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Policy Intervention and Supply Response: The British Potato Marketing Scheme in Retrospect

by

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ABSTRACT

In 1996 the Potato Marketing Scheme was abolished ending forty years of institutional control over the British potato market. This paper offers a retrospective analysis of the control mechanisms adopted and develops a theoretical model of supply response that reflects this policy environment. Developing a framework first proposed by Ennew and White (1989) supply response is disaggregated according to costs in relation to quota allocation. Econometric results not only confirm the validity of the theoretical formulation but also provide an insight in to supply response in a deregulated setting.

Keywords: Potato Marketing Scheme, dichotomous supply response, cointegration

I Introduction

As part of a government drive toward the freeing-up of markets, the Potato Marketing Scheme (PMS), as administered by the Potato Marketing Board (PMB), was abolished in 1995 by the Minister for Agriculture and Fisheries ending forty years of market intervention. With an estimated production value which peaked at £814m in 1994/5 the effects of this deregulation are profound for the 15,000 maincrop producers; notably it will introduce greater uncertainty into a market which hitherto had been subject to strict controls (especially area quotas and support buying) to stabilise prices. Being the principal staple in the British diet the implications for consumers are also significant. Certainly, price decline and increased price volatility presaged the cessation of the Scheme (Ennew and Peston 1993). While it is too early to assess whether these widely-anticipated price effects have actually materialised, we reflect here on the impact of the Scheme on planting decisions and prices with a view to informing the debate concerning deregulation, not least because the deregulation of similar schemes in other countries is currently being contemplated.

The main body of the paper comprises an econometric model of the regulated potato market over the period 1965 to 1995. This span of years covers the period of effective PMB control of the market. Modelling is via a vector error correction model (VECM) allowing for non-stationarity of the data where appropriate. Two sub-models are estimated, one for area response and one for price determination. These results *inter alia* permit estimates to be made of the price elasticity of demand and the price elasticity of area supply response in the deregulated market.

Previous studies of the British Potato market have tended to model supply response at the aggregate level (see *inter alia* Ingersent 1969, Revell 1974, Jennings and Young 1980) but doing so ignores differences arising from variations in size and efficiency of the individual farm which is known to characterise British potato production. Claydon (1995) reports that in 1992 the largest 6% of the growers planted 32% of the total area whereas the smallest

33% planted just 7%. The skewed nature of the distribution is by no means a recent phenomenon but rather an enduring feature of the British market - arguably an artefact of the policy itself. Recognising that the response to prices and policy variables of diverse enterprises is likely to differ, we follow Ennew and White (1989), by implicitly acknowledging differing cost structures across farms in an area response model. While our adopted classification is somewhat crude, in that we merely distinguish the decisions of growers planting over-quota from those planting within quota, we find empirical support for this simple bifurcation of the aggregate. Specifically, we estimate the responses of within-quota plantings and excess plantings to relevant policy variables.

As an adjunct to the modelling of area response we also discuss the role of the PMS on price formation. In particular, the model relates market price to the volume of production, the prevalence of support buying, random variability in imports and a step dummy to account for a change in import policy in 1979.

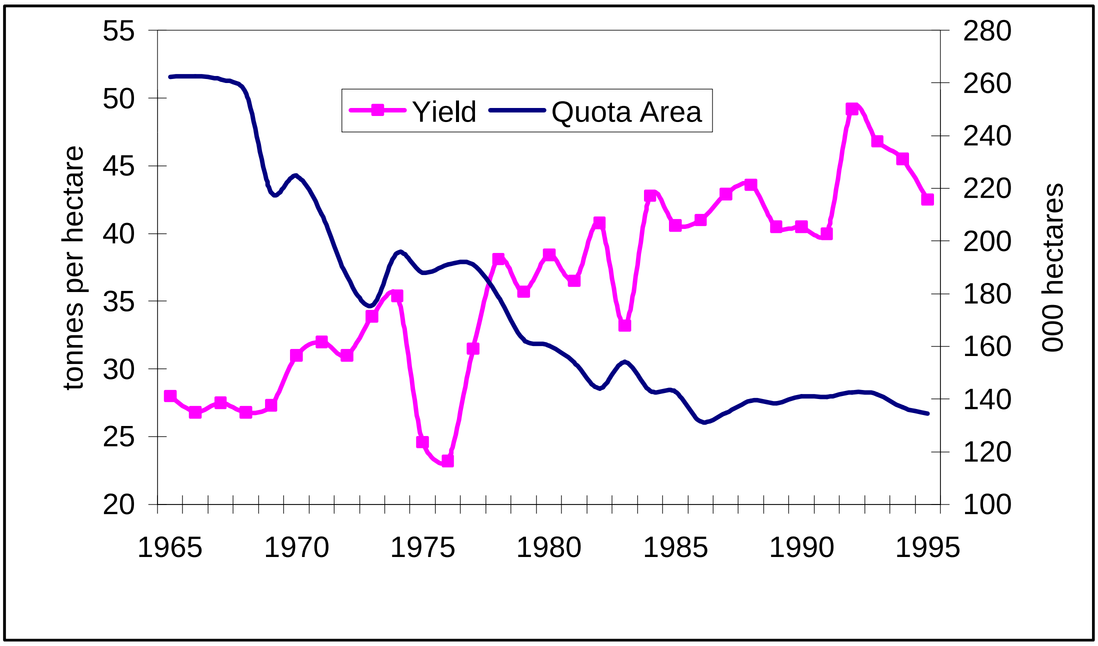
The paper will proceed as follows. Section II provides a brief outline of major policy changes during the PMB's stewardship that establishes the institutional backdrop to the theoretical discussion of Section III where we formulate the economic model. Section IV applies time-series data to this model to quantify the equilibrium relationships and dynamic behaviour using appropriate techniques. Finally, in Section V, we present the implications of the results with a view to the future evolution of the market.

II Potato Market Policy in Great Britain

Founded amidst the price depression of the 1930s the Potato Marketing Board was established as a compulsory producer association to offset the increasing market power of downstream users (see Morgan 1991). Given the importance of potatoes in the British diet, wartime control lasted well into the 1950s. When the PMB was reconstituted in 1955 as the policy-administering body for the Ministry of Agriculture's PMS, it returned to its original objective of supply control with

the aim of maintaining "reasonable" producer prices (Marsh 1985). These were determined at the Annual Review and necessitated strict supply control owing to the positive trend in yield that had emerged in the 1930s (Ennew 1985). The Board was empowered to employ both *ex ante* and *ex post* policy instruments (area quotas and support buying respectively), with which the Ministry sought to limit available market supplies, particularly in high yielding years, to avoid price levels which were harmful to farm incomes. With price and income elasticities of demand close to zero and output variability commonplace the potato market also exhibited a high degree of price volatility, a feature that was potentially harmful to both producers and poorer consumers.

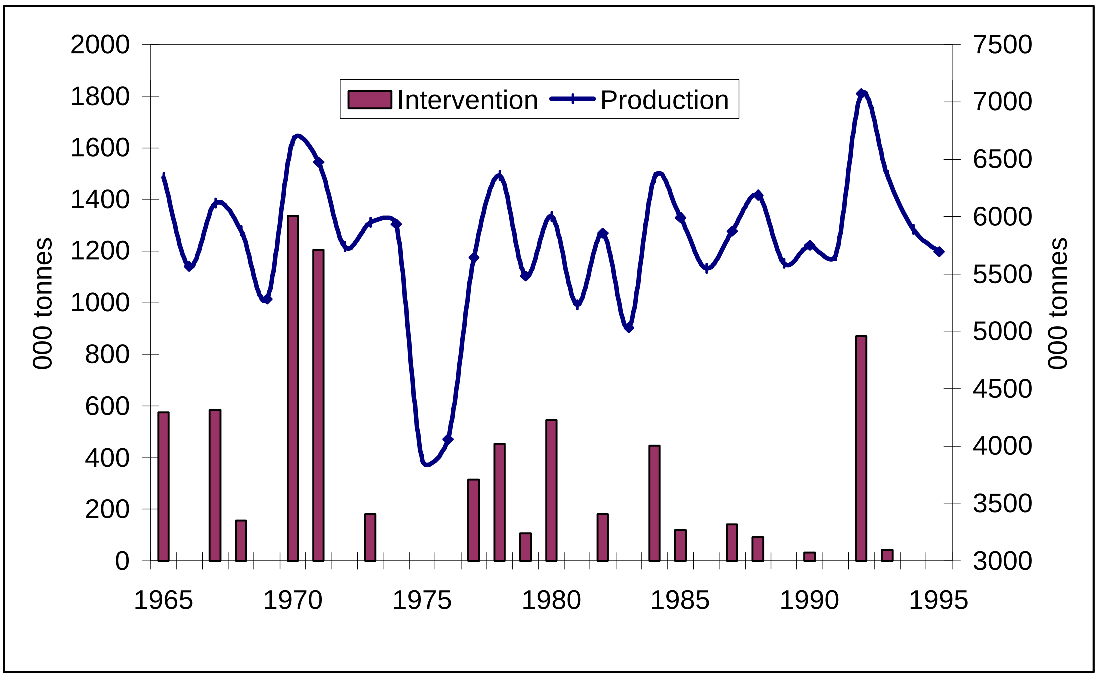
Figure 1: Potato Yields and Quota Area in Great Britain



The operation of the PMS was largely funded by members who paid a per hectare levy on planted potato area. The *ex ante* control was based on limitations imposed on the area planted to potatoes via a system of quotas. Initially, a Basic Area (a maximum of 20% of arable land) was allocated to all registered producers onto which a quota, expressed as a percentage, was imposed thus establishing a ceiling on area planted (Quota Area). To ensure compliance with the set quota, excess levies were imposed on all land planted over quota, the value of these instruments being determined simultaneously every Spring. The twin instruments of *ex ante* policy were thus interdependent, and in practice, tightening the quota would necessitate increasing the excess levy in order to deter plantings in excess of the quota. As Figures 1 and 2 illustrate Quota Area fell throughout the period to offset rising yields, resulting in ‘de-trended’ though variable annual production. Given the relatively static nature of demand, market price tended to fluctuate inversely with production variability, as is most clearly demonstrated during the drought years of 1975/6. Whilst the policy was not designed to protect against such upward price movement it did ensure that price did not slump in the face of rising yields or free-fall during bumper harvest years such as 1970, 1971 and 1992. To avoid intervention drawing-in imports the policy was underpinned until 1979 by an import ban on all maincrop potatoes.[1] As Figure 3 shows, price tended to fluctuate around some long-run mean level, although close inspection of the data does indicate a possible drop in this level following removal of the import ban.

Figure 2: Potato Production and Support Buying

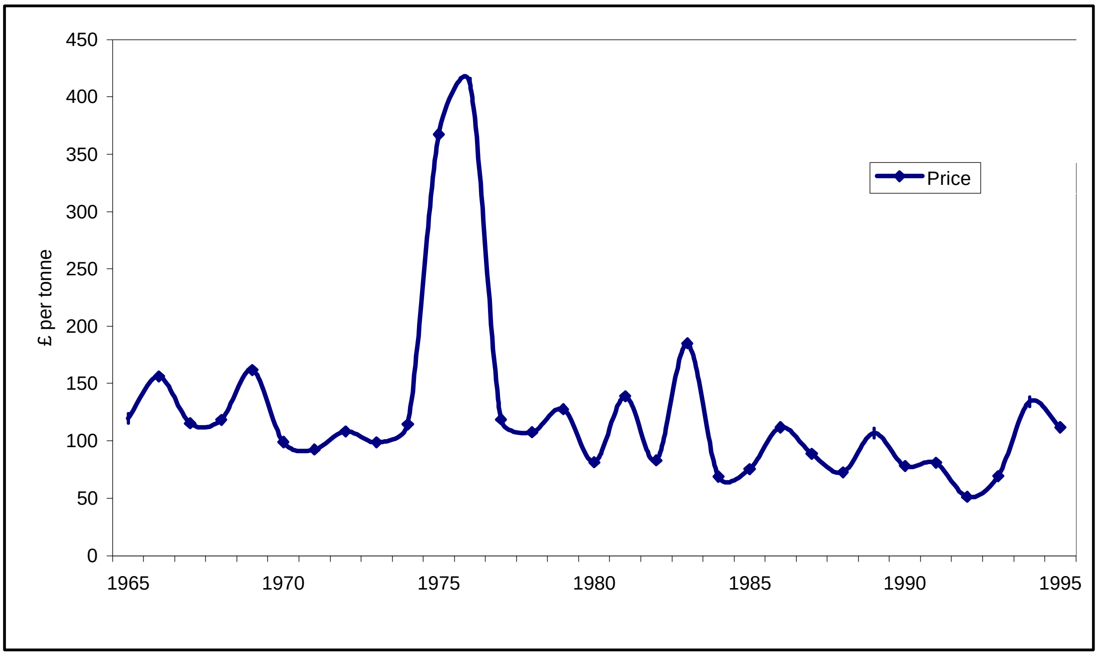
[1] However, when yields were low, imports were allowed via special licences (e.g. 1975 saw imports of 321,000 tonnes or 7% of total British production). For an analysis of the impact of trade liberalisation on price variability see Greenaway *et al*. (1993).



If the *ex ante* controls proved less than effective then the Board could draw upon its power as a support buyer. This *ex post* measure ensured excess supplies of harvested potatoes could be purchased from producers and sold for stock-feed or destroyed, again with the aim of maintaining price levels. Support buying was sporadic in its occurrence and size having happened twenty times since 1960 and ranged from the removal of 32,000 tonnes in 1990 to 1,336,000 tonnes in 1970, approximately 0.5% and 19% of production respectively (see Figure 2).

By the late 1960s the policy framework started to show signs of stress owing to high operating costs. Given increasing yields, the costs of support-buying grew rapidly and thus area policy was tightened by the Ministry with the introduction of a Target Area Scheme which represented a shift towards a more formulaic approach to area control. The Scheme aimed to identify the area (the so-called Target Area) which if planted in an average-yield year would give an output that would meet domestic demand. A more rigorous control resulted on area planted that was later buttressed by substantial increases in the excess levy in the 1980s. Excess levy rose from £356 per hectare in 1986 to £856 per hectare in 1991, attaining levels that were seen as penal by most, if not all, growers.

Figure 3: Real Price of Potatoes in Great Britain



This tightening of area control was accompanied by recognition that structural change was hampered by the quota system; large/low-cost growers could not expand their planted area. Responding to this, the PMB permitted the leasing of quota in the mid-1970s and sale of quota became possible by the end of that decade. Despite the inherent obstacles to obtaining quota (see Burrell 1989) the market cost of leasing was generally half the level of the per hectare excess levy. Thus, quota transfer where feasible represented a potentially attractive alternative to excess planting with the result that some 5000 hectares of quota were leased annually. Quota transfer proved to be a vital policy change as it gave the most efficient producers the opportunity to expand the scale of their operations and invest in new technology, both of which could improve yields and the quality of the crop.

The removal of the import ban at the behest of the EC Court in 1979 necessitated a further change in policy to ensure that the PMB did not become the 'buyer of last resort' for northern European potato producers. In fact, imports post 1979 have varied between 31,000 and 374,000 tonnes (averaging at some 135,000 tonnes) which would have represented a significant potential threat to PMB

funds had the guaranteed price been maintained in real terms. As a consequence the guaranteed price was maintained in nominal terms only and support buying was restricted to 600,000 tonnes a year (approximately 10% of production): the price safety net would now be lower in high yielding years.

On reflection it is clear that since its inception the PMB evolved in response to changes in the external environment. However, less apparent were the internal pressures that arose from the need to justify the PMB's role at periodic Ministerial Reviews of the PMS and changes in the industry. In the1970s potato processors emerged as a key voice for reform reflecting their growing significance as purchasers brought about by changes in consumer demand for potatoes. Their main concern was that the PMS hampered the potential for scale economies and added to their input costs. The Potato Processors Association (PPA) lobbied the Ministry for the abolition of the PMS, warning that they would offset shortfalls in domestic production with imports.

These pressures, spurred by the Government's free-market philosophy, increased throughout the 1980s. In 1990 it was decided that the PMB would no longer have sole responsibility for the PMS but would be replaced by the Joint Consultative Committee which comprised representatives of potato users as well as the PMB. Unable to resist the momentum for change the Minister for Agriculture declared in 1993 the abolition of the PMS by 1996. The winding-down of intervention began in 1993 with the removal of support buying powers, which in effect rendered the quota redundant. The 1995/6 season was the last in which a quota was set. In 1997 the PMB ceased to exist and in its stead, the British Potato Council was established which sought to act as an information gathering and marketing body for the entire potato sector. Without the ability to intervene in the British market the BPC is by no means the growers' association the PMB represented but rather seeks to offer advice and information to processors, merchants, consumers and producers of potatoes.

III Conceptualising the Market

The preceding section documented the evolution of potato market policy and in so doing highlighted the key instruments of regulation. Here, we focus attention on the impact of these regulatory mechanisms on the planting behaviour of the individual grower.

(a) An Area Response Model

Given the heterogeneous nature of production in agriculture, the response of different producers to market stimuli will vary quite widely. It is well known that the opportunity costs of production are not necessarily equal across all farms and thus modelling response to change in the aggregate will tend to mask these differences. To measure the response exactly would require highly detailed, disaggregated costs data which is typically unavailable. To circumvent the data problem, it is common in the empirical supply response literature to adopt a reduced form representation in preference to a fully specified structural formulation. The ease and tractability of the reduced form is exemplified by the popularity of the partial adjustment, adaptive expectations model developed by Nerlove, in which area planted is determined by lagged price, lagged plantings and other variables such as the lagged prices of competing crops. However, in the context of a market in which growers' decision making is constrained by the operation of an area quota/excess levy policy there is some doubt as to the validity of a 'quota-augmented' Nerlovian specification (Jennings 1981, Ennew and White 1989).

Ennew and White (1989) propose an alternative specification of the reduced form that usefully exploits the presence of area control in the modelling of area response. Specifically, plantings are split into those within quota and those in excess of quota: hereafter referred to as 'within-quota' plantings and 'excess plantings' respectively. In general, excess plantings occur on land with a low opportunity cost. This segmented model allows some growers to act differently to others in response to policy variables and market signals. In the context of a market in which the levy for excess plantings is prohibitive to some, but not to others, this flexibility is clearly advantageous to an understanding of aggregate area response.

As Ennew and White (1989) highlight, the imposition of a quota does not necessarily imply that all producers plant exactly up to their quota; indeed a rational producer would be expected to produce an output at which the marginal revenue accruing from production equates to the marginal net costs, irrespective of quota entitlement. These net costs may be envisaged as a measure of the opportunity cost of potato production and may include a penalty for exceeding quota area. Given differences in opportunity cost (and also other factors such as yields and price expectations) across growers the simultaneous occurrence of under- and excess plantings may be expected.[2] In this scenario opportunities for arbitrage exist between under- and excess-planters. Providing the authorities allow quota to be traded, a market in quota entitlement will emerge to re-distribute the global quota from those with high opportunity costs to those with low opportunity costs. In a perfect market for quota this leads to the elimination of under-planting, but there may be some producers who still find it profitable to over-plant despite having to incur a levy for doing so, with the level of excess plantings depending on the severity of the levy.

Transactions costs and market imperfections may mean that some producers are unable to sell quota and others are unable to buy it at the market price (Ennew and White, 1989 p 247; Burrell, 1989). In an empirical setting, it is thus not improbable that excess and under-plantings co-exist. Indeed, since 1965, average under-plantings have been some three times the level of excess plantings and typically represent around 8% of quota area (PMB 1996).

To illustrate how changes in market and policy variables impact differently on the two groups, consider the following model in which production is risk neutral and price expectations and yields are constant across growers. Differences in cost schedules purely reflect scale economies and differences in opportunity costs. Figure 4(a), depicts a market comprising three growers, with marginal cost

[2] Underplantings represent quota allocation that is not planted.

curves[3], MC_h, MC_m and MC_l to denote high, medium and low production costs respectively. Summation of these schedules produces total area planted, denoted by H in Figure 4(b),

$$H = H\left(\sum_{j=1}^{3} MC_j\right)$$

The demand function for potato area is denoted by D in Figure 4(b) and is derived from consumer demand for potatoes. Equilibrium in the market occurs at price P_1 and area H_1 implying plantings of h_h, h_m and h_l in an unregulated market.

To simplify the exposition assume that a global quota Q is set at the free market level and is distributed uniformly to growers, such that $q_i = q_m = q_l$ and $(Q = H_1)$ in Figure 4. With this (arbitrary) allocation of the global quota only the medium cost grower plants to quota; the high cost producer plants less and the low cost producer more than quota. However, without a penalty for under- or excess-planting, growers continue to plant according to market fundamentals and the area and price of the competitive equilibrium remains.

Although the quota is merely notional in the absence of a levy it is instructive to decompose aggregate area response (H) into 'within-quota' and 'excess-quota' plantings in the unregulated case (*i.e.* when levy is zero) since it is with these sub-groups that the analysis proceeds when levies are applied. In Figure 4(b) the schedules $\hat{P}W$ and $P_0 E(L = 0)$ define within quota and excess quota plantings in the unregulated case. Both functions are positively related to price and exhibit discontinuities that reflect the switch by growers from land that is within quota to land that does not have quota. At market prices below P_0 there is no incentive for any grower to exceed quota: area planted is completely within quota, hence W becomes H and excess plantings are zero. As price rises, quota acts as a constraint and thus production can expand only via plantings in excess of quota.

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3 In the diagram, all schedules are drawn in price-area space since if we assume a constant yield there is a one-to-one mapping from output to area.

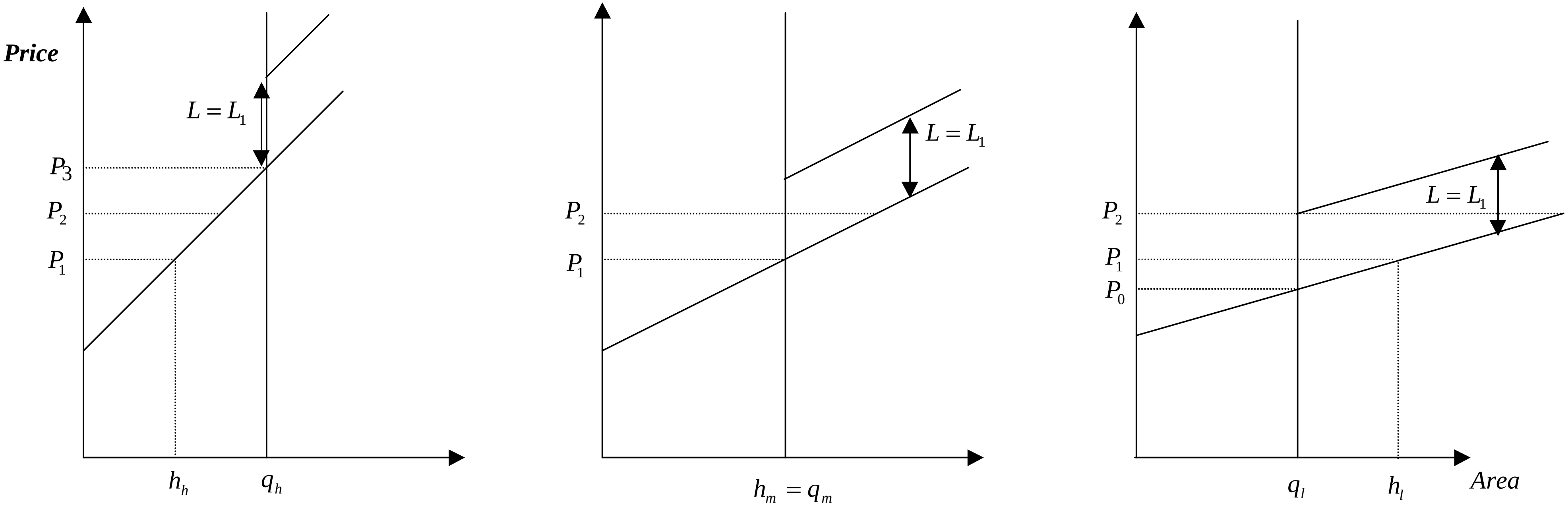
For example, as prices rise above P_0, the low cost grower's quota entitlement is exhausted, implying that production can only increase by planting over quota entitlement q_l. Thus, excess plantings, represented by $E(L=0)$, emerge in the market. Excess plantings from the low cost grower are augmented at P_1 and P_3, since these prices trigger excess-quota plantings from the medium and high cost growers. At prices above P_3, no grower can expand production using quota entitlement and any response to higher prices must be met from excess plantings.

A global quota defines the limit of the total area planted and is enforced by a (per hectare) levy on farmers exceeding their individual quota allocation. As Figure 4(a) illustrates, some farmers do not plant up their quota while others actually plant in excess of their entitlement, aggregate area planted being the sum of these individual choices. The quota setting authority can set a levy at a rate that ensures total actual plantings do not exceed global quota. *In extremis,* while the authority cannot guarantee that every grower will plant their quota, it can ensure that an individual never exceeds his quota by setting a prohibitive rate of levy on excess plantings. In such circumstances, the quota becomes an upper bound on area planted.

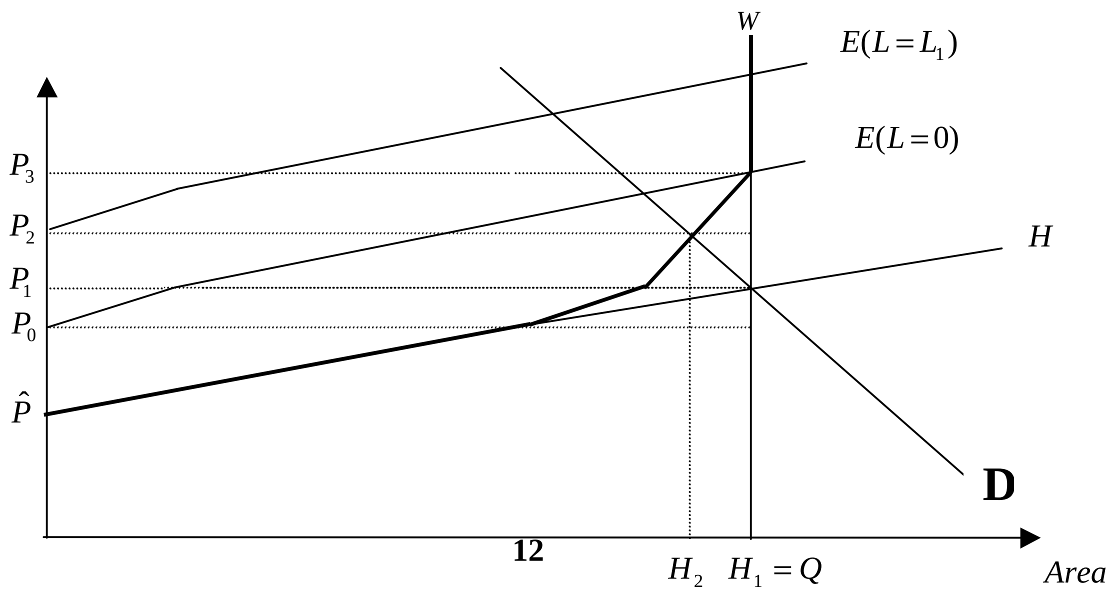
The effect of a levy on an individual grower depends on quota entitlement, costs and market price. A rational producer will plant in excess of quota only where market price exceeds net costs (MC plus levy). In terms of Figure 1(a) marginal costs are shifted vertically by the extent of the levy on plantings in excess of individual quota. Given the initial allocation of quota among the growers and a market price of P_1, excess plantings are zero at a levy rate of L_1, the *extremis* case. Given production from excess planters has fallen, market price rises to P_2 in Figure 1(b) and the schedule of excess plantings is shifted vertically to $E(L=L_1)$. With this price and levy combination, area planted falls to H_2 and an area $Q-H_2$ represents the under-plantings of the high cost grower in 1(a). At rates of levy between the limiting cases of 0 and L_1, excess plantings co-exist with under-plantings; the area of excess plantings

Figure 4: Derivation of Area Response

a) Grower Level



b) Industry Level



and under-plantings given by the horizontal distances $(D-W)$ and $(Q-W)$ respectively in Figure 4(b). In sum, this representation of the market underlines a number of salient characteristics:

1. **It highlights the interdependence between the policy instruments of quota and excess levy, in that while excess levy is necessary to maintain the integrity of quota its magnitude determines the degree of compliance. Therefore, Target Area may be achieved through a number of quota-levy combinations. For example, setting a prohibitive excess levy allows target area to be met solely by quota whereas a lower levy, which would allow for some excess-plantings, would need to be combined with a tighter quota. The trade-off between the two instruments is a policy parameter that we seek to uncover in the empirical section that follows.**

2. **Note that whereas in Figure 4(b) a tightening of policy reduces area, that in turn increases price, this result relies on the assumption of constant yield. In practice yield rose throughout the PMB era, necessitating a continual tightening of the quota simply to maintain production and price at historical levels. To examine the impact of trending yield on quota policy, consider Figure 5 in which the south-west quadrant represents a simplified version of Figure 4(b). Given a yield of α and the demand function *D*, a price P^* occurs when production is at V^*, necessitating a Target Area of A^*. As yields rise, say by λ, a smaller Target Area is required to maintain price at P^* and this requires a tightening of quota to A^{**}. The demand curve for land pivots inwards to *D'* reflecting the decrease in demand for land associated with the lower price of potatoes. Thus, the tightening of quota undertaken by the PMB throughout the period did not have the price-raising effects implied by Figure 4(b), but was driven by a need to offset the effects of technological change on potato yields.**

3. **The excess levy impacts on all growers (through changes in market price) not simply those planting in excess of their quota. Furthermore, the effect of the levy in aggregate is the sum of two opposing responses, since over the**

relevant range, excess plantings are inversely related to the size of the excess levy but within-quota plantings are positively related to the levy.

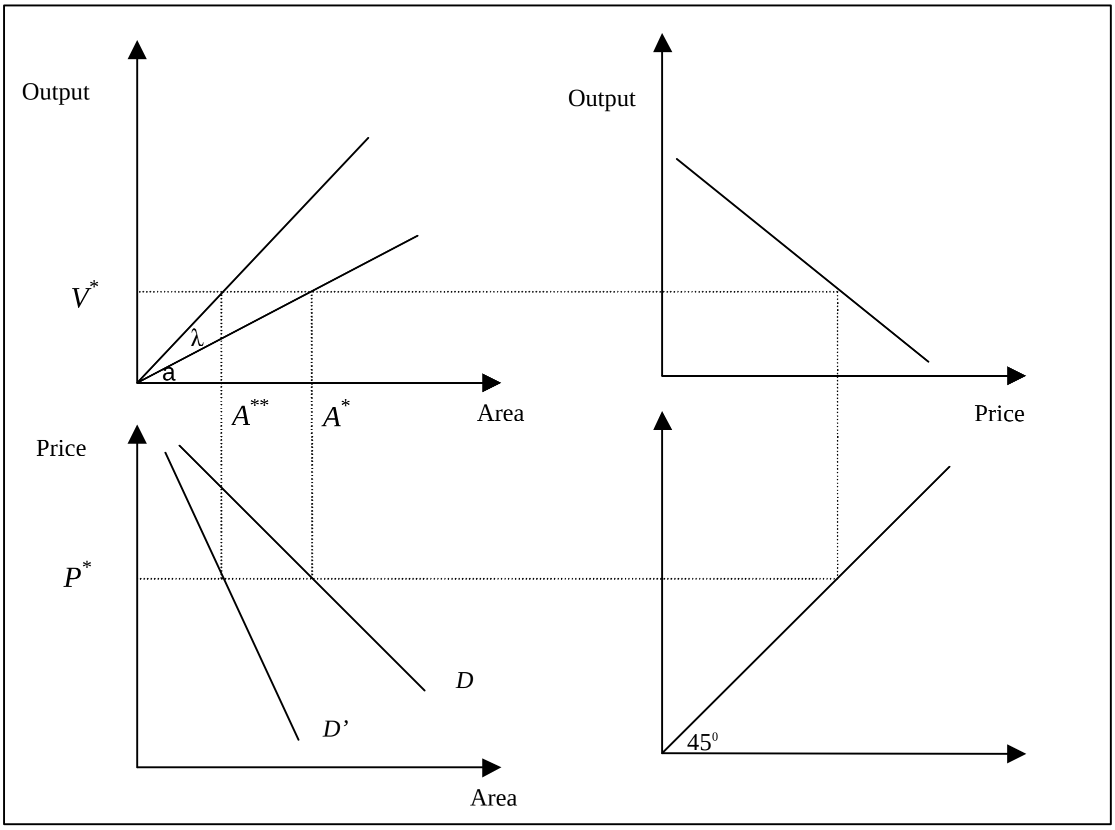
4. In a situation characterised by heterogeneous production costs, it is not merely the *level* of the global quota that is important but its *distribution* among growers. In the prohibitive levy case the structure of production is solely determined by the allocation of quota. Since levies drive a wedge between the returns from within- and excess-quota production, area response with respect to price is no longer straightforward. As demonstrated by the prohibitive levy case in Figure 4(a), all area response below P_2 derives from within quota land; excess plantings remain unaffected by price throughout this range despite the underlying responsiveness of land with low opportunity cost.

This characterisation of a quota-controlled market may also offer some insight into the likely outcomes of the market in a deregulated setting. Assuming that deregulation *per se* does not affect growers' cost structures, the unregulated market is represented by the no-levy case developed above. In this context, the effects of deregulation are thus felt by all growers and not merely those who were previously quota constrained. Moreover, growers do not respond in unison; low cost growers may be expected to expand their plantings while others are likely to contract. In other words, relaxation of the quota policy induces structural change in the industry in so far as the distribution of production is allocated according to market fundamentals rather than quota entitlement. Expansion of area from low cost growers increases total production and depresses market price. In turn, other growers adjust their plantings, implying that some high cost land is driven into alternative uses. Furthermore, released from the constraints of quota, plantings become more responsive to price signals as the low cost plantings represented by $E(L=0)$ in Figure 1(b) become increasingly more important in the aggregate.

Consequently, far from being redundant in a deregulated market, the dichotomous formulation offers a convenient framework in which to study area response, since it dis-aggregates the market on the basis of underlying (yet

unobserved) production costs. Needless to say, the model is subject to the limitations common to comparative static analysis in general and it would be foolhardy to expect a neat carry-over into an empirical setting. Of particular concern is the possibility that the underlying cost structure is disrupted by the process of deregulation itself (reflecting *inter alia* increased price risk) since the model assumes an invariant cost structure. We return to this and other caveats in the concluding section.

Figure 5: Technological Change and Target Area



(b) The Market

As an *entre* to the empirical analysis it will be instructive to conceptualise how components of the model are determined and the relationships between them. Key features of the market lend themselves well to modelling. In particular, given an income elasticity that is close to zero and generally constant tastes, we adopt a

formulation in which market price is solely supply-determined. In turn, quantity supplied is the product of (a trending) yield and area planted, the latter being of a dichotomous nature, as set out above. Consequently, the specification of the empirical model consists of three distinct but inter-connected parts, to which we now turn.

The determinants of market price, P_t, consist of the volume of domestic production, V_t, intervention buying I_t and an indicator of import penetration, $XRES_t$. Rather than model the foreign market directly, we simply include deviations around trend yield to represent shifts in the foreign supply schedule (see Morgan 1991). The model is completed by a step dummy variable to represent the repeal of the import ban in 1979. To simplify matters further, we treat foreign and domestic potato yields, (U_t and Y_t respectively) as exogenous to the market, since it is reasonable to assume that yields are largely driven by (exogenous) technology.[4] Note that in this formulation market price is solely quantity determined so that the observed price-quantity combinations that emerge essentially trace the co-ordinates of a static demand curve.

The remaining aspects of the empirical model relate to the within and excess quota plantings, W_t and E_t. This dichotomous formulation allows each to respond independently to both the price and the policy variables; quota Q_t and excess levy[5] per tonne L_t. Since harvest prices are unknown at planting growers form expectations on the basis of past prices. Whilst the expectations generation mechanism is not modelled directly it is implicit in the empirical analysis that they are of a backward-looking nature. Finally, an identity is established such that total area planted H_t is simply the sum of E_t and W_t.

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4 The endogeneity of yields depends on the potentially complicated relationship between agricultural technology and the relative prices of potatoes and competing crops. Following a useful suggestion on an earlier draft we tested for the presence of a relationship between nitrogen price and potato yield but found no evidence supporting this hypothesis.

5 The excess levy is imposed on a per hectare basis but to ensure compatability with the price series, the levy is calculated on a per tonne basis by dividing real levy by trend yield.

As a benchmark against which to evaluate empirical estimates the following *a priori* relationships are posited. *Ceteris paribus*, the levy L_t would be expected to have a negative effect on excess plantings E_t and a positive effect on within quota area W_t, the reason for the latter being that as levy increases, more low cost producers will seek to rent quota from under-planters. The level of quota Q_t may be expected to exert a positive effect on W_t and a negative effect on E_t reflecting the relaxation of the area constraint. Although changes in price P_t are expected to induce positive changes in both W_t and E_t, theory and intuition suggest that excess plantings are proportionately more responsive to price changes, although in absolute terms the aggregate will be dominated by the response of the within quota plantings.

IV Statistical Analysis

(a) Econometric Method

Central to the preceding discussion is the notion that the behaviour of over-quota planters is fundamentally different to that of within-quota planters. Where this is the case, there will exist two distinct area response relationships in a structural economic model of the market, each of which represents an 'equilibrium' relationship. In these circumstances single equation methods are inappropriate since the potential for multiple equilibria and their inter-dependence is denied. The implications of this denial are well known, and at worst, yields estimates that are a mixture of the underlying separate relations rather than any single one of them (see *inter alia* Doornik and Hendry 1997, Harris 1995). In the current case, where multiple equilibria are thought to exist *a priori*, adoption of a general multi-equation approach consequently holds considerable appeal. A vector autoregression (VAR) provides an appropriate framework in these circumstances and acts as a useful precursor to the estimation of a simultaneous equations model which we obtain via a theory-

relevant reduction of the general system. The final area response model is data-congruent and parsimoniously encompasses the system and known rivals.

As much of the foregoing method is now commonplace we will merely sketch an outline of the method adopted (see Hamilton 1994, Harris 1995, Hendry and Doornik 1997 for details). Let $\mathbf{z}_t$ define a $(n \times 1)$ vector of I(1) potentially endogenous variables modelled as an unrestricted vector VAR of lag order k

$$\mathbf{z}_t = \mathbf{A}_1 \mathbf{z}_{t-1} + \ldots + \mathbf{A}_k \mathbf{z}_{t-k} + \mathbf{u}_t \qquad \mathbf{u}_t \sim \mathrm{IN}(\mathbf{0}, \Sigma) \tag{1}$$

where each of the $\mathbf{A}_i$ is an $(n \times n)$ matrix of parameters to be estimated by the data. Equation (1) is the reduced form representation of the system (in that each variable in $\mathbf{z}_t$ is regressed only on lagged values of itself and all other lagged variables in the system) and hence may be estimated efficiently by ordinary least squares since all regressors are predetermined.

Equation (1) can be reformulated as a vector equilibrium correction model (VECM):

$$\Delta\mathbf{z}_t = \Gamma_1 \Delta\mathbf{z}_{t-1} + \ldots + \Gamma_{k-1} \Delta\mathbf{z}_{t-k+1} + \Pi\mathbf{z}_{t-k} + \mathbf{u}_t \tag{2}$$

where $\Gamma_i = -(\mathbf{I} - \mathbf{A}_1 - \ldots - \mathbf{A}_i)$ $(i = 1, \ldots, k-1)$ defines the dynamic (or short-run) impacts and $\Pi = -(\mathbf{I} - \Pi_1 - \ldots - \Pi_k)$ expresses the equilibrium (or long-run) relationships in the system. Following Johansen (1988) it is convenient to decompose Π into two $(n \times r)$ matrices such that

$$\Pi = \alpha\beta' \tag{3}$$

where *r* is the rank of Π, i.e. the number of independent columns of β. Given that all components of $\mathbf{z}_t$ are I(1) by assumption, and that in general, linear combinations of I(1) components are also I(1), Π will generally be a null matrix with a corresponding rank of zero. Consequently, $\Delta\mathbf{z}_t$ is simply a function of its own past, long-run information being unimportant to the short-run behaviour.

In the special case where components of $\mathbf{z}_t$ cointegrate, *i.e.* form linear combinations that are I(0), *r* will determine the number of cointegration relations, or 'equilibrium' relationships in the system. In other words, the rank of the long-run matrix indicates the number of equilibrium relations present among the *n* variables in the system. In the presence of cointegration the $\Pi = \alpha\beta'$ decomposition is particularly useful since it delivers a neat economic interpretation of the parameters in Π. The *r* stationary linear combinations of $\mathbf{z}_t$ are described by the coefficients in the *r* columns β and hence $\beta'\mathbf{z}_{t-k}$ represents the short-run deviations around each of these *r* long-run relations.

Given that α is also of dimension $(n \times r)$ each element in this matrix represents an adjustment (or equilibrium correction) coefficient that loads deviations from one of the *r* equilibrium relations into one of the *n* equations. Thus the loading matrix links the long- and short-run components of the model and comprises coefficients which feed back information about long-run disequilibrium to the short run for correction. The magnitude of each 'error correction' coefficient determines the speed of adjustment towards the equilibrium state in each equation of (4), so that a high coefficient implies rapid adjustment and a low coefficient slow adjustment in the relevant equation.

In what follows it will be useful to augment (2) to accommodate any deterministic terms (constants, dummy variables) and stationary {I(0)} variables. Collecting these in a vector denoted $\mathbf{w}_t$ we formulate a VECM of the form

$$\Delta\mathbf{z}_t = \sum_{i=1}^{k-1}\Gamma_i\Delta\mathbf{z}_{t-i} + \Pi\mathbf{z}_{t-k} + \Omega\mathbf{w}_t + \mathbf{u}_t \qquad (4)$$

As a final step we model the area response relationships as a system of simultaneous equations, recognising the contemporaneous linkages that exist between within-and excess quota plantings. The reduced form representation of (4) is readily transformed into a system of simultaneous equations via pre-multiplication of an appropriate $(n \times n)$ non-diagonal matrix $\mathbf{A}_0$, the off-diagonal elements of which specify the structure of the linkages between the endogenous variables. This yields a structural economic representation of the form

$$\mathbf{A}_0\Delta\mathbf{z}_t = \sum_{i=1}^{k-1}\mathbf{A}_i\Delta\mathbf{z}_{t-i} + \mathbf{a}\boldsymbol{\beta}'\mathbf{z}_{t-k} + \mathbf{A}_0\boldsymbol{\Omega}\mathbf{w}_t + \boldsymbol{\varepsilon}_t \qquad \boldsymbol{\varepsilon}_t \sim \mathrm{NI}(0,\Theta) \tag{5}$$

where $\mathbf{A}_i = \mathbf{A}_0\boldsymbol{\Gamma}_i, \boldsymbol{\varepsilon}_t = \mathbf{A}_0\mathbf{u}_t$, $\mathbf{a} = \mathbf{A}_0\boldsymbol{\alpha}$ and $\Theta = \mathbf{A}_0\Sigma\mathbf{A}_0'$. Estimation of (5) requires that the equations are identified, and extraneous information about the market can be usefully employed to suggest the plausible exclusion restrictions required to satisfy the rank and order conditions for identification (see Hamilton 1994, pp.243-247). In the current context, where the regulatory framework administered by the PMB exerts such a defining influence over the market, there is a wealth of information that we exploit to assist in the identification process. In the empirics that follow equation (5) is estimated by full information maximum likelihood (FIML) using PCFIML 9.0 (Hendry and Doornik, 1997).

As a complement to the area response model we also estimate the price relation in this market. In contrast to that above, the price model is simple, both in terms of formulation and estimation. This follows from the assumption that price is (solely) supply determined and suggests that single equation methods suffice. Furthermore, given that the PMB's quota policy sought to maintain supply and thus price around constant levels all variables entering the price relation are stationary *a priori*. In the absence of non-stationarity, co-integration ceases to be relevant and statistical inference based upon ordinary least squares is legitimate. The price model is estimated as

$$P_t = \sum_{i=0}^{p}\boldsymbol{\Phi}\mathbf{x}_{t-i} + \boldsymbol{\Omega}\mathbf{d}_t + \nu_t \qquad \nu_t \sim IN(0,\sigma^2) \tag{6}$$

where $\mathbf{x}_t$ comprises the variables that contribute to available supply and the vector $\mathbf{d}_t$ specifies deterministic components such as constant terms, time trend and dummy variables.

(b) Empirical Analysis[6]

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[6] Due to the large volume of statistical output generated in systems analysis we merely report those results that are particularly pertinent to modelling strategy. Detailed output has been supplied to the referees and is available from the authors by request.

Data

The area response and price models are estimated using 31 annual observations relating to the 1965 to 1995 sample period. For the area response model the vector of endogenous variables $\mathbf{z}_t$ comprises E_t, excess plantings (000 hectares); W_t, within quota plantings (000 hectares); I_t, intervention buying (000 tonnes per year); Q_t, annual quota area (000 hectares); and L_t, the levy on excess plantings (£ per tonne). The model is augmented with three additive dummy variables: $SD80_t$, a step dummy for the repeal of the import ban (1980 to 1995 $SD80_t = 1$, zero otherwise); $ID75_t$ an impulse dummy for the extraordinarily low rainfall in the mid-1970s ($ID75_t = 1$ in 1975 and 1976, zero otherwise) and $ID95_t$ an impulse dummy to take account of the change in levy policy in the PMB's final year ($ID95_t = 1$ in 1995, zero otherwise). Lagged values of a real price variable P_t (constant 1985 £s per tonne) are also included as an indicator of historical profitability of the crop and is treated as weakly exogenous to current plantings accordingly. In the price model, the vector $\mathbf{x}_t$ comprises variables determining available supply, namely, production, V_t (000 tonnes); intervention buying, I_t (000 tonnes); and foreign yield variability, $XRES_t$ (deviation about trend yield tonnes per hectare).

As part of a descriptive statistical analysis the data were tested for the order of integration using an ADF regression on levels and first differences. The empirical results concur with our priors in that the endogenous variables of the area response model (E_t, W_t, Q_t, L_t) are I(1) in levels and the variables in the price relation ($P_t, I_t, XRES_t$) are I(0) in levels. Foreign (and domestic) yield are best approximated as trend-stationary and accordingly we use simple linear trend models to estimate yield trends.

The Area Response Model

Modelling begins by specifying a VAR for equation (1) of sufficient generality to induce white noise residuals in u_t. Despite evidence of residual non-normality in the levy equation a VAR(3) model is adopted as an adequate, albeit over-parameterised, representation of the data. Figure 6 shows the plot of actual and fitted values for each of the endogenous variables in the model. Table 1 reports asymptotic and degree of freedom corrected versions of the *maximal eigenvalue* and *trace* test statistics developed by Reimers (1992). Given that asymptotic (unadjusted) test statistics tend to over-reject (reject the null too frequently) in small (typical) samples the Reimers–adjusted statistics offer a more reliable indication of the actual number of cointegrating vectors in the data. Reading from the table it is clear both test statistics indicate the presence of two long-run relations at the 5% significance level.[7]

Table 1 : Cointegration Test Results

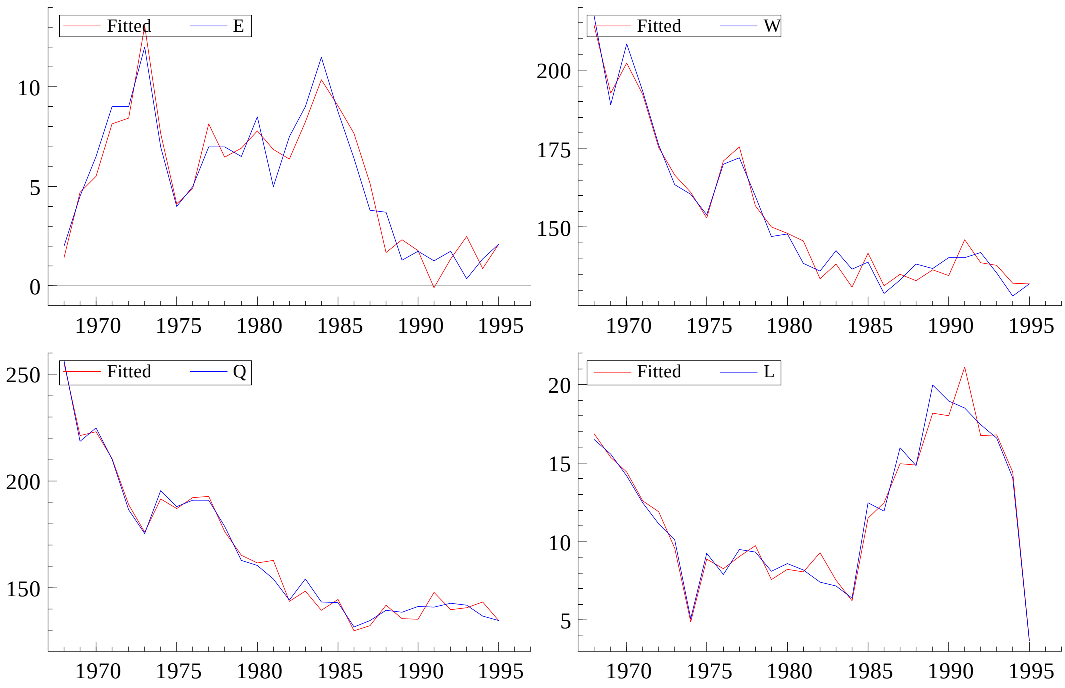
$H_0 : rank = r$	Maximal Eigenvalue test Asymptotic Reimers		95% critical value	Trace test Asymptotic	Reimers	95% critical value
$r = 0$	60.0**	34.4**	27.1	118.4**	67.6**	47.2
$r \leq 1$	43.7**	25.0*	21.0	58.3**	33.3*	29.7
$r \leq 2$	14.5*	8.3	14.1	14.6	8.4	15.4
$r \leq 3$	0.2	0.1	3.8	0.2	0.1	3.8

***significant at 95%; **significant at 99%**

Before we report the parameters of the two cointegrating relationships, it should be appreciated that, in general, each relationship must be identified in order to be treated as a valid estimate of an underlying long-run relationship.

[7] Note that the tendency to over-reject using the asymptotic test statistics is (as expected) present in this case.

Figure 6; Actual and Fitted Values from the VAR(3) Model



This owes to the fact that the (Johansen) method of estimation only provides information on the uniqueness of the cointegration space that is spanned by cointegration vectors, not the vectors themselves. In essence, any one vector may be a linear combination of the others and hence may appear as nonsensical from an economic point of view, despite satisfying the requirements of cointegration.[8] In the current case, 'uniqueness' is apparent since each cointegration relation represents a mutually exclusive area response relationship. In effect, there is a single restriction imposed on each vector, namely that W_t does not enter the long-run relationship for E_t and that E_t does not enter the long-run relationship for W_t. Consequently, no linear combination of, say, the first vector could be confused with the second because each has a single variable that is specific to that relationship alone. Normalising on E_t and W_t respectively the (unique) long-run relations and their standard errors (in parentheses) are given by

[8] A clear technical treatment of the. uniqueness issue is given in Harris (1995) pp.110-116.

$$E = 30.359 - 0.11Q - 0.30L \qquad\qquad W = 55.640 + 0.54Q + 1.19L$$
$$(4.78) \quad (0.09) \quad (0.08) \qquad\qquad (8.29) \quad (0.14) \quad (0.14) \qquad \textbf{(7)}$$

implying that increases in the quota and levy deter excess plantings yet increase within-quota plantings. These responses are precisely those predicted in Section II and tend to confirm the dichotomous nature of area response. Combining the estimates in (7) with the associated long-run elasticities in Table 4 the picture that emerges may be described as follows. First, even in the long run, within-quota plantings do not fully adjust to the tightening of quota. This result is likely to reflect the existence of under-plantings that allow producers to maintain area planted despite a shrinking quota. Interestingly, having once stood at around 44,000 hectares, under-plantings had fallen to around 1,100 by the end of the sample indicating the substitution implied by the statistical results.

Second, the fact that excess plantings also respond to the tightening of quota probably suggests that at the margin land is transferred from within–quota plantings to excess plantings, despite the fact that this switch in status incurs the excess levy. At –0.67 the levy elasticity suggests that, while effective, the levy policy was by no means prohibitive. Interestingly, at least some of those dissuaded from excess planting re-appear as within-quota planters: presumably for them, the cost of leasing quota from under-planters is less than the levy. Furthermore, although excess plantings appear to be at least six times more responsive to the policy variables than within-quota plantings, the fact that excess plantings have generally been less than 5% of quota area means that the within-quota area response dominates the aggregate.

Table 4: Long-run Area Response Elasticities (at mean values)

	Excess Plantings E_t	**Within Quota Plantings** W_t
Quota Q_t	**-3.66**	**0.60**
Levy L_t	**-0.67**	**0.09**

The equilibrium relations in (7) also shed light on the nature of the policy process itself: in particular, the interdependence of quota and levy in bringing about

Target Area. Aggregating the responses of the excess- and within-quota planters and rearranging in terms of *L* suggests that on average the PMB required a levy of some £20 per hectare to enforce every one thousand hectare reduction in quota.

Having established the long-run properties of the system we revert to the (equivalent) equilibrium correcting form, given by (2), where all variables are I(0) thus validating the use of conventional test statistics. This VECM embodies the long-run relationships of (7) but is still in reduced form since it ignores the contemporaneous linkages of a simultaneous system. Exploiting extraneous market information helps us to satisfy the (rank and order) conditions for identification of this system and yields the structural economic representation, details of which are reported in the appendix.

The 18 zero restrictions that are embodied in the final version are accepted at the 28% significance level ($\chi^2(18):21.08$) and thus the model represents a valid simplification of the original VAR. As illustrated in Figure 7 the model generally performs well, with R^2 measures of 0.77, 0.86, 0.88 and 0.94 respectively which compares favourably with the performance of the Ennew-White (1989) model (for which R^2 is 0.20, 0.70 for ΔE_t and ΔW_t when fitted over the same sample period). Given that both models contain the same variables, the improvement in fit is presumably attributable to the additional information embodied in a more appropriate dynamic specification, inclusion of the equilibrium error correction terms and the use of systems rather than single equation methods.

Given the brevity of the current sample and complexity of the inter-relationships, the fit of the policy variables and within quota plantings are impressive, although as Figure 6 indicates the erratic nature of excess plantings is more difficult to model. Here, in the interest of brevity, we merely highlight the main features of the model under the following headings:

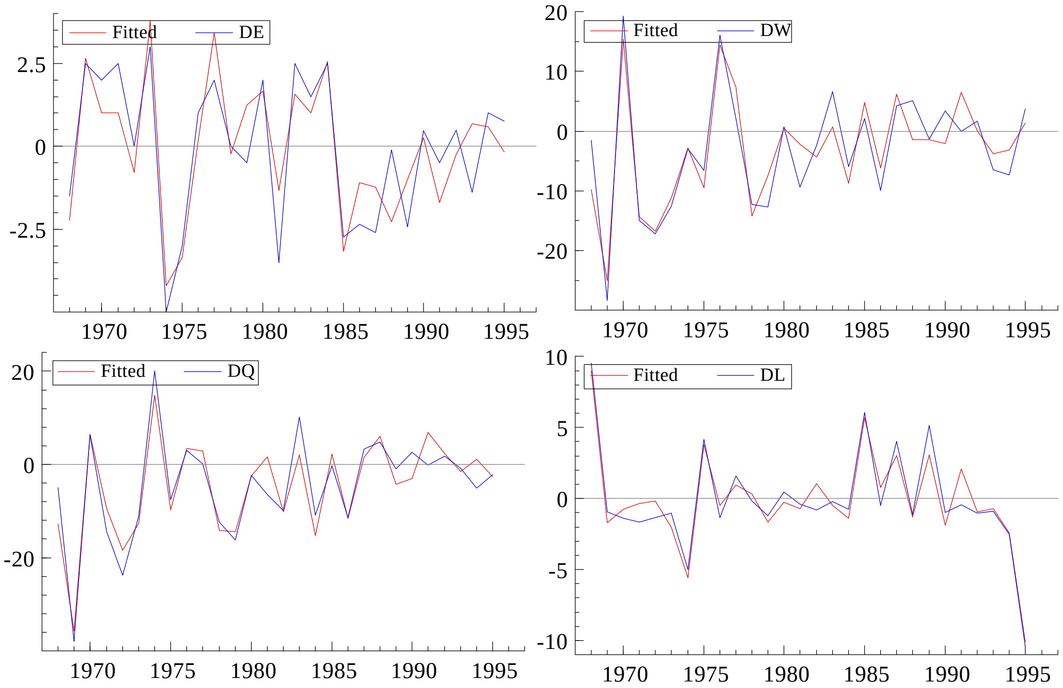
Policy Variables

It is apparent from the large number of significant parameters in both the levy and quota equations that the policy process does not take place in a vacuum but responds to both the historical levels and recent changes in prices and plantings. The sign of the loading (α) coefficients in these equations is consistent with the notion of error correction and the coefficients themselves are some of the most significant in the equations. The importance of the European Court's ruling on the import ban is also clearly detected, necessitating an estimated 10,000 hectare tightening of quota area and an increase in the excess levy of some £5 per tonne (around 30% of the pre-ban level of the levy).

Within-Quota Plantings

Given that the lion's share of area is within-quota, it is perhaps not surprising that contemporaneous changes in the policy environment as well as long-run effects are key in determining the within-quota area response. Estimates suggest that in the short run area response is sluggish: a five hectare change in quota induces a one hectare change in within quota plantings. Furthermore, a one pound per tonne increase in the levy increases within-quota area by almost 600 hectares. Interestingly, this response is substantially greater than the price effect, possibly reflecting that the levy information impacts on this year's return with certainty whereas (lagged) price is only a naïve expectation of future returns and hence conveys weaker information. This difference lends empirical support to the decision to model them separately in contrast to the Ennew and White (1989) approach.

Figure 7: Actual and Fitted Values from the Simultaneous Equations System



Excess Plantings

In a similar fashion to the within-quota equation, results indicate that excess plantings respond to long-run dis-equilibrium in *both* planting sub-sectors, suggesting that, for the most productive land, its use remains unchanged irrespective of its status in relation to quota. The corollary of this switching is that average yields rise as marginal land is taken out of production, reinforcing the technology-driven trend in yields. This effect illustrates the complex influence of policy on plantings: while quota tends to ossify industry structure, hence retarding average yield growth, it can also be seen as a stimulant to yield-enhancing investment. Curiously, however, changes to the current levels of the policy variables do not seem to exert a statistically significant effect on excess plantings, although one and two period lags of these variables clearly do. It is significant that the response to prices in both area-models is similarly modest. For example, the estimates indicate that a £10 per tonne increase in price induces a mere 250 hectare increase in each sector. This result is precisely that which we would expect given that it is the policy environment rather than price that determines planting decisions. In a setting where policy adjusts to maintain

price, price expectations play a relatively insignificant role as farmers are unlikely to expect prices to deviate from the historical mean.

The Price Model

Applying the data to equation (6) yields the results that are reported in the appendix, although for illustrative purposes the plot of actual and fitted price is shown in Figure 8. The final specification models log price, ($\ln P_t$), as a function of current production (V_t), support buying (I_t), foreign yield variation and a step dummy for the policy shift in 1980, ($SD80_t$). The signs of the coefficients are as expected, and in general, statistically significant at conventional levels. While intervention buying affects available supplies, the coefficients on production and support buying would not be expected to be equal and opposite because intervention purchases only occur in a depressed market and thus will tend to be of lower value than the typical market transaction. The estimates imply that 100,000 tonne decrease in production leads to a 5.7% increase in price whereas an equivalent intervention purchase induces a price rise of only 1.6%. A formal test of coefficient equality is strongly rejected (see appendix). Using the estimated production coefficient the price flexibility of production (at the mean) is -3.4 implying that the price elasticity of demand is approximately -0.3.

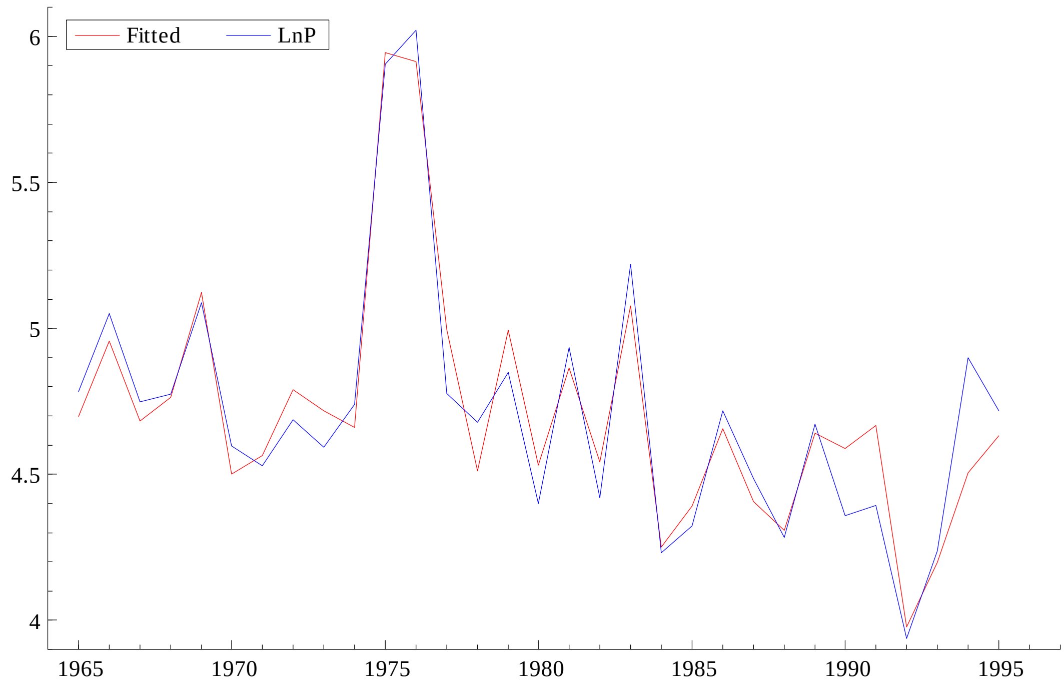
The estimates suggest that the impact of support buying on one tail of the distribution of prices appears to have raised average farm-gate price over the period by £4:80 per tonne. However given the sporadic nature of support buying such an average may offer a misleading impression of the actual price raising effect in high yielding years. For example, in 1970 1.3 million tonnes of potatoes were withdrawn from the market, bolstering prices by an estimated 21%.

The model also detects the *ceteris paribus* impact of the removal of the import ban in 1979; it estimates that without any change in production or policy, real price would have been some 27% lower on average. In practice, there was a scaling down of the support buying programme (see section 2) and a tightening of quota policy by sharp increases in the excess levy in the 1980s (see section 2

and Figure 6). This can be viewed as an attempt to offset, at least partially, the impact of increased import penetration.

These results also provide a 'back of the envelope' estimate of the costs of the Potato Marketing Scheme which we calculate to be around £26 million per year or around 5% of total market value, most of which is captured by producers. Although somewhat of an 'upper bound', owing to the fact that prices might not have fallen to our assumed free market level, this appears to be the price British consumers have paid for price stability under the policies of the PMB.[9]

Figure 8: Actual and Fitted Potato Price (£ per tonne)



V Conclusion

The twin objectives of the PMB, like those of similar agricultural parastatals,

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9 We estimate that the with-and-without policy average prices to be £109 and £103 per tonne respectively corresponding to average outputs of 6.0 and 6.1 million tonnes. The increase in consumer costs are thus (109*6.0)-(103*6.1)=26.

were to maintain reasonable prices for producers and dampen the inherent instability in the market. A combination of *ex ante* and *ex post* instruments were employed for these purposes including area quotas and intervention buying to offset the effect of technology and clement weather on annual production. Such was the efficacy of policy that price remained constant despite a strong trend in yield and static demand. However, a European Court ruling in 1979 and the Government's more market-orientated philosophy hastened the demise of the PMS: a step change in price resulted and the Scheme finally ceased in 1996. Our estimates suggest that the approximate cost to the consumer was around 5% of market value.

Using an approach first proposed by Ennew and White (1989) we develop an area response model that incorporates the essence of the PMS. This provides a foundation for the empirical modelling and delivers testable hypotheses. We find two distinct long-run (cointegrating) relations reflecting the dichotomous planting decision of whether to exceed or remain within quota allocation with signs consistent with those implied by the theoretical model. An effective policy would relegate the importance of price to producers who would attribute movements in prices to merely random influences. We find that price is a stationary variable and plays no role in the long run relationships.

Among other results, the empirical analysis confirms the widely accepted view that the price elasticity of demand for potatoes at the farm-gate is low - here it was estimated at around -0.3. However, a caveat is required since the analysis did not distinguish between the derived demand for ware sales and processing use. Given that over the past decade or so a rising proportion of production has been sold to the processing sector, further analysis is required to establish the individual derived demand elasticities for the two categories of use.

So what are the implications for a deregulated market? Most significantly, it is likely that price would regain its importance as a signal of relevant market information. The estimated long-run response elasticity of excess plantings (marginal area) to excess levy of -0.67 indicates that the response of area at the margin to net returns per tonne is potentially quite large. However, there are at

least two caveats to this conclusion. First, despite (limited) quota transferability, structural change was inhibited in the regulated market and deregulation is probably fostering a rationalisation of production (subject to the limits imposed by rotational constraints). Second, growers are faced with increased price risk in the deregulated setting. Both of these forces may restrict long-run price response.

Writing at the end of 1998, some two years after deregulation, it is still too early to gauge accurately the response to the new environment that farmers now face, not least because the price of potatoes has doubled and halved in the interim. Having been used to the relative stability afforded by the PMS producers are likely to seek alternative market-based mechanisms and may increasingly turn to forward and futures contracts to reduce their exposure to price risk.

References

Burrell, A. (1989) (ed.) ***Milk Quotas in the European Community*, CAB International, Wallingford.**

Ennew, C.T. (1985) 'The Potato Market in Great Britain: Structure, Conduct and Performance Under Uncertainty' Unpublished Ph.D. thesis, Department of Economics, University of Nottingham.

Ennew, C.T. and Peston, M. (1993) 'Evaluating the Impcat of the Possible Removal of Area Control in Great Britain's Potato Market' School of Management and Finance Discussion Paper, no.10, University of Nottigham.

Ennew, C.T. and White, B. (1989) 'The Implications of Quotas and Supply Control Policy in the British Potato Market' ***European Review of Agricultural Economics*, 16(2), 243-256.**

Doornik, J. and Hendry, D.F. (1997) Modelling Dynamic Systems Using ***PcFiml 9.0 for Winndows*** **International Thomson Business Press, London.**

Greenaway, D., Morgan, C.W., Rayner, A.J. and Reed, G.V. (1993) 'Trade Liberalisation and Domestic Price Instability in an Agricultural Commodity Market' ***Applied Economics*, 25, 199-205.**

Harris, R. (1995) ***Using Cointegration Analysis in Econometric Modelling*, Prentice Hall, London.**

Hamilton, J.D. (1994) ***Time Series Analysis*, Princeton University Press, Princeton, New Jersey.**

Jennings, A.N. (1981) 'An Evaluation of Potato Stabilisation Policies in Great Britain, Including the Implications of Free Intra-EEC Trade' Unpublished Ph.D. thesis, Department of Economics, University of Nottingham.

Johansen, S. (1988) 'Statistical Analysis of Cointegration Vectors' ***Journal of Economic Dynamics and Control*, 12, 231-54.**

PMB (1996) ***Potato Statistics in Great Britain*, Potato Marketing Board, London.**

Marsh, J.S. (1985) 'Economics, Politics and Potatoes – The Changing Role of the Potato Marketing Board in Great Britain' ***Journal of Agricultural Economics*, 36, 325-43.**

Morgan, C.W. (1991) 'Great Britain's Potato Stabilisation Policies and the European Market' Unpublished Ph.D. thesis, Department of Economics, University of Nottingham.

Reimers, H.E., (1992) 'Comparisons of Tests for Multivariate Cointegration', ***Statistical Papers*, 33, 335-59.**

Appendix: Regression Results

Area Response Model**: Estimation by FIML (sample: 1968 to 1995)**

Equation 1 for ΔE

Variable	Coefficient	Standard Error	t-value	t-probability
ΔE_1	1.4553	0.26868	5.417	0.0001
ΔE_2	0.88874	0.16951	5.243	0.0001
ΔW_1	-0.45379	0.10338	-4.390	0.0005
ΔQ_1	0.16177	0.078323	2.065	0.0555
ΔQ_2	-0.12932	0.025266	-5.119	0.0001
ΔL_1	1.6048	0.23641	6.788	0.0000
ΔL_2	0.71487	0.13664	5.232	0.0001
CIE3_1	-2.8953	0.39084	-7.408	0.0000
CIW3_1	1.3687	0.19823	6.905	0.0000
I D75	14.719	2.5917	5.679	0.0000
P_1	0.022056	0.0046385	4.755	0.0002
P_2	-0.010160	0.0036941	-2.750	0.0142
Constant	7.1685	2.5981	2.759	0.0140

Equation 2 for ΔW

Variable	Coefficient	Standard Error	t-value	t-probability
ΔW_1	0.88161	0.33179	2.657	0.0172
ΔQ_1	-0.89752	0.24989	-3.592	0.0024
ΔL_1	-1.4830	0.56327	-2.633	0.0181
CIE3_1	2.0137	0.89472	2.251	0.0388
CIW3_1	-1.8531	0.57699	-3.212	0.0054
P_1	0.029133	0.012198	2.388	0.0296
DQ	0.19969	0.13071	1.528	0.1461
DL	0.59487	0.22972	2.590	0.0198
Constant	31.201	8.2409	3.786	0.0016

Equation 3 for ΔQ

Variable	Coefficient	Standard Error	t-value	t-probability
ΔE_1	-2.8297	0.99346	-2.848	0.0116
ΔE_2	-2.3175	0.69999	-3.311	0.0044
ΔW_1	1.9156	0.37878	5.057	0.0001
ΔQ_1	-1.3182	0.30263	-4.356	0.0005
ΔL_1	-5.7601	0.85249	-6.757	0.0000
ΔL_2	-2.6247	0.57523	-4.563	0.0003
CIE3_1	7.6459	1.3665	5.595	0.0000
CIW3_1	-5.2436	0.75011	-6.990	0.0000
S D80	-10.001	4.1463	-2.412	0.0282
I D95	-20.279	5.5908	-3.627	0.0023
I D75	-46.608	10.497	-4.440	0.0004
P_1	-0.027246	0.017849	-1.526	0.1464

P_2	**0.040287**	**0.017283**	**2.331**	**0.0332**
P_3	**-0.029704**	**0.012234**	**-2.428**	**0.0273**
Constant	**61.988**	**17.260**	**3.591**	**0.0024**

Equation 4 for ΔL

Variable	**Coefficient**	**Standard Error**	**t-value**	**t-probability**
ΔE_1	**-0.95088**	**0.20057**	**-4.741**	**0.0002**
ΔW_1	**0.17425**	**0.066707**	**2.612**	**0.0189**
ΔW_2	**-0.17236**	**0.046341**	**-3.719**	**0.0019**
ΔQ_1	**-0.037737**	**0.064013**	**-0.590**	**0.5637**
ΔQ_2	**0.32917**	**0.0395508.323**		**0.0000**
ΔL_1-	**0.49145**	**0.12796**	**-3.841**	**0.0014**
ΔL_2	**0.39534**	**0.10659**	**3.709**	**0.0019**
CIE3_1	**0.88332**	**0.11623**	**7.600**	**0.0000**
SD80	**5.4032**	**0.99336**	**5.439**	**0.0001**
ID95	**-5.9877**	**1.3150**	**-4.553**	**0.0003**
P_1	**-0.012994**	**0.0041329**	**-3.144**	**0.0063**
P_2	**0.014344**	**0.0047375**	**3.028**	**0.0080**
Constant	**-26.793**	**3.9549**	**-6.775**	**0.0000**

Diagnostic tests
Vector portmanteau 4 lags= 61.142
Vector AR 1-1 F(16, 28) =0.69579 [0.7744]
Vector normality χ^2(8)=9.4162 [0.3084]

Test of model reduction
χ^2(18) = 21.077 [0.2756]

Note:
The variables CIE_1 and CIW_1 are (lagged) deviations from the long-run relationships for excess plantings and within-quota plantings respectively.

The Price Model **: Estimation by OLS (sample : 1965 to 1995)**

Dependent variable : lnP

Variable	**Coefficient**	**Standard Error**	**t-value**	**t-prob**	**PartR^2**
Constant	**8.1109**	**0.35008**	**23.169**	**0.0000**	**0.9538**
V	**-0.00056989**	**6.5258e-005**	**-8.733**	**0.0000**	**0.7458**
I	**0.00016247**	**0.00010683**	**1.521**	**0.1404**	**0.0817**
XRES	**-0.018292**	**0.010703**	**-1.709**	**0.0993**	**0.1010**
SD	**-0.27005**	**0.059143**	**-4.566**	**0.0001**	**0.4450**

Diagnostic Tests

R^2 **= 0.90** **F(4,26) = 61.725 [0.0000]** σ **= 0.144335 DW = 1.90**
RSS = 0.5416463234 for 5 variables and 31 observations

AR 1- 1 F(1, 25) = 0.035083 [0.8529]
AR 1- 2 F(2, 24) = 0.069324 [0.9332]
ARCH 1 F(1, 24) = 0.0021294 [0.9636]
Normality χ^2 **(2)= 5.238 [0.0729]**
X_t^2 **F(7, 18) = 0.59595 [0.7512]**
RESET F(1, 25) = 0.16845 [0.6850]

Test of Model Reduction
F(6, 20) = 0.6305 [0.7043]

Test of the equality of production and intervention coefficients
χ^2 **(1) = 27.606 [0.0000]**