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## A Dynamic Ex ante Input Demand Model with Application to Western Canadian Agriculture

<sup>1</sup>G. Chabokrow, <sup>2</sup>R. Gray and <sup>3</sup>M. Ghorbani

<sup>1</sup>Research Centre for Agriculture and Natural Resource, Postal Code 71555-617, Shiraz, Iran

<sup>2</sup>Department of Agriculture Economics, 51 Campus Drive, S7N 5A8, Saskatoon, Canada

<sup>3</sup>Department of Agriculture Economics, Ferdowsi University of Mashhad, Mashhad, Iran

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**Abstract:** This research tries to study a dynamic Ex ante input demand model with application to western Canadian agriculture. The dynamic Ex ante input demand model combines the cost of capital adjustment and Ex ante output choice to create a dynamic model that is theoretically and empirically appealing. The four input empirical model provided a tractable means of estimating a dynamic Ex ante input demand system combined with an Ex ante supply function. The application to Western Canadian agriculture resulted in model that was dynamically stable and consistent with profit maximization. The results show that agricultural capital (machinery and buildings) is a quasi-fixed input, with significant adjustment costs and a slow rate of adjustment. Technological change and machinery investment are energy and material-using for western Canadian agriculture. There is some indication that agricultural wealth lowers the discount rate within the sector has a positive effect on capital investment.

**Key words:** Investment, agriculture, dynamic, adjustment rate, uncertainty, Canada

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### INTRODUCTION

Agricultural investment is an important determinant of future productivity, yet is poorly understood. The inherently dynamic nature of investment decisions has challenged both theoretical and empirical modeling. In this study, we develop the Dynamic Ex-ante Input Demand (DEID) framework, which is a theoretical model that combines the Ex ante cost function approach (Moschini, 2001) and dynamic cost of adjustment factor demand models (Berndt *et al.*, 1981; Treadway, 1974; Skjerpen, 2005; Morana, 2007). The model also incorporates the potential effects of wealth and income on the discount rate. By incorporating adjustment costs, Ex ante cost functions and discount rate effects, the DEID model provides a more robust dynamic framework for investment demand estimation.

At this study, the DEID framework is used to specify an empirical model of dynamic factor demands for Western Canadian Agriculture. The results of the empirical analysis reveal that adjustment costs are significant such that machinery stock change takes place over several years. There is also some evidence that agricultural wealth reduces the discount rate for investment.

### MATERIALS AND METHODS

**The theoretical model:** Dynamic Ex ante Input Demand (DEID) model developed in this paper is built on the basis of the cost of adjustment theory (Lucas, 1967; Pietola and Myers, 2000; Gardebroek and Lansink, 2004; Hennessy and Moschini, 2006) and the Ex ante cost function theory developed by Pope and Chavas (1994), Pope and Just (1996, 1998) and Moschini (2001). In the DEID model, quasi-fixed inputs dynamically move toward optimal levels while explicitly recognizing production uncertainty. Below a brief description of the cost of adjustment theory and Ex ante cost functions is presented prior to the formal development of the DEID model.

**Dynamic cost of adjustment models:** Eisner and Strotz (1963) developed the theory of adjustment in a dynamic optimization framework. Based on their theory, resources are used in adjusting capital stock and the present value maximized by the firm depends on the optimal level of inputs selected by the firm and on the paths of the current capital stock to the optimal level. Later, Lucas (1967), Gould (1968) and Treadway (1971) extended the study of Eisner and Strotz (1963). In all models, in spite of differences in their complexity, an objective function,

incorporating factor adjustment costs and a production function, is specified. In these models, the costs vary with the speed of capital adjustments. It is assumed that the values of the expected input and output prices do not change. This stationary expectation assumption is required if the dynamic optimization is to be well defined (Nerlove, 1972).

Following Berndt *et al.* (1979, 1980) and Berndt *et al.* (1981), the optimal adjustment paths for the quasi-fixed inputs are derived by incorporating a short-run cost/profit restricted function into a long-run dynamic optimization framework. As the rate of change of each quasi-fixed input increases in a given period, the amount of foregone output rises. In the single-product case, the effect is measured in terms of decreases in physical units of the product (Rezitis *et al.*, 1998). The optimal path of adjustment allows the analysis of short, intermediate and long-run elasticities for capital and other inputs.

**Ex ante estimation:** In the presence of production uncertainty, a cost function consistent with expected profit maximization is based on expected rather than actual output. Cost functions depending on expected output (and not actual output) are referred to as Ex ante cost functions (Pope and Just, 1996). Cost and factor demand equations are formulated and estimated as though they depend on the actual random sketch of output. Such cost functions will be referred to as Ex post functions.

As emphasized in the study by Pope and Just (1996), an estimation problem arises when the production technology is inherently stochastic. Importantly, agricultural production models include cases where some factors outside the producer's control affect output. When producers make their input choices prior to the resolution of this production uncertainty, the standard cost function specification, which is conditional on the realized output level, is not relevant. In this situation input choices conditional on the expected output level should be studied, i.e., estimate the structure of an Ex ante cost function.

Pope and Just (1996) proposed an Ex ante cost function approach using the dual distance function (Deaton, 1979) computation of expected output within the estimation process. They show that resulting estimator is consistent and asymptotically efficient. Moreover, they show using Monte Carlo simulation that biases and mean squared errors from conventional ex-post methods are substantial. An empirical application to US agriculture also produces a more plausible estimation than conventional methods (Pope and Just, 1996, 1998).

Moschini (2001) suggested an alternative procedure to estimate the Ex ante cost function. He shows that by

using the full implications of the expected profit maximization hypothesis and introducing the notion of an Ex ante supply function, the errors-in-variable problem inherent in ex post functions can be effectively removed. Moschini assumes that producers solve the expected profit maximization and expected production level depends on the output price  $P$ . The observable  $P$  provides the obvious instrument for unobserved expected output and for the Ex ante supply function. Moschini (2001) solved a system of Ex ante input demand equations along with the corresponding Ex ante supply equation and shows that this method yields consistent estimates of the parameters.

**The Dynamic Ex ante Input Demand (DEID) model:** The optimization problem facing the firm is to choose  $K_i(t)$ , the vector of quasi-fixed factors and  $X_i(t)$ , the vector of variable inputs, to minimize the present value of the cost of producing a planned flow of output,  $\bar{Q}(t)$ , subject to a production function given as:

$$\bar{Q}(t) = F(X(t), K(t), \dot{K}(t), t) \quad (1)$$

where,  $\bar{Q}$  is planned output,  $X$  is a vector of variable inputs,  $K$  is quasi-fixed input,  $\dot{K}$  is the rate of change of the quasi-fixed input and  $t$  stands for the time which represents the state of technology.

Following Treadway (1971, 1974) and Berndt *et al.* (1980), the quasi-fixed input is specified to be subject to increasing internal costs of adjustment:

$$\frac{\partial F}{\partial \dot{K}} < 0 \text{ and } \frac{\partial^2 F}{\partial \dot{K}^2} < 0 \quad (2)$$

The term  $\partial F / \partial \dot{K} < 0$  represents the internal cost of foregone output of a change in the stock of the quasi-fixed input. The markets for the quasi-fixed and variable inputs are assumed to be perfectly competitive. The firm minimizes the present value of the cost of producing a given flow of output subject to the production function. Thus, the present value of cost at time  $t = 0$  is given by:

$$C(0) = \int_0^\infty e^{-rt} \left( \sum_i \bar{p}_i X_i + \sum_i \bar{k}_i I_i \right) dt \quad (3)$$

where,  $r$  is the firm's discount rate,  $I_i = \dot{K}_i + \delta_i K_i$  is the gross addition to the stock of the  $i$ th quasi-fixed input,  $\delta_i$  is the depreciation rate,  $\bar{p}_i$  are the prices of variable inputs and  $\bar{k}_i$  is the price of quasi-fixed input. The problem of the firm is to minimize  $C(0)$ .

The discount rate of the firms in the industry is assumed to be an increasing function of the prime interest

rate,  $r'$  and a decreasing function of wealth,  $w$  and cash flow, made up of income,  $m$  and government payments  $g$ , or :

$$r(t) = R[r'(t), w(t), m(t), g(t)] \quad (4)$$

As with most applied dynamic models is assumed that price and discount rate expectations reflect only prevailing values and that the input prices will increase at a constant exponential rate, implying that relative factor price expectations are static and that the constant rate of inflation can be factored out to transform  $r$  into a constant real discount rate.

To identify planned output, conditions of profit maximization are used to equate marginal cost and output price. Planned output, will be function of output prices, factor prices, capital stock, the rate of change in capital stock and time  $t$ , or:

$$\bar{Q}(t) = S(P, \bar{p}_1, \bar{k}_1, K(t), \dot{K}(t), t) \quad (5)$$

where, the supply function corresponds to the marginal cost of planned output.

**The empirical model:** In order to show empirically the dynamic model, which was theoretically developed, a functional form must be specified for the restricted normalized cost function  $G$  and the continuity assumptions incorporated in the theoretical model must be modified to conform to the data constraints. It is assumed that the net changes in quasi-fixed inputs ( $\dot{K} = \partial K / \partial t$ ) can be represented by discrete net changes ( $\Delta K = K_t - K_{t-1}$ ) and that output in period  $t$  is produced by quasi-fixed input in place at the beginning of that period. In terms of functional form, the quadratic normalized restricted cost function of Berndt *et al.* (1979, 1980) is modified so that coefficients of the demand equations represent effects of price changes on input-output ratios rather than on input levels (Morrison and Berndt, 1981).

An important assumption is that expectations of the relevant price variables are fixed at the current level for all future periods; that is, static price expectations are assumed. This assumption allows for the existence of a fixed long-run equilibrium position toward which the firm is striving; that is, the assumption of static expectations implies that the firm's target is not moving during time unless actual prices change.

To shows a tractable DEID model consider a production function where expected output,  $\bar{Q}$ , is a function of three variable inputs, labor ( $L$ ), energy ( $E$ ) and material ( $M$ ) and one quasi-fixed input, machinery ( $K$ ). When investment within a period affects production

relationships, the expected production function can be written as:

$$\bar{Q} = f(K, L, E, M, I, T) \quad (6)$$

where,  $I$  is net investment and  $T$  is the technology level. Given exogenous prices and fixed capital in short-run, the theory of duality between cost and production functions implies that, given short-run cost-minimizing behavior, the underlying production function can be represented uniquely by a normalized restricted cost function:

$$G = G(P_E, P_L, P_M, K_{-1}, \Delta K, \bar{Q}, T) = L + P_E E + P_M M \quad (7)$$

Where:

$P_E$  = Normalized price of energy,  $P_E = p_E / p_L$

$P_M$  = Normalized price of material,  $P_M = p_M / p_L$

$P_L$  = Price of labor

$K$  = Capital stock

$\Delta K$  = Change in capital stock

$Q$  = Output

$T$  = Time (intended to represent technological change)

The functional form chosen to approximate normalized restricted cost function is quadratic because of a few desirable properties (Treadway, 1971). Thus the normalized variable cost function in quadratic form can be specified as:

$$\begin{aligned} G = L + P_E E + P_M M = \bar{Q} [ & \alpha_0 + \alpha_{0T} T + \alpha_E P_E + \alpha_M P_M + \alpha_{ET} P_E T + \alpha_{ET} P_E T \\ & + \frac{1}{2} (\alpha_{EE} P_E^2 + \alpha_{MM} P_M^2) + \alpha_{EM} P_E P_M ] + \frac{1}{2} \alpha_{KK} K_{-1}^2 / \bar{Q} \\ & + \alpha_K K_{-1} + \alpha_{KT} K_{-1} T + \alpha_{EK} P_E K_{-1} + \alpha_{MK} P_M K_{-1} \\ & + \alpha_{KT} \Delta K \cdot T + \alpha_K \Delta K + \alpha_{EK} P_E \Delta K + \alpha_{MK} P_M \Delta K \\ & + \alpha_{KK} K_{-1} \Delta K / \bar{Q} + \frac{1}{2} \alpha_{KK} (\Delta K)^2 / \bar{Q} \end{aligned} \quad (8)$$

Internal costs of adjustment,  $C(\Delta K)$ , consists of all terms of the variable cost function  $G$  given by Eq. 8 involving  $\Delta K$  and can be shown as:

$$\begin{aligned} C(\Delta K) = & \alpha_{KT} \Delta K \cdot T + \alpha_K \Delta K + \alpha_{EK} P_E \Delta K + \alpha_{MK} P_M \Delta K \\ & + \alpha_{KK} K_{-1} \Delta K / \bar{Q} + \frac{1}{2} \alpha_{KK} (\Delta K)^2 / \bar{Q} \end{aligned} \quad (9)$$

This expression can be simplified somewhat by restricting the nature of quadratic adjustment cost such that when the rate of capital adjustment,  $\Delta K$  is equal zero the marginal adjustment costs at that point must also be equal to zero. This implies that:

$$\frac{\partial C(\Delta K)}{\partial \Delta K} = C'(\Delta K) \Big|_{\Delta K=0, K=K^*} = \alpha_K + \alpha_{KT} T + \alpha_{EK} P_E + \alpha_{MK} P_M + \alpha_{KK} K_{-1} / \bar{Q} = 0 \quad (10)$$

Which implies that the parameters  $\alpha_K, \alpha_{KT}, \alpha_{EK}, \alpha_{MK}, \alpha_{KK}$  must also be equal to zero. When these restrictions are imposed, the normalized restricted cost function imposing the expected output  $\bar{Q}$  will be reduced to:

$$\begin{aligned} G = L + P_E E + P_M M = \bar{Q} & [\alpha_0 + \alpha_{0T} T + \alpha_E P_E + \alpha_M P_M \\ & + \alpha_{MT} P_M T + \alpha_{ET} P_E T + \frac{1}{2} (\alpha_{EE} P_E^2 + \alpha_{MM} P_M^2) \\ & + \alpha_{EM} P_E P_M] + \frac{1}{2} \alpha_{KK} K_1^2 / \bar{Q} \\ & + \alpha_K K_{-1} + \alpha_{KT} K_{-1} \cdot T + \alpha_{EK} P_E K_{-1} + \alpha_{MK} P_M K_{-1} \\ & + \frac{1}{2} \alpha_{KK} (\Delta K)^2 / \bar{Q} \end{aligned} \quad (11)$$

The adjustment costs are reduced to:

$$C(\Delta K) = \frac{1}{2} \alpha_{KK} (\Delta K)^2 / \bar{Q} \quad (12)$$

Using the Shepard-Uzawa-McFadden lemma, the short-run optimal demand equations for energy and material would be derived from the Eq. 11 as:

$$E / \bar{Q} = \alpha_E + \alpha_{ET} T + \alpha_{EE} P_E + \alpha_{EM} P_M + \alpha_{EK} K_{-1} / \bar{Q} \quad (13)$$

$$M / \bar{Q} = \alpha_M + \alpha_{MT} T + \alpha_{MM} P_M + \alpha_{EM} P_E + \alpha_{MK} K_{-1} / \bar{Q} \quad (14)$$

The short-run demand function for labor is determined from:

$$\frac{L}{\bar{Q}} = \frac{G}{\bar{Q}} - P_E \frac{E}{\bar{Q}} - P_M \frac{M}{\bar{Q}} \quad (15)$$

Therefore, the demand function for labor would be defined as:

$$\begin{aligned} L / \bar{Q} = \alpha_0 + \alpha_{0T} T - \frac{1}{2} (\alpha_{EE} P_E^2 + 2\alpha_{EM} P_E P_M + \alpha_{MM} P_M^2) + \alpha_K K_{-1} L / \bar{Q} \\ + \alpha_{KT} K_{-1} T / \bar{Q} + \frac{1}{2} \alpha_{KK} T K_{-1}^2 / \bar{Q} + \frac{1}{2} \alpha_{KK} (\Delta K)^2 / \bar{Q}^2 \end{aligned} \quad (16)$$

The adjustment cost related term only directly affects the labor equation. The solution for the equilibrium capital stock  $K^*$  can be derived as:

$$K^* = \left( \frac{-1}{\alpha_{KK}} \right) (\alpha_K + \alpha_{KT} T + \alpha_{EK} P_E + \alpha_{MK} P_M + u_K) \bar{Q} \quad (17)$$

where,  $u_K$  is the rental price of the quasi-fixed input. The investment identity would be written as:

$$\Delta K = M^* (K^* - K_{-1}) \quad (18)$$

where,  $M^*$  is called the speed of adjustment coefficient and can be derived as:

$$M^* = -\frac{1}{2} \left[ r - \left( r^2 + \frac{4\alpha_{KK}}{\alpha_{KK}} \right)^{1/2} \right] \quad (19)$$

The adjustment coefficient should be less than or equal to one (instantaneous adjustment) and greater than zero. A necessary and sufficient condition for this is

$$\frac{\alpha_{KK}}{\alpha_{KK}} \leq 1 + r$$

The adjustment coefficient  $M^*$  is negatively related to the interest rate, that is

$$\frac{\partial M^*}{\partial r} < 0$$

Higher interest rates decrease the speed of adjustment of the capital stock to desired levels.

Substituting  $M^*$  from Eq. 19 and  $K^*$  from Eq. 17 into Eq. 18, the demand equation for the quasi-fixed input becomes:

$$\begin{aligned} \Delta K / \bar{Q} = \frac{1}{2} \left[ r - \left( r^2 + \frac{4\alpha_{KK}}{\alpha_{KK}} \right)^{1/2} \right] \\ \left[ \left( \frac{1}{\alpha_{KK}} \right) (\alpha_K + \alpha_{KT} T + \alpha_{EK} P_E + \alpha_{MK} P_M + u_K) + \frac{K_{-1}}{\bar{Q}} \right] \end{aligned} \quad (20)$$

Assuming the unobserved realized discount rate of the industry,  $r$ , is a linear function of the observed prime interest rate,  $r'$  farm wealth,  $w$ , net farm income,  $m$  and government payments to farmers,  $g$  as a linear function to the system of equations using the new investment function:

$$\begin{aligned} \Delta K / \bar{Q} = \frac{1}{2} \left[ r' - \beta_0 w - \beta_1 m - \beta_2 g - \left( [r_p - \beta_0 w - \beta_1 m - \beta_2 g]^2 + \frac{4\alpha_{KK}}{\alpha_{KK}} \right)^{1/2} \right] \\ \left[ \left( \frac{1}{\alpha_{KK}} \right) (\alpha_K + \alpha_{KT} T + \alpha_{EK} P_E + \alpha_{MK} P_M + u_K) + \frac{K_{-1}}{\bar{Q}} \right] \end{aligned} \quad (21)$$

Based on the discussion and Eq. 5 the Ex ante supply function would be can be derived from equating the output price to marginal cost, which from Eq. 8 is equal to:

$$\begin{aligned} P = \alpha_0 + \alpha_{0T} T + \alpha_E P_E + \alpha_M P_M + \alpha_{MT} P_M T \\ + \alpha_{ET} P_E T + \frac{1}{2} \alpha_{EE} P_E^2 + \frac{1}{2} \alpha_{MM} P_M^2 + \alpha_{EM} P_E P_M \\ - \frac{\frac{1}{2} \alpha_{KK} K_{-1}^2 + \frac{1}{2} \alpha_{KK} (\Delta K)^2}{\bar{Q}^2} \end{aligned} \quad (22)$$

By inverting Eq. 22 to solve for  $\bar{Q}$ , the Ex ante supply function is equal to:

$$\bar{Q} = \left[ \frac{\frac{1}{2}\alpha_{KK}K_{-1}^2 + \frac{1}{2}\alpha_{EK}(\Delta K)^2}{\alpha_0 + \alpha_{0T}T + \alpha_{EE}P_E + \alpha_{EM}P_M + \alpha_{MT}P_MT + \alpha_{ET}P_ET + \frac{1}{2}\alpha_{EE}P_E^2 + \frac{1}{2}\alpha_{MM}P_M^2 + \alpha_{EM}P_ET + P} \right]^{\frac{1}{\alpha_{KK}}} \quad (23)$$

Thus, the final system of behavioral equations to make a DEID model includes the short-run input demand equations for energy (Eq. 13), material (Eq. 14) and labor (Eq. 16), the investment demand (Eq. 21) and the Ex ante supply function (Eq. 23). The DEID system is a simultaneous nonlinear dynamic model and therefore must be estimated though a non linear three stage least square regression process.

The empirical model for Western Canada is estimated using annual aggregated data from Alberta, Saskatchewan and Manitoba for the period 1975-2000 obtained from various Statistics Canada publications. Aggregate material input was compiled from data on the use of agricultural feed, seed, pesticides and fertilizer. The aggregate stock of energy was compiled from total expenditures of fuel and electricity. The value of labor is calculated as the value of payments to hired workers plus estimation for the value of unpaid family labor using the mean wage rate of hired workers and the number of farms. The wealth of farms was calculated a total farm asset minus debt, income was the reported net farm income and government payments were direct payments as reported by Statistics Canada. Prime lending rates were obtained from Bank of Canada reports. The aggregate stock of capital was compiled using the stocks of agricultural machinery and buildings. The net investment data were computed as the annual changes in the corresponding stocks of the quasi-fixed input. Aggregate output was compiled using the output of livestock and crops. All price indices are aggregated using Tornquist-Divisia indices and were normalized by the price of labor with a 1986 base period. Each variable was examined for its time series properties using the ADF test and found to be stationary.

## RESULTS AND DISCUSSION

The parameters for the model were estimated using the NL3SLS (non-linear three stage least squares) in reviews, which utilizes the iterative Gauss-Seidel method for solution. Convergence for the model was obtained over a range of start values.

The estimated value for each parameter and its associated asymptotic standard errors, t-statistics and p-values for western Canada are shown in Table 1. The estimated parameters generate a plausible model structure.

Table 1: Dynamic investment model for Western Canada, 1975-2000

Parameter	Estimate	SE <sup>(a)</sup>	t- statistics	p-value
$\alpha_0$	5.02E-05	1.67E-05	3.011914	0.0036
$\alpha_E$	-7.12E-06	3.91E-06	-1.82056	0.0727
$\alpha_M$	1.91E-05	2.64E-05	0.723612	0.4716
$\alpha_K$	-0.24109	0.081029	-2.97535	0.0040
$\alpha_{ET}$	2.69E-07	1.24E-07	2.173397	0.0330
$\alpha_{EE}$	-2.87E-06	1.97E-06	-1.45655	0.1495
$\alpha_{EM}$	3.75E-06	1.72E-06	2.176681	0.0327
$\alpha_{EK}$	0.062432	0.004414	14.14561	0.0000
$\alpha_{MT}$	1.23E-07	1.04E-06	0.118243	0.9062
$\alpha_{MM}$	-1.51E-05	4.09E-06	-3.70516	0.0004
$\alpha_{MK}$	0.105057	0.013728	7.652707	0.0000
$\alpha_{0T}$	-1.54E-06	5.11E-07	-3.02125	0.0035
$\alpha_{KT}$	0.006928	0.001611	4.301275	0.0001
$\alpha_{KK}$	1038.716	180.7901	5.745427	0.0000
$\alpha_{kk}$	32825	2923.527	11.22787	0.0000
$\beta_w$	1.95E-05	1.52E-05	1.28284	0.2036
$\beta_m$	-1.4E-04	0.000362	-0.38102	0.7043
$\beta_g$	2.95E-04	0.000546	0.540189	0.5907
$M^{*(b)}$	0.14			
DRC <sup>(c)</sup>	3.31E-46			

<sup>(a)</sup>Standard error, <sup>(b)</sup>Adjustment coefficient, <sup>(c)</sup>Determinant residual covariance

The own-price coefficients for each equation have the expected sign. Overall, the model is dynamically stable as adjustment rate lies between zero and unity.

The estimates of parameters  $\alpha_{ii}$  are negative implying that the variable input demands are downward sloping. The  $\alpha_{KK}$  parameter, which indicates the effects of rental prices on the optimal stocks of the quasi-fixed inputs, is significant at the 0.001 significant levels.

The estimates of  $\alpha_{kk}$  are positive, implying that the demand for capital has a negative slope. The  $\alpha_{kk}$  coefficient governs the sign of the rate of change of marginal adjustment costs. It is always positive and significant; suggesting that while apparent adjustment costs may be negative, continuing increases in investment within a period would lead to positive adjustment costs at some stage.

The coefficient  $\alpha_{kk} > 0$  indicates that variable costs increase as the speed of adjusting the machinery stock increases. The positive sign of  $\alpha_{EK}$  and  $\alpha_{MK}$  coefficients indicate that the quantity of energy and material used increase if capital stock rises.

**Technical change:** Technical change as proxied by a time trend has a number of interesting effects. The negative and statically significant coefficient  $\alpha_{0T}$  indicates that disembodied technology increases productivity and lowers costs over time. The positive coefficients for the interaction with energy, materials and machinery, indicates that these technology change has been labor saving but energy, materials and machinery using. This technical is consistent with the increase in farm size and the intensification that has taken place over the period.

**Rate of adjustment:** The adjustment rate  $M^*$ , measures the degree to which the firm closes the gap in one year

Table 2: Adjustment coefficient rates, 1975-2000

Years	W. Canada
1975	0.14
1980	0.12
1985	0.13
1990	0.12
1995	0.14
2000	0.15
Average <sup>(a)</sup>	0.14

<sup>(a)</sup>For total period (1975-2000)

between its desired capital stock and the actual beginning period capital stock. The adjustment rate  $M^*$  can be calculated for each year using Eq. 19 from the estimated coefficients reported in Table 1 and the data. As reported in Table 2 average adjustment coefficient for Western Canada is 0.14. This means that in the first year, following an exogenous change such as an increase in energy prices, 14% of the difference is closed between the capital stock actually held by the firm at the beginning of the year and its new desired optimal stock of capital. It takes five years to move half of the way to the desired capital stock. While this adjustment rate is slow, it is not surprising given the long expected life of farm machinery and buildings.

**Adjustment costs:** The calculation of annual adjustment cost reveal a far more interesting pattern. As shown in Fig. 1, adjustment approached a billion dollars per year in the 1970s as the industry responded to significant increases in the price of grain. The adjustment costs then fell to very low levels between 1983 and 1992, in response to higher capital stock and low grain prices. During the early 1990's adjustment costs increased to moderate levels in response to price increases and subsequently declined.

**Dynamic demand elasticities:** An important part of this study is the estimation of elasticities in dynamic models that characterize agriculture adjustment process. The estimates of short- intermediate- and long-run elasticities are calculated at their mean values and for each year of the period and reported in Table 3. The reported short-run elasticities are by definition those where stock of capital is held fixed. The intermediate-run elasticities represent a one year period of adjustment. They are equal to the long-run elasticities reduced by the partial adjustment factor  $M^*$ . The long-run elasticities are those in which capital stock is allowed to fully adjust to a price change.

Consistent with a process of cost minimization, the own-price input demand elasticities are negative for all time frames and the long run price elasticities are greater than short run price elasticities. The own-price elasticity values increase substantially from the short to long run, but notably even in the long run the demands are inelastic.

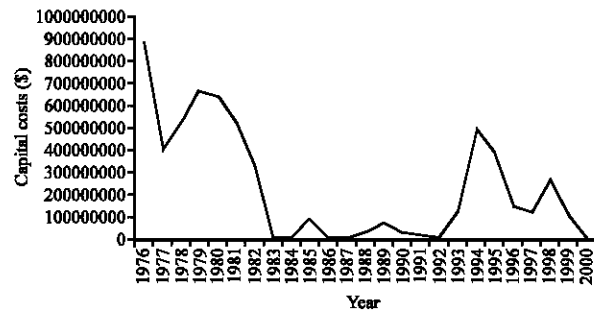


Fig. 1: Capital adjustment costs, Western Canada 1975-2000

Table 3: Short, intermediate- and long-run elasticity estimates for Western Canada, 1975-2000

Elasticity	Short run	Intermediate run (1 year)	Long run (full adjustment)
$\varepsilon_{KK}$	0.0	-0.13	-0.94
$\varepsilon_{KE}$	0.0	0.04	0.29
$\varepsilon_{KM}$	0.0	0.06	0.48
$\varepsilon_{EK}$	0.0	-0.11	-0.82
$\varepsilon_{EM}$	0.25	0.19	-0.17
$\varepsilon_{EE}$	-0.19	-0.23	-0.44
$\varepsilon_{MK}$	0.0	-0.08	-0.61
$\varepsilon_{ME}$	0.11	0.08	-0.07
$\varepsilon_{MM}$	-0.44	-0.49	-0.76
$\varepsilon_{KQ}$	0.0	0.22	1.0
$\varepsilon_{EQ}$	1.86	1.74	1.0
$\varepsilon_{MQ}$	1.64	1.55	1.0

The cross-price input demand elasticities reveal a more interesting pattern. In the short run material and energy are complements but in the long-run show a pattern of substitutability. Capital is complementary with both energy and material in the short-, intermediate- and long-run while Energy and Material are substitutable. The absolute values of cross-price elasticities for the price of energy are low, since energy is a small percentage of total costs. Therefore, one percent change in the price of energy may induce a small relative change in capital or material. The cross price elasticities are quite small even in the long run, thus reflecting limited substitution possibilities. Material appears to be the least responsive to own price changes, while demand for capital stocks, are the most responsive in the long run.

There is little difference between short-run and long-run own-price elasticities for energy and material. The lack of divergence between short-run and long-run energy and material own-price elasticities is indicative of an independent relationship between capital and energy and between capital and material in the long-run. In other words, farmers are able to quickly adjust their Energy and Material usage to the desired level, but not Capital usage. As the quasi fixed input, the demand for capital is most affected by adjustment costs. Figure 2 shows both the short and long run demand for capital over the study

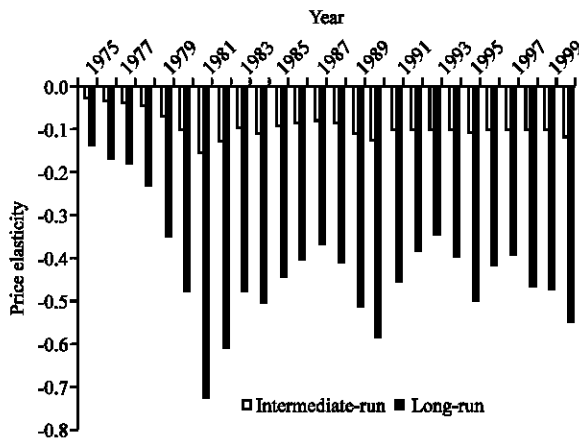


Fig. 2: Own price elasticity for capital, Western Canada, 1975-2000

period. The demand is most elastic when adjustment costs are low and more inelastic when adjustment costs are high.

**Wealth and income effects on the discount rate:** The beta coefficients in the investment equation capture the impacts that wealth, have on the agricultural discount rate relative to prime lending rates. Given the negative signs used in the specification, positive coefficients indicate a negative impact on the discount rate.

As shown in Table 1, none of these coefficients are differ statistically from zero at a 5% probability level. Wealth has the expected negative impact on the agricultural discount rate with a probability of 20%. Market income and government payment have positive and negative effects, respectively, but are not statistically different than zero. Thus there is some evidence that wealth may decrease the agricultural discount rate while there is no evidence that current income or cash flow affected the discount rate.

## CONCLUSION

The Dynamic Ex ante Input Demand model combines the cost of capital adjustment and Ex ante output choice to create a dynamic model that is theoretically and empirically appealing. The four input empirical model provided a tractable means of estimating Ex ante input demand system along with an Ex ante supply function. The dynamic model also provides a means of estimating the impact of wealth and income on industry discount rates and investment demand.

The application to Western Canadian agriculture resulted in model that was dynamically stable and

consistent with profit maximization. The results show that Agricultural machinery is a quasi-fixed input, with significant adjustment costs and a slow rate of adjustment. Technological change and machinery investment are energy and material-using for western Canadian agriculture. All short run input demands are inelastic and increase slightly in the long-run. Moreover, there is no change in the substitutability of inputs from the short-run to the long-run. Capital and energy as well as capital and material are substitutable, while energy and material are complementary. There is some indication that wealth lowers the discount rate within the sector has a positive effect on Canadian agricultural investment. As an improved approach to examine investment behavior, this model could be applied to other sectors and other countries.

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