Investment Reluctance: Irreversibility or Imperfect Capital Markets? Evidence from German Farm Panel Data

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Silke Hüttel [a*], Oliver Mußhoff [b], Martin Odening [† a]

a Humboldt University Berlin, Faculty of Agriculture and Horticulture, Farm Management Group

b Martin-Luther-University Halle-Wittenberg, Institute of Agricultural and Nutritional Sciences, Farm Management Group

***Correspondence: Luisenstraße 56, D-10099 Berlin, Germany.
Phone: +49-30-2093-6459, fax: +49-30-2093-6465,
e-mail: silke.huettel@agrar.hu-berlin.de**

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Abstract

Investment behavior at the firm level is characterized by lumpy adjustments and frequent periods of inactivity. Low investment rates are particularly puzzling in transition economies where an urgent need of modernization exists. The literature offers two explanations for. Firstly, neo-institutional finance theory focuses on the impacts of imperfect capital markets on investment decisions showing that the limited availability of financial funds may confine firms' investments. Secondly, real options theory asserts that the interaction of irreversibility, uncertainty and flexibility may also result in investment reluctance. In this paper we suggest a generalized model that combines imperfect capital markets and real options effects. We also offer an econometric implementation that has the structure of a generalized tobit model. This model is applied to German farm panel data. We demonstrate that ignoring real options effects may lead to erroneous results when estimating the impact of imperfect capital markets on investment decisions.

Keywords: investment decision; irreversibility; uncertainty; q-model; capital market imperfections; generalized tobit model; transition

JEL classification: D81; D92; O12

Observed investment behavior at the firm level is characterized by lumpy investments and frequent periods of inactivity. Low investment rates are particularly puzzling in transition economies where an urgent need of modernization and rationalization exists. Numerous studies have already tried to provide a better understanding of firm-level investment pointing out the important role of finance (amongst others, BOND and MEGHIR 1994; GILCHRIST and HIMMELBERG 1998 and for agricultural investment e.g., BENJAMIN and PHIMISTER 2002; BARRY, BIERLEN and SOTOMAYOR 2000). As imperfect capital markets are characterized by informational asymmetries and agency problems induce transaction costs, a gap between firms' cost for internal and external finance arises. Henceforth, investment and finance decisions are not separate[1]. This is in particular the case in transition economies where underdeveloped institutions and weak macroeconomic conditions lead even to constrained capital access (amongst others, PAVEL, SHERBAKOV and VERSTYUK 2004; RIZOV 2004). The aforementioned empirical studies affirm a direct effect of imperfect capital markets. Therefore, the well known standard investment model with strictly convex costs attached to adjusting the capital stock is extended by imposing financial restrictions in order to account for costly or limited access to capital. Accordingly, investment is sensitive to the cash flow as a proxy for internal financial ability (BOND and VAN REENEN 2003).

However, the extended standard investment model fails to explain observed lumpy investment (CHIRINKO 1993). An alternative explanation of investment reluctance is offered by the real options theory, that has a close relationship to the stochastic adjustment cost theory. Real options theory affirms that inaction periods occur when costs for the adjustment of the capital stock are at least partially sunken (irreversible) and future revenues are uncertain. Costly reversibility arises when installing new capital

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[1] HUBBARD (1998) gives a comprehensive review about imperfect capital markets.

involves costly learning or disruption costs, or alternatively when high capital specificity leads to a lack of resale possibilities. Of particular interest is the interaction of uncertainty, irreversibility and the opportunity to postpone investment (DIXIT and PINDYCK 1994). This means, investment is influenced by the value of the real option to invest and delaying investment might become optimal. In this context, a more general form of the adjustment cost function is required in order to account for irreversibility (HAMERMESH and PFANN 1996). It is assumed that these costs are asymmetric, only partially convex and kinked at zero investment (CABALLERO 1997). The resulting optimal path of investment depending on the marginal valuation of capital is non-smooth and characterized by a range of inaction. For instance ABEL and EBERLY (2002), NILSEN and SCHIANTARELLI (2003) or LETTERIE and PFANN (2007) give empirical evidence about asymmetric adjustments of the capital stock.

This study strongly recommends that imperfect capital markets inducing additional transaction costs are a major determinant of investments. In transition economies these effects are expected to be even more pronounced as weak macroeconomic conditions hinder the development of capital markets. However, impacts of imperfect capital market cannot solely explain empirical investment behavior characterized by reluctance. We aim to advance the understanding of investment behavior and endorse that costly reversibility and uncertain future expectations are major determinants along with the availability of finance. Thus, we combine issues of two strands of investment literature – the neo-institutional finance theory and the real options theory. To our knowledge do empirical applications so far not provide any bridging application. Accordingly, this is the innovative part and the main contribution of this study as more recent papers do not combine these aspects (LENSINK and BO 2001).

For these purposes we develop an extended q-model with the intention of exploring the coexistence of capital market imperfections, irreversibility and uncertainty referring to ABEL and EBERLY (1994). The empirical model has the structure of a generalized tobit model. By means of this model we intend to show that simpler linear models, assuming a smooth adjustment of the capital stock over time, fail to explain empirical investment behavior when capital market imperfections, costly reversibility and uncertainty coexist. The application of this model to German farm level panel data aims to investigate first, if and how imperfect capital markets, irreversibility and uncertainty jointly affect empirical farm investment behavior. The second objective is to substantiate if farms in transition economies are confronted with higher transaction costs induced by higher degrees of informational asymmetries. The more precise question is to find out whether these farms show a higher investment cash flow sensitivity. The comparison of West and East Germany delivers insights into the differences between established market economies and transition economies.

The remainder of this article is organized as follows. First, background information on the rural capital market in Germany is given. The theoretical basis and the extended q-model follow. Next, the econometric model is presented, followed by the descriptive evidence and results. Finally, concluding remarks and suggestions for future research round off the paper.

Agricultural Finance in Germany

Like most other small and medium size firms, farms in Germany have limited direct access to capital markets. Major sources of investment financing are self financing and debt financing. The latter is particularly important for expanding farms. The largest part of agricultural investments is financed by bank credits (76 %) which is comparably high. Credit substitutes, for instance leasing, are not yet widespread in agricultural finance

(BAHRS, FUHRMANN and MUZIOL 2004). Within the bank credits the cooperative banks have the largest share of agricultural credits by about 47 %, private credit banks and the local savings banks have a share of 12 % and 33 %, respectively. Such credits are mainly long term credits with fixed interest rates. More recently, there is a strong tendency with a reduced period with fixed interest rates (BLISSE et al. 2004). Additionally, programs offered by the Landwirtschaftliche Rentenbank[2] are available. These credits are designed for farms and characterized by more favorable conditions compared to banks. However, the access to debt capital is different in West and East Germany. These differences, which were most pronounced immediately after the German reunification in 1990, vanish in the course of time, but still exist.

In the transition period of East Germany, starting in 1989, macroeconomic stability established rather quickly compared to other Central and Eastern European Countries. This rapidly established stability was a precondition for the development of financial markets and a banking system. Actually, most of the major West German banks expanded to East Germany and established a network of branch offices comparable to those in the old federal states. Nevertheless, at the beginning of the nineties financial problems hindered the development of competitive farms in East Germany (ROTHE and LISSITSA 2005). Former co-operatives, state owned farms as well as newly established farms had an enormous capital demand for replacement and expansion investments. Contrary, banks were reluctant to issue loans for the following reasons. First of all, the restructured or newly established farms had no history in the sense of documented economic performance under market conditions. The assessment of credit worthiness, however, is usually based

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[2] This bank is a public law institution with the aim to support the agricultural sector. The Landwirtschaftliche Rentenbank provides refinancing for all types of projects associated with agriculture or rural areas within the European Union.

on past financial records. A second problem concerned missing collateral. Farms in East Germany showed a low equity share. This difference of financial leverage can be traced back to the unequal share of leased land. While family farms in West Germany own about 50 percent of their land, farms in East Germany typically operate on leased land (with a share of 90 %). The problem of missing collaterals was aggravated by the legal status chosen by the former socialistic cooperatives and state owned farms. The dominating legal forms of successors of the former socialistic farms were co-operatives, stock companies and corporations, which are all characterized by limited liability. In addition, the property rights of the farms' assets were unclear for a rather long time period. Finally, the access to debt capital was frequently hindered by the existence of old credits stemming from the socialistic period. Though there was a partial debt relief, considerable debt was remaining without corresponding assets of comparable value.

In view of the aforementioned peculiarities of East German farms we conjecture that moral hazard and adverse selection problems in the lender-borrower relationship are more pronounced in these farms compared West German family farms. These problems come along with a higher default risk and/or higher transaction costs for potential lenders, which in turn may lead to higher cost of borrowing or credit rationing (BARRY, BIERLEN and SOTOMAYOR 2000). In other words, it can be hypothesized that the degree of capital market imperfections is different in both parts of Germany. As a result, the cash flow sensitivity of investment should be higher in East than in West German farms. Hence, the German reunification may be considered as a natural experiment about the impact of capital market imperfections on the investment behavior in agriculture. In what follows we examine this relationship empirically.

A q-Model for Irreversible Investment in Imperfect Capital Markets

We refer to a dynamic and stochastic adjustment cost model in line with ABEL and EBERLY (1994) or HAMERMESH (1992)[3]. We extend this model in order to account for additional transaction cost induced by imperfect capital markets.

Theoretical Model

The partial equilibrium model comprises production and investments for a representative firm. The relationship between product price p_t and quantity y_t in continuous time t is described by an iso-elastic demand function with a stochastic demand parameter X_t described by a Geometric Brownian Motion (GBM):

$$dX_t = \mu \cdot X_t \cdot dt + \sigma \cdot X_t \cdot dz \tag{1}$$

where μ denotes the drift rate, σ the standard deviation and dz is a Wiener increment denoting productivity shocks that capture imperfect competition in product markets. Output is Cobb-Douglas in capital K_t and labor L_t. Thereby is assumed that the latter can be adjusted without additional costs. Firm i maximizes the present value of net income depending upon its current capital stock K_{i0} and its initial stochastic demand variable X_{i0}. The maximized value of the firm (V_{it}) is defined as the discounted difference of expected profits (π_{it}) and the costs attached to adjusting the capital stock $C(I_{it}, K_{it-1}, F_{it})$ as a function of (dis)investments denoted by I_{it}, the capital stock K_{it-1} and finance F_{it}.

$$V_{it}(K_{i0}, X_{i0}) = \max_{I} \int_{0}^{\infty} E[\underbrace{h \cdot X_{it}^{\eta_X} \cdot K_{it}^{\eta_K}}_{\text{profit } \pi_{it}} - \underbrace{C(I_{it}, K_{it-1}, F_{it})}_{\text{adjustment costs}}] \cdot e^{-r_i \cdot t} \cdot dt \tag{2}$$

It follows that $h = (1-\alpha) \cdot \left(\alpha/\omega\right)^{\alpha/(1-\alpha)} \cdot A^{1/(1-\alpha)} > 0$, where A denotes a technology parameter, α the production elasticity of labor and ω refers to labor cost (ABEL and

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[3] HAMERMESH (1992) presents this kind of model for labour adjustments.

EBERLY 1994). $h \cdot X_{it}^{\eta_X}$ is the respective marginal revenue product of capital at time t, $\eta_X = 1/(1-\alpha) > 1$ and $\eta_K = 1$ denote the respective competition parameters of demand and capital. r_i denotes the firm individual discount rate which is constant over time (BÖHM, FUNKE and SIGFRIED 1999).

Costly reversibility and possible capital market imperfections do not allow the use of quadratic and symmetric adjustment costs. Hence, the adjustment cost function is:

$$C(I_{it}, K_{it-1}, F_{it}) = \begin{cases} a^0 + a_1 \cdot K_{it-1} + b_1 \cdot I_{it} + g_1 \cdot \left(\dfrac{I_{it}}{K_{it-1}}\right)^2 \cdot K_{it-1} + d_1 \cdot \dfrac{I_{it}}{K_{it-1}} \cdot F_{it} & \text{if } I > 0 \\ 0 & \text{if } I = 0 \\ a^0 + a_2 \cdot K_{it-1} + b_2 \cdot I_{it} + g_2 \cdot \left(\dfrac{I_{it}}{K_{it-1}}\right)^2 \cdot K_{it-1} + d_2 \cdot \dfrac{I_{it}}{K_{it-1}} \cdot F_{it} & \text{if } I < 0 \end{cases} \quad (3)$$

The first part refers to costs attached to investments, the last part describes the costs arising by disinvestments and when the firm does neither invest nor disinvest zero adjustment costs occur, i.e. $C(I_{it}, K_{it-1}, F_{it}) = 0$.

The first term, a^0, represents the 'true' fixed costs independent of the capital stock whereas the second term, $a_{1/2} \cdot K_{it-1}$, represents fixed costs proportional to the capital stock but independent of the level of investment. The third term, $b_{1/2} \cdot I_{it}$, captures capital costs which are proportional to investment. Thereby denotes b_1 capital costs when investing and b_2 denotes the respective cost when disinvesting. These could be acquisition cost itself. The fourth term, $g_{1/2} \cdot \left(I_{it}/K_{it-1}\right)^2 \cdot K_{it-1}$, represents the internal adjustment costs which are quadratic in investment and strictly convex as the traditional q-theory proposes (ABEL and EBERLY 2002). If reversibility is costly, it is essential that $b_1 \geq b_2 \geq 0$ and $g_1, g_2 \geq 0$ (BÖHM, FUNKE and SIGFRIED 1999). This gap between the acquisition and resale price of capital reflects capital specificity and accounts for transaction costs when adjusting the capital stock (COOPER and HALTIWANGER 2006).

When $a_{1/2} > 0$ and/or $a^0 > 0$ fixed (sunk) costs are connected with the investment decision and are completely sunken.

By means of the last term, $d_{1/2} \cdot (I_{it}/K_{it-1}) \cdot F_{it}$, additional costs are incorporated arising when imperfect capital markets induce additional costs, for instance, transaction costs to acquire finance. Intuitively, when capital markets are imperfect, informational and agency problems induce transaction costs. Hence, investment and finance decisions are not separable. Firms with a low financial ability need to acquire costly capital as equity capital does not suffice. Accordingly, F_{it} represents financial variables and accounts for the relationship between transaction costs and the internal financial ability. The investment sensitivity to those variables that proxy internal funds give evidence about imperfect capital markets (HUBBARD 1998).

The firm's maximization is subject to the evolvement of the capital stock over time:

$$K_{it} = (1 - \delta_i) \cdot K_{it-1} + I_{it} \tag{4}$$

where δ_i denotes the depreciation rate. In accordance with the dynamic programming approach the optimal path of investment follows the Bellman equation. We now define $q_{it} = \partial V_{it}/\partial K_{it-1}$ as the marginal valuation of a unit of installed capital. Hence, the optimal path of investment solves the term $\max_{I} \{ -C(I_{it}, K_{it-1}, F_{it}) + I_{it} \cdot q_{it} \}$. As usual, the first order condition (FOC) leads to the optimal investment rate (I_{it}^+ / K_{it-1}) and disinvestment rate (I_{it}^- / K_{it-1}). However, since the maximand is zero when the firm does neither invest nor disinvest, it is required that q_{it} should pass the upper (q_{1it}) threshold which is derived by finding a value for q_{it} solving $I_{it}^+ \cdot q_{it} > C(I_{it}^+, K_{it-1}, F_{it})$. Investment occurs as

$$\frac{I_{it}^+}{K_{it-1}} = -\frac{b_1}{2g_1} + \frac{1}{2g_1} \cdot q_{it} - \frac{d_1}{2g_1} \cdot \frac{F_{it}}{K_{it-1}} \tag{5a}$$

when

$$q_{it} > q_{1it} = b_1 + 2 \cdot \sqrt{\frac{a^0 \cdot g_1}{K_{it-1}} + a_1 \cdot g_1} + d_1 \cdot \frac{F_{it}}{K_{it-1}} \tag{5b}$$

and accordingly disinvestment occurs as

$$\frac{I_{it}^-}{K_{it-1}} = -\frac{b_2}{2g_2} + \frac{1}{2g_2} \cdot q_{it} - \frac{d_2}{2g_2} \cdot \frac{F_{it}}{K_{it-1}} \tag{6a}$$

when q_{it} passes the respective lower (q_{2it}) threshold which is similarly derived by finding

a value for q_{it} solving $I_{it}^- \cdot q_{it} < C(I_{it}^-, K_{it-1}, F_{it})$. Thus, disinvestment is induced when

$$q_{it} < q_{2it} = b_2 + 2 \cdot \sqrt{\frac{a^0 \cdot g_2}{K_{it-1}} + a_2 \cdot g_2} + d_1 \cdot \frac{F_{it}}{K_{it-1}} \tag{6b}$$

and when $q_{2it} \leq q_{it} \leq q_{1it}$ zero investment is optimal. This range of q_{it} is also known as

the range of inaction. Intuitively, the dependence on the financial ability induced by

imperfect capital markets ($d_{1/2} \cdot F_{it}/K_{it-1}$) widens the range of inaction such that: the larger

the financial ability, the smaller is the increase of the range of inaction. Similarly, the

lower the financial ability of a firm the larger is the increase of the range of inaction. In

the empirical application to German farm level panel data we represent financial ability

by the cash flow. In order to ensure this relationship between transaction costs and

finance an inverse cash flow-adjustment-cost-relationship is required[4]. Accordingly, the

model comprises irreversible investment and impacts of imperfect capital markets on the

optimal path of investment.

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[4] In the empirical data set we expect also a negative cash flow. In order to avoid distortions in this case we
use the cash flow and not the inverse cash flow in the empirical model specification. We expect that the
inverse relation should be represented by the estimated coefficients.

In all cases, q_{it} refers to the shadow value of capital defined as the discounted future expectations of the marginal productivity of a unit of installed capital. ABEL and EBERLY (1994) provide:

$$q_{it} = h \cdot \int_0^\infty E_t \left\{ X_{it+s}^{\eta_X} \right\} \cdot e^{-(r_i + \delta_i) \cdot s} ds = \frac{h \cdot X_{it}^{\eta_X}}{r_i + \delta_i - 0.5 \cdot \eta_X \cdot (\eta_X - 1) \cdot \sigma_i^2} \tag{7}$$

According to (7), q_{it} is proportional to the average capital productivity measured by market data. The important feature of this specification is the incorporation of the variance (σ_i^2) of the stochastic part of the demand function accounting for uncertain future revenues. By means of this specification uncertainty directly affects q_{it}. It follows that an increase in σ_i increases q_{it}. As investments and q_{it} are positively related an increasing volatility rises investment. However, if the initial value of q_{it} is in the range of inaction, a small increase in σ_i does not induce an investment or disinvestment (ABEL and EBERLY 1993)[5].

Econometric Model

We use farm level panel data which do not contain any market information to construct q_{it} as defined above. However, an average-type proxy variable would even be inappropriate in this context. In order to make the model estimable q_{it} is approximated in terms of observable variables:

$$q_{it} = \beta' Z_{it} + \varepsilon_{it} \tag{8}$$

where β is a parameter vector to be estimated and Z_{it} is the information set for q_{it} containing variables which proxy the information about the shadow value of capital. For the first set of variables, in line with NILSEN, SALVANES and SCHIANTARELLI (2007), it is

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[5] For a further discussion see ABEL et al. (1996).

assumed that the shadow value of capital is proportional to the sales (revenues) to capital ratio, $(S/K)_{it}$. This holds when the production function is Cobb Douglas in labor and capital. Further, it is assumed that the firm acts as a price taker, the operating profit π_{it} is proportional to the capital stock and farms use an AR(2) process to forecast the sales to capital ratio. Hence, present, once lagged and twice lagged values as well as the respective quadratic terms of the sales to capital ratio are used in the information set. The second approximation set of variables refers to this definition of the shadow value of capital (GILCHRIST and HIMMELBERG 1995):

$$q_{it} = \int_0^\infty E\left[\pi_{it} - C(I_{it}, K_{it-1}, F_{it})\right] \cdot e^{-(r_i+\delta_i)s} ds$$

Thus, the information set of q_{it} consists alternatively of first order lags and the respective quadratic terms of the profit to capital ratio in line with LETTERIE and PFANN (2007). In order to account for the stochastic demand function and uncertain future revenues we use additionally the deviation of revenue changes over the years, σ_i. We are aware that this is a very simple approximation of the shadow value of capital, however, we provide several variations of the information set.

The used approximation of q_{it} (8) introduces the error terms ε_{it} which are assumed to be normally independently distributed (*n.i.d.*) with variance σ_ε^2. These reflect idiosyncratic shocks which are not observable to the econometrician. The disturbances account also for measurement errors within the estimation of the shadow value of capital. Accordingly, the stochastic and empirical representation of investment is given by

$$\frac{I_{it}^+}{K_{it-1}} = c_0^+ + \beta' Z_{it} + c_2^+ \cdot \frac{CF_{it}}{K_{it-1}} + \varepsilon_{it} \tag{9a}$$

when[6]

$$\gamma_0^+ + \gamma_1^+ \cdot \frac{1}{K_{it-1}} + \beta' Z_{it} + \gamma_2^+ \cdot \frac{CF_{it}}{K_{it-1}} + \varepsilon_{it} > 0 \tag{9b}$$

and disinvestment is described by

$$\frac{I_{it}^-}{K_{it-1}} = c_0^- + \beta' Z_{it} + c_2^- \cdot \frac{CF_{it}}{K_{it-1}} + \varepsilon_{it} \tag{10a}$$

when

$$\gamma_0^- + \gamma_1^- \frac{1}{K_{it-1}} + \beta' Z_{it} + \gamma_2^- \cdot \frac{CF_{it}}{K_{it-1}} + \varepsilon_{it} < 0 \tag{10b}$$

where CF_{it} denotes the cash flow of farm i at time t.

Estimation

This model has the structure of a generalized two-sided tobit model (DiIORIO and FACHIN 2006 refer to a double censored tobit model). The parameter estimates can be obtained by either maximum likelihood estimation of the full model or alternatively by a two-stage method. For convenience we use the two-stage Heckman procedure (HECKMAN 1976, 1979; CAMERON and TRIVEDI 2005). In the first step, we estimate a generalized ordered probit model (BOES and WINKELMANN 2006) to derive the probabilities of investment, disinvestment and inaction. Using these results of the first stage we obtain the shadow value of capital q_{it}. In addition, the results from the first step are used to estimate the necessary selectivity regressors. These are required in the second stage to account for the sample selection bias induced by the selection equations (9b) and (10b). These regressors are also known as inverse Mill's ratios. In the second step, the (dis)investment functions ((9a) and (10a)) are estimated using the Mill's ratios as additional explanatory variables.

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[6] In order to make the model estimable the thresholds q_1 and q_2 are linearly approximated:

$$b_1 + 2 \cdot \sqrt{a^0 \cdot g_1 / K_{it-1} + a_1 \cdot g_1} \cong \gamma_0^+ + \gamma_1^+ \cdot 1/K_{it-1} \text{ and } b_2 - 2 \cdot \sqrt{a^0 \cdot g_2 / K_{it-1} + a_2 \cdot g_2} \cong \gamma_0^- + \gamma_1^- \cdot 1/K_{it-1} .$$

This ensures that the parameter estimates of the investment and disinvestment functions are unbiased and consistent (MADDALA 1983).

For the generalized ordered probit model the dummy variable I_{it}^D is defined indicating whether a firm invests ($I_{it}^D = 1$), disinvests ($I_{it}^D = -1$) or is inactive ($I_{it}^D = 0$). The inverse capital stock, $1/K_{it-1}$, enters the model only through the selection equations (9b) and (10 b) and gives therefore an useful exclusion restriction to identify the model (CAMERON and TRIVEDI 2005). The generalized ordered probit model can be written as:

$$\log L =$$

$$\sum_{I_{it}^D = 1} \log \left(1 - \Phi \left(\frac{\gamma_0^+ + \gamma_1^+ \cdot K_{it-1}^{-1} - \beta' Z_{it} + \gamma_2^+ \cdot CF_{it} / K_{it-1}}{\sigma_\varepsilon} \right) \right) +$$

$$\sum_{I_{it}^D = -1} \log \Phi \left(\frac{\gamma_0^- + \gamma_1^- \cdot K_{it-1}^{-1} - \beta' Z_{it} + \gamma_2^- \cdot CF_{it} / K_{it-1}}{\sigma_\varepsilon} \right) + \qquad (11)$$

$$\sum_{I_{it}^D = 0} \log \Phi \left(\frac{\gamma_0^+ + \gamma_1^+ \cdot K_{it-1}^{-1} - \beta' Z_{it} + \gamma_2^+ \cdot CF_{it} / K_{it-1}}{\sigma_\varepsilon} \right) - \Phi \left(\frac{\gamma_0^- + \gamma_1^- \cdot K_{it-1}^{-1} - \beta' Z_{it} + \gamma_2^- \cdot CF_{it} / K_{it-1}}{\sigma_\varepsilon} \right)$$

where $\Phi(\cdot)$ denotes the standard normal cumulative distribution function. The parameters can only be identified up to a scale parameter and are normalized by σ_ε which will be denoted by $\sim$.

For the second step it is necessary to define the inverse Mill's ratios for the (dis)investment equations, λ_{it}^+ and λ_{it}^-, respectively. These account for the non-linear selection and are defined as the expected value of ε_{it} conditional on being in the investment or disinvestment regime

$$\lambda_{it}^+ = \frac{\phi \left(\tilde{\gamma}_0^+ + \tilde{\gamma}_1^+ \cdot K_{it-1}^{-1} - \tilde{\beta}' Z_{it} + \tilde{\gamma}_2^+ \cdot CF_{it} / K_{it-1} \right)}{1 - \Phi \left(\tilde{\gamma}_0^+ + \tilde{\gamma}_1^+ \cdot K_{it-1}^{-1} - \tilde{\beta}' Z_{it} + \tilde{\gamma}_2^+ \cdot CF_{it} / K_{it-1} \right)} \qquad (12a)$$

$$\lambda_{it}^- = \frac{\phi \left(\tilde{\gamma}_0^- + \tilde{\gamma}_1^- \cdot K_{it-1}^{-1} - \tilde{\beta}' Z_{it} + \tilde{\gamma}_2^- \cdot CF_{it} / K_{it-1} \right)}{\Phi \left(\tilde{\gamma}_0^- + \tilde{\gamma}_1^- \cdot K_{it-1}^{-1} - \tilde{\beta}' Z_{it} + \tilde{\gamma}_2^- \cdot CF_{it} / K_{it-1} \right)} \qquad (12b)$$

where $\phi(\cdot)$ denotes the standard normal density function. Accordingly, the resulting equations for the second stage are defined as follows.

$$\frac{I_{it}^+}{K_{it-1}} = c_0^+ + c_1^+ \cdot \left(\tilde{\beta}'Z_{it} - \hat{\lambda}_{it}^+\right) + c_2^+ \cdot \frac{CF_{it}}{K_{it-1}} + u_{it}^+ \tag{13a}$$

$$\frac{I_{it}^-}{K_{it-1}} = c_0^- + c_1^- \cdot \left(\tilde{\beta}'Z_{it} + \hat{\lambda}_{it}^-\right) + c_2^- \cdot \frac{CF_{it}}{K_{it-1}} + u_{it}^- \tag{13b}$$

where u_{it}^+ and u_{it}^- are zero mean error terms. The parameters are defined as $c_0^+ = -b_1/2\gamma_1$, $c_0^- = -b_2/2\gamma_2$, $c_2^+ = -d_1/2\gamma_1$, $c_2^- = -d_2/2\gamma_2$ ((5a) and (6a)). The Mills ratios (λ_{it}^+ and λ_{it}^-) are multiplied by the parameters c_1^+ or c_1^-, respectively, as the error terms enter the equation through the proxy variable for q_{it} (NILSEN, SALVANES and SCHIANTARELLI 2007). It is assumed that Z_{it} are uncorrelated with the errors u_{it}^+, u_{it}^- and ε_{it} to ensure that the generalized ordered probit model yields consistent estimates and standard errors of the parameters. As there is only one single generated regressor for each equation the asymptotic t-statistics can be used for inference and the estimators are consistent (PAGAN 1984).

In order to demonstrate the advantages of our approach a simpler linear benchmark model is defined. The model represents that kind of model which is often used in the analysis of empirical investment behavior as described in BOND and VAN REENEN (2003) or ADDA and COOPER (2003).

$$\left(\frac{I_{it}}{K_{it-1}}\right)^b = \alpha_0 + \alpha_1 \cdot \left(\tilde{\beta}'Z_{it}\right) + \alpha_2 \cdot \frac{CF_{it}}{K_{it-1}} + u_{it} \tag{14}$$

where the superscript b denotes the benchmark model. The disturbances u_{it} are assumed to be identically independently distributed (*i.i.d*). A significant cash flow parameter indicates the dependence of finance and therefore imperfect capital markets. However, this kind of model does not account for any costly reversibility and ignores furthermore

the bias in the linear estimation without selectivity regressors. By means of this model the ambition is to find out how simpler linear models behave in comparison to the generalized tobit model with respect to the cash flow sensitivity. The ambition is to show that the 2-sided tobit model is the appropriate specification when explaining investment behavior. It is expected that the parameter estimates of the benchmark model differ significantly from those given by the second stage regressions.

Data and Descriptive Statistics

We use farm level panel data from the national German farm accountancy data network (FADN) covering the years from 1996 to 2006 (from here: BMELV Testbetriebsnetz). This dataset is based on annual balance sheet data from representative farms in Germany and must conform to consistent accounting procedures given by the European Commission (EU COMMISSION 1989). Specialists in horticulture, orchards, fishery and forestry are excluded as those have a different capital structure and are difficult to compare with specialists in agriculture. In the estimation only farms with at least four consecutive years are considered to ensure consistency, particularly in the estimation of σ_i, the measure of uncertainty. Outliers are imposed by removing farms from the data sample that are below the 1 % percentile and above the 99 % percentile of the (dis)investment capital ratio and the sales to capital ratio. These rules are common in investment literature (BENJAMIN and PHIMISTER 2002; GILCHRIST and HIMMELBERG 1998). Accordingly, the used data set is unbalanced and contains roughly 12 500 farms (approximately 2 100 in the East and 10 400 in the West) with 6.9 years on average[7].

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[7] It has to be acknowledged that the sample is not fully representative as we do not use any aggregation factors.

35 % of the observations in the West are zero investments and 23 % are investments whereas in the East 17 % are zero investments and 36 % investments. This indicates for East and West unequal proportions and the largest share of observations belongs to the disinvestment regime. Information on annual investments are presented in table 1. For each year available in the data set the mean investment rate of Germany, East and West Germany is given.

Table 1. Annual Investment Rates for Germany

| | Germany | | West Germany | | East Germany | |
year	mean investment rate	no. of observations	mean investment rate	number of observations	mean investment rate	no. of observations
1996	0.10	2 520	0.08	1 954	0.16	566
1997	0.10	2 712	0.09	2 148	0.14	564
1998	0.10	2 827	0.09	2 278	0.15	549
1999	0.11	2 269	0.10	1 708	0.14	561
2000	0.10	2 558	0.09	2 024	0.13	534
2001	0.09	2 721	0.09	2 139	0.11	582
2002	0.11	2 228	0.10	1 680	0.14	548
2003	0.11	2 170	0.11	1 605	0.13	565
2004	0.11	1 879	0.11	1 428	0.13	451
2005	0.11	2 041	0.10	1 492	0.12	549
2006	0.10	1 949	0.09	1 425	0.13	524

Note: The database is the BMELV Testbetriebsnetz 1996-2006.

The aggregated investment rates are rather constant over time. However, in the Eastern federal states a higher variation and higher average investment rates are observable. This might be a first indication for necessary modernization investments in the transition period. However, it needs to be acknowledged that the used capital stock in Eastern farms might be under-evaluated since it was installed before 1990.

The data confirm the unequal capital structure at the farm level in East and West Germany. The average equity ratio amounts to 56 % and 82 % of total capital stock, respectively. This rather high equity ratio in the West indicates financial strength of the farms which might additionally be a signal for a lower dependence on finance. In equal measure it can be shown that the average debt capital ratio (due to missing values in the data set only bank loans are considered) is only 17 % in the West whereas bank loans in

the East are more important with a share by about 33 %. This comparably high share in the East signals a stronger dependency on the access to capital.

In table 2 we present the ranked (dis)investment rates according to size using decentiles. The highest rank (1) implies the largest annual (dis)investment rate by the farm whereas rank 10 accounts for the smallest annual (dis)investment rate per farm. For each rank the number of observations, the mean (dis)investment rate and the respective standard deviation are given.

Table 2. Ranked Investment and Disinvestment Rates for Germany

	investment rate			*disinvestment rate*		
rank	no. of observations	mean	standard deviation	no. of observations	mean	standard deviation
1	2588	0.4267	0.1481	4420	-0.1374	0.0388
2	2587	0.1957	0.0230	4420	-0.0753	0.0082
3	2588	0.1246	0.0137	4420	-0.0542	0.0044
4	2587	0.0882	0.0078	4420	-0.0419	0.0028
5	2587	0.0654	0.0053	4420	-0.0339	0.0019
6	2588	0.0494	0.0041	4420	-0.0281	0.0015
7	2587	0.0371	0.0031	4420	-0.0235	0.0013
8	2588	0.0277	0.0026	4420	-0.0188	0.0012
9	2587	0.0188	0.0023	4420	-0.0144	0.0013
10	2587	0.0101	0.0033	4421	-0.0088	0.0023

Note: The database is the BMELV Testbetriebsnetz 1996-2006.

The three highest ranks compared to the remaining ranks show comparably high means whereas the subsequent means in the lower ranks decline rapidly. In addition, rank one to three account for 74 % of the total investment expenditures. DOMS and DUNNE (1998) provide simulated rankings and show that the expected ranking for strictly convex adjustment costs would induce a smooth decline with equal steps. Thus, the ranking of the German farm level panel data showing unequal steps is a first indication for a reluctant investment behavior of German farms accompanied by a tendency of lumpy adjustment of the capital stock. Moreover, the mean disinvestment and investment rate (median) over all observations is 0.004 (0.01) with a skewness of 3.32. The mean

(median) investment rate is 0.10 (0.05) and the mean (median) disinvestment rate is -0.04 (-0.03). These findings indicate asymmetries in the adjustment of the capital stock. Summarizing, the basic features of the explanatory variables are shown in table 3 using the common summary statistics as the mean, the standard deviation, the skewness and kurtosis.

Table 3. Summary Statistics of the Main Explanatory Variables

variable	no. of observations	min	max	mean	standard deviation	skewness	kurtosis
$(I_{it}/K_{it-1})^+$	25 874	0.001	0.833	0.104	0.129	2.606	10.815
$(I_{it}/K_{it-1})^-$	44 201	-0.250	-0.001	-0.040	0.030	-2.160	8.505
(CF_{it}/K_{it-1})	103 212	-7.505	3.229	0.028	0.127	0.787	179.894
$(S/K)_{it}$	103 212	0.023	3.404	0.347	0.406	2.987	14.418
$(S/K)_{it-1}$	85 562	0.023	3.402	0.335	0.336	2.961	14.319
σ_i	103 212	0.005	4.606	0.489	0.302	2.508	14.406
$1/K_{it-1}$	103 212	2.850E-08	0.001	2.480E-06	5.120E-06	15.814	520.081

Note: The database is the BMELV Testbetriebsnetz, 1996-2006.

Estimation Results

The used data set is unbalanced whereas the panel mortality in the FADN is assumed to be fully exogenous. Hence, there is no need to account for any possible sample selection bias founded in this unbalanced structure (WOOLDRIDGE 2002). All estimation results were obtained by STATA 9. We used several definitions of the information set for q_{it}, however, the results are similar, thus we present results derived by this set: $Z_{it} = \left[(S/K)_{it-1}, (S/K)^2_{it-1}, \sigma_i \right]$. It contains the first order lags and the respective quadratic term of the sales to capital ratio and the standard deviation of farm individual revenue changes, σ_i, to account for uncertain future revenues. In all estimation steps a farm type

dummy DT_{it}[8] and a size dummy DS_{it}[9] are used to reduce possible effects which could bias the constant terms. Further, farm individual averages of all explanatory variables are included to account for possible heterogeneity between the farms[10].

In table 4 the estimated coefficients of the generalized ordered probit model from the first stage are presented. For East and West Germany the estimated coefficients and the respective standard errors are given. It has to be considered that the point estimates are normalized by σ_ε. The marginal effects are not presented in detail. The results for East Germany support the complete information set of q_{it} as the lagged sales to capital ratio as well as the respective quadratic term are significant at the usual levels. The sign of the quadratic term is rather unsatisfactory as it is negative. However, the point estimate is rather low and the net effect of the sales to capital ratio is still positive. This indicates an increasing investment probability with increasing revenues. Unexpectedly, the results for the Western federal states reject the lagged sales to capital ratio whereas the quadratic term is positively related to the investment probability and significantly different from zero. Thus, increasing revenues rise the probability to invest.

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[8] Dummy variables for cash crop farms, pig and poultry farms, specialists in grazing livestock, permanent crops and mixed farms are defined referring to the standard gross margins.

[9] Referring to standard classification criteria (EUROSTAT) for West Germany the following size classes are defined: 8-16 European Size Units (ESU), 16-50 ESU, 50-100 ESU and >100 ESU whereas for the East we use 8-16 ESU, 16-50 ESU, 50-100 ESU, 100-250 ESU and >250 ESU.

[10] We are aware that this is a rather simple approximation in order to consider unobserved heterogeneity appropriately. The extension of the model specification with respect to random effects is left for future research.

The findings affirm *uncertainty* belonging to the information set for q_{it}. At first glance the differing signs of the parameter estimates for σ_i between East and West Germany are surprising. Thereby, only the parameter estimates for East Germany are consistent with the theoretical model. The marginal effects for East and West are rather small but also differ by sign. An increase in uncertainty increases the probability to invest (+0.04) and induces a declining probability to disinvest (-0.05). On the contrary, the estimates for West Germany indicate that an increase in uncertainty induces a decline in the probability to invest (-0.03) but increases probability to disinvest (+0.03).

Table 4. Results from the First Stage Generalized Ordered Probit Model

	East Germany		West Germany	
Proxy variables for q				
$(S/K)_{it-1}$	1.924		0.051	
	[0.173]**		[0.066]	
$((S/K)_{it-1})^2$	-0.444		0.147	
	[0.069]**		[0.027]**	
σ_i	0.125		-0.062	
	[0.036]**		[0.016]**	
Variables of the investment and disinvestment thresholds q_1 and q_2				
	q_1	q_2	q_1	q_2
CF_{it}/K_{it-1}	0.963	0.906	0.404	0.835
	[0.094]**	[0.095]**	[0.063]**	[0.072]**
$1/K_{it-1}$	-50 584	103 491	-22 361	120 907
	[10 521]**	[10 205]**	[2 933]**	[3 604]**
Constant	0.011	-0.066	-1.153	0.242
	[0.100]	[0.100]	[0.094]**	[0.076]**
Log-Likelihood	*-11 907*		*-69 447*	

Note: Standard errors are in brackets. Single (*) and double (**) asterisks denote significant at 5 % and 1 %, respectively.

The *range of inaction* depends on the constant, the inverse capital stock and the cash flow. If irreversibility is present, the parameter estimates for the constant terms and the inverse capital stock need to be significant with differing point estimates by investment and disinvestment probability. To induce optimal inactivity, the resulting investment threshold q_{1it} exceeds the disinvestment threshold q_{2it}. The cash flow coefficient

indicates additional transaction costs to acquire finance for investments and is expected to be significant if agency problems or informational asymmetries characterize the capital market. Imperfect capital markets should increase the range of inaction but an increasing financial ability should reduce the respective investment threshold.

In the West, the point estimates of the constant, the inverse capital stock and the cash flow parameter differ significantly by the investment and disinvestment threshold which is confirmed by the Wald-test rejecting the null of equal parameters. The respective thresholds for West Germany are:

$$\hat{q}_{it} > \hat{q}_{1it} = 1.153 + 22\,230/K_{it-1} - 0.404 \cdot CF_{it}/K_{it-1} \tag{15a}$$

$$\hat{q}_{it} < \hat{q}_{2it} = -0.242 - 120\,970/K_{it-1} - 0.835 \cdot CF_{it}/K_{it-1} \tag{15b}$$

Using the means of the respective variables the upper threshold is on average 1.17 and the respective lower threshold is about -0.47. Interestingly, the thresholds might be negative inducing that even losses or in other words a negative capital productivity is possible without inducing a disinvestment.

In the East, the constant term is rejected for the investment and disinvestment threshold. This implies that the range of inaction is mainly determined by the inverse capital stock, i.e. the size of the farm, and the cash flow. The parameter estimates for the capital stock differ significantly by investment and disinvestment threshold indicating a range of inactivity induced by costly reversibility. The parameter estimates for the cash flow do not significantly differ; the respective Wald-test cannot reject the null of equal estimates for the investment and disinvestment threshold. Accordingly, additional transaction costs due to capital market imperfections affect the investment and disinvestment decision at the same level.

The *cash flow sensitivity* is of particular interest as it reflects imperfect capital markets. The results confirm weaker capital markets and a stronger dependence on finance for East

Germany. The cash flow sensitivity of the investment trigger (0.96) exceeds the respective estimate for the West (0.40). This difference in the cash flow sensitivity between East and West Germany is even more pronounced when only co-operatives, stock companies and corporate farms as the main legal form of the former state owned co-operatives are considered (+2.66). Interestingly, the cash flow parameters show nearly no difference between East and West Germany with regard to the impact on the disinvestment probability. It seems that liquidity has the same importance in the disinvestment decision regardless of the capital market conditions. In the Western federal states, the effect of finance on the investment decision is less pronounced than on the disinvestment decision. The marginal effects for the Western federal states affirm a positive relation of the cash flow and the probability to invest (+0.09) whereas the relation is negative for the disinvestment threshold (-0.29). In the East, the effects have the same direction as in the West but are more pronounced (+0.35 and -0.36).

It can be shown that irreversibility, uncertainty and the dependence of finance coexist and affect investment decisions of farms. Under weaker conditions in the capital market the availability of finance is more important confirmed by the higher cash flow sensitivity in East Germany. In table 5 the results of the second stage regression explaining the (dis)investment rates and the results of the rather simple benchmark model (14) are given. The estimates confirm a positive and significant relation of the derived *shadow value of capital* to the investment and disinvestment rates. However, the point estimates are rather low. These findings are consistent with the theoretical model and give evidence on the quadratic term of the adjustment cost function. The point estimates in East and West for the disinvestment equation are higher than the point estimates for the investment equation indicating asymmetric adjustments.

Table 5. Results from the Second Stage Regressions

Variable	East Germany			West Germany		
	$(I_{it}/K_{it-1})^+$	$(I_{it}/K_{it-1})^-$	$(I_{it}/K_{it-1})^b$	$(I_{it}/K_{it-1})^+$	$(I_{it}/K_{it-1})^-$	$(I_{it}/K_{it-1})^b$
q_{it}	0.048	0.143	0.16	0.027	0.203	0.264
	[0.014]**	[0.006]**	[0.009]**	[0.008]**	[0.002]**	[0.007]**
CF_{it}/K_{it-1}	0.106	0.072	0.133	0.211	0.071	0.137
	[0.014]**	[0.006]**	[0.009]**	[0.008]**	[0.003]**	[0.005]**
Constant	0.141	-0.193	0.017	0.109	-0.179	-0.007
	[0.015]**	[0.007]**	[0.010]	[0.021]**	[0.003]**	[0.008]
Observations	4 352	6 385	10 737	15 333	28 899	44 232

Note: Standard errors are in brackets. Single (*) and double (**) asterisks denote significant at 5 % and 1 %, respectively.

The *constant term* is not rejected at the 1 % significance level attesting the linear term of the adjustment cost function. The unequal point estimates suggest costly reversibility. The constant term is expected to be negative, which is only confirmed by the disinvestment equations. Interestingly, the *cash flow sensitivity* is rather low for the East and West. The investment cash flow relation is positive and at first glance, this relation seems different compared to the financial parameter in the theoretical model. As mentioned above, an inverse relationship between the cash flow and investment is required. An increase in the inverse cash flow would induce increasing investment rates even though the sign of the inverse cash flow in the investment equation is negative. This reduction of the investment rate arises from the additional transaction costs in imperfect capital markets but declines as financial ability increases.

The results of the simpler benchmark model, $\left(I_{it}/K_{it-1}\right)^b$, which does not account for any selectivity bias and ignores the range of inaction, show that the parameter estimates differ in comparison to the results of the second stage regressions. The constant term is rejected in the simple model and the quadratic term of the adjustment cost function is given a higher weight compared to the second stage regressions. Ambiguously, the impact of the cash flow on investment, i.e. the cash flow sensitivity, is overestimated in the East and underestimated in the West. At first glance there is no statement possible which model

should be preferred. Therefore, the Chow-test, based on the F-test, is applied in order to test if the parameter estimates differ leading to a separate estimation of the investment and disinvestment equations (DAVIDSON and MACKINNON 2004). The Chow-test rejects the null of equal parameters at 1 %. This confirms the differences – founded in a more sophisticated theoretical basis – and indirectly, the need to account for the range of inaction.

Conclusions

The aim of this study has been to explain empirically observed phenomena as frequent periods of zero investments, high investment reluctance and in transition economies, rather low investment rates despite the need of rationalization and modernization investments. More precisely, the intention has been to show that imperfect capital markets, irreversibility and uncertainty coexist and jointly affect investment behavior of farms. Imperfect capital markets released by agency problems induce additional transaction costs to acquire finance or even a limited access to capital. However, impacts of agency problems and informational asymmetries in the capital market cannot solely explain investment reluctance. Costly reversibility and uncertain future expectations lead to retention and a range of inactivity along the optimal path of investment. Therefore, we have defined a stochastic and dynamic investment model which explicitly accounts for consequences of capital market imperfections inducing the dependence on finance and for coexistent irreversibility and uncertain future revenues. This is achieved by an augmented adjustment cost function as the presence of irreversibility does not allow to use strictly convex adjustment costs as traditional q-theory proposes. This augmented cost function accounts for sunk costs, costly reversibility and transaction costs to acquire finance. The econometric model is consistent with the theoretical model and has the structure of a two-sided generalized tobit model. The application of this model to German farm level panel

data delivers insights into a transition economy (East Germany) and allows direct comparisons to an established market economy (West Germany).

The empirical results confirm coexistent capital market frictions, costly reversibility and uncertainty. The findings support the hypothesis that farms in East Germany face significantly higher transaction costs expressed in terms of a higher cash flow sensitivity. Contrasting these findings with results from a simpler linear model, solely accounting for imperfect capital markets, affirms that a disregard of irreversibility reduces the informative power of such models.

We conclude that a more general form of models like tobit models are required to account for both, capital market imperfections as well as sunk costs and the respective range of inaction. These insights provide a new basis to explain farm growth, development of farm structure and thus structural change. Beyond the scientific guess of this paper the results imply that farmers' reluctance to invest is a result of dynamically optimal behavior when capital markets are perfect. Hence, a slow capacity adjustment per se does not justify policy intervention. When additionally capital markets are imperfect, retention of capacity adjustments increases as access to capital is limited. If there is evidence on imperfect capital markets, policy intervention should also focus on the reduction of the degree of imperfection to facilitate finance. The design of support schemes, for instance investment subsidies or retirement programs in the context of payments from the European Union, should take these findings into account.

Nonetheless, we are aware that the empirical model specification has potential for improvement. Main point for future research is the consideration of unobserved heterogeneity within the estimation. Another important issue refers to the comparison of the complex tobit model with the simpler linear model. After we have shown the limited validity of such models, we further aim to quantify the direction of the expected bias

within empirical applications disregarding the range of inaction and to find out how this bias limits conclusions drawn from such findings.

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