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in Energy Installations

Alfons Oude Lansink
Email: Alfons.Oudelansink@alg.abe.wau.nl

Kyosti Pietola

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Alfons Oude Lansink[1] and Kyosti Pietola[2]

1) Wageningen University, Farm Management Group, Wageningen
2) Agri-Food Research Finland, Economic Research, Helsinki

Contact author:

Dr. Alfons Oude Lansink
Wageningen University
Farm Management Group
Hollandseweg 1
6706 KN Wageningen
The Netherlands
Email: Alfons.Oudelansink@alg.abe.wau.nl

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Abstract

This paper applies a semi-parametric approach to estimating a generalised model of investments in energy installations. The model accounts for irreversibility and lumpiness of investments by linking a parametric specification of the unobservable dynamic shadow price to observed investment behaviour using a non-parametric specification of the adjustment cost function. The results suggest that marginal costs of investments in energy installations increase quickly at small investment levels, whereas the increase slows down at higher investment levels. Therefore, standard parametric adjustment cost models are likely biased such that they over-estimate small investments and under-estimate large investments.
Keywords: Investments, horticulture, semi-parametric estimation

1. Introduction

The Dutch glasshouse industry is an important user of energy and accounts for approximately 4% of greenhouse gas emissions in the Netherlands. Recently, the Dutch glasshouse industry made a covenant with the government aiming at reducing the use of energy. In the covenant, the Dutch glasshouse industry has agreed to improve its energy efficiency by 65% in 2010 compared to the level of 1980 (Anonymous, 1997). Investments in energy saving installations are an important option for firms in the sector to reduce their energy intensity and CO_2 emissions. Econometric modelling of investments in energy installations may provide insight in the relative importance of different factors underlying investment decisions. However, econometric modelling is troubled by the fact that most investments are lumpy decisions as firm operators can choose from only a limited number of investment options (e.g. the number of different installations is limited). Moreover, inspection of data reveals that investments in energy installations are largely irreversible, due to e.g. rapid technical change and costs to de-install energy installations. Ideally, models of investments in energy installations should account for irreversibility and lumpiness of decisions.

Econometric models of investments in capital assets have frequently applied the adjustment cost theory which hypothesises that it is costly to producers to adjust the quantity of capital. In the literature on adjustment cost theory, the functional specification of the adjustment cost function has been the subject of substantial debate. The symmetric smooth convex (quadratic) adjustment cost specification has been very popular in empirical research due to its empirical tractability and computational ease. However, this specification is largely inappropriate for individual firm level data that typically exhibit patterns of negative, zero and positive investments (Oude Lansink and Stefanou, 1997). The notion of asymmetric adjustment costs, i.e. quasi-fixed factor adjustments differ for expansions and contractions, has been emphasised by Goodwin (1951). Chang and Stefanou (1988) and Oude Lansink and Stefanou rejected symmetry on individual data of Pennsylvania dairy farms and Dutch cash crop farms, respectively. Similarly, Pfann and Palm (1993) and Pfann (1996) rejected symmetry on aggregate data of Dutch and UK manufacturing sectors. Hsu and Chang (1990) show that a discontinuity of the adjustment cost function at the origin is likely to result in a pattern of zero and nonzero investments. As such, they provide a rigorous link between asset

fixity theory of Johnson (1956) and adjustment cost theory. Additionally, Rothschild (1971) and Davidson and Harris (1981) suggested that the existence of non-convex adjustment costs results in lumpy investments; evidence for non-convexities was found by Whited (1998) on data of US manufacturing firms.

In a recent paper, Abel and Eberly (1994) develop a general theoretical model of investment under uncertainty. The adjustment cost function incorporates fixed costs of adjustment, different purchase and resale prices of capital goods and adjustment cost asymmetries. Regimes for negative, zero and positive investments are characterised by two critical shadow values of capital, i.e. a lower and an upper value. Investments are positive if the shadow price of capital exceeds the upper critical value and are negative for shadow values smaller than the lower critical value.

An empirical problem in the model of Abel and Eberly is the appropriate specification of the adjustment cost function. First order conditions for optimal investments and the lower and upper shadow value of capital depend on marginal adjustments. However, cost asymmetries, different purchase and resale prices of capital goods and fixed adjustment costs result in an adjustment cost function that may not be differentiable at the zero investment level. As a result, first order conditions are not identified for zero investments. Previous authors (Chang and Stefanou, 1988; Oude Lansink and Stefanou, 1997) addressed this problem by using Heckman's two stage estimator for censored data that ignores all censored observations in the second stage. Pietola and Myers (2000) rule out the possibility of negative investments *a priori* and estimated the censored investment behaviour by Tobit –type Maximum Likelihood estimation method.

The purpose of this paper is to develop an empirically tractable model of investment in energy installations using firm level data. The approach adopted is to empirically link the unobserved shadow price of capital to observed investment behaviour. Marginal adjustment costs are approximated non-parametrically, by discretising investments. The resulting ordered probit model is applied to a rotating panel of Dutch glasshouse firms over the period 1991-1995.

The paper proceeds with a discussion of the theoretical framework underlying decisions in energy installations. This is followed by a presentation of the empirical model and data. Section 5 discusses the results and summary and conclusions follow in section 6.

2. Theoretical framework

Dutch glasshouse producers are assumed to maximise at any point in time the value of variable profits (revenues minus variable costs) given by the function $\pi(p_t, K_t, Z_t)$[1], where p_t and K_t, are vectors of netput prices and quantities of capital inputs, respectively; Z_t is a vector of fixed inputs and factors exogenous to the firm.

Producers are assumed to maximise the expected present value of variable profits (π) minus costs of adjusting the capital stock (C):

$$V(p_t, K_t, Z_t) = \max_{I_t} \sum_{t=0}^{\infty} \rho_t E_t \left\{ \pi(p_t, K_t, Z_t) - C(I_t) \right\}$$

(1)

subject to the transition equation for capital stock

$$K_{t+1} = I_t + (1-\delta)K_t$$

(2)

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[1] Alternatively, $\pi(p_t, K_t, Z_t)$ could represent a revenue function. In that case p_t represents a vector of output prices and Z_t is a vector of inputs and exogenous factors.

where $V(\cdot)$ is the optimal value function, E_t is the expectations operator conditional on the information available at time t and ρ_t is the real discount rate which is defined as $\rho_t = (1+r)^{-t}$ with r reflecting the real interest rate. Adjustment costs are incurred on gross investments (I) and include all costs associated with the purchase or sale of a capital asset, including the purchase costs (or revenues from sale) of the capital asset, search costs and learning costs. In the transition equation, δ is the depreciation rate.

The maximisation problem in (2) is solved using the Bellman equation:

$$rV(p_t, K_t, Z_t) = \max_I \{ \pi(p_t, K_t, Z_t) - C(I_t)) \} \tag{3}$$

The literature uses different assumptions on the shape of the adjustment cost function to provide optimal solutions for (3). The first approach ignores the existence of irreversibility of investments and assumes the adjustment cost function is symmetric and twice continuously differentiable and convex investments. The second approach assumes that the optimality conditions have a corner solution at zero investment. The corner solution can result from e.g. asymmetric adjustment costs or from irreversible investments (i.e. investments are largely sunk costs). Model specifications of this type have been used in more recent applications (Chang and Stefanou, 1988; Oude Lansink and Stefanou, 1997, Pietola and Myers 2000). The third approach is applied in this study and generalises the model to multiple corners, kinks or thresholds that affect the optimal size of individual investments. This approach is motivated irreversibility and lumpiness of investments.

Interior solution

Ignoring the corner solutions and differentiating the Bellman equation (3) with respect to the investment (I) gives the first order condition for optimal investments:

$$V_K(p, K, Z) = C_I(I^*) \tag{4}$$

where V_K is the unobserved dynamic shadow price. Condition (4) is satisfied by the optimal investment $I^*(p,K,Z)$. [2]

Irreversibility and optimal zero investment

When adjustment costs are asymmetric or investments are at least partially irreversible, the adjustment cost function is not differentiable with respect to investment at zero. Marginal adjustment cost $C_I(0)$ may not exist at zero. Nevertheless, the right hand limit for the derivative exists. Define $C_I^+(0)$ as the upper limit of the first derivative of C with respect to I when I approaches zero from the right:

$$C_I^+(0) = \lim_{I \to 0^+} C_I(I) \tag{5}$$

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[2] Other decision rules, such as output supplies and input demands can be derived by differentiating the Bellman equation with respect to prices and applying the envelope theorem. The derivation of these rules is similar in all three cases and is skipped here.

Adding the resulting Kuhn-Tucker conditions, the optimal investments I^* meet:[3]

$$I^*(p,K,Z) = 0 \qquad\qquad\qquad\qquad if\ \ V_K(p,K,Z) \le C_I^+(0) \qquad\qquad (6a)$$

$$V_K(p,K,Z) = C_I(I^*)\ \text{and}\ I^*(p,K,Z) > 0 \quad if\ \ V_K(p,K,Z) > C_I^+(0) \qquad (6b)$$

Thus, positive investment is observed if the shadow price for capital exceeds the marginal adjustment cost, when I approaches 0 from the right. Otherwise, optimal investment is zero.

Under this setting, testing the shape of the adjustment cost function in the regime of positive investment, as applied in the previous dual models, requires that the shadow price of capital is equal to the marginal adjustment cost –a requirement that is likely to be violated when investments are lumpy.

Multiple thresholds

When the adjustment cost function is generalised to allow for potential kinks or discontinuities within the regime of positive investment, say at an arbitrary $I = I_j$ (for $j = 0,1,2...J$), the optimality conditions (6) become

$$I^*(p,K,Z) = 0 \qquad\qquad if\ \ V_K(p,K,Z) \le C_I^+(0) \qquad\qquad\qquad (7a)$$

$$I^*(p,K,Z) \in (I_j, I_{j+1}) \qquad if\ \ C_I^+(I_j) < V_K(p,K,Z) < C_I^-(I_{j+1}) \qquad (7b)$$

where $C_I^-(I_j)$ is the lower limit of the first derivative of C with respect to I when I approaches the threshold value I_j from the left. It is evident that the ranking conditions in (7) account for multiple censoring in the adjustment cost function.

Since $C_I(I_j)$ may not exist, the marginality conditions (e.g. (4) and (6b)) corresponding to an increasing, differentiable and convex adjustment cost function can no longer be used for characterising optimal investments. These conditions are now replaced by ranking conditions of the form:

$$C^+(0) > 0 \qquad \text{and} \qquad C_I^+(0) > 0 \qquad\qquad\qquad\qquad (8a)$$

$$C^-(I_j) \le C^+(I_j)\ \text{and}\ C_I^-(I_j) \le C_I^+(I_j) \qquad \text{for j=1,2,...,J} \qquad (8b)$$

3. Empirical Model

Empirical implementation of the model in (7) requires a specification for the shadow price for installed capital $V_K(.)$ and an approximation for the (possibly non-differentiable) adjustment cost function. The parametric form for the unobserved dynamic shadow price of installed capital (V_K) is given by:

$$V_{K_{it}}(p_t, K_{it}, Z_{it}) = \alpha p_t + \beta K_{it} + \gamma Z_{it} + u_i \qquad\qquad\qquad (9)$$

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[3] As Abel and Eberly (1994) show, these conditions can be extended to incorporate the regime of negative investments.

where $i=1,..,H$ indexes the firm and $t=1,..,T_i$ indicates periods with length varying across firms; u_i is a random firm-specific term (distributed as $N(0,\sigma^2)$) capturing firm-specific factors that are unobservable from the data set such as managerial capabilities and factors related to the structure and location of the firm. Note that the linear specification of V_K is consistent with a quadratic specification of the optimal value function ($V(\cdot)$), i.e. a specification that is frequently used in the literature[4].

There is no exact parametric specification that could be used in ranking optimal investments across the investment thresholds (over j's) given in (7) since the adjustment cost function is not necessarily continuously differentiable. Therefore, a non-parametric approximation to the unknown adjustment cost function is used. A discrete indicator DC_I is defined in stacking the shadow price for capital (9) across the investment thresholds. The indicator takes the following values:

$$DC_I = 0 \quad if \ I^* = 0$$
$$DC_I = 1 \quad if \ 0 < I^* \leq \bar{I}_1$$
$$DC_I = 2 \quad if \ \bar{I}_1 < I^* \leq \bar{I}_2 \qquad\qquad (10)$$
$$...$$
$$DC_I = J \quad if \ I^* \geq \bar{I}_{J-1}$$

where $\bar{I}_1,..,\bar{I}_J$ are arbitrary bounds of the discrete intervals of investments. Note that the indicator DC_I is linked to the size of the investment, since $I_j > I_{j-1}$ for j=1,..,J-1. It should also be noted that the unit distance between different investment levels in the discrete variable DC_I merely ensures a consistent ranking of investment levels; the absolute distance is not used during estimation.

Combining (9) and (10) results in a random effects ordered Probit model that gives parameter estimates for α, β and γ and a set of threshold parameters $\mu_0,...,\mu_{J-1}$, corresponding to J different investment levels. The relation between the discrete variable DC_I, the threshold parameters $\mu_0,...,\mu_{J-1}$ and the unobserved dynamic shadow price of installed capital V_K is given by:

$$DC_I = 0 \quad if \ V_K \leq \mu_0$$
$$DC_I = 1 \quad if \ \mu_0 < V_K \leq \mu_1$$
$$DC_I = 2 \quad if \ \mu_1 < V_K \leq \mu_2 \qquad\qquad (11)$$
$$...$$
$$DC_I = J \quad if \ V_K \geq \mu_{J-1}$$

The parameters μ_i are estimated as free parameters in the model under the condition: $\mu_0 \leq \mu_1 \leq,..,\leq \mu_{J-1}$. This condition ensures convexity of the adjustment cost function in investments,

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[4] Since the shadow price is linear in output price, the optimality conditions (7) are also consistent with output price uncertainty that follows a Wiener process (Pietola and Myers 2000).

i.e. marginal adjustment costs are non-decreasing in investments. The threshold parameters provide non-parametric information about the relation between the size of the investments and the first derivative of the unknown adjustment cost function. The *relative* size of the parameters indicates the degree of convexity of the adjustment cost function in investments. However, there is no direct explanation for their *absolute* values as they should be corrected for an unknown constant term and the standard deviation of the model.

4. Data

Data on glasshouse firms covering the period 1991-1995 are obtained from a stratified sample of Dutch glasshouse firms keeping accounts on behalf of the LEI accounting system. The panel data set used for estimation is incomplete, i.e. it contains 1056 observations on 294 firms. The data set contains observations from three different firm types: firms specialised in vegetables production, cut-flower production and pot-plant production. Firms are represented in the sample for at least two years.

The observations on investments are discretised using fixed threshold levels of investments in energy installations. The threshold levels and the resulting frequency distribution are reported in Table 1. A large share of the observations (75%) is concentrated in the first and second investment category. All other categories have much smaller proportions.

Table 1: Frequency distribution of different investment levels

ψ_l	I^*	Number	Proportion
0	0	360	0.339
1	$0 < I^* \leq 50.000$	443	0.418
2	$50.000 < I^* \leq 100.000$	98	0.092
3	$100.000 < I^* \leq 150.000$	47	0.044
4	$150.000 < I^* \leq 200.000$	24	0.022
5	$200.000 < I^* \leq 300.000$	35	0.033
6	$300.000 < I^* \leq 400.000$	15	0.014
7	$400.000 < I^* \leq 500.000$	10	0.009
8	$500.000 < I^* \leq 750.000$	15	0.014
9	$750.000 < I^* \leq 1000.000$	4	0.003
10	$I^* \geq 1000.000$	10	0.007

A detailed description of the explanatory variables used in this research is found in Table 2. The prices of output, energy and services are calculated as Törnqvist price indexes, with prices of individual components obtained from the LEI/CBS. The price index varies over the years and firm types, but not over firms of the same type. This implies that prices are exogenous from the perspective of the firm. The price of output consists of prices of vegetables, fruits, pot-plants and flowers. The price of energy consists of prices of gas, oil and electricity, as well as delivery of thermal energy by electricity plants. The price index of services includes services by contract workers and services from storage and delivery of outputs. All prices are normalized by the price of materials, consisting of seeds and planting materials, pesticides, fertilizers and other materials.

Capital invested in energy installations and structures (i.e. buildings, glasshouses, land and paving) is measured at constant 1990 prices and is valued in replacement costs. Labour is measured in quality-corrected man-years, and includes family as well as hired labour. The

quality correction on labour is performed by the Agricultural Economics Research Institute, in order to aggregate labour from able-bodied adults with labour from young family members and labour from partly disabled workers.

Other firm characteristics that may affect investments in energy installations are firm type, availability of a successor and heating technology. The variable 'vegetables firm' distinguishes food producers (i.e. producers of vegetables) from non-food producers, i.e. producers of cut-flowers and pot-plants. The motivation for this is that food markets may differ from non-food markets (e.g. consumer preferences, perishable products). Also, the technology of food production is different from the technology of non-food production, which may cause different investment behaviour. Availability of a successor may extend the time horizon of the firm operator, thereby increasing the optimal investment level. Heating technology is represented by a dummy that indicates whether firms use a traditional technology (central heating boiler) for heating the glasshouse or more advanced energy saving technologies such as co-generators[5], heat storage and thermal deliveries by electricity plants. Firms using a traditional heating technology are expected to have a smaller demand for replacement investments.

Table 2: Description of Data.

Variable	Dimension	Mean	Standard Deviation
Price Output	Base year 1990	0.926	0.077
Price Energy	Base year 1990	1.013	0.031
Price Services	Base year 1990	0.899	0.063
Capital in Energy Installations	Guilders*100.000	0.393	0.475
Capital in Structures	Guilders*100.000	10.081	8.936
Labor	Man years	7.009	4.913
Vegetables firm	1 if firm is vegetables firm	0.364	0.481
Successor	1 if successor available	0.223	0.417
Traditional heating	1 if traditional heating	0.738	0.440
Trend	1991=0	1.892	1.367

6. Results

Results of the Maximum Likelihood estimation of the random effects ordered Probit model of investments in energy installations are found in Table 3. The parameter estimates and t-values indicate that four out of ten parameters associated with prices, inputs and firm characteristics are significant at the critical 5% level. In addition, all estimated threshold parameters[6] $\mu_1,...,\mu_9$ and the standard deviation of the random effect are highly significant at the critical 5% level.

The parameter estimates show that, in line with prior expectations, output price has a positive effect on investments in energy installations. Price of energy has a positive and significant (at 5%) impact on investments in energy installations, suggesting that energy and energy installations are substitutes, i.e. firms can reduce the costs of energy by investing in new energy saving installations. Capital in energy installations has a negative impact (significant at 13%) on investments, implying that the value function is concave in this variable. Larger quantities of already installed capital reduce the dynamic shadow price of capital and lower the probability of investments. Labour has a (highly) significant positive impact suggesting labour is

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[5] Co-generators produce electricity and heat simultaneously (van der Velden, 1996).

[6] As usual in ordered probit models, the first threshold parameter has been restricted to zero, i.e. $\mu_0 =0$.

a complement of capital in energy installations, i.e. firms that employ more workers have better opportunities to get good returns on investments in energy installations. The prices of outputs and services and the quantity of capital in structures do not have significant impacts on investments in energy installations.

The parameter estimate related to vegetables firm in Table 3 shows that vegetables firms have a smaller demand for investments in energy installations than non-food (i.e. cut flower and pot-plant) firms, although the difference is not significant at 10%. Specialised vegetables firms have smaller investments in energy installations than other firms since they operate at a smaller scale than cut flower and pot-plant firms do. In line with prior expectations, availability of a successor has a significant and positive impact on investments. Furthermore, firms using traditional heating have a significantly lower demand for investments in energy installations than firms using more advanced heating technologies. This is consistent with the prior expectation that firms using traditional heating technology have smaller requirements for replacement investments than firms using more expensive up-to-date technology. Another explanation might be that firms using traditional heating are less concerned with keeping their technology up-to-date, i.e. firms using a traditional heating technology are more cautious in investing in new installations.

Table 3 also shows that the standard deviation of the random firm-specific effect is highly significant at the critical 5% level (i.e. one-sided critical value is 1.645). This result implies that unobservable firm-specific factors, such as management and location of the firm play an important role in investment decisions on energy installations.

Table 3: Parameter estimates of random effects ordered probit model

Variable	Parameter	t-value
Constant	-4.760	-1.904
Price Output	1.107	1.128
Price Energy	3.284	2.000
Price Services	1.305	1.369
Capital in Energy Installations	-0.292	-1.541
Capital in Structures	0.013	1.134
Labor	0.071	6.282
Vegetables firm	-0.230	-1.437
Successor	0.261	2.063
Traditional heating	-0.806	-5.406
Trend	-0.055	-1.503
μ_1	1.498	20.903
μ_2	1.959	24.745
μ_3	2.246	25.399
μ_4	2.427	26.914
μ_5	2.767	28.230
μ_6	2.982	27.548
μ_7	3.170	27.339
μ_8	3.586	26.262
μ_9	3.766	21.054
σ	0.569	7.380

The threshold parameters $\mu_1,...,\mu_9$ have been estimated as free parameters in the model, so there is no useful explanation for their absolute size. However, the relative distance between μ_i and μ_{i+1} provides evidence about the relation between marginal adjustment costs and the size of the investments as depicted in Figure 1. That is, the true marginal adjustment costs can be obtained by a linear transformation of the threshold parameters and vice versa. Furthermore, it should be

noted that the marginal adjustment costs are assumed to be zero at the zero investment level and are assumed to be positive for positive investments. These assumptions implicitly follow from restricting μ_0 at zero in order to allow identification of the remaining threshold parameters. However, this restriction is not unreasonable for the model at hand, i.e. the theoretical model implies that the first derivative of a non-negative and convex adjustment cost function does not exceed zero for *I=0* and exceeds zero for strictly positive investments. The shadow value of capital has to lie in the range of (0 - 1.5) in order to generate a positive investment level.

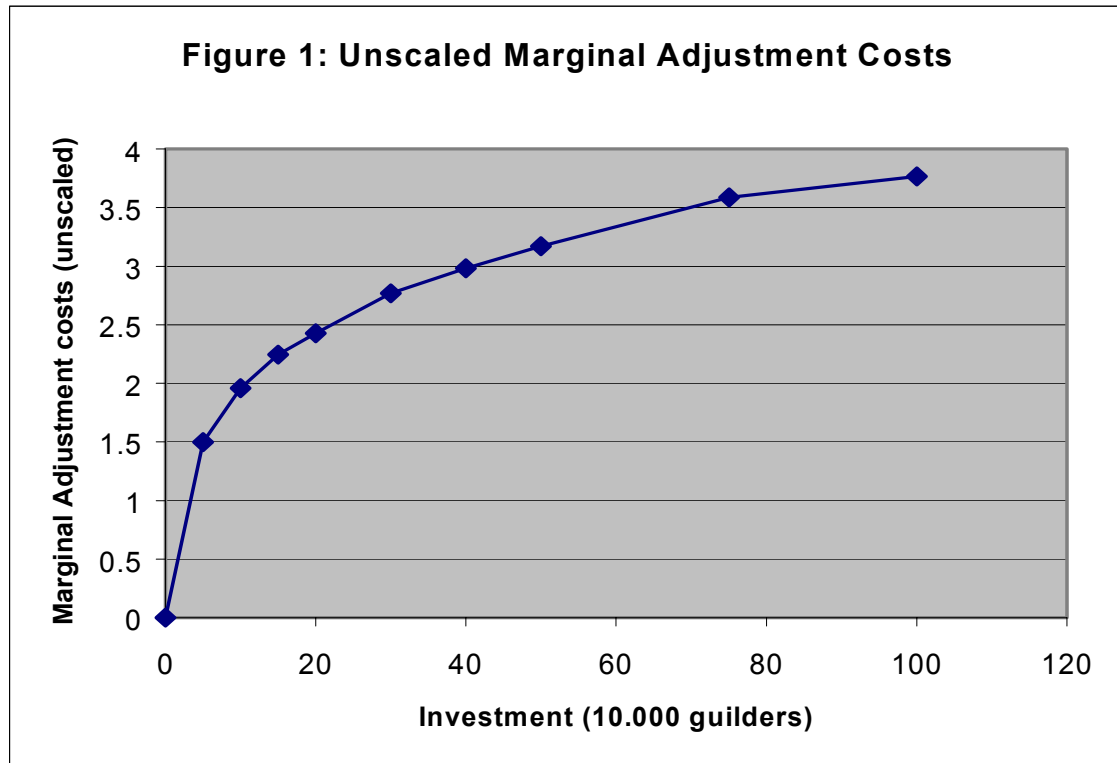**Figure 1: Unscaled Marginal Adjustment Costs**

Figure 1 shows that marginal adjustment costs are concave in the level of investments, i.e. they rapidly increase for small amounts of investments, whereas the increase slows down at higher investment levels. The rapid increase of marginal adjustment costs in the range between zero and 50.000 guilders provides indirect evidence for the existence of an option value (Dixit and Pindyck, 1994) of investments in energy installations. The option value arises if firm operators have the option to postpone an irreversible investment and as Dixit and Pindyck (1994) argue, it may be seen as an additional adjustment cost.

The shape of the marginal adjustment cost curve in Figure 1 suggests that a parametric specification of the adjustment cost function should at least contain first, second and third order terms to reflect the 'true' adjustment cost structure. A standard quadratic specification, implying a linear relation between investments and marginal adjustment costs would underestimate marginal adjustment costs for small investments and overestimate marginal adjustment costs for large investments. Consequently, such a model more likely predicts the occurrence of small investments and less likely predicts the occurrence of (very) large investments. The shape of the

marginal adjustment cost curve Figure 1 also suggests that the adjustment cost function becomes linear at high levels of investments, i.e. marginal adjustment gradually become constant[7].

More insight in the model is obtained from elasticities of investments to changes in model variables. The elasticities in Table 4 measure the impact of a 1% increase of the output and variable input prices and fixed input quantities on the size of investments in energy installations. At the sample mean, the value of ψ_I^* is 0.550, predicting an investment level between zero and 50.000 guilders[8]. However, assuming that the marginal adjustment cost curve is piecewise linear, the expected investments in energy installations are approximated as 0.550/1.498*50000 = 18356. Elasticities in Table 4 are obtained by calculating the expected investments before and after increasing a variable by 1%. Table 4 shows that in price variations have a relatively large impact on the size of the investments in energy installations. Investments are in particular responsive to changes in the price of energy, i.e. a 1% increase in the price of energy increases investments in energy installations by 6.04%. Therefore, it can be concluded that a tax on energy may be an effective instrument to induce firms to invest in new energy saving installations. Capital that is already invested in energy installations has a negative impact, although the impact is much smaller in absolute terms than the impact of prices and labour. Table 4 also confirms that labour plays an important role in investments in energy installations.

Table 4: Elasticity of investment in energy installations to changes in output price and quantity of inputs at the sample mean

Variable	Elasticity
Price Output	1.863
Price Energy	6.045
Price Services	2.134
Capital in Energy Installations	-0.209
Capital in Structures	0.232
Labor	0.901

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[7] Nickel, (1978, p37) also suggests that adjustment cost functions may become linear at higher levels of investments.

[8] The random firm effect is not included here. By assumption, the random firm effect is, on average equal to zero.

Conclusions

Econometric modelling of investments in energy installations should account for lumpiness and irreversibility of investment decisions. Previous approaches to modelling investments are restricted by the assumption of a parametric specification of the adjustment cost function. Assuming a parametric specification imposes a rigid structure on adjustment costs *a priori* and may preclude efficient use of all available observations (i.e. zero investment observations). This paper adopts a semi-parametric approach to modelling investments in energy installations. The adjustment cost function is estimated non-parametrically, while satisfying theoretical curvature conditions, using a random effects ordered probit model.

The results show that marginal adjustment costs increase rapidly for small investments whereas the increase slows down for higher investments. Using a standard quadratic adjustment cost function for investments in energy installations likely over-estimates small investments and under-estimates large investments. Investments in energy installations are found to be very responsive to changes in prices and in particular to changes in energy prices. Therefore, an energy tax may be a very effective instrument to encourage firm operators to invest in new energy saving installations. Availability of labor and unobservable and observable (e.g. successor and heating technology) firm characteristics also play an important role in investments in energy installations.

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