An Alternative Estimation Framework
for Firm-Level Capital Investment *

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February 2006
Discussion Paper 2006/02

Abstract

Our understanding of the effect of investment-financing constraints in transition economies faces significant problems, both in terms of choice of the underlying theoretical model of investment behaviour and in the estimation framework adopted. These problems drive the choice in this paper of implementing a double hurdle estimation routine based on the Abel and Eberly (1998) investment model. We find evidence that a model incorporating intermittent adjustment of capital stock and using rates of capacity utilisation captures different effects compared to a standard accelerator model. Application of this methodology to sample of firms from Romania and Spain suggests that firms in Romania may be more financially constrained than previously estimated.

Keywords: investment, financing constraints, double hurdle, transition

JEL Classification: D21, D92

* I would like to thank Mark Schaffer, Alan Bevan, Atanas Christev, Jozef Konings and Hartmut Lehmann for their comments, and participants at the CEPR Transition Economics Workshop for Young Academics, Slovenia 2001 for suggestions and advice on an earlier version. The remaining errors remain the responsibility of the author.

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I 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 The accelerator remains the simplest method, and that most commonly applied to transition, but it has been superseded elsewhere by more rigorous approaches, notably the $q$ and Euler equation models, which are based on the same problem of intertemporal maximisation under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. The assumption that adjustment costs are convex and symmetric about zero generates an investment smoothing process so as to avoid large, and costly, changes in capital stock. As disaggregated data has become available the lack of evidence for this smoothing behaviour has led to the formulation of models incorporating a fixed cost of adjustment incurred by the firm, where this non-convexity generates intermittent investment expenditure. This feature of investment behaviour is observed in our sample of firms from Spain and Romania.

We therefore propose an alternative model as developed by Abel and Eberly (1998) incorporating non-convex costs of adjustment in order to account for the absence of investment smoothing in our data. This theoretical model has yet to be applied, such that there is no established routine for its estimation and we therefore make the case for the use of a double hurdle model. The econometric routine model separates the investment behaviour into two equations; one describing the likelihood of investment occurring and another for the actual expenditure, conditional on it being non-zero. In the Abel and Eberly model the former can be modelled using the value of capacity utilisation, the lack of data on which may be a reason for the model not having been estimated previously.

We find in favour of the model, showing that a threshold equation using rates of capacity utilisation explains the binary choice of whether to invest or not. We also find that this use of a two-part model, modelling the decision of whether to invest or not separately from the decision of how much to invest, allows us to control better for changes in the de-
mand for investment finance. This permits the interpretation of different investment-cash flow sensitivity as being representative of financing constraints, rather than resulting from linkage between current and expected future profitability. The addition of this ‘selection’ process to a traditional accelerator mechanism leads to the conclusion that Romanian firms may not be benefiting from soft finance and face a steeper supply schedule than firms in Spain, contrary to the evidence from a traditional accelerator model.

II Financing constraints in transition economies

II.1 Availability of external finance

Although there is considerable variation in the development of financial markets across the transition economies, even for the frontrunners there is no ‘enabling environment’ as of yet\(^2\). The second round of the Business Environment and Enterprise Performance Survey undertaken by the European Bank for Reconstruction and Development and the World Bank in 2002 revealed that access to external finance continues to be a major determinant of, and in some cases constraint upon, the business climate and investment (EBRD (2002)). However in seeking to understand why this is the case we must recognise that the depth of the financial sector of most transition economies does not support the analysis of investment finance in the same vein as developed economies. While the proportion of investment financed by the retention of funds within the firm is approximately equal across the two groups\(^3\), the major difference is in the residual sources of finance.

Almost all the transition countries have established stock exchanges, but most of them are dormant; they have very low levels of market capitalisation (11% of GDP)\(^2\).

\(^2\)For a description of the cross-country variation in financial market development see Berglof and Bolton (2002).

\(^3\)See, for instance, Bevan and Fennema (2003) who report that, for Russian firms, approximately 80% of investment was financed internally in 1997 as compared to the 85% reported for the same year in the United States in Brealey and Myers (2000, p. 384).
and low turnover of stock (30%) (Claessens, Djankov and Klingebiel (2000)). There are, as always, exceptions to this generalisation. Hungary, the Czech Republic and Poland have developed stock markets with capitalisation comparable to other emerging markets which are liquid and, in the case of Hungary, weakly efficient (Rockinger and Urga (2000)). However, the broad picture is one where ownership is concentrated, turnover is low and the exchanges are dominated by trading in a small number of stocks (Berglof and Bolton (2002)). This view is emphasized by the listing of the most successful firms from transition economies on more developed markets such as the United States and Germany.

Considerable transfer of equity is nevertheless occurring, but outside the stock markets through foreign direct investment. Among the transition countries, the biggest recipients of FDI have been the states of Central and Eastern Europe and the Baltics. In these countries it has served to fill the financing gap left by the underdevelopment of local markets, becoming an important source of external finance; net FDI flows represented 22% of gross capital formation for the CEEB region in 2000 (World Bank, (2002)). Given that this will not be spread equally across the population of firms, it illustrates the importance of FDI as a source of investment finance for the subset of firms that are attracting it.

Of the alternative source of market-based external finance available in developed economies, bond issuance, transition economies are also underdeveloped, particularly in terms of issuance by the private sector. In 2000, transition economies had smaller bond markets than the average emerging market; total volume of bonds outstanding as a percentage of GDP was 24%, against an average of 36% for emerging markets (Bank for International Settlements (2002)). Of this smaller market, the dominance of public

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4 The current regulatory changes in the United States may, however, drive some of this trading back to domestic markets, although clearly this risks increasing financial constraints for those who had access to these markets.

5 This might not be the panacea that it first appears to be. Harrison and McMillan (2001) find, for the Ivory Coast, that large borrowing in domestic financial markets by firms that are recipients of FDI exacerbates the credit constraint for domestic firms without foreign interests.
debt is considerable; 88% of issuance, both domestic and international, was by the public sector. A further indication of the underdevelopment of domestic debt markets is that, of the 12% of bond issuance by the private sector, the majority of this (7%) was raised on international markets.

II.2 Provision of credit by the banking sector

Given the development of financial intermediation in transition, it is not surprising that, with the exception of those firms with large foreign shareholdings, the dominant source of external finance is bank-based debt. This reliance is not, ipso facto, a constraint on economic growth; the theoretical literature on comparative financial systems\textsuperscript{6} suggests that the economic environment may be such that bank intermediation is preferable to that by the market. Furthermore, at the simplest level, a functioning banking system underpins the development of financial markets because it provides the payments mechanisms that permit the operation of financial markets.

Diamond (1984) identifies a positive role for banks in their ability to gather information to the benefit of corporate governance mechanisms, a point made strongly for transition economies by van Wijnbergen (1997). Boot and Thakor (1997) show that the disciplining mechanisms provided by bank and market intermediation are different; markets ensure efficient investment through information dissemination, whereas banks reduce post-lending moral hazard problems through their positional power. Therefore, for economies characterised by information asymmetries such as transition economies, the solution to the principal-agent problem provided by banks may be superior because the information available is insufficient to allow markets to operate effectively.

Allen and Gale (1999) also demonstrate that the structure of bank intermediation

\textsuperscript{6}Allen and Gale (2001) provide a comprehensive review of the literature on comparative financial systems.
will facilitate intertemporal risk management relative to that by the market, which will allow greater provision of credit for the restructuring costs incurred in certain transition economies. Linked to this, many transition economies derive a large proportion of GDP from industries with established technology and high fixed costs which are best served by relationship-banking (Allen and Gale (1995)), where market intermediation could retard the recovery and development of these sectors because of the short-term nature of the financial relationship.

Further evidence suggesting that intermediation by the banking sector may not be undesirable is provided by the ‘financial services’ view of financial intermediation. This viewpoint does not postulate either bank or market intermediation to be superior, but rather that the volume and quality of intermediation is the determinant of economic growth. Empirical evidence supporting this is given by Levine (2002) who found little evidence favouring either side, but rather that the aggregate level of intermediation, either bank or market, exhibits a strong, positive link with economic growth. La Porta, Lopez-de-Silanes, Shleifer and Vishny (1997) demonstrate the relative weight attached to markets versus banks is a function of the underlying legal framework, where the degree of protection of property rights determines the type of intermediation that is dominant. Rajan and Zingales (1998) take the view that “(r)eationship-based systems can survive in environments where laws are poorly drafted or contracts not enforced” (p. 41).

Evidence for this view is provided by Tadesse (2002) who splits his sample by the aggregate level of financial development, as measured by private sector credit and stock market turnover. He finds that at low levels of development bank-based intermediation is associated with higher growth rates, whereas at higher levels of development allocation of credit by the market is superior. La Porta, Lopez-de-Silanes, Shleifer and Vishny (1998) show that the level of financial intermediation is strongly related to the strength

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7A country is defined as having an underdeveloped financial system if it scores below the mean on both bank development and stock market development.
of the legal system, such that underdeveloped systems will also be those with the weaker legal systems. This further suggests that bank intermediation under relatively weak legal systems leads to better growth prospects.

These findings that the degree of bank intermediation in transition countries could be beneficial rests, however, on the assumption that banks are acting as effective intermediaries. Fries and Taci (2002) suggest that this may be too strong an assumption in many transition economies. Comparing two time periods, 1994 and 1999, they find that the average transition economy has experienced a reduction in the total credit to GDP ratio over the five years. This becomes particularly important when benchmarked against the ‘representative’ market economy for the level of GDP - most transition economies are below this benchmark and, a greater cause for concern, are moving away from the benchmark. Even in the leading transition countries, the CEECs and the Baltics, only two are converging on the benchmark. Therefore rather than closing the financing gap through the expansion of credit faster than GDP growth this evidence suggests that the credit constraint is becoming tighter for the majority of transition economies.

This possible constraint on economic growth becomes all the more severe on consideration of what should be the main ‘engine of growth’ in transition economies: the non-governmental sector. Fries and Taci find that this sector suffers disproportionately from the underdevelopment of the banking sector. Bank credit to firms and households is under-supplied relative to the market economy benchmark, driving the earlier reported result of general underprovision of credit by the banking sector. Furthermore this

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8For an indication as to the development of the system of commercial law in transition economies see the annual EBRD Transition Report.

9This result should, however, be viewed in the light of the restructuring of the banking sector after the problems of bank solvency resulting from poor lending decisions in the early transition period as well as the inherited loan portfolio. As a result, for certain economies a reduction in the extension of credit by the banking sector was desirable.

10The corollary to this is that lending to the government sector is well in excess of the level of the market benchmark. It is, however, important to note that this result is partially driven by the fiscal pressures generated by high infrastructural investment during the transition period.
constraint is tightening over the period 1994-1999 for the majority of countries; only in Estonia, Kazakhstan, Poland, the Slovak Republic and Slovenia did the extension of credit to the non-government sector increase as a proportion of GDP despite the growth of the sectoral contribution to GDP. This suggests that the low levels of lending to the non-government sector is not a demand problem, but rather one of supply; effectively an over-reliance on government lending by the banking sector\textsuperscript{11}.

The implication for the financing constraint methodology of the reliance on bank-based debt is a simplification; it gives firms a binary choice, internal finance or bank debt, rather than the hierarchy of alternatives faced in developed economies.

\section*{II.3 Evidence for financing constraints}

Given the level of development of financial markets described above, the frequent identification of financing constraints in studies of transition economies is not startling\textsuperscript{12}. Of more importance in the context of transition is whether there is a systematic bias against certain types of enterprises which impedes their functioning as an engine for growth\textsuperscript{13}.

However our understanding of the nature of these constraints in transition has been complicated by difficulty in controlling for an investment opportunity. The most common model of investment applied in the transition literature is the accelerator, a model that has been effectively rejected for developed economies because it leaves the dynamics of

\textsuperscript{11}This view is indirectly confirmed by Weller and Morzuch (1999) who examine the question of why banks in CEECs were relatively unaffected by the financial crisis in 1998. They conclude that the continued reluctance on the part of banks in CEECs to engage in lending even to an expanding real sector, never mind a contracting one, has helped to stabilize banks. Obviously, the most stable banking sector is the one that does not give out credit, and hence does not incur any risks” (p. 12)

\textsuperscript{12}This should be set against the result that in economies with highly developed financial markets such as the United States researchers also find evidence for financing constraints for subsets of firms.

\textsuperscript{13}Furthermore the application of investment equations to transition is of interest because it gives an indication of the extent to which firms are adapting to the principle of profit-maximisation.
adjustment unexplained. The alternatives that have succeeded it elsewhere, the $q$ and Euler equation models, are difficult to apply to transition. $q$-models rely on stock market information, such that for economies where few stocks are listed and are relatively illiquid, the informational content of stock prices is low. For Euler equations, based on the same model of intertemporal optimisation under convex, symmetric adjustment costs, the time dimension needed to achieve convergence in GMM generally precludes their application to transition.

Given these issues the accelerator model is clearly a sensible alternative. However, insignificance of an accelerator term (showing the response of investment expenditure to a change in sales) is common, particularly where data from early in the transition period is used. This insignificance of the accelerator term in an equation augmented with cash flow still reflects the broader issue of financial constraints, effectively estimating a Meyer-Kuh ‘liquidity accelerator’ model. However the interpretation of the coefficient on cash flow as representing access to external finance is dependent on controlling for the investment opportunity, effectively holding the demand curve for investment finance constant. If this cannot be done the coefficient also captures the relationship between contemporaneous and expected future profitability.

\textsuperscript{14}See Anderson and Kegels (1997) who find no significance of a sales accelerator term for Czech firms in 1993-4, and therefore estimate a liquidity accelerator. Bratkowski, Grosfeld and Rostowski (2000) argue that 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. Particularly for the small \textit{de novo} private firms which make up their sample this linkage may be weak, such that they implement an alternative, using employment growth as the control. For the subset of firms receiving bank credit this proxy is significant, whereas for other firms it is not. This suggests that bank credit is extended to those firms with a greater profit orientation, but it is not clear to what extent this also captures the complementarity of factors of production rather than their profitable use.
II.4 Negative investment-cash flow sensitivity

Estimation of financing constraints in transition economies often identifies negative investment-cash flow sensitivity for particular subsets of firms. The theoretical framework developed by Kaplan and Zingales (2000) shows that this could occur only if the cost of access to external finance is falling in the size of finance raised, a result lent support by Stafford (1999). However generalisation of this result to the transition context is problematic because Stafford uses a sample of firms selected in order to minimise information problems and, therefore, the price differential between internal and external finance. This set of firms is clearly different from those operating in transition economies across dimensions such as ownership and corporate governance such that an alternative explanation must be found for this empirical observation.

The most common suggestion is that this negative coefficient represents the inverse of a positive one; the absence of all financial constraints, in particular the presence of a Kornai soft budget constraint.\textsuperscript{15} (e.g. Lízal and Svejnar (2002), p. 361). This interpretation is not without problems. Firstly, the investment expenditure of a firm that is confident that it will be bailed out should not be constrained by the availability of internal funds, therefore the proxy for these funds should be insignificant in an investment equation.\textsuperscript{16} Even if the bailout was consistently given to those firms that had the worst cash flow position, the political motivation is labour reallocation problems rather than the financing of investment expenditure. Secondly, this negative coefficient is often identified in the presence of a positive and significant coefficient on the accelerator term. This second significance is effectively dependent on the adoption of profit-maximising behaviour by

\textsuperscript{15}The soft budget constraint hypothesis has been extended to include many models based on asymmetric information and moral hazard issues, although here we utilise the original definition of the soft budget constraint as an \textit{ex post} paternalistic bailout (Schaffer (1998)).

\textsuperscript{16}The corollary suggested by this statement is that the finding of zero investment-cash flow sensitivity in investment equations estimated for transition countries should not be necessarily be interpreted as representing efficient capital markets. Given the relatively low development of financial markets described above, this lack of sensitivity to internal funds may be an indication of soft budget constraints.
the firm, which lies awkwardly with the requirement for the extension of soft budgets to
the firm.

Lízal and Svejnar also propose an alternative explanation, based on the negative
coefficient on internal funds for the subset of firms owned by private individuals. They
further examine this result, splitting the sample into firms with less than 100 employees
and those with more than 100 to assess the effect of firm size. The rationale for this is
that for the newly established firms, which make up a large proportion of private firms in
transition economies, profits may be very low, or even negative, while investment rates are
high in the start-up phase, such that investment and cash flow may be negatively related.
Estimating by size sub-sample, the negative coefficient is not present for the large firms,
whereas for the small firms the effect strengthens\(^\text{17}\) consistent with the above rationale.
This result does not, however, extend to the full sample of small firms where for most
sub-samples the coefficient on cash flow is insignificant.

A further alternative is given by Perotti and Gelfer (2001), who reverse the intuition;
rather than less profitable firms, \textit{ceteris paribus}, investing more than their more profitable
counterparts, they depart from the statement that more profitable firms invest less. This
is caused by expropriation, where these firms are being used as ‘cash-cows’ for other
firms that have some call on the cash flow, in the case of Perotti and Gelfer through
membership of a financial-industrial group.

However no consensus has been reached about the empirical finding of negative cash
flow sensitivity. A number of papers have identified it and have offered different expla-
nations, but further possibilities such as the understateing of profit for fiscal reasons by
companies may also have an effect. At this point we do not have a sufficient number
of occurrences to develop a hypothesis explaining this result peculiar to the estimation
of investment equations for transition countries, particularly when it occurs concurrent

\(^{17}\text{This second result is so strong that it is the primary driver for the finding of significant negative}
cash flow sensitivity across the full sample of small firms.\)
with a weak control for investment demand.

II.5 Cross-country evidence

Konings, Rizov and Vandenbussche (2002) examine 4410 firms in the period 1994-1999 in Poland (454), the Czech Republic (1044), Bulgaria (1182) and Romania (1730). They observe higher rates of investment in Poland and the Czech Republic, the early reformers, than in Romania and Bulgaria, and in the growth rate of sales. Estimating a sales accelerator model with GMM-IV to address possible endogeneity of the regressors they identify the presence of financing constraints in the sub-samples from both Poland and Czech Republic, with little evidence in the case of Bulgaria and no evidence in Romania. Given the relative development of financial markets across the countries they interpret this as an indication that firms in the slower reformers operated under soft budget constraints during the sample period.

This result should be contrasted against that reached by Budina, Garretsen and de Jong (2000) who use the same datasource, the AMADEUS dataset, to analyse 1,003 firms in Bulgaria between 1993-1995. They find a highly significant coefficient on cash flow in an augmented accelerator formulation, and analyse the difference in constraints by firm size and levels of long-term debt. All variables in the dataset are constructed from the average of the period 1993-5, where the dependent variable, the investment-capital ratio, is contemporaneous with the regressors, change-in-sales and cash flow. This use of averages, without lags, greatly increases the likelihood of feedback from investment to cash flow; investment undertaken in 1993 will have a positive effect on cash flow in 1995. Although the results are consistent with priors as to the reduction in the costs of external finance for large firms and those with low leverage (see Devereux and Schiantarelli (1990) and Hu and Schiantarelli (1998)), the likely magnitude of the endogeneity problem weakens these results.
II.6 Within-country effects

Ownership and size effects  Lízal and Svejnar (2002) use quarterly data for an unbalanced panel of Czech firms from 1992 to 1998 to estimate an accelerator expressed in levels. They find that the proportion of firms for which the accelerator term is significant increases from just over 50% in 1993 to almost 100% by 1998, interpreting this as a shift towards profit maximising behaviour over the time dimension. They further show that the magnitude of the investment-cash flow sensitivity experienced by the full sample of firms increases over time, although there are many subsets of firms for which the effect is not clear-cut. The estimated absence of financing constraints for the majority of firms at the start of the time dimension is taken as a suggestion that the Calvo and Coricelli (1994) credit crunch hypothesis is not applicable to the Czech Republic during the observation period.

By the end of the observation period in 1998 the accelerator term is significant for the majority of firms, which they interpret as being consistent with profit maximising behaviour. The implied degree of financing constraint is not uniform, where for some groups there is a significant negative coefficient but for most groups there is no evidence of financing constraints. Exceptions to this are found in the state-owned enterprises and for the group with mixed ownership structures; both experience constrained access to external finance relative to the mean. They conclude that the lack of evidence for financing constraints for large firms, coupled with the large portfolios of non-performing loans acquired by Czech banks during the sample period, implies that these firms operated under near unlimited supplies of capital.

In a recent paper Perotti and Vesnave (2004) estimate the incidence of financing constraints in Hungary and the effect of foreign ownership, using Tobin’s $q$ as the control for investment opportunity. A panel was constructed using data from 56 firms over the period 1992-98, and fixed effects estimation applied to correct for unobserved heterogeneity.
The authors note that no regression that they carried out yielded a significant coefficient on their measure of average $q$. Possible weakness of $q$ models is well-documented in the literature; firstly, as Gilchrist and Himmelberg (1995) argue, the predicted values of the adjustment cost parameters have been too high (parameters $a$ and $b$ in the Summers cost function (1981)) and, secondly, the statistically significant inclusion of other variables such as sales and cash flow (e.g. FHP) has shown that $q$ is not a sufficient statistic to describe investment activity. However, the insignificance of $q$ in all regressions suggests that the underdevelopment of stock markets in transition economies may further weaken the control, particularly if there is a systematic mismeasurement of the investment opportunity related to the sample-split criterion. This possibility was raised by Poterba in his comment on the FHP paper and would occur if foreign-owned firms trade at a premium relative to the market because of certain beliefs about corporate governance and security of investment but not related to future profitability, bringing about the zero coefficient on $q$ for foreign firms. Therefore it is with caution that the interpretation that foreign owned firms reduce the cost of external finance can be made, but the finding that the degree of leverage (measured by total debt) constrains investment is consistent with the results from Western countries (e.g. Hu and Schiantarelli (1998)).

**Group membership** Perotti and Gelfer (2001) assess the impact of membership of an industrial group in Russia on access to external finance, distinguishing between vertical and horizontal groups. The former are a result of the Russian privatisation process where new Russian banks succeeded in gaining large equity holdings in the industrial sector, later consolidated with relative ease due to the lack of competition in capital markets. Although their role remains unclear, “the general consensus is that these firms have barely engaged in restructuring and remain largely inertial”. (p. 1603). However, it is plausible that the presence of a bank at the top of the hierarchy may alleviate the credit constraints of the firms below it, as well as strengthening corporate governance within the
group through more active shareholding (see the results of Hoshi, Kashyap and Scharfstein for Japan (1991) as an example of these effects). By contrast, the horizontal groups tend to be industrial alliances for purposes of market sharing and lobbying, and therefore not to bring about better corporate governance nor an improvement in access to external finance.

The use of Tobin’s $q$ to control for investment opportunities in a cross-section of firms in 1996 is significant across the full sample, although the introduction of interaction terms for the sub-samples reveals that this is primarily driven by significance for the bank-led groups where $q$ is significant at the 1% level. There is weak evidence to suggest that non-group firms are more financially constrained than group firms; investment is sensitive to the level of internal funds. Group firms that belong to a horizontal group exhibit similar levels of financial constraint, but membership of a bank-led group is associated with a negative coefficient on cash flow. This evidence is weak because of the difficulty in the control, but for financial-industrial groups this is not the case such that the negative cash flow coefficient represents the degree of financing constraint. As addressed previously the interpretation that they suggest is that rather than improving the environment for a firm, membership of a bank-led group leads to financial reallocation across the group; cash-generating firms are used as ‘cash-cows’. However, given that the behaviour of these firms is more consistent with profit-maximisation as shown by the coefficient on $q$, this may be too negative an interpretation; there may also be efficient reallocation of financial assets occurring within the group.

Volchkova (2001) replicates this study, but implements an augmented accelerator formulation. Her focus is not on distinguishing between bank versus non-bank groups, but she splits her sample along the basis of firms that are de facto groups and those that are de jure groups and registered in the Financial Groups Registry Book 1997. This second group is, however, too small to use in estimation such that her comparison is the degree of
financial constraint between *de facto* group members and independent firms. She shows that the investment-cash flow sensitivity is higher for firms that are members of groups than those that are not, although this result is restricted to large firms. The results suggest that large firms within Russian financial-industrial groups are operating under near perfect capital markets (based on the sum of coefficients on interaction terms), as contrasted with the other large firms in the sample which exhibit negative investment-cash flow sensitivity. She therefore confirms the suggestion by Perotti and Gelfer that groups are of benefit in Russia in that they are more successful in resolving asymmetric information problems, whilst at the same time not allowing soft lending and managerial discretion to distort investment behaviour\textsuperscript{18}.

### III An alternative model for an investment opportunity

Lucas (1967) showed that the implication of convex adjustment costs for investment is that the firm will stagger investment over periods, similar to the prediction of incomplete adjustment in the flexible accelerator formulation. If adjustment costs are modelled using a strictly convex function, with the minimum at zero, then at this point the marginal productivity of a factor of production must be greater than its marginal cost (except in the special case where the profit function is flat at zero). Given this, unless the optimal capital stock has been reached and has remained constant, as have future expectations, it is always profitable for a firm to invest under the assumption of convex, symmetric, adjustment costs.

\textsuperscript{18}There are, however, two possible reservations associated with this result. Volchkova does not report the level terms associated with the interactions, such that we cannot exclude the problems of non-monotonicity suggested by KZ. Secondly no comparison of profit-maximising behaviour, as suggested by coefficients on the accelerator term, is reported so it is not possible to distinguish between the “cash-cow” versus reallocation effects found in the Perotti and Gelfer study.
Although we leave a more detailed description of the data until later, we note at this point that of 299 observations for the investment-capital ratio, 71 firms report zero investment expenditure. Under the assumption of convex adjustment costs this would not be optimal behaviour, such that we seek an alternative.

III.1 Are adjustment costs convex?

As disaggregated data has become available to researchers, the evidence that smooth investment is a construct of aggregation to the sectoral level has grown, suggesting that adjustment costs are neither convex nor symmetric. Doms and Dunne (1998) found, using a balanced panel of plants, periods of high investment activity directly followed by periods of zero investment, a result clearly 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.

Rothschild (1971) raises the issue of whether the convexity assumption for adjustment costs is reasonable, describing the two sources postulated by Eisner and Strotz as weak (p. 608). He argues that it is equally plausible to assume that firms will be price takers in factor markets or that internal costs of adjustment could be decreasing in the speed of adjustment rather than increasing. He links the prevalence of the assumption of strict convexity to its ability to justify the use of distributed lags in investment equations because convex costs generate a permanent response of investment behaviour to changes in market conditions.

In their review of adjustment costs in factor demand models a quarter of a century later Hamermesh and Pfann (1996) issue the same caveat. In the original study by Holt

19Chirinko 1993, however, argues that external adjustment costs provide the more plausible explanation for the assumption of convexity.
et al. that proposed adjustment costs of this form, the authors believed the quadratic curve to be a suitable first approximation and that the assumption of symmetry was a simplification. “That this was an approximation and that symmetry need not be imposed were quickly forgotten in the published literature, no doubt because of the analytical tractability of” the convex, symmetric, adjustment cost function (p. 1269).

Although there are a number of alternative assumptions about adjustment costs, the difficulty is that these costs are unobservable and therefore can only be studied and tested indirectly through the dynamics of the adjustment process. One such alternative is that the costs are not symmetric about zero. It is evident that some contraction in the capital stock is costless, that resulting from depreciation, but contraction over and above this value through divestment may be subject to high costs. This might occur through a ‘lemons’ effect resulting from asymmetric information, such that the value of the capital good is significantly discounted in the secondary market. Pfann and Verspagen (1989) propose a generalised asymmetric information cost function where

$$AC(\Delta K_t) = -1 + \exp(\beta \Delta K_t) - \beta \Delta K_t + \frac{1}{2} \gamma (\Delta K_t)^2$$

where $\beta$ measures the difference between the costs of investment and divestment, such that if $\beta = 0$ the standard convex, symmetric adjustment cost function is implemented. This form of adjustment cost results in a different path under profit maximisation which is shown by Palm and Pfann (1997) to no longer be described by a Koyck-distributed lag function, where they find that $\beta$ is statistically significant, evidence for asymmetry in their application to labour markets. This asymmetry may also be complete in the absence of secondary markets, for instance because of asset specificity, such that investment undertaken is effectively irreversible. The effect of this irreversibility has been developed

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20The failure of the neo-classical assumption of efficient secondary markets is all the more likely in the transition context.
by Dixit and Pindyck (1994) as the ‘option theory of investment’, where they show that it introduces a value to delaying investment expenditure under uncertainty about the future, effectively creating a call option \(^{21}\).

Rothschild’s proposal that adjustment costs could be decreasing in the size of adjustment would occur if there were some fixed cost, independent of the size and speed of adjustment, which must be overcome before investment activity occurs. Bertola and Caballero (1990) show that the adoption of fixed costs per adjustment decision under an uni-directional process leads to adjustment being intermittent and large, applying this \((S,s)\) decision rule to investment expenditure (1994). The suggestion that costs may not be convex and symmetric leads Caballero and Leahy (1996) to predict the demise of marginal \(q\) because under fixed costs investment is no longer a monotonic function of \(q\). This is shown to be preemptive by Barnett and Sakellaris (1998) and Abel and Eberly (2001), who incorporate non-convex adjustment costs along with convex costs into the \(q\)-model. Although both identify multiple regimes in the responsiveness of investment to changes in average \(q\), they do not agree on the form of the non-linearity; Barnett and Sakellaris find a concave relationship, exhibiting lower sensitivity of investment to \(q\) at higher values of \(q\), whereas Abel and Eberly find evidence for a S-shaped function, where investment is relatively insensitive to \(q\) at high and low values, but with “disproportionately large” effects around unity. Barnett and Sakellaris argue in favour of models incorporating non-convex adjustment costs because they are able to capture the ‘zeroes and lumps’ nature of investment activity and, further, that irreversibilities can explain the asymmetry of the investment-profit linkage. They conclude that at plant-level the convex adjustment cost model performs poorly, although they find that at the aggregate level these non-convexities are less important.

\(^{21}\)Abel, Dixit, Eberly and Pindyck (1996) allow the presence of secondary markets to show the presence of a put option through the resale of installed capital. Under this model investment is governed by the ‘Goldilocks’ principle; news that is neither too good nor too bad does not affect investment levels.
Rather than specifying an investment model, Cooper and Haltiwanger (2000) use indirect inference procedures to test a model of adjustment dynamics incorporating both convex and non-convex costs. They find that quadratic adjustment costs are a suitable approximation for some costs such as hiring and layoff, inventory, overtime and machine setup costs, but again that the convex adjustment cost model cannot replicate the periods of inactivity and the non-linear, asymmetric, relationship between investment and profitability observed in their sample. The evidence therefore would suggest that adjustment costs have both convex and non-convex components, where each captures different aspects of the process. That said, at the disaggregated level of the firm, the exclusion of the possibility of fixed costs implies a smoother process than is found in the data, where this represents a major topic of further research.

III.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 omitted. 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. However Corrado and Mattey (1997) illustrate, based on evidence from an NBER survey, that this doubt is predominantly in the mind of economists, and

"managers generally are quite precise about how much their facilities can produce without extraordinary efforts" (p. 152)

Its implementation has also been hampered by 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 electricity usage (Berndt and Wood (1975 and
An alternative approximation is used by Fazzari and Mott (1987) who test the application of a post Keynesian investment function

\[ I^* = I(u, CF, CC) \]

where \( u \) is the rate of capacity utilisation, \( CF \) the internal cash flow and \( CC \) the firm’s interest obligations, or cash commitment. Since they do not directly observe the rate of capacity utilisation, they estimate this using sales as a proxy for \( u \) (hence effectively estimating an accelerator model) and find statistical significance for both sales and internal finance in their application to 835 firms between 1970 and 1982.

Capacity utilisation has been introduced directly into accelerator theory by Chenery (1952) in order to explain the observed occurrence of partial adjustment. He assumes that there are two types of fixed 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.

22 The principle underlying this proxy is that there is both an econometric and engineering complementarity between energy use and capital stock. The deflation of total capital stock by an energy index in a production subfunction yields an estimate for the degree of utilisation of the stock, effectively converting the capital stock into a flow of capital services.

23 Also see Steindl (1976) for a theoretical exposition of the importance of capacity utilisation for investment behaviour in the Keynesian tradition.
A model of investment incorporating capacity utilisation rates

Abel and Eberly (1998) 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 irreversibility. 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 model.\footnote{We only give an outline of the model, and therefore refer the reader to the original article.}

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)

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

This implies the profit function for the firm

\[
\pi (X, u, K, L) = X \left( u^\nu K^\beta L^\alpha \right)^{1-\nu} - \omega u^\eta L - mu^\rho K, \quad \frac{\nu}{\alpha} > \eta \geq 1, \rho \geq 1
\]
where $X$ is a composite shock to the revenue function, $X \equiv X_1 X_2^{1/2}$. $\omega$ 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, $Z$, which being a product of variables evolving according to gBm will also do so. $Z$ is defined as

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

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

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

where $A_{\pi} \equiv \Delta / \rho \left[ \left(1 - \frac{1}{\epsilon}\right)^{\frac{1}{\Delta}} (1 - \frac{1}{\epsilon})^{-\left[\nu + \alpha (\rho - \eta)\right]} \left(\frac{\nu - \alpha \eta}{\rho}\right)^{\frac{1}{\Delta}} \left(1 - \frac{1}{\epsilon}\right)^{\left(\nu - \alpha \eta\right)} \alpha^{\frac{\alpha}{\Delta}} \left(1 - \frac{1}{\epsilon}\right) \right]$. Therefore the value of the firm is given by

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

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 $K_i$ 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 to the system, this state variable rises above a trigger value, $b$. Once the trigger is exceeded, investment occurs to return the state variable to a target value, $c$, where these trigger and target values are determined by the costs of adjustment that the firm faces when it does invest. It can be shown that capacity utilisation

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

where $Q^*$ is capacity output 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.

This shows 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. The Abel and Eberly model provides an alternative to the accelerator mechanism for application to transition economies, and one which both explicitly models the adjustment mechanism and the taking of expectations, and as such is a model more in keeping with advances in the modelling of investment behaviour. It also has certain departures from the accelerator, which we show with two simple examples.\footnote{For expositional simplicity we ignore the presence of productivity shocks.} If we assume that the environment described by the Abel and Eberly model is representative of the “true” world:

1. 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.

2. 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 \( \varepsilon > 1 \) 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 information beyond that of a standard
change in sales accelerator.

**IV Estimation framework**

**IV.1 Estimation procedure**

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 the state variable is returned. 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 $\kappa$, where $\kappa$ 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 \textit{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.

The Tobit is also a mixed model composed of a discrete distribution for zero values and a continuous distribution for positive values, but which imposes the constraint that the regressors and coefficients of the two distributions are the same. We use a more general model, allowing the determinants of zero and non-zero values to be different; Cragg (1971) extended the Tobit model to incorporate this separation of determinants in an application to demand by consumers for durable goods, similar to the demand for durable investment goods by firms. The original double hurdle, expressed as
made the assumption that the two error terms were unrelated, where $Z$ is the matrix of variables postulated to determine the selection process and $X$ the matrix of variables determining the level of the dependent variable, $Y^*$. In this paper we make the extension suggested, amongst others, by Jones (1992) that

$$(\varepsilon_1, \varepsilon_2) \sim N(0, \Sigma)$$

where

$$
\Sigma = \begin{pmatrix}
\sigma^2 & \rho \\
\rho & 1
\end{pmatrix}
$$

We estimate this dependent double hurdle model using a maximum-likelihood routine programmed for Stata, where this estimation procedure has a number of advantages over those previously applied in the transition literature.

1. We explicitly model the censored nature of gross investment rates, where previous studies have used gross and net investment almost interchangeably. As Tobin (1958) showed, omission of the censoring will lead to biases in the coefficients.

2. The separation of the model into two equations allows the modelling of firms which, despite productive investment opportunities, are too financially constrained to undertake investment activity (condition 1 above) from those firms that do not have the investment opportunity (condition 2). If we can improve the control for the second set of firms, the measure of financing constraint will more cleanly capture the first, reducing possible bias on the coefficient for internal funds in single equation
models.

IV.2 Data description

The data used is the product of a survey by the European Bank for Reconstruction and Development into the adoption in Romania and Poland of the Copenhagen criteria for accession to the European Union. Carlin, Estrin and Schaffer (2000) assess convergence with regards to:

1. The existence of a market economy

2. The ability to withstand competitive pressures

3. The adoption of the *acquis communautaire*

for a sample of firms in the transition economies, benchmarking their progress against firms from a low-income EU member; Spain. Although the focus of this dataset is on regulatory compliance, quantitative data on firm production and financial status was included as well as information on firm characteristics such as ownership in order to construct performance measures. The survey, carried out in the summer of 1998, contains information on a sample of approximately 200 firms in each country selected randomly from databases maintained by the statistical office in the cases of Romania and Poland and a commercial database for Spain. These firms were required to be in the manufacturing sectors most open to international competition and were selected from two major locations in each country; Warsaw and Katowice in Poland, Bucharest and Brasov in Romania and Madrid and Barcelona in Spain.

Through interviews with one or more senior management, performance data was collated for 1995 through to 1997 for variables including labour force, the cost and revenue structures and investment expenditure. However, possibly because the onus of the survey was on qualitative rather than quantitative data, there is a significant number of firms for
which we do not have data for all three years. We conduct a series of consistency checks, requiring broad comparability between the sales-to-capital ratio, the relationship between wage costs and the labour force and between investment expenditure and changes in capital stock over the three years. These simple checks result in a reduction of the sample to 63 firms for Poland, 104 for Romania and 118 for Spain. Using the reported values we construct the ratios required for the estimation of the investment equation described above.

- **Gross investment** is constructed from two variables; the total value of annual sales and the annual expenditure on investment as a percentage of sales. Values for 1996 and 1997 are deflated by the producer price indices (EBRD (2002)) to construct a series in constant 1995 prices, and then normalised by the book value of capital stock to net out size effects.

<table>
<thead>
<tr>
<th></th>
<th>Poland</th>
<th>Romania</th>
<th>Spain</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>.155</td>
<td>.098</td>
<td>.096</td>
</tr>
<tr>
<td>1996</td>
<td>.181</td>
<td>.109</td>
<td>.088</td>
</tr>
<tr>
<td>1997</td>
<td>.193</td>
<td>.077</td>
<td>.115</td>
</tr>
</tbody>
</table>

  Table 1: Mean gross investment rates

- **Capacity utilisation** are the reported rates based on the actual output of the firm expressed as a percentage of the maximum possible output for the year for a given capital stock. This is the direct response to the question, posed to managers, “At what percent of maximum production capacity did you operate?” and is therefore the same construction of the variable referred to by Corrado and Mattey and in

\[26\] It is possible that this construction will generate some rounding down of low values of investment because small percentages may be reported as zero, although we argue that this is less problematic with the use of gross rather than net investment. This zone of ambiguity about the value of zero investment is specifically addressed by Asano (2002).
the model of investment derived by Abel and Eberly reported above. Since the values are reported for the end of the year there is the possibility of feedback from investment to the utilisation rate and therefore we use the lagged value of capacity utilisation as an instrument, where the correlation coefficient between rates of capacity utilisation in 1997 and 1996 is 0.93 at 99% confidence.

Figure 1: The relationship between investment rate and capacity utilisation for Spain(o) and Romania(x)

The plot of the firm investment rate against capacity utilisation shown in figure 1 illustrates that there is a relationship between the two, lending support to the Abel and Eberly model. The location of the mass of points below an imaginary line at approximately 40° indeed suggests that large capital stock adjustments do not occur at low levels of utilisation, but are more prevalent at higher rates, but equally that a high rate of capacity utilisation is not a sufficient condition for a high investment rate.

- **Cash flow** is calculated from reported profits plus depreciation, as suggested by Meyer and Kuh (1957) and used by FHP, as our measure for the internal funds of the firm. Possible endogeneity of cash flow was suggested in the early literature on liquidity accelerators, where Eisner (1963) only included the lagged value of cash flow as an explanatory variable. FHP (1988, p. 172) noted that this may be of concern and repeated their estimation using the lag of cash flow to eliminate possible feedback between investment and contemporaneous cash flow, finding that this did not substantially change their results. Given the possible effects as illustrated by Budina, Garretsen and de Jong (2000), we verify that the one period lag of

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27We also tested the use of EBITD as a proxy, but rejected it in favour of the Meyer and Kuh measure.
cash flow is a good instrument for contemporaneous cash flow, finding them to be highly correlated in the dataset (0.95 for 1997/6 and 0.75 for 1996/5, both at 99% confidence), and therefore we proceed using the one-period lag of cash flow, also normalised by capital stock.

- *Sales* is simply constructed from the change in sales, in constant 1995 prices, reported between time periods $t$ and $t - 1$, normalised by capital stock. However, Romania experienced a recession of 6% of GDP in 1997 after consecutive years of strong economic growth, where the effect of this can also be seen in the reduced investment rates for 1997 in table 1. In the sample of firms contained in the survey the decline in sales was deeper, exhibiting a 29% fall in the value of sales between 1996 and 1997, after a 9% increase in the previous period. The effect of this is that the use of the lagged sales to address endogeneity is problematic as it is not a valid proxy because of low correlation between the two periods, and we therefore use the two-year average of the change in sales to reduce both feedback and volatility.

<table>
<thead>
<tr>
<th>Poland</th>
<th>Romania</th>
<th>Spain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>S.D.</td>
<td>Mean</td>
</tr>
<tr>
<td>Gross investment 97</td>
<td>.193</td>
<td>.246</td>
</tr>
<tr>
<td>% zeroes</td>
<td>12</td>
<td>24</td>
</tr>
<tr>
<td>Capacity utilisation 96</td>
<td>74.3</td>
<td>16.5</td>
</tr>
<tr>
<td>Δ sales 95–97</td>
<td>.226</td>
<td>.703</td>
</tr>
<tr>
<td>Cash flow 96</td>
<td>.324</td>
<td>.465</td>
</tr>
</tbody>
</table>

Table 2: Variables used for estimation

The variation between the investment rates for the countries is consistent with the relative GDP growth rates shown in table 3 for 1997 (EBRD (2003)), and the relatively low number of zero observations in Poland is consistent with the hypothesis that cyclical variations in aggregate economic activity explain a significant proportion of the binary
choice of whether to invest or not. However the lower percentage of zero observations in Romania as compared to Spain is not consistent with this hypothesis, but may be a reflection of high levels of restructuring occurring in the Romanian economy such that the investment decision is less strongly influenced by GDP fluctuations. We can also see from table 3 that the provision of credit to the non-government sector by the financial sector is considerably lower for the transition counties in 1997 than for Spain (IMF (1998)), where we expect this to have a significant impact on the availability of external finance and hence the importance of internally generated funds to finance investment.

<table>
<thead>
<tr>
<th></th>
<th>Poland</th>
<th>Romania</th>
<th>Spain</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP growth rate (%)</td>
<td>6.8</td>
<td>-6.1</td>
<td>5.4</td>
</tr>
<tr>
<td>Provision of credit to non-governmental sector as % of GDP</td>
<td>18.1</td>
<td>8.5</td>
<td>77.1</td>
</tr>
</tbody>
</table>

Table 3: Economic indicators for 1997

The low number of internally consistent observations for Poland, coupled with the low proportion of firms exhibiting zero investment levels, create the problem that it is not possible to estimate the coefficients of the threshold equation for Poland because we only observe 8 firms with zero investment rates. Given that the average rates of capacity utilisation are comparable for Poland and Romania we would expect, under the Abel and Eberly model, for there to be a similar probability of the first hurdle being satisfied in the two countries. The difference in zero observations might therefore be a result of less censoring in the structural equation, as a result of superior access to external finance. However we do not have sufficient information to distinguish between this explanation and that of model inadequacy in application to Poland. We therefore exclude the small sample of Polish firms, concentrating our analysis for the purposes of estimation on the

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28This is, to some extent, a simplification because there is no reason to expect that the trigger values \((b)\) will be the same across countries.
222 firms from Romania and Spain.

Bevan and Fennema (2003) demonstrated that the effect of size on commercial credit documented in the literature on developed economies is also present in transition economies, and therefore it is important to check that the distribution of firm size in the sample is comparable for the two countries. For Romania we find a mean labour force in 1997 of 499, and for Spain 369. As shown in table 4 the proportion of large firms in the sample is greater in Romania than for Spain, consistent with the effects of the structure of industry prior to the transition process, but the difference is not clear enough to draw inference with respect to the effect of size on external finance in the sample.

<table>
<thead>
<tr>
<th></th>
<th>Romania</th>
<th>Spain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>50</td>
<td>70</td>
</tr>
<tr>
<td>25%</td>
<td>110</td>
<td>105</td>
</tr>
<tr>
<td>Median</td>
<td>341</td>
<td>160</td>
</tr>
<tr>
<td>75%</td>
<td>684</td>
<td>377</td>
</tr>
<tr>
<td>Maximum</td>
<td>3000</td>
<td>4500</td>
</tr>
</tbody>
</table>

Table 4: Firm labour size in 1997

V Results

V.1 Abel and Eberly model

The simplest investment equation that is implied by the Abel and Eberly model contains capacity utilisation in both the structural and threshold equations, where the variable describes the proximity to the trigger value and the magnitude of investment expenditure, if undertaken, does not converge. Just-identification of the system through the non-linearity introduced by the correlation coefficient appears to generate this result, where the introduction of cash flow to both equations is also insufficient to allow convergence.
We therefore identify the system by instrumenting for capacity utilisation using the change in sales variable in the structural equation, retaining its use in the threshold equation to capture the ‘trigger’ effect of the utilisation rate as predicted in the model and suggested by figure 1. We also estimated models instrumenting for $CU$ in just the threshold equation, and in both, but find the performance of the above system to be superior as well as in accordance with our theoretical model. The suitability of the change in sales as an instrument for capacity utilisation is based on the high correlation between the two variables, and also clearly parallels the standard accelerator formulation of the investment equation.

Our prior is that we do not expect cash flow to influence the binary choice of whether to invest or not through the threshold equation but only through the effect of financial constraints on the probability of censoring in the structural equation, in line with Fisher-type separability. We test this prior by estimating a model including both cash flow and cash flow interacted with the Romania dummy in both equations, but find that we reject the restrictions of the exclusion of the two cash flow terms from the threshold equation at the 99% confidence level (the LR $\chi^2$ test value is 14.62 against a critical value of 9.21)\(^{29}\).

Therefore the general structural equation that we estimate is

$$ \frac{I_{97}}{K_{96}} = \beta_0 + \beta_1 R + \beta_2 \frac{\Delta S_{95-7}}{K_{96}} + \beta_3 \frac{\Delta S_{95-7}^R}{K_{96}} + \beta_4 \frac{CF_{96}}{K_{95}} + \beta_5 \frac{CF_{96}^R}{K_{96}} $$

and the threshold equation is given by

$$ t \left( \frac{I_{97}}{K_{96}} \right) = \gamma_0 + \gamma_1 R + \gamma_2 CU_{96} + \gamma_3 CU_{96}^R + \gamma_4 \frac{CF_{96}}{K_{95}} + \gamma_5 \frac{CF_{96}^R}{K_{96}} $$

\(^{29}\)Throughout this section we rely strongly on the implementation of likelihood ratio tests. It can be shown in elementary likelihood theory that the use of Wald tests which rely on the asymptotic result that $\sigma_{\hat{\beta}}^{-1} = -H(\hat{\beta})^{-1}$ may be weak for a finite number of observations, such that LR tests give better results for our sample size. The counter to this is, of course, that for large $n$, the use of a $\chi^2$ distribution becomes questionable.
where R denotes interaction with the dummy for Romania. \( i(.) \) is the indicator function taking the value 1 if investment is non-zero, and 0 otherwise. Estimation of these equation yields the parameter values shown in table 5 below.

<table>
<thead>
<tr>
<th></th>
<th>Coefficient</th>
<th>Standard error</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \Delta S )</td>
<td>0.0652</td>
<td>0.0187</td>
</tr>
<tr>
<td>( \Delta S^R )</td>
<td>-0.0435</td>
<td>0.0356</td>
</tr>
<tr>
<td>( CF )</td>
<td>0.0808</td>
<td>0.0422</td>
</tr>
<tr>
<td>( CF^R )</td>
<td>0.1250</td>
<td>0.0575</td>
</tr>
<tr>
<td>( R )</td>
<td>-0.0528</td>
<td>0.0397</td>
</tr>
<tr>
<td>Constant</td>
<td>0.0577</td>
<td>0.0339</td>
</tr>
<tr>
<td>( CU )</td>
<td>0.0668</td>
<td>0.0266</td>
</tr>
<tr>
<td>( CU^R )</td>
<td>-0.0195</td>
<td>0.0216</td>
</tr>
<tr>
<td>( CF )</td>
<td>-0.5142</td>
<td>0.9835</td>
</tr>
<tr>
<td>( CF^R )</td>
<td>-0.8796</td>
<td>1.112</td>
</tr>
<tr>
<td>( R )</td>
<td>3.070</td>
<td>2.041</td>
</tr>
<tr>
<td>Constant</td>
<td>-3.597</td>
<td>0.9632</td>
</tr>
<tr>
<td>( \rho )</td>
<td>-0.4551</td>
<td>0.3925</td>
</tr>
<tr>
<td>( \sigma )</td>
<td>0.1483</td>
<td>0.0106</td>
</tr>
<tr>
<td>LL</td>
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</tbody>
</table>

Table 5: Full model

As mentioned above, despite the cash flow terms in the threshold equation not being significant in \( t \)-tests, the restriction of their joint exclusion is rejected in a LR test. That the coefficients should be negative is initially counter-intuitive; firms with, \textit{ceteris paribus}, higher cash flow are less likely to undertake an investment project. We verify that this result is not driven by outliers, excluding firms with cash flow greater than 50% of capital stock. Although the exclusion of 40 firms attenuates the coefficient, the sign and significance remain, such that this might be a result of firms with high cash flow retaining these internal funds for a large investment adjustment which is too large to finance with the cash flow of a single year.

We therefore strap the model down, excluding insignificant variables and testing the exclusion at each stage using likelihood ratio tests. Although we cannot exclude both
cash flow variables in the threshold equation, the exclusion of a separate term for Romanian firms cannot be rejected, and the same applies with respect to interacted capacity utilisation. In the structural equation we cannot reject exclusion of a differing accelerator term for Romanian firms, but exclusion of a separate cash flow variable is rejected, again at the 99% confidence level (the LR $\chi^2$ test value is 10.66 against a critical value of 6.64). Therefore the exclusion of insignificant regressors yields the parsimonious model reported in table 6.

<table>
<thead>
<tr>
<th></th>
<th>Coefficient</th>
<th>Standard error</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta S$</td>
<td>.0535</td>
<td>.0160</td>
</tr>
<tr>
<td>$CF$</td>
<td>.1081</td>
<td>.0359</td>
</tr>
<tr>
<td>$CF^R$</td>
<td>.1194</td>
<td>.0553</td>
</tr>
<tr>
<td>$R$</td>
<td>-.0253</td>
<td>.0287</td>
</tr>
<tr>
<td>Constant</td>
<td>.0330</td>
<td>.0197</td>
</tr>
<tr>
<td>$CU$</td>
<td>.0469</td>
<td>.0139</td>
</tr>
<tr>
<td>$CF$</td>
<td>-1.301</td>
<td>.3843</td>
</tr>
<tr>
<td>Constant</td>
<td>-.5880</td>
<td>.8989</td>
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<tr>
<td>$\rho$</td>
<td>-.5805</td>
<td>.2222</td>
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<tr>
<td>$\sigma$</td>
<td>.1519</td>
<td>.0092</td>
</tr>
<tr>
<td>LL</td>
<td>22.322</td>
<td></td>
</tr>
</tbody>
</table>

Table 6: Parsimonious model

The significance of the traditional accelerator term and the significant inclusion of the threshold equation gives confidence in the control for the profitability of an investment opportunity, implying the demand curve for investment finance is held constant. Under these conditions and given that the intercept term for Romania is insignificant, such that $\left( \frac{dI}{dk} \right) = 0$ in the KZ framework, we can therefore interpret the positive and significant coefficient on cash flow interacted with Romania, $CF^R$, as being generated by costly access to external finance in relation to the baseline of Spanish firms consistent with expectations as to the effect of relative underdevelopment of the financial system. The result that Romanian firms are financially constrained contradicts that reached by
Konings, Rizov and Vandenbussche (2002) for their sample of 1730 firms in Romania, where they find no sensitivity of investment to cash flow and interpret this as a result of soft-budget constraints. This absence of financing constraints may be a reflection of differences in the sample of firms, but it is also feasible that it is linked to the model choice, to which we now turn.

V.2 Comparison of models

We have shown that the estimation procedure above does describe investment expenditure in our sample of firms, but the crucial test is whether it extends our understanding beyond what we know from more conventional applications of the accelerator framework. The rationale for the use of a two equation model, further separating the production and financial sides of the firm, was that it would reduce potential bias on the estimated coefficient for cash flow as a measure of financing constraint, and therefore we compare the above results to a standard Tobit estimation.

<table>
<thead>
<tr>
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<th>Double hurdle</th>
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<th>Tobit</th>
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</thead>
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</tr>
<tr>
<td>$CF$</td>
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<td>.0359</td>
<td>.0746</td>
<td>.0370</td>
</tr>
<tr>
<td>$CF^R$</td>
<td>.1194</td>
<td>.0553</td>
<td>.0248</td>
<td>.0515</td>
</tr>
<tr>
<td>$R$</td>
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<td>$CU$</td>
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<td></td>
</tr>
<tr>
<td>$CF^{-1}$</td>
<td>-1.301</td>
<td>.3843</td>
<td></td>
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<tr>
<td>Constant</td>
<td>-.5880</td>
<td>.8989</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\rho$</td>
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<td>.2222</td>
<td></td>
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</tr>
<tr>
<td>$\sigma$</td>
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<td>.0092</td>
<td>.1618</td>
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<tr>
<td>LL</td>
<td>22.322</td>
<td>11.054</td>
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</tbody>
</table>

Table 7: Comparison of models

Firstly it is noteworthy that the Tobit model is rejected in favour of the double hurdle model as a description of the investment process in the sample. Since the Tobit model
is directly nested in the double hurdle model, the exclusion of the threshold equation represents four linear-form restrictions; the three variables of the equation and $\rho$. The LR test statistic of these 4 restrictions is 22.54 against a critical value for the $\chi^2_4$ distribution of 13.28 at the 99% confidence interval such that we reject the restriction that only censoring is present; the binary choice of investing or not is not directly related to the magnitude of investment undertaken.

The introduction of the threshold equation, with or without the inclusion of cash flow in this equation, drives the change in the result on $CF^R$. To be sure of this we estimated a model retaining only capacity utilisation in the threshold and find that, although the exclusion of $CF$ in the threshold is rejected statistically in an LR test, it does not influence the magnitude (.122) and standard error (.059) of the coefficient on $CF^R$. Therefore it is not the decomposition of the cash flow coefficient in the Tobit estimation into two effects that removes the downward bias, but the inclusion of the threshold allowing distinction between the two reasons for zero observations. This effect of not accounting for this is of sufficient magnitude to reject the postulate that firms in Romania are more financially constrained than those in Spain in the Tobit model. The full model reported in table 5 suggests that the negative effect of cash flow on the binary choice is greater for Romanian firms, although this is not a statistically significant difference. This result would also be consistent with the earlier suggestion that this coefficient is a reflection of earnings retention for large investment projects which cannot be financed externally, where we would expect this rationale to be greater under the less developed financial markets in Romania.

If we construct predicted values for the double hurdle model then, using the standard 50% probability cutoff for the probit model, only three Romanian firms are predicted to undertake zero investment because of the threshold. This seems at odds with the magnitude of the change in the coefficient on cash flow for Romanian firms, but the intuition of
the econometric programming provides an explanation. The implicit assumption of the Tobit formulation is that each firm has a 100% probability of undertaking an investment project, such that any zero observation is the result of censoring potentially resulting from financial constraints. In the double hurdle model there occurs implicit deflation of the contribution to determining the structural coefficients by the predicted threshold probability. This can be demonstrated through examination of the component of the likelihood functions for positive observations of investment, where for expositional clarity we show this for the independent double hurdle.

For the Tobit model this is given by

$$\prod_+ \left( \frac{1}{\sigma_{\varepsilon_1}} \phi \left( \frac{Y - B'X}{\sigma_{\varepsilon_1}} \right) \right)$$

whereas for the double hurdle model it is

$$\prod_+ \Phi (A'Z) \frac{1}{\sigma_{\varepsilon_1}} \phi \left( \frac{Y - B'X}{\beta} \right) \sigma_{\varepsilon_1}$$

Therefore in determining the coefficients of the structural equation observations are deflated by the probability that a non-zero investment rate is observed, $\Phi (A'Z)$. Therefore a firm to which we attribute a 90% probability of observing positive investment ($\Phi (A'Z) = .9$) is given 50% more weight in determining the coefficients in the structural equation, and hence the degree of financial constraint, than a firm ascribed a 60% probability. Intuitively this is because, for the firm with a 60% probability, it is less clear whether a zero observation results from the threshold equation or from censoring through financial constraint (the distinction between conditions 1 and 2 in section [V.1]).

We also check whether the significance of $CF^R$ is linked to the inclusion of capacity utilisation in the regression equation, adding it to the Tobit specification above. We find that its inclusion is statistically significant, but that it is not the driver of the
change in the coefficient on cash flow for Romanian firms. We therefore argue that it is the augmentation of the accelerator model with the threshold equation incorporating capacity utilisation that improves the control for the investment opportunity, allowing the coefficient on cash flow to better capture the degree of financing constraint.

VI Conclusion

In this paper we propose an alternative model for investment, one that is more consistent with recent evidence on the lumpiness of investment at the firm level, and applied it to firms from Romania and Spain. Although the strength of possible conclusions is reduced by problems generated by a relatively small sample size, we have clearly shown that this alternative model captures different effects from the models more commonly applied in the literature. The combination of the Abel and Eberly theoretical model of investment with an adaptation of the Cragg estimation framework for the demand for durable goods leads to the suggestion that firms in Romania are financially constrained by the low level of intermediation in the economy, where a more traditional Tobit model does not identify these effects.

That we find that Romanian firms experience a steeper supply schedule for external finance than firms in Spain is not a surprising result, given the evidence presented for the development of financial markets, particularly the degree of credit creation to the non-government sector reported in table 3. It is in the absence of the finding using the traditional accelerator model that we gain greater insight into the paucity of our understanding of financing constraints in transition as reviewed in this paper. There are limitations to the empirical analysis presented, most notably the relatively small sample size given the complex estimation method, but this preliminary exploration of the application of the Abel and Eberly model to transition clearly suggests an avenue for future research in identifying the effect of low levels of financial development on firm-level
investment in transition economies.
References


