according to geometric Brownian motion and a constant, the capital stock. Therefore y should share the same distribution as Z , which is lognormally distributed. Since capacity utilisation is a non-linear function of y we cannot make as direct a link, but instead make the first-order approximation that it is normally distributed.

According to the theory, investment must be a positive monotonic function of capacity utilisation because the higher the utilisation rate, the further the firm will be from the target value to which it returns the state variable. Therefore we make a second approximation that it too is normally distributed at values superior to the trigger value. This normal distribution is truncated at κ , where κ is just greater than zero, because gross investment can only take non-negative values. Firms for whom the shock or change in costs described by Z is negative or insufficiently positive to take it above the trigger value are observed to undertake zero gross investment, the probability of which is described by a jump function. The theoretical model predicts that this probability will be declining in capacity utilisation, because as capacity utilisation rises each firm will be ex ante closer to its trigger value, such that a smaller shock is required to take it outside the zone of inactivity. Therefore we estimate the model using a mixed distribution composed of a single probability of observing zero investment and a normal distribution for firms undertaking positive values of investment.

3.2 Estimation procedure

The Tobit is also a mixed model composed of a discrete and a continuous distribution which imposes the constraint that the regressors and coefficients of both distributions are the same. The model outlined above suggests that capacity utilisation should be an explanatory variable in both distributions, but that simplification that the response of investment to changes in capacity utilisation is linear may be too restrictive. We therefore use a more general model where the coefficients may be different for the firms undertaking investment activity from those which do not, introducing a simple non-linearity to the response function, making the extension suggested by Heckman that there should be some selection process present. The Tobit II [31] model consists of two main parts, a structural equation and an index equation. The structural equation describes the latent, unobserved, dependent variable;

$$y_i^* = \beta_1' x_{1i} + \varepsilon_{1i} \quad (1)$$

where y_i^* denotes desired investment rates and x_{1i} the vector of exogenous variables which we postulate determine the level of investment. The question of observation is dependent on a threshold equation

$$d_i^* = \beta_2' x_{2i} + \varepsilon_{2i} \quad (2)$$

where if $d_i^* > 0$ we observe investment rate y_i , and if $d_i^* \leq 0$ we observe investment level $y_i = 0$, such that d_i is a one-zero variable describing whether investment occurs or not. The intuition of this model is that we have one equation which describes whether a firm invests or not, and a second which, if investment does occur, determines how much. We assume the errors $(\varepsilon_{1i}, \varepsilon_{2i})$ to be bivariate normally distributed with expectations zero, variances σ_1^2 and 1 respectively, and correlation coefficient ρ . If $\rho = 0$ the two decisions of whether to invest and how much to invest are independent, and if $\rho = 1$ we have a univariate distribution such that the two are effectively the same decision and no selection process is present. If this is the case, we then can make the restrictive assumption that $\beta_1' x_{1i} = \beta_2' x_{2i}$ and $\varepsilon_{1i} = \varepsilon_{2i}$ such that the model simplifies to a standard Tobit procedure.

The likelihood function for the Tobit II model is given by

$$L = \prod_0 \Phi(-\beta_2' x_{2i}) \prod_1 \left\{ \Phi \left(\frac{\beta_2' x_{2i} + \frac{\rho}{\sigma} (y_i - \beta_1' x_{1i})}{\sqrt{1 - \rho^2}} \right) \frac{1}{\sigma} \phi \left(\frac{(y_i - \beta_1' x_{1i})}{\sigma} \right) \right\}$$

where \prod_0 stands for the product of those i for which $y_i = 0$ and \prod_1 for those where $y_i \neq 0$, and Φ the cumulative density function and ϕ the probability distribution function respectively.

However our use of gross investment rates adds a further complication because it is censored at zero such that in estimating the index equation we do not know whether a zero is a "true" zero. Following Jones [32] we can express the model as

$$\begin{aligned}
y &= y^* = \beta'_1 x_{1i} + \varepsilon_{1i} && \text{if } \beta'_1 x_{1i} + \varepsilon_{1i} > 0 \text{ and } \beta'_2 x_{2i} + \varepsilon_{2i} > 0 \\
&= 0 && \text{if } \beta'_1 x_{1i} + \varepsilon_{1i} \leq 0 \text{ and } \beta'_2 x_{2i} + \varepsilon_{2i} > 0 \\
&&& \text{or, } \beta'_1 x_{1i} + \varepsilon_{1i} > 0 \text{ and } \beta'_2 x_{2i} + \varepsilon_{2i} \leq 0 \\
&&& \text{or, } \beta'_1 x_{1i} + \varepsilon_{1i} > 0 \text{ and } \beta'_2 x_{2i} + \varepsilon_{2i} \leq 0
\end{aligned}$$

where " $\beta'_1 x_{1i} + \varepsilon_{1i} \leq 0$ and $\beta'_2 x_{2i} + \varepsilon_{2i} > 0$ " describes a zero as result of censoring, and not due to the threshold, a "false" zero. This model stems from the Cragg [33] double-hurdle model, although it makes the extension that the two error terms are dependent. The likelihood function for this model is given by

$$\begin{aligned}
L &= \prod_0 (1 - \Phi(\beta_2 x_2, \beta_1 x_1 / \sigma, \rho)) \\
&\quad \prod_1 \left\{ \Phi \left(\frac{\beta_2 x_2 + \frac{\rho}{\sigma} (y - \beta_1 x_1)}{\sqrt{1 - \rho^2}} \right) \frac{1}{\sigma} \phi \left(\frac{(y - \beta_1 x_1)}{\sigma} \right) \right\}
\end{aligned}$$

3.3 Data description

The data used is the product of a European Bank for Reconstruction and Development survey assessing the cost of progress towards EU accession for a sample of approximately 200 firms in each of Poland, Romania and Spain, where the last, a relatively low-income EU member, provides a benchmark for performance. The dataset also contains information on the financial status and labour and capital stocks and flows for the period 1995 through to 1997, from which we isolate the variables needed for our investment equation.

Certain procedures have been followed to identify problem observations, where this had led to reduction in the number of firms to 69, 113 and 117 firms for Poland, Romania and Spain respectively. We have excluded firms for which we do not have observations across all three time periods, or for which we have missing values. The most significant problem, however, is that of inconsistency between reported investment and capital stock, where in many cases either variable may be incorrect such that we cannot identify the most likely error.

The major implication of this reduction in the number of observations in the dataset is that it is no longer possible to estimate the investment equation by sub-samples because they are too small for precise estimation. Therefore

we pool the data, using country and ownership dummies to distinguish between the effects on the different sub-samples. It should be noted that Spain is treated as a homogeneous group as regards ownership because almost all firms are *ab initio* private firms, with the exception of two state-owned and one privatised firm which we have excluded rather than attempting to control for them.

An important choice made in this paper is to estimate the investment function using gross investment as the dependent variable, where in preceding papers either gross or net is used, often treating the two as interchangeable. The difficulty in this approach is in the calculation of net investment: when taken from balance sheet data as is often done it ignores the fact that reported depreciation is, to all extents and purposes, a choice variable determined by issues of taxation. Calculation through intertemporal changes in the reported stock of capital are relatively stable in developed economies, but where issues such as high inflation (in particular of producer prices) and the vintage of capital stock are present the link between changes of stock and the flow of investment expenditure is more fraught. It is for these reasons that we attempt to minimise these issues through the use of reported gross investment.

A major problem associated with the estimation of investment equations is the noise present in the data, where investment is a volatile process. Furthermore the use of annual point estimates for investment is difficult because of a lag between the time of purchase and the operational inception of the new capital. In order to reduce this effect we smooth the data by using between estimates, constructed as the average of the observations for 1996 and 1997¹⁸. In the case of cash flow where we require a lag due to reasons of endogeneity, we use the one period lag of cash flow in 1995¹⁹.

4 Estimation results

4.1 Model structure

In order to facilitate estimation of the double-hurdle model we do not include all variables in both the structural and the threshold equations, but make identifying restrictions. According to the model being tested capacity utilisation is both a determinant of the probability of undertaking investment

¹⁸All variables have been deflated by producer price indices, and are expressed in 1995 constant prices.

¹⁹We construct cash flow by calculating EBITD (earnings before interest, tax and depreciation).

activity and the level of investment if undertaken, and as such should be present in both equations. We postulate that cash flow should only have an impact on the level of investment undertaken and not on whether there is investment activity because if the firm has sufficient productive assets such that it does not wish to invest, levels of internal finance will be of no consequence. The effect of insufficient internal funds to finance desired investment will be picked up by cash flow variables included in the structural equation, even where a firm that is so highly financially constrained such that desired investment is forced to zero²⁰. This would suggest that the structural equation should contain both capacity utilisation and cash flow, interacted with ownership and country dummies, whereas the threshold equation includes just capacity utilisation and the dummies²¹.

Using the likelihood function given above, we estimate a double-hurdle procedure, finding support for our hypotheses. However numerical evaluation of the model is complicated by singularity of the inverse Hessian, such that we proceed with a more simple procedure.

4.1.1 Tobit II (or not Tobit II)

We initially specify the most general system, including all possible cash flow variables, so as to test our structural model, where the results are reported in Appendix B. The sensitivity of the Tobit II process is well documented, where it may fail to converge to correct values²², but more importantly in this model is the problem of specification of the threshold equation. Monte Carlo simulations by Flood and Gråsjö [34] show that for a Tobit II data generation process if the threshold equation is incorrectly specified through the omission of variables, Tobit II estimation is biased and Tobit I performs

²⁰This special case also requires the firm to have no stock of retained earnings as well as negative cash-flow in prior periods, such that it has no working capital.

²¹A further problem associated with previous estimation of the incidence of cash flow constraints in transition economies, most notably that of Anderson and Kegels [29], is the interpretation of coefficients across separate sub-samples. Using this methodology it is not possible to draw comparisons because all else is not being held constant, such that we could, and do, observe large variations in the coefficients on other included variables across the samples. We therefore apply a more restrictive form, seeking to identify whether specific types of firm have cash flow sensitivities significantly different from the mean, rather than the previous approach which actually tests for a cash flow accelerator in sub-samples.

²²The STATA[®] manuals report a failure to converge on a dataset generated by a Heckman process.

better because it excludes the misspecified equation²³. Given these problems in the estimation of the model, we must use caution when interpreting the estimation results.

We find support for our model incorporating capacity utilisation rates, where it is significant in both equations determining both the choice of whether to invest or not and the level of investment observed if undertaken. It should also be noted that the classical accelerator change-in-sales variable is statistically insignificant in the threshold equation where we omit it from further estimation, but is significant in the structural equation²⁴. This does therefore suggest that the presence of a profitable investment opportunity is not fully controlled for by the use of capacity utilisation. We find support for our hypothesis that the cash flow should only impact the level of investment undertaken and not the binary choice because the cash flow variable is insignificant in the threshold equation. We have also controlled for the possibility that the ownership of firms will influence the likelihood that they invest, but find ownership dummies to be insignificant in the threshold equation. We retain them, despite insignificance, in the structural equation because of interactions with cash flow. The significance of country dummies in explaining the binary decision to invest supports a hypothesis of high levels of investment being undertaken in transition countries.

The estimated coefficient on the inverse Mills ratio (λ) is significant, supporting the existence of a selection process. In contrast to this, the reported correlation coefficient of the two error terms (ρ) is equal to one, i.e. they are perfectly correlated. As addressed previously this implies that the decision whether to invest is the same as that of how much to invest, and therefore can be described by a univariate distribution. However, the estimated standard error of 5×10^{-16} on the corner solution for ρ suggests estimation problems, such that we also model the system with the less sensitive Tobit I procedure²⁵.

| | Bias (%) | Estimation procedure | |
|-------------------------|----------|----------------------|----------|
| | | Tobit I | Tobit II |
| ²³ Intercept | | -63.1 | 12.6 |
| $x_1(x_1=x_2)$ | | 32.0 | 3.8 |
| $x_1(x_1 \neq x_2)$ | | 9.6 | -72.2 |

[34]

²⁴The LR statistic for the full model against the parsimonious model is 5.2 (χ_4^2).

²⁵Which is in itself suggested by the correlation coefficient being equal to one.

4.1.2 Tobit I

A standard Tobit model excludes the threshold equation, having the simpler form of

$$\begin{aligned} y_i &= \beta'x_i + u_i \text{ if } y_i > 0 \\ y_i &= 0 \text{ otherwise} \end{aligned}$$

where the likelihood function for the model is given as

$$L = \prod_0 (1 - \Phi\left(\frac{\beta x}{\sigma}\right)) \prod_1 \left\{ \frac{1}{\sigma} \phi\left(\frac{(y - \beta_1 x_1)}{\sigma}\right) \right\}$$

Heckman [35] shows that a result of ignoring the possibility of a selection process is that variables that do not belong in the true structural equation may appear significant in the determination of the dependent variables if their impact on the choice of whether to invest or not is not isolated. Given that our best estimate of the determinants of the selection process are a subset of those in the structural equation we retain the same independent variables for Tobit I estimation as used in Tobit II estimation.

The results, reported in Appendix C, support the use of capacity utilisation as a proxy for the profitability of investment activity, where it is highly statistically significant. The accelerator term is, however, no longer significant, such that we omit it from subsequent estimation. The strong, positive, significance of the dummies for Poland and Romania again show that investment levels are higher across the board in these countries as compared to Spain, such that we interpret this as a result of the need to restructure. However the possibility remains that we have omitted structural variables common to transition countries from the estimation procedure, where their effect is incorporated into these constant terms. Furthermore we find no evidence to suggest that the form of ownership influences investment except where interacted with cash flow variables, the insignificance of the ownership dummies suggesting that no particular group is more likely to undertake investment.

4.2 Are firms financially constrained?

We consistently find that cash flow is a significant explanatory variable in the level of investment undertaken. This can be interpreted as an indication of the presence of a wedge between internal and external sources of finance, and that firms are constrained in their access to external finance. However we also remain aware of the possibility that this result indicates weakness in controlling for investment opportunity.

The results of Tobit II estimation broadly support our priors as to the differentials in access to external finance across the sub-samples of firms. We find that all Romanian firms exhibit investment-cash flow sensitivity, which for state owned and privatised firms is greater than the mean, possibly reflecting the relative development of financial markets. Amongst Polish firms, all of which exhibit investment-cash flow sensitivity less than the mean, state owned enterprises are the least constrained in their access to external finance, possibly the result of preferential treatment. The result that Polish privatised firms have greater investment-cash flow sensitivity than ab initio private firms is unanticipated, but may be a reflection of residual doubts in financial markets about the autonomy of these firms. Although Tobit I estimation is less effective in identifying differences across the sub-samples, the results are qualitatively similar, with the notable exception of Romanian privatised firms which is the only sub-sample with sensitivity statistically different from the mean. Where relative measures of financing constraints have remained the same for most categories, Romanian privatised firms are less constrained than the mean, where previously the converse was the case.

Furthermore our finding that the remainder of the population of firms are constrained also requires careful interpretation, where a number of different alternatives are possible. It may be that the case that these firms all experience similar conditions in external capital markets, but we suggest that this is too strong a conclusion. We expect, for reasons of financial market development, that there may be different effects present in each country. It is plausible that Spanish financial markets operate more effectively, such that the result may be driven by poor quality firms in the Spanish sample which are unable to raise external capital and are therefore constrained. It may also be a reflection of the stock of capital present in the Spanish market, where transition economies have been aided by significant flows of foreign direct investment.

5 Conclusions

In this paper we have used a population of firms from Poland, Romania and Spain to test an alternative model of investment, which we have specified using capacity utilisation rates. We show that this model performs better than a standard accelerator formulation, where we find under some estimation procedures that a change-in-sales variable is insignificant. Although we expect that a selection process is present in the model, where firms that do not invest are different from those that do, we have difficulty in estimating this effect. We attribute this to possible misspecification as well as to

small sample size, and therefore replicate our estimation using a more robust procedure. Further research into this model is clearly required to assess its validity, where a dataset with larger samples and a greater time dimension would add to our understanding, and this paper represents only a preliminary exploration of the Abel and Eberly model.

In terms of applied results we find that investment levels in the transition countries are significantly higher than those observed in Spain, but are unable to identify strong differences amongst ownership categories within these countries. However, we do observe differences in sensitivity to internal cash flow where we have taken a pessimistic view, suggesting that there is evidence that capital markets are not functioning adequately in transition economies. This occurs where *ab initio* firms are financially constrained by lack of access to external finance and, we suspect, in a lack of discipline imposed on firms that are able to exercise positional power. Other studies on this question by Lizal and Svejnar [28] and Anderson and Kegels [29] show the importance of including further financial variables such as firm payables and receivables, where these influence both the specification of the model and the results with respect to the question of financing constraints. We cannot replicate this result and therefore suggest that these effects should be taken into account when interpreting the estimation, as well as the issues raised by the Kaplan-Zingales critique before drawing significant policy conclusions.

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A Data

| Variable | | Mean | Standard deviation | N |
|-------------------------|--------------|---------|--------------------|-----|
| Gross investment | | .12071 | .15978 | 299 |
| Capacity utilisation | | 77.339 | 17.869 | 299 |
| Δ sales | | -.01647 | 1.0485 | 299 |
| Cash flow ⁻¹ | Full | .33734 | .45960 | 299 |
| | Spain | .34937 | .40272 | 117 |
| | Pol. ab ini. | .43567 | .60126 | 17 |
| | Pol. pri. | .19689 | .18207 | 36 |
| | Pol. soe. | .33218 | .57018 | 16 |
| | Rom. ab ini. | .52031 | .63734 | 37 |
| | Rom. pri. | .30112 | .50641 | 51 |
| | Rom. soe. | .22288 | .31255 | 25 |

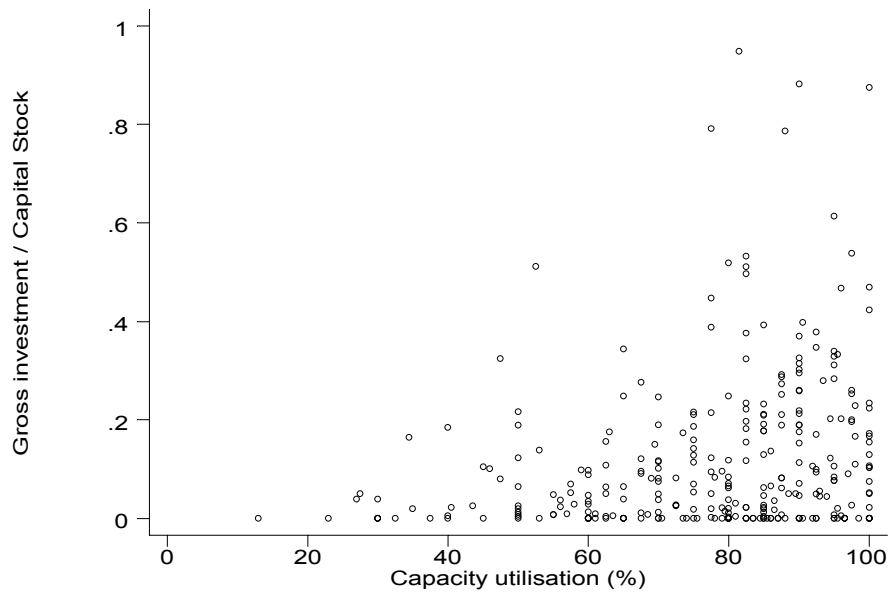


Figure 1: Investment and capacity utilisation rates

B Tobit II results

B.1 Full model

| Equation | Variable | | Coefficient | Standard error |
|------------|-------------------------|--------------|-------------|----------------|
| Structural | Cap. util. | | .00267*** | .00062 |
| | Δ Sales | | .02334 | .01540 |
| | Cash flow ⁻¹ | Full | .08367** | .03666 |
| | | Pol. ab ini. | -.05703 | .07653 |
| | | Pol. pri. | .02699 | .03258 |
| | | Pol. soe. | -.09493** | .04331 |
| | | Rom. ab ini. | -.01011 | .03270 |
| | | Rom. pri. | .06928 | .07685 |
| | | Rom. soe. | .10819*** | .02754 |
| | | Ab initio | .07464* | .04127 |
| | | Privatised | .01554 | .03353 |
| | | Poland | .19713*** | .04398 |
| | | Romania | .09159** | .03707 |
| | Constant | | -.26935*** | .06644 |
| Threshold | Cap. util. | | .01394*** | .00379 |
| | Δ Sales | | -.03064 | .18681 |
| | Cash flow ⁻¹ | | .25555 | .22638 |
| | Ab initio | | .41583* | .23262 |
| | Privatised | | .27414 | .18022 |
| | Poland | | 1.0299*** | .25515 |
| | Romania | | .39831 | .26042 |
| | Constant | | -1.3789*** | .43489 |
| | | Rho | | 1.0000 |
| | Sigma | | .1704319 | .01566 |
| | Lambda | | .1704319 | .01566 |

*, **, *** represent significance at the 10, 5 and 1 percent levels respectively. Standard errors are Huber-White robust.

B.2 Parsimonious model

| Equation | Variable | | Coefficient | Standard error | |
|------------|-------------------------|--------------|-------------|----------------|--------|
| Structural | Cap. util. | | .00313*** | .00067 | |
| | Δ Sales | | .03025** | .01250 | |
| | Cash flow ⁻¹ | Full | | .04045*** | .00247 |
| | | Pol. ab ini. | | -.02181* | .01140 |
| | | Pol. pri. | | -.00646** | .00265 |
| | | Pol. soe. | | -.08072** | .03337 |
| | | Rom. ab ini. | | -.00837 | .01287 |
| | | Rom. pri. | | .12042** | .06156 |
| | | Rom. soe. | | .13332*** | .01032 |
| | | Ab initio | | .03737*** | .01341 |
| | Privatised | | -.00896*** | .00333 | |
| | Poland | | .18508*** | .03763 | |
| | Romania | | .08023*** | .02739 | |
| Constant | | -.25924*** | .06220 | | |
| Threshold | Cap. util. | | .01634*** | .00350 | |
| | Poland | | .74918*** | .16950 | |
| | Romania | | .32162*** | .14100 | |
| | Constant | | -1.0949*** | .32067 | |
| | Rho | | 1.0000 | 0.0000 | |
| | Sigma | | .17253 | .01705 | |
| | Lambda | | .17253 | .01705 | |

*, **, *** represent significance at the 10, 5 and 1 percent levels respectively. Standard errors are Huber-White robust.

C Tobit I results

C.1 Full model

| Variable | | Coefficient | Standard error |
|-------------------------|--------------|-------------|----------------|
| Cap. util. | | .00271*** | .00069 |
| Δ Sales | | .01104 | .01185 |
| Cash flow ⁻¹ | Full | .11049*** | .04165 |
| | Pol. ab ini. | -.08108 | .07811 |
| | Pol. pri. | -.03081 | .15364 |
| | Pol. soe. | -.11090 | .08504 |
| | Rom. ab ini. | -.02775 | .06079 |
| | Rom. pri. | -.10299 | .07231 |
| | Rom. soe. | .09152 | .11695 |
| Ab initio | | .07380 | .04838 |
| Privatised | | .04890 | .04307 |
| Poland | | .19166*** | .04489 |
| Romania | | .09257** | .04066 |
| Constant | | -.28091*** | .06815 |
| Standard error | | .17383 | .00844 |

C.2 Parsimonious model

| Variable | | Coefficient | Standard error |
|-------------------------|--------------|-------------|----------------|
| Cap. util. | | .00274*** | .00069 |
| Cash flow ⁻¹ | Full | .11601*** | .04130 |
| | Pol. ab ini. | -.07990 | .07822 |
| | Pol. pri. | -.04239 | .15342 |
| | Pol. soe. | -.11260 | .08516 |
| | Rom. ab ini. | -.03328 | .06063 |
| | Rom. pri. | -.12692* | .06780 |
| | Rom. soe. | .07936 | .11640 |
| Ab initio | | .07666 | .04838 |
| Privatised | | .05203 | .04302 |
| Poland | | .19319*** | .04494 |
| Romania | | .08855** | .04050 |
| Constant | | -.28448*** | .06821 |
| Standard error | | .17411 | .00846 |

*, **, *** represent significance at the 10, 5 and 1 percent levels respectively.