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Price and quantity controlled agricultural markets and disequilibrium econometrics: a survey

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ABSTRACT

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This survey reviews the literature on estimating single markets in disequilibrium in the presence of regulated price and/or quantity controls, e.g., minimum price regimes and/or marketing quotas. Most of the literature is found to describe pure econometric technique, with only a few applications having emerged to date. Various reasons for the broad non-acceptance of this literature are offered, including a perceived lack of realism. Proposals to close this econometric theory–application gap are put forward, including: the use of effective demand concepts in specifying demand and supply functions; synthesizing some closely related literature on agricultural price/quantity controls with disequilibrium econometrics (i.e., endogenous government policy and the effects controls have on yield uncertainty and price risk); and outlining more 'applicable' econometric technique extensions.

1. INTRODUCTION

Many agricultural markets throughout the world operate under the imposition of price and/or quantity controls, e.g., minimum price regimes and/or marketing quotas. [1] Given that such controls are designed and regulated by government based organisations, then for successful implementation of welfare (politically) desirable controls, a clear understanding of the effects these controls have on market operations must be held by

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[1] For example, controls in various forms exist (or have existed) in Australia for tobacco, hens, sugar, rice, wheat and wine grapes; in the United States for rice, tobacco, peanuts, corn, soybeans, imported beef and sugar; for the European Community with sugar and milk; in Canada for eggs, turkeys and broilers; for Japan imported peanuts and for Spanish rice.

policy makers. This motivates the use of theory consistent econometric techniques for analysing price and quantity controlled agricultural markets. In this survey we review the use of 'markets in disequilibrium' econometric methods for analysing such markets.

The analysis of agricultural markets with controls typically focuses upon the estimation of welfare losses and transfers due to regulations. Historically, changes in producer and consumer surpluses and deadweight social losses have been quantified through the use of formulae derived by Nerlove (1958), which assume linear demand/supply functions and employ estimated or hypothesized elasticities. Examples include O'Mara (1981), Veeman (1982) and Johnson and Norton (1983). In the bulk of this literature only scant attention however, has been devoted to the procedures used to estimate or hypothesize elasticities. It is clear, that the fundamental issue of how to model the process which determines quantity and price transacted in the presence of price and/or quantity controls is given secondary importance.

In response to this neglect, Rausser and Stonehouse (1978) and Chambers and Just (1982) stress that to rigourously and accurately model agricultural markets with controls, specialised econometric techniques which recognize the specific discrete and discontinuous nature of regulations (i.e., qualitative and limited dependent variable models) must be employed. Methods for estimating markets in disequilibrium fall under this umbrella. Specifically, given observations on transacted price and quantity and exogenous regressors, disequilibrium econometric techniques allow modellers to consistently estimate the data generating demand and supply functions under the assumption that demand does not equal supply. The seminal paper on estimating markets in disequilibrium appeared some twenty years ago (see Fair and Jaffee, 1972), while most of the recent advances have been surveyed by Quandt (1988).

It is obvious that for agricultural trading markets where binding price and/or quantity controls exist, the motivation for modelling disequilibrium trading is indisputable, i.e., by definition if such controls are binding then demand cannot equal supply in the conventional sense. This recognition has lead to a body of literature which describes disequilibrium econometric methods specifically for the conventional textbook theory of price controls. The bulk of this literature dates back to the early 1980s and principally describes econometric technique only. In spite of the large number of markets which operate under controls, to date, only a handful of disequilibrium applications have emerged. It would appear that an econometric technique–application gap prevails.

In this survey, we shall seek to provide reasons for the emergence of this technique–application gap and then suggest directions the literature might follow to improve the frequency of technique application. In particular, it will be argued that the gap has emerged for the following reasons: the agricultural economics profession's desire for 'case studies' rather than 'standardized solution frameworks'; the profession's limited access to the literature; the complexity of the methods; and the techniques' perceived lack of realism. Consequently, we will explore the following suggestions for improving the applicability of the techniques: establishing a stronger theoretical base for disequilibrium models by incorporating effective demand concepts; synthesizing some closely related literature on price/quantity controls and disequilibrium econometrics; and outlining more 'applicable' econometric technique extensions.

In the next section, disequilibrium techniques for estimating controlled markets from a conventional microeconomic textbook base will be surveyed, after which, reasons for the technique–application gap will be expounded. The remainder of the paper outlines extensions and modifications which seek to improve the applicability of the techniques. Section 3 discusses the concept of effective demand and outlines methods for its incorporation into disequilibrium models for the analysis of markets with controls. In Section 4, we will synthesize some closely related literature on price/quantity controls with disequilibrium econometrics, for example, the literature on the effects controls have on yield uncertainty and price risk, and that on endogenous government policy. Econometric extensions of the standard disequilibrium model are then outlined in Section 5, including, modelling disequilibrium trading for observations under which controls are non-binding or non-existent. Section 6 concludes.

2. DISEQUILLBRIUM ECONOMETRICS FOR CONVENTIONAL THEORIES OF PRICE AND QUANTITY CONTROLS

Before detailing the disequilibrium econometrics for theories of controls, it will prove instructive to outline the canonical disequilibrium model which has evolved out of the literature. The model consists of stochastic demand and supply equations and a deterministic minimum condition [see Quandt (1988, chapter 2) for greater detail]:

$$\begin{aligned} Q_{\mathrm{t}}^{d} &= X_t^{\mathrm{d}}\alpha + \alpha_1 P_t + u_t^{\mathrm{d}} \\ Q_t^{\mathrm{s}} &= X_t^{\mathrm{s}}\beta + \beta_1 P_t + u_t^{\mathrm{s}} \end{aligned} \tag{1}$$

$$Q_t = \textsc{min}\left(Q_t^{\mathrm{d}}, Q_t^{\mathrm{s}}\right) \tag{2}$$

Here, Q_t^{d}, Q_t^{s}, Q_t and P_t define quantity demanded, quantity supplied, quantity transacted and price, respectively; X_t^{d} and X_t^{s} define exogenous non-stochastic regressors; α, β, α_1, β_1, σ_{d}^2 and σ_{s}^2 define estimable parameters; while u_t^d and u_t^s represent identically and independently distributed (IID) error terms with variances of σ_d^2 and σ_s^2, respectively.

Equation (2) describes the quantity transaction rule relating the observed Q_t to the unobserved Q_t^d and Q_t^s. Theoretically, this minimum condition encapsulates notions of voluntary and efficient trade, that is, no agent is forced to trade more than they desire and all mutually advantageous trades will have been completed. Econometrically, maximum likelihood methods are typically used to estimate the model. A particular feature of the estimation process is the recognition of error term truncations in the likelihood function, for the unobserved long-side of the market.

A popular extension of the canonical model is to endogenize price by adding to equations (1) and (2):

$$\Delta P_t = P_t - P_{t-1} = \lambda\left(Q_t^d - Q_t^s\right) \tag{3}$$

Here, λ represents an estimable price adjustment parameter which is expected to be positive. That is, price rises (falls) given excess demand (supply). Again, maximum likelihood techniques are typically used to estimate the model. Many applications of these models appear in the literature, covering diverse areas such as: housing starts, business loans, consumption goods, the labour market, investment goods, physicians services, and export goods.

Some studies have employed these canonical disequilibrium models to analyze agricultural markets with controls. Ziemer and White (1982) (with ensuing comments in Shonkwiler and Spreen (1983) and Ziemer and White (1983)) used the model defined by equations (1) to (3) to examine the U.S. fed beef sector. Theoretically, they list many possible reasons for disequilibrium trading including an increasing level of government involvement and specific beef price controls in the early 1970s. The estimated price adjustment coefficient implied slow market clearing adjustment and over the price controlled period the disequilibrium specification outperformed the equilibrium ($Q_t = Q_t^d = Q_t^s$) specification. To investigate the welfare implications of disequilibrium trading, White and Ziemer (1983) calculated conventional measures of consumer and producer surplus. They estimated that the net consumer surplus resulting from disequilibrium trading, was generally positive during the period beef price controls were operative.

Chambers, Just, Moffitt and Schmitz (1981, 1982a) (hereafter CJMS) [with ensuing comments in Martin (1982) and CJMS (1982b)] also investigated an agricultural market with controls using canonical disequilibrium models, in particular, the U.S. import beef market with its import quotas. Motivation for modelling disequilibrium trading, stems from the presence of quotas which they argue, do not represent strict upper limits on imports as quotas could and were often suspended. Even so, it is argued that the quotas' existence lead to 'voluntary' limits on imports of beef. The CJMS (1981) study employed the price adjustment equation, but not the CJMS (1982a) study. Results differed remarkably between studies. For example, supply elasticity fell from 2.817 to 0.77 and the estimated surplus gain to the U.S. of quota deregulations increased from an average US$1.72 million per month to US$40.0 million.

The non-robustness of CJMS's estimates is certainly undesirable and could have resulted from the too simplistic information inefficient structure of the exogenous price model or the inappropriateness of the excess demand price adjustment equation for the market. On the other hand, as argued by Martin (1982), the models may be mis-specified because of his view that the import restraints were in fact binding for part of the sample period, and those constraints should some how have been explicitly modelled. In effect, CJMS only implicitly model quantity constraints through their use of canonical disequilibrium models and their perception that the quotas were never strict upper limits.

Following on from Martin's (1982) criticism, rather than use canonical disequilibrium models to analyze markets with controls, to be more theory consistent one should explicitly recognize the specific disequilibrium ramifications of controls. We shall now review the literature which adapts disequilibrium econometric methods to cater for the conventional textbook theories of how markets operate under controls.

Three principal papers lay the foundation for price controls, i.e., Chambers, Just and Moffitt (1980) (hereafter CJM) [2], Gourieroux and Monfort (1980) (hereafter GM) and Maddala (1983b). It appears that the three foundation studies have independently derived similar estimation methods for price controlled markets, but do so for slightly different situations and specifications. With price controls three possibilities exist: a minimum level, a maximum level or both (buffer stocks). CJM and GM only detail the minimum case, while Maddala describes the latter two cases. Given its seemingly wider applicability and the similarity of all three cases, the minimum price level case only is detailed here.

The theory employed is the conventional microeconomic textbook theory of minimum prices (e.g., Hirshleifer, 1984, pp. 39–40) and is canvassed in terms of Fig. 1. 'Choice-theoretic' demand (Q^{d}) and supply (Q^{s}) curves are drawn within the quantity-price space. Equilibrium is depicted at the co-ordinate (Q^*, P^*). Assume the imposition of a minimum price $\bar{P} > P^*$, as depicted. Two intersections with the behavioural schedules occur, buyers

[2] Part of the results presented in this working paper have subsequently appeared in Chambers and Just (1982, pp. 305–309) and Chambers, Just and Moffitt (1985).

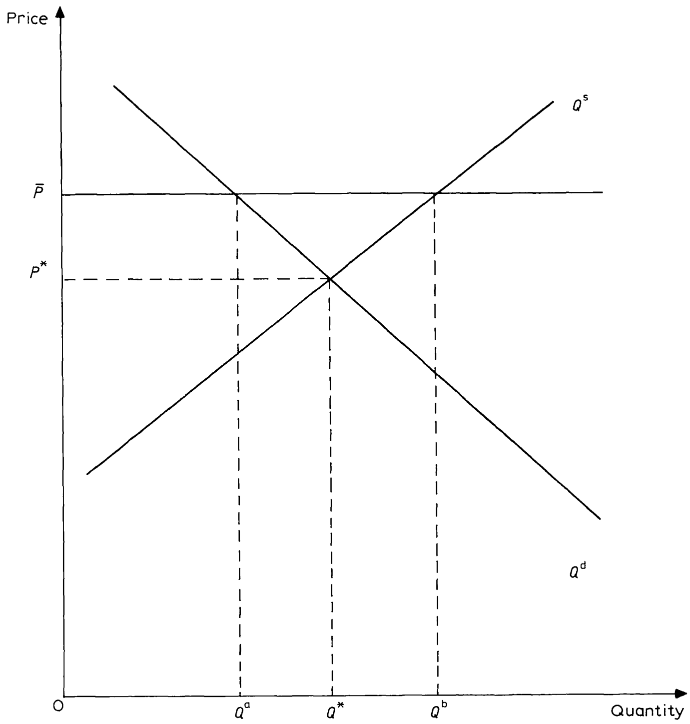

Fig. 1.

desire Q^{a} while sellers Q^{b}. It is typically assumed that voluntary and efficient trade exists and at $\bar{\mathrm{P}}$ the minimum of the two desired quantities is realised, i.e., $Q = Q^{\mathrm{a}}$. The excess of quantity $(Q^{\mathrm{b}} - Q^{\mathrm{a}})$ it is argued is either bought by some regulating authority, dumped on the export market, destroyed or stored. If however, $\bar{P} \leq P^*$ and no other reasons for disequilibrium trading appear relevant, then market forces imply equilibrium trading, i.e., $Q = Q^*$.

Econometrically, the theory can be specified as:

$$\begin{aligned} Q_t &= Q_t^{\mathrm{d}} < Q_t^{\mathrm{s}} \qquad \text{if} \quad P_t = \bar{P}_t \\ Q_t &= Q_t^{\mathrm{d}} = Q_t^{\mathrm{s}} \qquad \text{if} \quad P_t > \bar{P}_t \end{aligned} \tag{4}$$

where all terms are defined as for equations (1).

For this construct three cases can be distinguished, characterised by what data is observable. The convention is to assume that both $\bar{P}_t$ and P_t are observed. Secondly, $\bar{P}_t$ might be observed but not P_t. Thirdly, in some agricultural support price schemes, the regulating authority buys the excess supply which exists given $P_t = \bar{P}_t$ and hence even in disequilibrium both demand and supply are observed as are $\bar{P}_t$ and P_t. Details on the associated two-stage and maximum likelihood estimation procedures, together with formulae for predicting the consequences of deregulation, are provided in Appendix A.1.

Beyond these basic estimation procedures for price controlled markets, a number of closely related miscellaneous issues and extensions exist. First, an additional equation endogenously modelling the minimum price can be added to the basic system. Again various estimators exist depending upon what data is considered observable, these have been discussed by all three papers cited above. Chambers, Just and Moffitt (1985) apply these techniques to the Californian retail milk market, assuming the unobservability of $\bar{P}_t$. A limited information maximum likelihood estimator was employed, given that minimum prices varied from region to region but one could only get access to statewide prices. Demand (-0.107) and supply (0.085) were estimated to be highly price inelastic. While the demand elasticity was consistent with previous studies the supply estimate was much more inelastic than previous estimates. Another unexpected result was an estimated negative coefficient on the production cost variable in the minimum price equation. Concern for the statistical imprecision of this estimate and the simplicity of the specification were expressed. Given that the entire thrust of the paper was to model unobserved minimum prices, then the unexpected result with costs is highly disturbing.

Second, the basic minimum price disequilibrium econometric model has been modified to include rational expectations for price in the supply equation. Chanda and Maddala (1983, 1984) suggest that $E(P_t \mid I_{t-1})$, which recognizes the error truncation imposed by minimum prices, does not have a closed form within the model described by equation (4), and hence recommend approximations based on tobit methods. Shonkwiler and Maddala (1985) apply these concepts to support prices and U.S. corn by assuming supply agents have perfect foresight when forming price expectations, i.e., they know when the price support will be binding. For estimation it is assumed that both demand and supply are observed even given binding minimum prices since the regulating authority buys the excess supply. Estimated elasticities were 0.392 for supply and -0.727 for demand, the latter not considered to be unrealistic given that demand includes government purchases. It was concluded that predictions from the perfect foresight assumption out performed both those based on tobit approximations and future prices.

In contrast, Holt and Johnson (1989) employ methods from the general non-linear rational expectations literature [i.e., Fair and Taylor (1983)] to fully incorporate all the information implied by the rational expectations hypothesis within the minimum price disequilibrium model. This is achieved by explicitly recognizing the consequent cross-equation restrictions, the error truncation imposed by minimum prices and employing an iterative estimation procedure for both the parameters and the expected price. They also analyse support prices and U.S. corn assuming that both demand and supply are observed. Estimated elasticities were 0.457 for supply and -0.346 for demand. The estimated demand elasticity is much smaller than that estimated from an alternative equilibrium specification with naive expectations. The result that the disequilibrium model produces smaller demand elasticities than the counterpart equilibrium model is also a finding of other studies. The estimated supply elasticity is comparable with that of Shonkwiler and Maddala (1985). Their general conclusion is that the assumption of complex non-linear rational expectations within the context of the minimum price disequilibrium model can be empirically implemented, and is more suitable than an assumption of traditional equilibrium with naive expectations for the U.S. corn market.

Holt (1992) extends the Holt and Johnson (1989) framework further by estimating a multi-market bounded price variation model for the U.S. corn and soybean markets. Again rational expectations incorporating support price truncations are modelled using an iterative estimation procedure, but here demand and supply functions recognize cross-price linkages. Results indicate that cross-price influences are important with three of the four cross price elasticities being statistically significant. All estimated price elasticities are within the range of elasticities reported by other studies. Hypothetical deregulations of price supports and acreage diversion programs are also simulated. Results suggest that deregulation will have a significant impact upon the corn market but a much less pronounced effect on the soybean market.

There appears to be no barrier to translating these econometric techniques for analysing price controls to quantity controls. Oczkowski (1991) provides some of this translation by describing econometric techniques for the conventional textbook theory of marketing quotas. The theory (e.g., Hirshleifer, 1984, pp. 223–224) can be described with reference to Fig. 2. Assume a quota $\overline{Q} < Q^*$ is imposed on supply, two intersections from the behavioural functions lead to two price desires, P^d for buyers and P^s for sellers. Q is sold at "whatever price the market will bear" and hence the trading price is $P = P^d$. Conversely, if the quota is imposed on demand (e.g., import quotas) then the trading price is $P = P^s$. If $\overline{Q} \geq Q^*$ and no other market impurities exist then $Q = Q^*$.

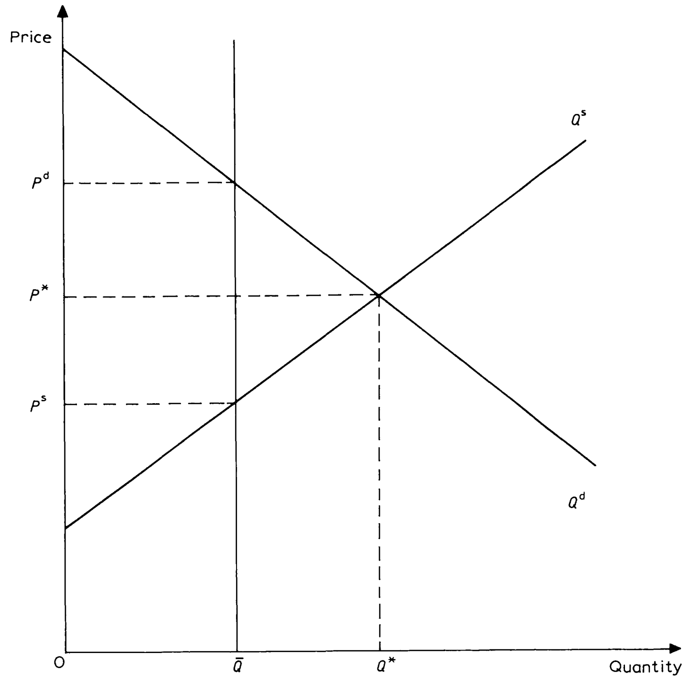

Fig. 2.

For the supply quota case the econometric model is:

$$\begin{aligned} P_t &= P_t^{\mathrm{d}} > P_t^{\mathrm{s}} && \text{if} \quad Q_t = \bar{Q}_t \\ Q_t &= Q_t^{\mathrm{d}} = Q_t^{\mathrm{s}} && \text{if} \quad Q_t < \bar{Q}_t \end{aligned} \tag{5}$$

$$\begin{aligned} P_t^{\mathrm{d}} &= X_t^{\mathrm{d}}\alpha^* + \alpha_1^* Q_t + u_t^{\mathrm{d}p} && u_t^{\mathrm{d}p} \sim \mathrm{IID}\left(0, \sigma_{\mathrm{d}p}^2\right) \\ P_t^{\mathrm{s}} &= X_t^{\mathrm{s}}\beta^* + \beta_1^* Q_t + u_t^{\mathrm{s}p} && u_t^{\mathrm{s}p} \sim \mathrm{IID}\left(0, \sigma_{\mathrm{s}p}^2\right) \end{aligned} \tag{6}$$

$$\begin{aligned} \alpha^* &= -\alpha/\alpha_1 \qquad \alpha_1^* = 1/\alpha_1 \qquad \sigma_{\mathrm{d}p}^2 = \sigma_{\mathrm{d}}^2/\alpha_1^2 \\ \beta^* &= -\beta/\beta_1 \qquad \beta_1^* = 1/\beta_1 \qquad \sigma_{\mathrm{s}p}^2 = \sigma_{\mathrm{s}}^2/\beta_1^2 \end{aligned} \tag{7}$$

The price demand/supply functions are determined by inverting Q_t^{d} and Q_t^{s} and can be formally justified from notional optimisation principles (see Huang, 1983). The relations between the parameters in (7), gained from the inversion, are important for theoretical consistency reasons and because if P_t^{s} had unique parameters and given that it is always unobserved (and hence recognized through truncations) then such parameters would not be estimable in any meaningful way. The case of import quotas can be treated in a similar way. Details on the associated estimation procedures are provided in Appendix A.2.

It is clear from the forgoing discussion that the bulk of the cited literature principally focuses on econometric technique, only a few applications have so far emerged. Even though the natural evolution of a new analytical procedure typically involves the development of econometric technique first and then its application, the acceptance of this literature has been laboriously slow given that the foundation studies appeared in the early 1980s. We offer the following suggestions for the emergence of the technique–application for the literature on disequilibrium econometrics and markets with controls.

First, we can point to the agricultural economics profession's desire for more 'case studies' rather than 'standardized solution frameworks'. As reported by Just and Rausser (1989), based on anecdotal evidence, the profession now takes a dim view "of our recent graduates [who] spend most of their time wondering about the applications they can make of standardized solution frameworks rather than finding interesting problems that require the development of customized frameworks" (p. 1179). This view is also supported by survey results of the profession. The existing disequilibrium econometrics on controlled markets could be viewed in this light as standardized solutions which possess a 'have model will travel mentality.' That is, the econometric techniques have been developed as a general body of tools seemingly applicable to many controlled market situations. The profession's skepticism of the universality of any analytical method and the desire for customized solutions could help explain the profession's reluctance to adopt whole heartedly the existing literature.

Secondly, the profession's limited exposure to the existing literature might also help explain the existence of the technique-application gap. Of the three foundation papers [Chambers, Just and Moffitt (1980), Gourieroux and Monfort (1980) and Maddala (1983b)] only latter is widely accessible, but even then, not in an agricultural economics journal. The CJM (1980) study represents a working paper with only part of these results having subsequently appeared in CJM (1985). The GM (1980) study also initially appeared as a working paper, its published version appears only in French. Further, most subsequent studies have appeared only in general economics journals such as *The Review of Economics and Statistics and Applied Economics* rather than agricultural economics journals. In part, this survey is designed to remedy this short-coming by bringing to the attention of the profession the existence, scope and applicability of these methods.

The complexities involved in applying these techniques is another likely reason for the gap's emergence. Most of the methods described require the use of maximum likelihood techniques and hence the implementation of specialised computer software designed for optimizing non-linear functions, such as GAUSS or GQOPT. The implementation of these packages typically requires the modeller to write a short computer sub-routine, defining the log-likelihood function and associated derivatives. As yet, simple one line commands as used in standard econometric packages such as TSP and SHAZAM, are not available for estimating these models. There is no doubt that these complexities do represent significant barriers to the simple and routine application of these methods by non-econometricans. This problem could be remedied by encouraging more collaborative research between agricultural economists and econometricans conversant with these techniques.

Finally, and related to the profession's skepticism of 'standardized solution approaches', the profession possibly perceives these techniques as lacking realism. For the most part, the techniques have simply adopted standard 'textbook' theoretical underpinnings which generally seem to lack sufficient complexity to be broadly appealing. Since the development of the 'textbook' model, various extensions have been proposed to enhance the applicability of the basic framework. The extensions include, redefining the behaviour of agents in the presence of controls, accounting for the effects controls have on yield uncertainty and price risk, and incorporating endogenous government policy. Only by recognizing these and other extensions will the techniques be perceived to be more realistic and hence applicable.

It is possibly the combination of all the above cited reasons which explains the emergence of the technique-application gap. As suggested, by encouraging more collaborative research with econometricans and improving the exposure of the techniques, wider applicability may be gained. However, it is probably the perceived lack of realism and the 'standardized solution approach' of the techniques which pose the greatest stumbling blocks for the methods' wider acceptance. To help clear this path, the remainder of the paper surveys various extensions of the standardized models. It is argued that by offering greater complexity and diversity greater applicability will be achieved. In the next section, the concept of effective demand is discussed and introduced into the analysis of controlled markets.

3. EFFECTIVE DEMAND AND THE DISEQUILIBRIUM ANALYSIS OF CONTROLLED MARKETS

In all the methods presented so far, no attention has been paid to the nature of the demand and supply functions. In this section we survey the literature on effective demand which argues that given the prospect of disequilibrium trading, agents' desires should be modelled to incorporate the expectation of rationing. Put broadly, effective demand is the quantity demanded expressed to the market when agents' incorporate rationing expectations into their choice-theoretic programs. [3] Conventionally, demand is formed by assuming agents maximize utility subject to a budget constraint, under the assumption that agents are able to buy as much as they desire given prices and income; the resulting demand is referred to as notional demand. Under circumstances of disequilibrium trading however, agents on the long side of the market will be rationed and hence cannot buy as much as they desire, and as such the conditions underlying notional demand are violated. Clearly, under these circumstances, to remain logically consistent, the expectation of rationing should also constrain optimisation and so warranting the specification of effective rather than notional demand.

Consider the following example to make explicit the distinction between notional and effective demand concepts. Assume that the typical supplier maximises the following utility function:

$$z(x^{\mathrm{s}}, m^{\mathrm{s}}) \tag{8}$$

with

$$\begin{aligned} x^{\mathrm{s}} &= \omega^{\mathrm{s}} - q \\ m^{\mathrm{s}} &= \overline{m}^{\mathrm{s}} + pq \end{aligned} \tag{9}$$

where x^{s} and m^{s} respectively define the final holdings of the transacted good and money; ω^{s} and $\overline{m}^{\mathrm{s}}$ respectively define the endowments of the good and money; and p and q represent the transacted price and quantity of the good. The substitution of equations (9) into (8) makes utility a function of q, it is assumed that $z(\cdot)$ is strictly concave in q and so its unconstrained maximization (with respect to q) defines a unique notional supply q^{s}.

To formalize effective supply assume that the supplier expects to be rationed, that is, less than q^{s} is expected to be transacted. Assume that the supplier holds some perception of how expressed supplies will turn into

[3] A great deal of literature exists on effective demand in macroeconometric models (e.g., Quandt 1988, chapters 5–7). In these multi-market models it is the spill-over from being rationed in one market which leads to effective demand in some other market. Given our emphasis on single isolated markets we abstract from the spillover effective demand definition and instead focus upon the expectation of rationing (for the isolated commodity to be traded) definition of effective demand.

transactions, if this expectation is held with certainty then the following deterministic perceived rationing scheme exists:

$$q = \phi(\tilde{q}^{s}) \tag{10}$$

where ϕ is a non-decreasing function. To form effective supply ($\tilde{q}^{s}$) the supplier must explicitly constrain optimization by this expectation of rationing. Thus effective supply is defined by maximizing equation (8) with respect to $\tilde{q}^{s}$ subject to equation (10). To give a specific example, assume the supplier faces a strict non-manipuable quota ($\bar{q}$) thus equation (10) becomes:

$$q = \phi(\tilde{q}^{s}) = \text{MIN}[\tilde{q}^{s}, \bar{q}] \tag{11}$$

Thus maximize (8) subject to (11) to determine $\tilde{q}^{s}$.

In spite of this literature most disequilibrium econometric models (both theoretical and applied) specify notional demand/supply functions. That is, most studies have implicitly assumed that all agents' expect to gain their notional desires at each trading session and hence specify notional demands as expressions to the market. Some studies has made this assumption explicit (see Laffont and Garcia, 1977, p. 1189).

The flaws with the argument for specifying notional rather than effective behavioural functions in disequilibrium models are many. The first relates to the role disequilibrium models have in explaining *actual* market operations. Consider the following argument. The endogenous observed variable in exogenous price models is Q_t the quantity transacted, and (Q_t, P_t) P_t is transacted price, in price adjustment models. The econometrican then derives a probability density function (PDF) and hence likelihood function to seek to explain these observed replications Q_t or (Q_t, P_t). The maximum likelihood method asks, given the model, which set of parameters is most likely to have generated that set of observations. In this vein, the amounts represented in minimum conditions and price adjustment equations should measure those demands expressed to the market. The market auctioneer (or whoever) at the market, compares these expressed desires to determine which quantity is transacted and to determine how much observed price should change. Hence, it is the demands which account for modified desires with the expectation of rationing which need to be specified in disequilibrium models and not some hypothesized, unexpressed, unknown notional desire.

Secondly, even given the acceptance of effective demand theory, one might still argue that notional behavioural functions are relevant. For example, given excess supply suppliers are rationed while demanders are not, hence suppliers express effective supplies and demanders notional demands. In such a situation the minimum condition still (probably) allocates quantity transacted to demand and thus the observed quantity equals the notional demand and so the notional function is relevant. The problem with this argument is that it ignores the long side of the market. The long side of the market plays a vital role in most econometric disequilibrium specifications. For most models without price equations, the long side of the market is recognized in truncations. For models with price equations, the price adjustment equation explicitly uses the long side to determine and adjust price. Thus if notional supply is specified when in fact effective supplies are expressed then one is not modelling actual market operations from observed data.

Thirdly, the role of expectations is ignored by the notional specifications. How do agents know before hand, that the market situation will be an excess supply one? Agents generally, do not possess this information, but rather must form expectations of rationing possibilities, given all past rationing experiences. This extremely important aspect is ignored by the notional justifications.

In the single market-effective demand literature [e.g., Benassy (1982, chapters 1–3) and Weinrich (1984)] discussions revolve around rationing aspects of disequilibrium trading and thus notions such as, the manipulability of rationing schemes, perceptions of rationing and transaction costs associated with expressing desires are highlighted. Econometrically, studies by Orsi (1982), Maddala (1990) and others, have made general and broad attempts at using effective demand concepts in single market disequilibrium models, while Eaton and Quandt (1983) and Oczkowski (1990) have built models from explicit and specific theories of effective demand.

Laffont and Monfort (1979), Dagenais (1980), Orsi (1982) and Maddala (1990) modify behavioural functions by incorporating so-called intertemporal spillover effects. Econometrically, the consequences are that lagged values of demand and supply appear as additional regressors. Theoretically however, only board notions about unsatisfied demand spilling over from previous periods are offered as justification for the specification. No explicit attempts are made to relate such concepts to the rational behaviour of agents in the face of rationing.

In contrast to these theoretically loosely based econometric specifications of effective demand, Eaton and Quandt (1983) provide econometric techniques for a specific effective supply theory of the labour market. A utility work-leisure choice framework is employed and it is assumed that workers face a stochastic, non-manipulable rationing scheme with transaction costs. Econometrically, the labour effective supply equation is modified to include a regressor which measures the probability of being rationed [i.e., $\Pr(Q_t^{\mathrm{d}} < \tilde{Q}_t^{\mathrm{s}})$, where $\tilde{Q}_t^{\mathrm{s}}$ is effective supply], the associated parameter is expected to be negative to explain the 'discouraged worker phenomenon'.

In essence, if a worker bears a transaction cost when placing labour on the market and if the probability of attaining work is low then the worker may not offer labour at all. To be specific, the specified model is:

$$Q_t^{\mathrm{d}} = X_t^{\mathrm{d}}\alpha + \alpha_1 P_t + u_t^{\mathrm{d}} \tag{12}$$

$$\tilde{Q}_t^{\mathrm{s}} = X_t^{\mathrm{s}}\beta + \beta_1 P_t + \rho \ \Pr\left(Q_t^{\mathrm{d}} < \tilde{Q}_t^{\mathrm{s}}\right) + u_t^{\mathrm{s}} \tag{13}$$

$$Q_t = \text{MIN}\left(\tilde{Q}_t^{\mathrm{s}}, Q_t^{\mathrm{d}}\right) \tag{14}$$

where Q_t^{d} represents conventional notional demand and $\tilde{Q}_t^{\mathrm{s}}$ represents effective supply.

Computationally, difficulties emerge when using $\Pr(Q_t^{\mathrm{d}} < \tilde{Q}_t^{\mathrm{s}})$ as a regressor in the $\tilde{Q}_t^{\mathrm{s}}$ equation. First, a single evaluation of the likelihood function requires the solutions of n (sample size) transcendental equations, this imposes vast computational costs. Second, Eaton and Qaundt's (1983) Monte Carlo simulations suggest that the likelihood function is flat with respect to the regressor's associated parameter (ρ), implying optimisation convergence problems. On the other hand, the likelihood ratio test for the associated parameter has acceptable power and the application to U.S. labour proved successful with expected signs on parameters with the discouraged worker phenomenon statistically confirmed.

Even though Eaton and Quandt (1983) only focus upon rationing affecting one side of the market, the two-sided case represents a simple extension which has been discussed by Maddala (1983a, pp. 324–326). Even given this literature, there appears to be another form for the rationing probability regressor which is both simpler and still theory consistent.

At the individual agent level most effective demand theories assume agents form some expectation of rationing based on the difference between their notional desires and how much they expect to be allocated. Then based on this difference an effective demand is optimally determined. In essence, effective demand is the means through which notional desires are sought given the prospect of rationing. In other words, the notional amount is still desired not the quantity associated with effective demand. To this extent measures of rationing based on notional differences appear attractive, i.e., $\Pr(Q_t^{\mathrm{s}} > Q_t^{\mathrm{d}})$ in the Eaton and Quandt (1983) framework. That is, let the following equation replace equation (13) in the Eaton and Quandt framework:

$$\tilde{Q}_t^{\mathrm{s}} = X_t^{\mathrm{s}}\beta + \beta_1 P_t + \rho \ \Pr\left(Q_t^{\mathrm{s}} > Q_t^{\mathrm{d}}\right) + u_t^{\mathrm{s}} \tag{15}$$

where, Q_t^{s} is conventional notional supply. Computationally, this avoids the need to solve transcendental equations and further overcomes the circular logic of an individual forming effective desires on the basis of the amount of expected effective rationing.

In contrast to the use of stochastic rationing schemes (hence the probability of rationing regressor) and the role of non-manipulability and transaction costs (hence the expected negative sign on the associated parameter), Oczkowski (1990) describes estimation techniques for a deterministic, manipulable rationing scheme basis of effective demand. Based on a preliminary theory of asymmetric manipulability (i.e., some knowledgeable agents manipulate the scheme while other uninformed agents act as non-manipulators), the relation between effective demand and notional demand is established in a deterministic sense (i.e., it is assumed that expectations are held with certainty) as follows:

$$\tilde{Q}_t^{\mathrm{d}} = Q_t^{\mathrm{d}} + \alpha_2\left[\mathrm{MAX}\left(0,\, Q_t^{\mathrm{d}} - Q^{\mathrm{se}}\right)\right] \tag{16}$$

$$\tilde{Q}_t^{\mathrm{s}} = Q_t^{\mathrm{s}} + \beta_2\left[\mathrm{MIN}\left(0,\, Q^{\mathrm{de}} - Q_t^{\mathrm{s}}\right)\right] \tag{17}$$

$$Q_t = \mathrm{MIN}\left(\tilde{Q}_t^{\mathrm{d}},\, \tilde{Q}_t^{\mathrm{s}}\right) \tag{18}$$

where Q^{se} is expected supply and Q^{de} is expected demand. As an example consider the case where $Q_t^{\mathrm{d}} > Q^{\mathrm{se}}$ and $Q_t^{\mathrm{s}} < Q^{\mathrm{de}}$, that is, demanders expect to be rationed and so from equation (16) demanders are modelled to express effective demand, while suppliers expect to be unrationed and from equation (17) are modelled to express notional supply. Note, that it is the amount of expected notional rationing which forms the basis of effective desires. The expected signs for α_2 and β_2 depend upon the costs and benefits from trying to manipulate rationing. For example, for demanders, if the benefits from manipulating the rationing scheme outweigh the costs then we expect effective demand to exceed notional demand and hence $\alpha_2 > 0$. Unfortunately, problems of identifying α_2 and β_2 occur when perfect expectations are assumed, i.e., $Q^{\mathrm{se}} = Q_t^{\mathrm{s}}$ and $Q^{\mathrm{de}} = Q_t^{\mathrm{d}}$. While the assumption of non-perfect expectations provides for tractable estimation only for particular error assumptions, i.e., errors added to equations (16) and (17) rather than (1) [see Oczkowski (1988a, chapter 3)] and for the Ginsburgh, Tishler and Zang (1980) (GTZ) specification where an error term is only added to the minimum condition involving effective desires, equation (18) and no errors are appended to equations (1) or (16) and (17). The GTZ specification has been examined as being computationally feasible in a series of Monte Carlo simulations, Oczkowski (1990, pp. 195–200). Further, the simulations show that significant parameter estimation bias occurs if an incorrectly specified notional model is used on data generated by the effective demand model.

It is a feature of both the cited effective demand models [i.e., equations (12)–(14) and (16)–(18)] that the standard notional demand model [i.e., equations (1) and (2)] is a special case of the effective demand model, i.e., with $\rho = 0$ or $\alpha_2 = \beta_2 = 0$ respectively. This implies that the standard model is a testable hypothesis within the effective demand model and that the undesirable consequences of specifying a notional model when an effective model generates the data are more serious than specifying an effective model when a notional model generates the data. Further, even if the effective demand model generates the data and hence is appropriately estimated, the underlying notional functions can still be identified by setting $\hat{\rho} = 0$ or $\hat{\alpha}_2 = \hat{\beta}_2 = 0$.

All this literature provides a foundation for modifying the standard disequilibrium econometric treatments of price/quantity controlled agricultural markets. Fundamentally, the techniques outlined and applied in Section 2 ignore a substantial body of literature which suggests that agents change their behaviour given the prospect of disequilibrium trading. Econometrically, we need only specify effective supply and notional demand given the excess supply nature of binding minimum prices. Appendix A.3 outlines the econometric methods which will provide this link between price/quantity controls and effective demand theories for markets with minimum price regimes.

These alternative approaches provide much more theory consistent econometric representations of price controlled agricultural markets than the conventional representations of Section 2. Clearly, the actual operations of the market should be examined in each specific instance to determine the underlying perceived rationing scheme. Given the identification of the scheme, then one of the models described above can be applied or if these are inappropriate then the procedures and techniques outlined provide the basis for 'personalizing' an appropriate effective demand based minimum price econometric model. The Monte Carlo evidence of Eaton and Quandt (1983) and Oczkowski (1988a, chapter 7, 1990) implies that the techniques in a general sense are certainly operational.

The case of quantity controls has been examined in Oczkowski (1988b, 1991). Theoretically, the announcement of strict legally enforceable quantity controls (quotas) mimics a deterministic non-manipuable rationing scheme with transaction costs, i.e., desires (of both buyers and sellers) equal to the known constraints are expressed to avoid the transaction costs associated with pointless searching,...etc. Given these publicly known controls then expectations play no role as both demanders and suppliers know perfectly the operating constraints. In Fig. 2, this leads to the effective demand schedule of: if $P \geq P^{\mathrm{d}} \Rightarrow \tilde{Q}^{\mathrm{d}} = Q^{\mathrm{d}}$, if $P < P^{\mathrm{d}} \Rightarrow \tilde{Q}^{\mathrm{d}} = \bar{Q}$; and the effective supply schedule of: if $P \leq P^{\mathrm{s}} \Rightarrow \tilde{Q}^{\mathrm{s}} = Q^{\mathrm{s}}$, if $P > P^{\mathrm{s}} \Rightarrow \tilde{Q}^{\mathrm{s}}$

$= \bar{Q}$. Multiple equilibria over the range $P^{\mathrm{d}} \geq P \geq P^{\mathrm{s}}$ emerges. This range can be interpreted as a bargaining range as individuals are motivated and observed to collude and act collectively. Based on the standard Zeuthen–Nash bargaining model and conditional indirect utilities for price preferences, a bargaining solution might be $P = (P^{\mathrm{d}} + P^{\mathrm{s}})/2$.

Econometrically, to handle any bargaining solution between P^{d} and P^{s}, specify the price generating equation to be:

$$P_t = \tau_t P_t^{\mathrm{d}} + (1 - \tau_t) P_t^{\mathrm{s}} + u_t^{\mathrm{b}} \qquad u_t^{\mathrm{b}} \sim \mathrm{IID}(0, \sigma_b^2) \tag{19}$$

where τ_t is the bargaining solution weight which might depend on exogenous regressors or could be treated as a constant, with P_t^{d} and P_t^{s} as defined in equations (6) and (7). Details on the associated econometric techniques are provided in Appendix A.4.

The model underlying (19) has been applied to the Australian tobacco leaf market (see Oczkowski, 1991, pp. 500–502). In general, all but one of the coefficients had expected significant signs. Elasticities were estimated to be -0.80 and 2.45 for demand and supply respectively, the latter not being considered unrealistically high given the storable nature of the output. The assumed constant bargaining coefficient was significant at $\tau = 0.42$. In terms of Marshallian surplus measures, buyers were estimated to gain on average 70.9% of the total surplus from bargaining, but were also expected to gain from hypothetical quota deregulations.

This approach to modelling quantity controls is certainly a stark departure from conventional techniques but in some cases it is argued to be more theory consistent and 'realistic'. In the Australian tobacco leaf case explicit formal negotiations between representatives of buyers and sellers do take place over price and hence the use of conventional techniques in analysing this market is clearly inappropriate. Further, many other agricultural markets which operate under quantity controls also appear to have prices influenced by negotiated marketing bodies' policies rather than pure market forces. Clearly, quota markets in which no explicit price influencing negotiations appear to take place must be analysed via alternative, but still effective demand consistent, techniques.

4. SYNTHESIZING DISEQUILIBRIUM ECONOMETRICS WITH AGRICULTURAL ECONOMICS

Given the emphasis on analyzing markets with controls a clear motivation exists for explicitly modelling the process which leads to the specific levels of the controls set. To this extent literature on endogenous government policy, as surveyed by Rausser, Lichtenberg and Lattimore (1982) could provide a useful basis for modifying disequilibrium models and so enhance their applicability. To lay the foundation we shall briefly outline some of this literature and then discuss how it might be adapted into disequilibrium models.

Rausser, Lichtenberg and Lattimore (1982) argue that various theoretical paradigms have been advanced to explicitly describe the process which leads to the setting of government policies such as support prices and import quotas. In particular four frameworks have been used: liberal-pluralist, theory of the state, theory of economic regulation and conflict resolution between rent-seeking interest groups. Empirically, two broad approaches have been followed: the estimation of policy criterion functions and the estimation of policy instrument behavioural functions. We shall discuss two specific representative recent studies to focus our attention more precisely.

Lopez (1989) employs the policy criterion function approach to analyze the U.S. sugar policy instruments of import quotas and target prices. Theoretically, it is hypothesized that the government chooses levels for the instruments such that its utility function is maximised. Utility is specified to be a function of the returns to the various market participants, i.e., producer, consumer, foreign countries', and the federal budget surpluses. The solution to the optimization program results in equations for the policy instruments which are functions of these surpluses. Empirically, Lopez explicitly incorporates these notions into a commodity market model by specifying stochastic equations for: quantity supplied (treating acreage and yield separately), quantity demanded and policy instrument equations for the price support and import quota levels.

The differences between Lopez's empirical approach and the previously surveyed disequilibrium literature provides insights into potentially useful disequilibrium models of endogenous government policy. In contrast to the disequilibrium literature, Lopez does not endogensize the market price and hence even given nonbinding support prices ignores the market equilibrium determination of price. Further, Lopez employs an instrumental variables approach for forming rational supplier price expectations and uses a seemingly unrelated regressions estimator (SURE) to estimate his model.

All this suggests the following approach for modelling endogenous government policy using the policy criterion approach for minimum prices. To the basic system of stochastic demand and supply functions and endogenous switching between equilibrium and excess supply, add an endogenous minimum price equation as a function of the various market surpluses. Maximum likelihood methods, as previously outlined, have already been developed for endogenous minimum prices, the only modification needed is the explicit recognition of endogenous quantity demanded and supplied as arguments in the minimum price equation to cater for producer and consumer surplus. This econometric extension can be handled within the maximum likelihood framework as the structure is similar to canonical disequilibrium models where price is endogensized with arguments of endogenous quantity demanded and supplied. Further, reduced form rational supplier price expectations can be accommodated for by employing the previously discussed Holt and Johnson (1989) approach. There appears to be no barrier to translating these notions to the policy criterion function analysis of quotas.

In contrast to the policy criterion function approach Beghin (1990) develops a game-theoretic model of policy formation which determines the bargaining strength and welfare of market participants. The approach is applied to food and agricultural prices in Senegal. Analytically, the solution to a Nash bargaining program (based on compensating variations (CV) of urban consumers, farmers and marketing boards) is expressed in terms of first order conditions for various agricultural commodity and input prices. Two approaches to estimation are contrasted. First, the first order conditions (involving the participants' CVs, their derivatives with respect to prices and exogenous shifters) are directly estimated after a first stage estimation of supply and demand functions. The second approach directly estimates the price behavioural functions by regressing prices against various exogenous regressors. These behavioural functions are derived from linear approximations of equilibrium bargaining strategies with reference to exogenous shifters.

In establishing a relation between Beghin's approach and disequilibrium models we note that the principal agricultural commodity price modelled by Beghin is that for groundnuts, this price is controlled by official agencies. This aligns with our price controls emphasis and hence suggests some applicability of the previously surveyed methods. In particular, for direct game-theoretic estimation, the first stage estimation of demand and supply functions should involve some use of disequilibrium methods given the existence of price controls and hence the consequent distorted market operations. Secondly, for the price behavioural equation approach simply employ the disequilibrium minimum price model with an endogenous minimum price equation using exogenous shifters as regressors. Unlike the earlier applications of the endogenous minimum price model (e.g., Chambers, Just and Moffitt, 1985) here the interpretation of estimates would be as linear approximations of equilibrium bargaining strategies.

Another body of agricultural economics literature which, if incorporated into disequilibrium models would enhance their applicability, is that on supplier price risk. Just (1974) introduced that notion that variation in expected prices could negatively impact upon supply response for risk adverse farmers. Empirically, Gallagher (1978), Martin and Urban (1984), Chavas and Holt (1990) and others, examine supply response (in isolation) with price risk effects in a price support framework. Effectively, a support price truncates the variance of expected price and so reduces the conventional impact of price risk on supply response. These studies show that truncated price risk effects do significantly and negatively impact upon supply response in the U.S. corn and soybean markets.

Holt (1989) incorporates these notions of truncated supplier price risk into the minimum price disequilibrium model assuming rational expectations. In particular, rational expectations of price, the variance of price and the third central moment of price, which recognize the truncations imposed by support prices, are specified in the supply function. For estimation, following Holt and Johnson (1989), an iterative procedure is used to determine expected prices within a maximum likelihood framework, given that the expressions for price risk do not have closed forms. This market disequilibrium model is applied to the U.S. corn market. Results indicate that price variance has a significant negative impact and the third moment a significant positive impact (implying a right skewed price distribution) on supply response.

To further enhance the applicability of the disequilibrium models of markets with quotas, the literature [i.e., Johnson (1982), Fraser (1986), Babcock (1990) and others] on the effects quotas have on supply response in the face of yield uncertainty should be recognized. In particular, crop output depends upon both yield and area planted, and given that yield is uncertain then there will be no guarantee that quota amounts will be exactly produced every season. To the extent that over-quota output does not sell at the same price as quota output, yield uncertainty will affect supply response in the presence of quotas. Babcock (1990) discusses results for both risk-neutral and risk-averse producers and shows that in the presence of quotas the effects of yield uncertainty are definitely non-zero but ambiguous in direction. The direction of the effects of uncertainty depend upon the relationship between the expected marginal revenue and marginal costs at the acreage level that fills the quota at mean yields.

Market disequilibrium models could incorporate yield uncertainty by including a measure of yield variation (e.g., based on the variance of past yields) in the supply function. There should be no definite expectation for the sign of the associated parameter but the magnitude of the variable would account for the degree of yield uncertainty. That is, the literature does show that the greater the uncertainty the greater the impact on supply response, and this would be adequately reflected by a measure such as yield variation. Econometrically, the incorporation of the variance of yield in the supply function might lead to some simultaneous equation bias, if yield is not endogensized, given that quantity supplied is a product of both yield and area planted. To avoid this problem either, the likelihood function can be extended further by adding an additional yield equation, or instruments could be used for the variance of yield and the standard likelihood function employed.

In this section we have identified three bodies of existing literature on markets with controls which potentially could play an important role in enhancing the applicability of disequilibrium models. The focus has been upon generalizing the existing models rather than dismissing them as irrelevant. The existing models are not fundamentally flawed but rather are too simplistic. The surveyed models do lay a useful foundation which can be built upon by incorporating the extensions described in this section.

5. ECONOMETRIC EXTENSIONS OF DISEQUILIBRIUM MODELS OF CONTROLLED MARKETS

In this section econometric technique extensions of the previously surveyed disequilibrium models will be discussed. Again, the focus is upon improving the applicability of the methods. First, estimation methods will be extended to allow for disequilibrium trading under regimes where controls are non-binding. We then discuss econometric representations of markets with simultaneous price and quantity controls and conclude with some comments on diagnostic testing for disequilibrium models.

Consider the minimum price disequilibrium model of Section 2 and observations which satisfy $P_t > \bar{P}_t$, that is, a non-binding minimum price. A priori there is no reason to assume, as in Section 2, that non-binding minimum prices imply a perfectly operating market and hence equilibrium trading. The existence of other institutional factors, non-competitive market structures, information and adjustment costs [i.e., Alchian (1970), Barro (1972), Rothschild (1973) and Benassy (1982, chapter 5)] implies that circumstances might arise where market forces are impeded from establishing equilibrium for every trading session.

On institutional factors, the existence of government regulations and institutional bodies such as price justification tribunals, trade unions, employer organisations and trade practice legislation and the like, directly inhibit the normal functioning of markets, thereby leading to price stickiness and thus disequilibrium trading. Information costs generally prohibit price setters in monopolistic structures, from setting market clearing prices. That is, in attempting to equate marginal revenue and marginal cost for profit maximisation, uncertain demand and costs in obtaining demand information imply that price adjustment toward optimality will be slow. Finally, the adjustment costs associated with changing prices, such as, costs in disseminating the new price information, might also lead to general price stickiness and thus trading at false prices.

The modelling of possible disequilibrium for $P_t > \bar{P}_t$ is seen as particularly important for data generated before the imposition of some price regulation regime, i.e., $\bar{P}_t \to -\infty$. That is, regulations are often imposed to stabilize markets which are inherently unstable, implying the existence of free market impediments and hence the need for some type of disequilibrium modelling. Further, given that the equilibrium model is nested within the disequilibrium model (as $\lambda \to \infty$ in equation (3)), then the consequences of mis-specfying a disequilibrium model for non-binding prices are not as serious as mis-specifying an equilibrium model for those observations.

Econometrically, Maddala (1983a, pp. 321–322) illustrates that the partial adjustment modelling of observed price to equilibrium price, which can be loosely based on notions of adjustment costs,... etc., does lead to the canonical price adjustment disequilibrium model, i.e., equations (1), (2) and (3). Given this, an appropriate minimum price disequilibrium model would specify strict excess supply (i.e., $Q_t = Q_t^{\mathrm{d}} < Q_t^{\mathrm{s}}$) for binding minimum prices and the canonical price adjustment model (i.e., equations (1), (2) and (3)) for non-binding prices. The technicalities of estimation and deregulation predictions for this construct and that for markets with quotas are described in Appendix A.5.

A further econometric technique extension of disequilibrium models is the modelling of markets with simultaneous price and quantity controls. For example, the Australian and U.S. tobacco leaf markets operate under minimum prices and quotas. It would appear that a combination of the previously exposed techniques would suffice to facilitate a simple econometric analysis of such markets. In particular, combining the simple theories underlying Figs. 1 and 2 leads to only four possibilities:

$$\begin{array}{lll} Q_t = Q_t^{\mathrm{d}} = Q_t^{\mathrm{s}} & \text{if} \quad P_t > \bar{P}_t & \text{and} \quad Q_t < \bar{Q}_t \\ Q_t = Q_t^{\mathrm{d}} < Q_t^{\mathrm{s}} & \text{if} \quad P_t = \bar{P}_t & \text{and} \quad Q_t < \bar{Q}_t \\ P_t = P_t^{\mathrm{d}} > P_t^{\mathrm{s}} & \text{if} \quad P_t > \bar{P}_t & \text{and} \quad Q_t = \bar{Q}_t \\ Q_t = Q_t^{\mathrm{d}} < Q_t^{\mathrm{s}} \quad \text{or} \quad P_t = P_t^{\mathrm{d}} > P_t^{\mathrm{s}} & \text{if} \quad P_t = \bar{P}_t & \text{and} \quad Q_t = \bar{Q}_t \end{array} \tag{20}$$

All expressions are as defined previously and to ensure theoretical consistency, P_t^{d} *and* P_t^{s} should be defined using the relations in equation (7). Imposing these restrictions implies that when both controls are binding then either $Q_t = Q_t^{\mathrm{d}} < Q_t^{\mathrm{s}}$ or $P_t = P_t^{\mathrm{d}} > P_t^{\mathrm{s}}$ is appropriate. To enhance the suitability of this model, the extensions alluded to in Sections 3 and 4, and allowing for disequilibrium trading when controls are not binding, should be addressed. An outline of the econometric details on these models of simultaneous controls is provided in Appendix A.6.

Finally, we shall make some comments on diagnostic testing in disequilibrium models. There is a strong current view in the general econometric literature (e.g., Beggs (1988) and MacKinnon (1992)) that econometric models should be tested for their compliance with the estimating procedures underlying assumptions. Such diagnostic testing is now standard practice for linear in parameter regression models. In contrast, for all the disequilibrium models for markets with controls cited in this survey, no such tests have been applied or as yet developed. This clearly alludes to a deficiency in the overall literature and necessarily casts doubt on the estimated models, given that one is asked to blindly accept all underlying assumptions. It is particularly a problem for disequilibrium models as, unlike the standard linear model, parameter estimates are inconsistent given either non-normality or heteroscedasticity.

Diagnostic tests for disequilibrium models of controls could be developed by using the conditional moment restrictions framework, as surveyed by Pagan and Vella (1989). These tests use the sample analogues of the restrictions on population moments to directly test the validity of the model's assumptions. Operationally, these tests can usually be carried out by running additional standard regressions and performing conventional t and F tests on the parameters of constructed additional regressors. These tests have been explicitly developed for other limited dependent variable models such as tobit, probit and models with sample selectivity. Given the general limited dependent variable structure of disequilibrium models, then these principles it appears can be applied. However, these tests still need to be explicitly worked out for all the previously cited disequilibrium models.

6. CONCLUDING COMMENTS

One of the claims often made by econometricans working with disequilibrium methods (e.g., Bera (1991)) is that disequilibrium methods represent one of the few areas of econometrics where an explicit relation is made between statistical technique and economic theory. That is, disequilibrium econometrics has been particularly designed to relate statistical tools to the specific economic concept of markets trading when demand does not equal supply. Given this, then one expects many applications of the proposed techniques, this however, is not the case for disequilibrium models of markets with controls.

After reviewing the literature on conventional disequilibrium models of markets with controls, we then alluded to various reasons for the emergence of this technique-application gap. It appears that the standard methods are based on a too simplistic economic theoretical structure. In response, the remainder of the paper described various extensions of the simple framework which should enhance applicability, given the additional complexity. In particular, demand and supply functions were modified by employing more theoretically consistent effective demand concepts in disequilibrium models. Next, we attempted to synthesize disequilibrium models with literature on endogenous government policy and the effects controls have on price risk and yield uncertainty. Finally, some pure econometric extensions were suggested to enhance model applicability.

No doubt the methods described represent an enormous advance upon the standard Marshallian consumer/producer surplus policy analysis of agricultural controls, which only make use of naively estimated elasticities (e.g., Veeman, 1982), The link between the surveyed literature and policy making is clear and strong. Since controls represent specific government policies then there is a need for policy makers to understand fully the operations of markets under such controls. The thrust of the entire surveyed literature is to rigourously and theory consistently model the behaviour of agents under such controls and hence aid in this policy making.

We expect that given the greater use of related literature such as literature on endogenous government policy, then the frequency of application of the surveyed disequilibrium models will be improved. Clearly, the foundations have been laid, yet many specific details of the proposed and other extensions need to be determined. Such details point to many fruitful avenues for future research.

In general, a stronger link needs to be developed between economic theory and the specified disequilibrium econometric model. For example, explicitly incorporating endogenous government policy theory into a theoretical framework which recognizes disequilibrium trading, could possibly lead to specific theory consistent relations (and hence testable restrictions for estimation) between the specified demand/supply functions and the endogenous policy equations. Further, the effects the expectation of rationing has on yield uncertainty and price risk and hence on the specified demand/supply functions, needs to be rigourously developed.

The econometric method surrounding disequilibrium models could also be developed further. Given the computational complexities involved in deriving maximum likelihood estimates for the models, it would be desirable to further develop simpler two-stage estimators as alternatives. However, a careful statistical evaluation of such alternative estimators should first be undertaken to ensure that the consequent loss in parameter efficiency, does not render the subsequent estimates useless. As suggested previously, diagnostic tests using the conditional moment restrictions framework also need to be developed for the surveyed models. Again however, these tests need to be carefully assessed to ensure that they are sufficiently powerful to serve as useful devices for model evaluation and development.

In conclusion, this survey presents a variety of models which 'appear' to be applicable to a wide range of agricultural price and quantity controlled situations. Operationally however, each and every market circumstance should be examined individually and then the suitability of the existing techniques assessed. The outlined techniques should be interpreted as providing an overall framework which if desired can be modified and adapted to analyse any peculiar controlled market with individual characteristics.

APPENDIX: ECONOMETRIC TECHNICALITIES

A.1. Minimum prices with conventional theory

Consider the model defined by equations (1) and (4) and the various cases of data observability outlined in the text. Two types of estimators have been proposed for the case where both P_t and $\bar{P}_t$ are observed, i.e., two-stage procedures and the maximum likelihood method. Three alternative two-stage estimation procedures have been suggested: CJM (pp. 17–19), GM (pp. 8–9) and Maddala (pp. 364–366). The CJM study employs Heckman's (1976) two-stage sample selection methods and works with equilibrium reduced forms, by focusing on the truncation imposed by $P_t^* < P_t = \bar{P}_t$. A drawback of the method however, is that in cases of overidentification unique structural form supply parameter estimates are only obtainable after some third stage. In any event it seems unnecessary to focus on reduced forms given the greater interest in structural forms. In contrast GM and Maddala use tobit methods as first stages and estimate structural forms directly by focusing on the truncation imposed by $Q_t^{\mathrm{s}} > Q_t = Q_t^{\mathrm{d}}$. The GM representation is favoured because it is simpler than Maddala's procedure.

To describe the preferred estimation procedure define two observation sets: denote observations satisfying $P_t = \bar{P}_t$ as belonging to the set ψ_1 and those observations satisfying $P_t > \bar{P}_t$ as belonging to the set ψ_2. GM first construct the tobit equilibrium reduced form for price:

$$
\begin{aligned}
P_t &= X_t \pi^p + v_t^p \quad && \text{if} \quad \bar{P}_t < P_t \\
&= \bar{P}_t && \text{otherwise}
\end{aligned}
\tag{21}
$$

Here X_t, π^p and v_t^p represent the appropriate reduced form price regressors, parameters and errors. The error v_t^p is assumed to be independently and identically distributed with variance σ_{vp}^2. One can apply Tobit methods to (21) and gain the consistent estimates: $\hat{\pi}^p$ and $\hat{\sigma}_{vp}^2$. These estimates can be used to construct predictions of conditional expectations:

$$\begin{aligned} \hat{P}_t &= \bar{P}_t && \text{if} \quad P_t = \bar{P}_t \\ &= X_t\hat{\pi}^p + \hat{\sigma}_{vp}\left(\phi\left(\hat{W}_t\right)/\Phi\left(-\hat{W}_t\right)\right) && \text{if} \quad \bar{P}_t < P_t \end{aligned} \tag{22}$$

where

$$\hat{W}_t = \left(\bar{P}_t - X_t\hat{\pi}^p\right)/\hat{\sigma}_{vp}$$

Here, $\phi(\cdot)$ and $\Phi(\cdot)$ define the standard normal density and distribution functions, respectively. Note, these predictions are for the observed P_t and not some underlying latent variable.

For supply structural form estimation, GM employ the ψ_2 observation set and use:

$$\begin{aligned} E\left(Q_t\middle|\bar{P}_t < P_t\right) &= X_t^s\beta + \beta_1 P_t + E\left(u_t^s\middle|\bar{P}_t < P_t\right) \\ \Rightarrow Q_t \quad &= X_t^s\beta + \beta_1 P_t + \left(\sigma_{s,vp}/\sigma_{vp}\right)\left(\phi(W_t)/\Phi(-W_t)\right) + e_{1t} \end{aligned} \tag{23}$$

where

$$\sigma_{s,vp} = \operatorname{cov}\left(u_t^s, v_t^p\right) \quad \text{and} \quad E\left(e_{1t}\middle|\bar{P}_t < P_t\right) = 0$$

To make (23) operational, replace P_t and W_t by their consistent predictors gained from the first stage and then apply OLS. This produces consistent supply structural form estimates.

Since demand is observable for all observations (i.e., $Q_t = Q_t^d$) then for all t:

$$Q_t = X_t^d\alpha + \alpha_1 P_t + u_t^d \tag{24}$$

where

$$E\left(U_t^d\right) = 0$$

To make (24) operational, gain the predictions for P_t from the first-stage tobit procedure and then apply OLS using all observations. GM then go on to describe consistent error variance estimation.

Maximum likelihood estimation is described by all three studies. Again, CJM (p. 16) propose working with the reduced form truncation imposed by $\bar{P}_t = P_t > P_t^*$ for observations under ψ_i. As a consequence the structural form supply parameters never actually appear in the likelihood function and hence in overidentification situations unique parameters will be unattainable. In contrast, Maddala (pp. 362–364) and GM (p. 6) focus on the structural form truncation $Q_t^{\mathrm{s}} > Q_t = Q_t^{\mathrm{d}}$ and suggest maximising the following endogenous switching likelihood function:

$$L = \prod_{\psi_1} \int_{Q_t}^{\infty} g(Q_t, Q_t^{\mathrm{s}})\, \mathrm{d}Q_t^{\mathrm{s}} \prod_{\psi_2} g(Q_t, Q_t) \tag{25}$$

Here, $g(Q_t^{\mathrm{d}}, Q_t^{\mathrm{s}})$ defines the joint density function for Q_t^{d} and Q_t^{s} with definitions as for equations (1). The integrating over the range ∞ to Q_t for supply under ψ_1 explicitly recognizes that Q_t^{s} is unobserved but definitely must exceed $Q_t = Q_t^{\mathrm{d}}$. Under ψ_2 both demand and supply are observed and the standard joint density prevails for $Q_t = Q_t^{\mathrm{d}} = Q_t^{\mathrm{s}}$. Given that maximum likelihood estimates are more efficient than their two stage counterparts, then in practice the estimates chosen should come from the maximisation of the log of (25) gained via a numerical optimisation algorithm using two stage estimates as starting values.

The situation of $\bar{P}_t$ observed and P_t unobserved, is principally studied by CJM (pp. 8–9) who propose a limited information maximum likelihood (LIML) estimator for this case. It is argued that without P_t observations the full information maximum likelihood (FIML) likelihood function cannot be constructed and so one must use the marginal density of Q_t to derive the likelihood function. Here given the unobservability of P_t then sample separation is unknown and hence a probabilistic reduced form unknown sample separation likelihood function is constructed.

The final situation where some regulating authority buys the excess supply and so both demand and supply are observed at $P_t = \bar{P}_t$, has been studied by GM (pp. 2–6) and briefly by Maddala (pp. 369–370). Given the observability of Q_t^{d} and Q_t^{s} then the likelihood contains no integrals and hence optimisation is relatively straight forward. GM describe the preferred two-stage procedure. GM then consider a special case where $\beta_1 = 0$, that is, current price is absent from the supply equation as with the cob-web model. Here, after concentrating the likelihood function, ML estimates can be gained by four standard OLS runs and the enumeration of some constructed formulae.

Beyond questions of estimation, the econometric issue of predicting the effects of deregulation is also an important consideration. Maddala (p. 344) discusses this issue for the observed P_t and $\bar{P}_t$ situation. After gaining estimates from maximum likelihood procedures [i.e., optimizing (25)], one can solve for the price reduced form parameters π^p and σ_{vp} from the structural form estimates and then construct the following predictions:

$$\begin{aligned} E\left(P_t^* \middle| \bar{P}_t \geq P_t^*\right) &= X_t\hat{\pi}^p + E\left(v_t^p \middle| v_t^p \leq \bar{P}_t - X_t\hat{\pi}^p\right) \\ &= X_t\hat{\pi}^p - \hat{\sigma}_{vp}\left(\phi\left(\hat{W}_t\right)/\Phi\left(\hat{W}_t\right)\right) \end{aligned} \tag{26}$$

Here the reduced form is defined as for (21) and (22). This prediction is of the latent underlying 'free market' price variable, which would have existed if one removed the observed effective minimum price.

A.2. Quotas with conventional theory

Consider the model defined by equations (1), (5), (6) and (7). A simple extension of the notions described above for minimum prices implies the following likelihood function:

$$L = \prod_{\psi_3} \int_{-\infty}^{P_t} h(P_t, P_t^{\mathrm{s}})\, \mathrm{d}P_t^{\mathrm{s}} \prod_{\psi_4} g(Q_t, Q_t) \tag{27}$$

where $h(P_t^{\mathrm{d}}, P_t^{\mathrm{s}})$ is the joint density of P_t^{d} and P_t^{s}, $g(Q_t^{\mathrm{d}}, Q_t^{\mathrm{s}})$ is the joint density of Q_t^{d} and Q_t^{s} as defined for (25), and observations satisfying $Q_t = \overline{Q}_t$ belong to the set ψ_3 and those observations satisfying $Q_t < \overline{Q}_t$ belong to the set ψ_4.

Clearly, a simple two-stage estimator and predictions for hypothetical deregulation can be constructed, using the same principals as those used for minimum prices. Further, the case of import quotas can be treated in a similar way and the extensions to unobservable data and endogenous $\overline{Q}_t$ clearly carry through.

A.3. Effective demand and minimum prices

For minimum prices emphasis need only be placed on observations stemming from $P_t = \overline{P}_t$ and observation set ψ_1. Once the relevant density is established for ψ_1, the conventional equilibrium ψ_2 density can be combined (given known sample separation) along the lines of endogenous switching regression methods and Section 2. Obvious candidates for the ψ_1 density are strict excess supply versions of Eaton and Quandt's (1983) probability rationing regressor approach, i.e., include either $\Pr(\tilde{Q}_t^{\mathrm{s}} > Q^{\mathrm{de}})$ or $\Pr(Q_t^{\mathrm{s}} > Q^{\mathrm{de}})$ in the effective supply equation and only specify notional demand, given $P_t > P_t^*$. Alternatively, employ Oczkowski's (1990) manipulable rationing approach, i.e., specify $\tilde{Q}_t^{\mathrm{s}} = Q_t^{\mathrm{s}} + \beta_2(Q^{\mathrm{de}} - Q_t^{\mathrm{s}}) + u_t^{\mathrm{s}}$ with $Q_t = Q_t^{\mathrm{d}} < \tilde{Q}_t^{\mathrm{s}}$. Implicit in both these specifications is that effective supply will not fall below notional demand at $P_t > P_t^*$, allowing for $\tilde{Q}_t^{\mathrm{s}} < Q_t^{\mathrm{d}}$ complicates estimation procedures enormously and possibly unnecessarily as intuitively it is difficult to envisage situations of binding minimum prices and excess demand.

A.4. Effective demand and quotas

A simple form of the model defined by equations (6) and (19), is to assume that $u_t^{dp} \equiv u_t^{sp} \equiv 0$, the substitution of exogenous regressors for P_t^d and P_t^s allows for standard least squares estimation and identification of all parameters if only if τ_t is treated as a non-constant defined by exogenous regressors and associated parameters. However, convention demands the recognition of all error terms, i.e., u_t^{dp}, u_t^{sp} and u_t^b, which complicates estimation procedures somewhat. For this ψ_3 subset when $Q_t = \overline{Q}_t$ a bivariate truncation must be recognized since both P_t^d and P_t^s are censored and unobserved. If notional equilibrium is assumed to prevail under non-binding quotas then the relevant likelihood function becomes:

$$L = \prod_{\psi_3} \int_{P_t}^{\infty} \int_{-\infty}^{P_t} k\left(P_t^d, P_t^s, P_t\right) \mathrm{d}P_t^s \, \mathrm{d}P_t^d \prod_{\psi_4} g(Q_t, Q_t) \tag{28}$$

where $k(P_t^d, P_t^s, P_t)$ is the joint density of P_t^d, P_t^s, and P_t defined in (6) and (19) respectively and $g(Q_t^d, Q_t^s)$ is as defined for (25). Computationally, this function requires enumeration of the bivariate normal distribution function.

The maximum likelihood estimator based on (28) has been examined by Oczkowski (1988a, chapter 7) using Monte Carlo techniques. Again computational feasibility seems apparent with no optimization failures in 30 replications based on a sample of 50 (i.e., 25 observations in both sub-sets), and acceptable biases for most parameters appears to exist. One identified problem however, is a significant and consistent underestimation bias for σ_b^2. This latter result appears to be similar to that found by Sneessens (1985) for the basic Maddala and Nelson (1974) [i.e., equations (1) and (2)] disequilibrium model.

A.5. Disequilibrium trading under non-binding controls

Consider the minimum price disequilibrium model defined by excess supply for binding minimum prices ($P_t = \overline{P}_t$ and subset ψ_1) and the canonical price adjustment disequilibrium model [equations (1)–(3)] for non-binding minimum prices ($P_t > \overline{P}_t$ and subset ψ_2). Applying endogenous switching regression concepts to this model implies that we simply include the relevant disequilibrium density function for observations under ψ_2. In particular, the likelihood function becomes:

$$L = \prod_{\psi_1} \int_{Q_t}^{\infty} g(Q_t, Q_t^s) \, \mathrm{d}Q_t^s \prod_{\psi_{21}} f_1(Q_t, P_t) \prod_{\psi_{22}} f_2(Q_t, P_t) \tag{29}$$

where $g(Q_t^d, Q_t^s)$ is defined as for (25); the subset ψ_{21} is defined by $P_t > \bar{P}_t$ and $\Delta P_t > 0$ and thus $f_1(Q_t, P_t)$ is the density function for Q_t and P_t when $Q_t = Q_t^s$ and $\Delta P_t = \lambda(Q_t^d - Q_t)$; while the subset ψ_{22} is defined by $P_t > \bar{P}_t$ and $\Delta P_t < 0$ and thus $f_2(Q_t, P_t)$ is the density function for Q_t and P_t when $Q_t = Q_t^d$ and $\Delta P_t = \lambda(Q_t - Q_t^s)$.

Difficulties do emerge however when constructing an appropriate two stage estimator and forming predictions of hypothetical deregulations. Specifically, if the excess demand price adjustment disequilibrium model prevails under ψ_2, then as before with equilibrium trading under ψ_2, the first stage for a two-stage estimator, requires some initial estimates of the endogenous P_t. Tobit methods, however, become intractable because the reduced form for price contains a lagged dependent variable, which computationally involves the evaluation of multi-dimensioned normal integrals.

Similar complexities emerge for predictions of deregulation since if $P_{t-1} = \bar{P}_{t-1}$, then minimum price specific information will be inappropriately used in forming hypothetical deregulation predictions. However, the final form for P_t, gained by continually substituting for P_{t-i} until prices generated under ψ_2 (say P_k) are reached, can be used together with the ML estimates to construct $E(P_t \mid \bar{P}_t > P_t)$ for deregulation predictions:

$$E\left(P_t \middle| \bar{P}_t > P_t\right) = \mu^{t-k} P_k + R_t - \sigma_u(\phi(D_t)/\Phi(D_t)) \tag{30}$$

where

$$D_t = \left[\bar{P}_t - \mu^{t-k} P_k - R_t\right]/\sigma_u$$

$$R_t = \sum_{i=1}^{t-k} \lambda \mu^i \left(X_{t-i+1}^d \alpha - X_{t-i+1}^s \beta\right)$$

$$\mu = \left[1 - \lambda(\alpha_1 - \beta_1)\right]^{-1}$$

$$\sigma_u^2 = (\mu\lambda)^2\left[\sigma_d^2 + \sigma_s^2\right]/(1 - \mu^2)$$

This predictor uses no information about P_t and Q_t generated under ψ_1, and hence will adequately resemble a hypothetical deregulated situation as long as some P_k formed under ψ_2 exists. For greater details on this disequilibrium extension for observations under ψ_2 and the minimum price model, see Oczkowski (1988a, pp. 97–100).

The modelling of disequilibrium under non-binding regimes can also be extended to models of quantity controls. The extension of likelihood functions is straight forward, however, deregulation predictions for quotas require the use of final forms, unknown sample separation notions and the recognition of bivariate truncations, given that it will not be known a priori whether $Q^d > Q^s$ or $Q^d < Q^s$ when deregulation occurs. For details, see Oczkowski (1988a, pp. 106–107).

Oczkowski (1988a, chapter 7) shows in a series of Monte Carlo simulations, that in terms of both parameter estimation and predictions of hypothetical deregulations, the disequilibrium assumption under the free market regime is only marginally less accurate than the equilibrium assumption. Oczkowski (1988a, chapter 8) applied the bargaining quantity controls model and the disequilibrium assumption under nonbinding quotas to the Australian tobacco leaf market. The parameter estimates were reasonably similar to the equilibrium assumption under non-binding quotas, as were the predictions of hypothetical deregulations. Moreover, the assumption of equilibrium nested within the disequilibrium model could not be rejected. Even given these findings, the disequilibrium assumption under non-binding regimes was shown to be computationally operational.

A.6. Simultaneous price and quantity controls

Consider the model defined in equations (1), (6), (7) and (20) for simultaneous minimum prices and quotas. A simple extension of endogenous switching regression methods implies the following likelihood function.

$$L = \prod_{\psi_a} g(Q_t, Q_t) \prod_{\psi_b} \int_{Q_t}^{\infty} g(Q_t, Q_t^s)\, \mathrm{d}Q_t^s \prod_{\psi_c} \int_{-\infty}^{P_t} h(P_t, P_t^s)\, \mathrm{d}P_t^s \times \prod_{\psi_d} \int_{Q_t}^{\infty} g(Q_t, Q_t^s)\, \mathrm{d}Q_t^s \tag{31}$$

here $g(\cdot)$ and $h(\cdot)$ are joint densities defined in (25) and (27), respectively. The sample sets are defined as: ψ_a if $P_t > \bar{P}_t$ and $Q_t < \bar{Q}_t$; ψ_b if $P_t = \bar{P}_t$ and $Q_t < \bar{Q}_t$; ψ_c if $P_t > \bar{P}_t$ and $Q_t = \bar{Q}_t$; and ψ_d if $Q_t = \bar{Q}_t$ and $P_t = \bar{P}_t$. Note, for the set ψ_b even given $\bar{Q}_t < \infty$ the integrating range of (Q_t to ∞) rather than (Q_t to $\bar{Q}_t$) is appropriate since it is not known a priori whether $Q_t^s < \bar{Q}_t$ or $\bar{Q}_t < Q_t^s$. The consequent use of unknown sample separation notions for this subset ψ_b leads to the previously stated density.

Oczkowski (1988a, chapters 4, 6, 7 and 8) considers the econometric extensions of this simple model in extensive detail. In particular, disequilibrium trading can be modelled for the ψ_a subset. Hypothetical deregulation prediction formulae can be constructed for both controls. For the case of disequilibrium trading under ψ_a and quantity deregulations, these expressions require the use of truncated trivariate (i.e., $Q_t^d < Q_t^s$ or $Q_t^s < Q_t^d$, $P_t < \bar{P}_t$, $Q_t > \bar{Q}_t$) final forms and unknown sample separation notions. The model has also been extended to incorporate effective demand and bargaining theories for demand and supply. Further, Monte Carlo results and an application to the Australian tobacco leaf market, show that these methods are operational.

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