Australian Journal of Agricultural Economics, Vol. 39, No. 3 (December 1995), pp. 247-261

EXPORT SUPPLY RESPONSE OF THE AUSTRALIAN CITRUS INDUSTRY*

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A model of export supply response of the Australian citrus industry is developed and estimated using cointegration and error correction techniques and quarterly data for the period 1983 to 1993. The estimates suggest that, even in the long run, the supply of citrus exports is inelastic with respect to relative price. The results also show that the adjustment of export supply to changes in relative price is not instantaneous, the domestic production capacity has a significant positive impact on export supply, and export supply in the June quarter in each year is significantly lower than in other quarters.

Introduction

Studies conducted so far on the marketing of Australian citrus fruits have suggested that the appreciation of the Australian dollar, domestic price of citrus, labour costs and transport costs make Australian citrus 'less competitive' in the world market (see, for example, ABARE 1992; Alexander 1991; Industry Commission 1993; Kidane and Gunawardana 1995). However, no systematic empirical work has been undertaken to analyse the export supply response of the citrus industry. The objective of this paper is, therefore, to develop and estimate a model of supply response of Australian citrus exports, in order to identify the nature and extent of export supply response to changes in relative prices and other variables. The citrus industry and the policy makers will benefit from a knowledge of empirical evidence on the magnitude and timing of export supply response to changes in economic variables.

The paper is organised as follows. Background information on the nature of the Australian citrus industry is provided in the ensuing section. The model, data and estimation procedure are then described in the

* The authors acknowledge, with thanks, helpful comments and suggestions made by two anonymous referees, Premachandra Athukorala, Eddie Oczkowski, Alan Morris, Hubert Fernando and the participants at the Staff Seminar of the Department of Applied Economics, Victoria University of Technology. Usual caveats apply. Earlier versions of this paper are presented in Gunawardana, Kidane and Kulendran (1995a; 1995b).

section on the analytical framework. This is followed by a discussion of estimation results. Conclusions are summarised in a final section.

Background

The citrus industry in Australia includes the growing and marketing of oranges, lemons, limes, mandarins and grapefruit. In terms of the gross value of production, citrus is the third largest fruit industry in Australia (ABARE 1992). The annual production of citrus increased from 491 thousand tonnes in 1983–84 to 726 thousand tonnes in 1992–93, an annual average rate of increase of 4.8 per cent. The expansion of production has come about both from an increase in the number of bearing trees of citrus and from an increase in the yield per bearing tree. The annual number of bearing trees increased from 6,065 thousands in 1983–84 to 7,504 thousands in 1992–93, at an annual average rate of 2.4 per cent. The yield of citrus per bearing tree increased at an annual average rate of about 2 per cent over the same period, from 81 kg to 97 kg (ABARE 1988; 1993).

Among the states in Australia, New South Wales and Victoria are the major producers of citrus, accounting for 90 per cent of the output in 1992–93. Queensland, South Australia and Western Australia account for the remaining 10 per cent of output. The governments in each state participate in the marketing activities by stipulating grading and labelling requirements, and by providing guidelines on competition policy. The Australian Horticultural Corporation and the Horticultural Research and Development Corporation are involved in, among other things, the dissemination of market information, and in the coordination and promotion of exports. However, prices of citrus fruits are determined by the forces of demand and supply. Growers are free to sell their produce directly to wholesalers, retailers, processors, exporters or to the public.

The total annual volume of citrus exports increased from 29,300 tonnes in 1983–84 to 85,900 tonnes in 1992–93, an annual average rate of increase of 19.3 per cent. Thus, the growth of exports has been faster than the growth of domestic production of citrus. The proportion of exports to total production of citrus increased from 6 per cent in 1983–84 to 11.8 per cent in 1992–93 (ABARE 1988; 1993). The real earnings[1] from exports of citrus increased from A$21 million in 1983–84 to A$71.5 million in 1992–93.

Australia exports fresh citrus fruits to Singapore, Malaysia, Hong Kong, Japan, USA and UK. About 57 per cent of citrus exports in 1992 was directed towards the Asian markets, mainly to Malaysia and Singapore (Industry Commission, 1993). However, Australia accounts for less than one per cent of world citrus exports. Therefore, Australia cannot influence the prices of citrus in the world market. Hence, foreign demand for Australian citrus exports can be considered as perfectly elastic at the given world price. This implies that export prices are determined exo-

[1] Nominal earnings deflated by the price index of exports of goods (1989/90 = 100).

genously (the 'small country' assumption). Therefore, the volume of Australian citrus exports at any given point in time is determined by domestic supply and demand conditions.

Citrus fruits are perennial crops and, therefore, the supply is characterised by a high degree of inflexibility in the short run. However, in the short run, output can be varied to a certain extent by varying the application of inputs, mainly fertiliser. In the long run, output can vary through shifts in production capacity resulting from the changes in the number of bearing trees. Currently, most of Australia's citrus output (about 88 per cent) is absorbed by the domestic market for fresh consumption and processing. Therefore, export volumes can also be varied through changes in the rate of domestic absorption.

Analytical Framework

The Model

Following economic theory of supply and previous empirical studies on export supply response[2], the basic model of export supply response is specified as:

$$(1) \qquad QX_t = f(RP_t)$$

where, QX_t is the quantity of fresh citrus exported (in tonnes), RP_t is an index of relative price of exports and t is the time subscript. The explanatory variable in the model, the index of relative price of exports (RP_t), measures changes in the relative profitability of exporting as against selling in the domestic market. It reflects the combined effect of the world price of citrus (in foreign currency) and Australian dollar/foreign currency nominal exchange rates, relative to the domestic market price of citrus.

The index of RP_t is calculated as:

$$(2) \qquad RP_t = (PXIN_t \, / \, PDIN_t) \times 100$$

where PXIN is an index of Australian dollar price of citrus exports and PDIN is an index of domestic wholesale price of citrus. Australian citrus exporters receive no export subsidies, nor are the citrus exports taxed. Therefore, the Australian dollar price of citrus exports (PX) used in this study is the *unit value of citrus exports* (total Australian dollar value of exports divided by total volume of citrus exports).[3]

The question of the most appropriate functional form for the supply of exports is unsettled, although most previous studies have preferred a

[2] See, for example, Ali (1978), Arize and Afifi (1987), Athukorala and Jayasooriya (1994), Goldstein and Khan (1978), Islam and Subramanian (1989) and Koshal, Shukla and Koirala (1992).

[3] In case of products subject to export subsidies (SX) and/or export taxes (TX), the export price should be adjusted as: Export Price x (1 – TX + SX).

log-log form over a linear functional form. This has been so mainly for the ease of computation of elasticities, but it is often the case that log-log form is superior on statistical grounds.

Thus, the empirical model for estimation is specified in log-log form as follows:

$$(3) \qquad LQX_t = L\alpha_0 + \alpha_1 LRP_t + \varepsilon_t$$

where the prefix 'L' stands for logarithm, and α_0 (the intercept term) and α_1 are the coefficients to be estimated. The random error term, ε, is expected to possess a zero mean, common variance and a normal distribution. The coefficient α_1 is expected to be positive.

Data

Data for this study consist of 44 quarterly observations for the period from March quarter 1983 to December quarter 1993. The data were collected from various sources. Data on the volume and value of exports of citrus were obtained from Australian Bureau of Agricultural and Resource Economics (ABARE), *Quarterly Review of the Rural Economy* and *Agriculture and Resource Quarterly*, various issues; ABARE, *Commodity Statistical Bulletin*, 1988 and 1993 issues; and Australian Bureau of Statistics, *Foreign Trade Data*, various issues. Data on the domestic wholesale prices of citrus fruits in Australia were collected from the Flemington Marketing Service of NSW Department of Agriculture. A summary of the data used in the estimation is provided in Appendix A.

Estimation Procedure

Following the conventional econometric procedures, equation (3) may be estimated through ordinary least squares (OLS) regression, using data in their level form. Previous export supply response studies have followed this procedure, reported high R^2, and obtained 'statistically significant' regressions (F-test) and coefficient estimators (t-test). However, if the data are non-stationary, these studies may be subject to criticism on the grounds of 'spurious regression' (Granger and Newbold 1974), and therefore, their estimation procedures need re-examination for statistical reasons.[4] If time series data for a particular variable are non-stationary, then its mean, variance and covariance may be changing through time. This means that the asymptotic distribution of the OLS coefficient estimators do not generally follow a normal distribution, and the validity of the statistical inferences using the standard t-test may be in doubt (Phillips 1986). In addition, the computed F statistic will not follow an F distribution under the null hypothesis and render F-tests invalid (Granger and Newbold 1974).

[4] A more detailed review of the relevant econometric literature here is provided in Kulendran (1995).

The non-stationary variables may diverge in the short run, but will converge to a common stochastic trend in the long run because of market forces or government policy decisions. That is, the variables are said to be cointegrated. In this case OLS regression can be used to obtain super-consistent long run coefficient estimates (Engle and Granger 1987).

A seasonal economic time series is said to be integrated of order (d, D) if the series becomes stationary after differencing d times (unit root), and seasonal differencing D times (seasonal unit root). If seasonality is present in a time series, unit root tests should be applied to determine whether the seasonal component exhibit stochastic non-stationarity. The procedure used to test for a unit root and seasonal unit roots of a time series is the HEGY unit root test [Hylleberg, Engle, Granger and Yoo (HEGY) 1990]. A description of the HEGY procedure is presented in Appendix B.

To examine the existence of a unit root and seasonal unit roots in the variables LQX_t (log of quantity supplied of exports) and LRP_t (log of relative price of exports), the HEGY regression is estimated for the period from March quarter 1983 to December quarter 1993 (number of observations = 44). Four alternative HEGY regressions are estimated, that is with intercept (I), with intercept and seasonal dummies (SD), with intercept, seasonal dummies and time trend (T) and with intercept and trend. If any of these four alternatives show that there is no unit root and that there are no seasonal unit roots, then this result is accepted. The results of the HEGY unit root test are presented in Appendix Table B.1. The test statistics in Appendix Table B.1 should be compared with the 5 per cent critical values for HEGY unit root tests (see Appendix Table B.2).

When the HEGY regression is estimated with intercept and time trend, the results in Table B.1 suggest that the data series LQX_t has a unit root at the zero frequency, and that the series has no seasonal unit roots. All four alternative HEGY regressions for the series LRP_t show that this series has a unit root only at the zero frequency, and that there are no seasonal unit roots. Thus, the conclusion can be reached that the order of integration of both series is I(1,0).

Having discovered that both series (LQX_t and LRP_t) are integrated of the order I(1,0), the Engle-Granger two-step procedure (see, Engle and Granger 1987) is used for the estimation and testing of a cointegrating relationship between the volume of citrus exports and the relative price of exports. In the first step, a cointegration regression (static OLS regression) is estimated, using the data in their level form. Then, the error term from the estimated model is tested for stationarity, using the Dickey-Fuller (DF) and Augmented Dicky-Fuller (ADF) tests. Since the non-stationary data are used in their level form, t-ratios cannot be used to test the significance of the estimated coefficients.

If the error term is stationary, the second step involves the modelling of short run dynamics (in an error correction model; ECM), using data in difference form. Differencing of data leads to a loss of long run information, but this information is reintroduced via the inclusion of the lagged residuals (error correction term) from the cointegration regression. The error correction term measures the extent to which the endogenous variables have temporarily departed from the long run relationship. If the error correction term is significant, this is evidence and confirmation of cointegration.[5] Since all the variables in the ECM are stationary, the standard t-test of coefficient significance is valid.

In addition to the Engle-Granger two-step procedure, an unrestricted error correction model (UECM) is estimated in order to derive long run price elasticity of export supply of citrus. In recent literature on modelling with non-stationary time series data, the Engle-Granger two-step procedure and the unrestricted error correction model (UECM) are considered as alternative techniques. The UECM has been found to be superior in terms of small sample properties.[6]

Results and Discussion

Cointegration Regression

The estimated cointegrated regression and the relevant test statistics are given in Table 1. The hypothesis of residual (error term) non-stationarity is rejected by Durbin-Watson (DW), DF and ADF tests. The estimates suggests that there is a cointegrating relationship between the quantity supplied of exports and the relative price of exports. A short run dynamic error correction model is estimated next, in order to provide confirmation for the cointegrating relationship and to identify the short run export supply responses.

TABLE 1
Estimated Cointegration Regression

(4) $LQX_t = 8.9568 + 0.016\ LRP_t$

Tests for Cointegration:

DW = 1.583

DF = -5.271 (95 per cent critical value: -3.481)

ADF = -6.178 (95 per cent critical value: -3.485)

[5] The meaning of 'equilibrium' in cointegration literature is that "... it is an *observed relationship* which has, on average, been maintained by a set of variables for a long period" (Cuthbertson, Hall and Taylor, 1992 p. 132). For a detailed survey of literature on cointegration and error correction techniques, see Muscatelli and Hurn (1992).

[6] We are grateful to Premachandra Athukorala for drawing our attention to this point. See also Muscatelli and Hurn (1992).

Short Run Dynamic Modelling of Export Supply Response

Following Engle and Granger (1987), the short run dynamics of export supply response are described by the error correction model specified below:

$$(5) \qquad \nabla LQX_t = L\beta_0 + \sum_{j=0}^{n} (\beta_1 \nabla LRP_{t-j} + \beta_2 \nabla LQX_{t-j}) + \beta_3 DM + \beta_4 DJ + \beta_5 DS + \beta_6 u_{t-1} + \varepsilon_t$$

where ∇ is the first difference term, u_{t-1} is the error correction variable estimated by the residuals from the cointegration regression equation (4), and ε_t is a white-noise error term. The coefficient β_6 measures the extent to which the change in the dependent variable and explanatory variables respond to the departures from the equilibrium condition. The short run convergence process of the dependent and independent variables to the equilibrium condition is assured when β_6 is negative. If β_6 is significant, then there is evidence and confirmation of cointegration.

Since seasonally unadjusted data are used in the estimation, and considering the perennial nature of citrus crops, the length of the lag structure (n) was set at eight periods. However, to account for any possible presence of seasonality in the dependent variable, quarterly dummies were also added, Thus, DM, DJ and DS represent March, June and September quarter dummy variables, respectively.

The general-to-specific modelling procedure was followed in selecting the preferred model. That is, equation (5) was estimated with different lag lengths for ∇LRP and ∇LQX, and the preferred model was selected according to a number of statistical and diagnostic tests. The tests are the t-ratio tests of coefficients, adjusted R^2, F test, DW test for autocorrelation, a Lagrange Multiplier test of autocorrelation (LM auto4), the RESET2 (F) test for misspecification of functional form, Jarque-Bera test for non-normal distribution of residuals and a LM test for heteroscedasticity (see Pesaran and Pesaran 1991).

The preferred error correction model estimates, together with the relevant test statistics, are included in Table 2.

TABLE 2

The Preferred Error Correction Model of Export Supply Response

(6) $\nabla LQX_t = 0.276 + 0.698\ \nabla LRP_{t-8} + 0.459\ \nabla LQX_{t-4}$

(2.793)*** (2.306)** (6.153)***

$-0.593\ DJ - 0.477\ \mu_{t-1}$

(-2.806)*** (-4.572)***

(Figures in parentheses are t-ratios; *** Significant at the 1 per cent level; ** Significant at the 5 per cent level.)

Adjusted $R^2 = 0.86$; $F_{(4,30)} = 53.744$; $DW = 1.826$

Autocorrelation: $\chi^2(4)$: 2.872 (prob: 0.580)

Ramsey's Specification Error: RESET(2): $F_{(1,29)}$: 0.004 (Prob: 0.947)

Jarque-Bera Normality: $\chi^2(2)$: 0.063 (prob: 0.969)

Heteroscedasticity: $\chi^2(1)$: 0.059 (prob: 0.808)

All the estimated coefficients in equation (6) are statistically significant. The significant coefficient for u_{t-1} provides evidence of a cointegrating relationship between exports and the relative price. Thus, the estimated ECM can be used to forecast the future volumes of citrus exports. The coefficient for the relative price variable suggests that the supply of citrus exports is inelastic with respect to the relative price of exports in the short run. The coefficient associated with the lagged dependent variable indicates that short run supply adjustment to changes in relative prices is not instantaneous. This is to be expected since citrus are perennial crops, and therefore, their output cannot be varied instantly in response to a change in relative price. The estimated coefficient for June quarter dummy indicates that the quantity supplied of exports in the June quarter is significantly lower than in other quarters.

An Unrestricted Error Correction Model (UECM)

The form of the UECM is as follows:

$$(7) \qquad \nabla LQX_t = L\delta_0 + \sum_{j=0}^{n} (\delta_1\ \nabla LRP_{t-j} + \delta_2\ \nabla LQX_{t-j}) + \delta_3\ TIME + \delta_4\ DM$$

$$+ \delta_5\ DJ + \delta_6\ DS + \sum_{j=0}^{n} (\delta_7\ LRP_{t-1-j} + \delta_8\ LQX_{t-1-j}) + \varepsilon_t$$

where ε_t is the random error, TIME is the time trend variable as a proxy for long run shifts in production capacity resulting from changes in fixed factors including citrus trees, infrastructure, and technological change. All other variables are as defined previously.

From equation (7), long run price elasticity of export supply is calculated as $-\delta_7/\delta_8$. Equation (7) was estimated with different lag lengths for the variables ∇LRP, ∇LQX, LRP and LQX, and a more parsimonious representation was obtained according to a variety of statistical tests similar to those described for equation (5). The estimated UECM and associated statistics are given in Table 3.

TABLE 3
The Preferred Unrestricted Error Correction Model of Export Supply Response

$$\nabla LQX_t = \underset{(2.371)^{**}}{3.638} + \underset{(2.803)^{**}}{0.718}\,\nabla LRP_{t-8} + \underset{(4.508)^{***}}{0.325}\,\nabla LQX_{t-4} \tag{8}$$

$$+ \underset{(3.769)^{***}}{0.029}\,TIME - \underset{(-4.545)^{***}}{0.881}\,DJ + \underset{(1.891)^{*}}{0.418}\,LRP_{t-3} - \underset{(-6.558)^{***}}{0.698}\,LQX_{t-1}$$

(Figures in parentheses are t-ratios: *** Significant at the 1 per cent level: ** Significant at the 5 per cent level; * Significant at the 10 per cent level.)

Long run price elasticity: 0.73 (t-ratio: 1.889)

Adjusted $R_2 = 0.90$; $F_{(6,28)} = 53.303$; $DW = 2.221$

Autocorrelation: $\chi^2(4)$: 4.546 (Prob: 0.377)

Ramsey's Specification Error: RESET(2): $F_{(1,27)}$: 0.054 (prob: 0.818)

Jarque-Bera Normality: $\chi^2(2)$: 1.985 (prob: 0.371)

Heteroscedasticity: $\chi^2(1)$: 0.333 (prob: 0.564)

All the estimated coefficients in equation (8) are significant. The diagnostic tests suggest that the estimated model is statistically sound. The estimate of the price elasticity of supply suggest that, even in the long run, the supply of citrus exports is inelastic with respect to the relative price of exports. For example, a 10 per cent increase in the relative price in the long run, *ceteris paribus*, will result in a 7.3 percent increase in the supply of exports. The model estimates also indicate that there is a significant positive relationship between the shift in production capacity and the long run supply of citrus exports. Further, the estimates confirm the lags in adjustment of export supply and the lower supply in the June quarter.

Conclusion

A model of export supply response of the Australian citrus industry was developed and estimated in this paper, using cointegration and error correction techniques. Quarterly data for the period from March quarter 1983 to December quarter 1993 were used in the estimation. Guided by the finding that both the quantity supplied of exports and the relative price (in log form) are cointegrated at the zero frequency, as identified by HEGY tests, the Engle-Granger two-step cointegration procedure was used. First, a static OLS regression was estimated to identify a cointegrating relationship between export supply and the relative price of exports. Second, short run dynamics of export supply response were identified through the estimation of an error correction model (ECM). Finally, long run price elasticity of supply was derived from the estimation of an unrestricted error correction model (UECM).

The cointegrating relationship between the quantity supplied of citrus exports and the relative price of exports is confirmed by the statistically significant error correction term in the ECM. The estimated short run dynamic ECM suggests that the supply of citrus exports is inelastic with respect to the relative price in the short run, and that supply adjustment to changes in relative prices is not instantaneous.

The estimated UECM shows that, even in the long run, export supply is inelastic with respect to relative price, and that there is a significant positive relationship between the domestic production capacity and the export supply of citrus. Both ECM and UECM indicate that the quantity supplied of exports in the June quarter is significantly lower than in other quarters. This may be attributable to higher domestic absorption (for fresh consumption and processing) resulting from lower prices due to higher level of citrus production in the June quarter.

Further research is needed to identify the factors contributing to the inelastic supply of citrus exports with respect to relative price of exports and the reasons for the tardiness in adjustment of export supply in response to changes in economic parameters in overseas and domestic markets. However, the results of the present study confirms the view that, since Australia is a price taker, Australian citrus exports are determined by domestic supply and demand conditions. Hence, in an environment of expanding domestic and overseas demand for citrus, the policy focus should be on the expansion of citrus exports through the implementation of measures contributing to rightward shifts in the domestic supply curve of citrus.

References

ABARE (Australian Bureau of Agricultural and Resource Economics) (1992), *Competitiveness of the US and Australian Citrus Industries*, Research Report 92.14, Australian Government Publishing Service (AGPS), Canberra.

ABARE (1988), *Commodity Statistical Bulletin*, AGPS, Canberra.

ABARE (1993), *Commodity Statistical Bulletin*, AGPS, Canberra.

ABARE (various issues), *Quarterly Review of the Rural Economy*, Canberra.

ABARE (various issues), *Agriculture and Resources Quarterly*, Canberra.

ABS (Australian Bureau of Statistics) (various years), *Foreign Trade Australia: Merchandise Exports*, Cat. No. 5424.0, Canberra.

Alexander, G.I. (1991), *Marketing of Fresh Fruit and Vegetables in Queensland*, Queensland Department of Primary Industries, Brisbane.

Ali, I. (1978), 'Estimating the determinants of export supply of India', *Indian Economic Journal* 31: 1-12.

Arize, A. and Afifi, R. (1987), 'Supply and demand for imports and exports in a simultaneous model', *Applied Economics* 19: 1233-1247.

Athukorala, P. and Jayasooriya, S. (1994), 'Short-run supply response of exports' in *Macroeconomic Policies, Crises, and Growth in Sri Lanka, 1969-90*, The World Bank, Washington, D.C., pp. 124-128.

Cuthbertson, H., Hall, S. G. and Taylor, M. P. (1992), *Applied Econometric Techniques*, Philip Allan, New York.

Engle, R. F. and Granger, C. W. J. (1987), 'Cointegration and error correction: representation, estimation and testing', *Econometrica* 55: 251-276.

Goldstein, M. and Khan, M. S. (1978), 'The supply and demand for exports: a simultaneous approach', *Review of Economics and Statistics* 60: 275-286.

Granger, C. W. J. and Newbold, P. (1974), 'Spurious regressions in econometrics', *Journal of Econometrics* 2: 111-120.

Gunawardana, P. J., Kidane, H. and Kulendran, N. (1995a), *Export supply response of the Australian citrus industry*, Working Paper No. 5/95, Department of Applied Economics, Victoria University of Technology, Melbourne, June 1995.

Gunawardana, P. J., Kidane, H. and Kulendran, N. (1995b), *Export supply response of the Australian citrus industry*, Paper presented to the 24th conference of economists, 25-27 September 1995, Adelaide.

Hylleberg, S., Engle, R. F., Granger, C. W. J., and Yoo, B. S. (HEGY). (1990), 'Seasonal integration and cointegration', *Journal of Econometrics* 44: 215-238.

Industry Commission (1993), *Horticulture*, Report No. 29, AGPS, Canberra.

Islam, N. and Subramanian, A. (1989), 'Agricultural exports of developing countries: estimates of income and price elasticities of demand and supply', *Journal of Agricultural Economics* 40: 221-131.

Kidane, H. and Gunawardana, P. J. (1995), 'Australian exports of horticultural crops with special reference to fresh citrus fruits: issues and prospects', Working paper No. 13, School of Management, Charles Sturt University, Wagga Wagga, June 1995.

Koshal, R. K., Shukla, V. S. and Koirala, G. P. (1992), 'Demand and supply of Indian exports: a simultaneous equation approach', *Journal of Asian Economics* 3: 73-83.

Kulendran, N. (1995), *Modelling international short-term tourist flow to Australia using the demand function approach*, Working Papers No. 1/95, Department of Applied Economics, Victoria University of Technology, Melbourne.

Maddala, G. S. (1992), *Introduction to Econometrics*, 2nd edition, Macmillan, New York.

Muscatelli, V. A. and Hurn, S. (1992), 'Cointegration and dynamic time series models', *Journal of Economic Surveys* 6: 1-43.

New South Wales, Department of Agriculture (various years), *Fruit and Vegetables: Prices and Receivable*, Flemington Wholesale Markets, Sydney.

Pesaran, M. H. and Pesaran, B. (1991), *Microfit 3.0, An Interactive Econometric Software Package: User manual*, Oxford University Press.

Phillips, P. C. B. (1986), 'Understanding spurious regressions in econometrics', *Journal of Econometrics* 33: 311-340.

APPENDIX A

Summary of Quarterly Data for the Key Variables in the Export Supply Response Model

Variable	Unit	Minimum	Maximum	Mean	Standard Deviation
QX*	tonnes	200	44,300	12,852	9,478
RP**	index	49.64	147.98	110.11	24.27

* Quantity supplied of citrus exports
** Relative price of exports

APPENDIX B

HEGY Unit Root Testing Procedure

The HEGY unit root testing procedure looks at all the seasonal frequencies and the usual standard zero frequency. In HEGY procedure, a seasonal differencing operator $(1 - B^4)$ for a quarterly data series is expressed as:

$$(1 - B^4) = (1 - B)(1 + B)(1 + B^2)$$
$$= (1 - B)(1 + B)(1 - iB)(1 + iB)$$

The unit roots 1, and -1 correspond to the zero frequency and biannual frequency. A pair of complex unit roots i and -i correspond to the annual frequency. The tests for these unit roots are derived from the regression:

$$\text{(B.1)} \quad Y_{4t} = \pi_1 Y_{1t-1} + \pi_2 Y_{2t-1} + \pi_3 Y_{3t-2} + \pi_4 Y_{3t-1} + \varepsilon_t$$

where

$$Y_{1t} = (1 + B + B^2 + B^3)X_t$$
$$Y_{2t} = -(1 - B + B^2 - B^3)X_t$$
$$Y_{3t} = -(1 - B^2)X_t$$
$$Y_{4t} = (1 - B^4)X_t$$

where Y is the variable concerned, and B is the backward shift operator. A deterministic component m_t, which may include seasonal dummies, a trend, and a constant term may also be included. Equation *(B.1)* can be estimated by the OLS method with additional lags of Y_{4t}, if necessary, to whiten the error term, εt. The Lagrange multiplier (LM) autocorrelation test (for order up to 4) can be used to check whether the model's residuals are serially correlated (Maddala, 1992, p. 250).

The null hypotheses to be tested are: H_0: $\pi 1 = 0$, H_0: $\pi 2 = 0$, and $H_0 = \pi 3 = \pi 4 = 0$, denoted I(1,1), implying that there is a unit root at the zero frequency (that is, $\pi 1 = 0$), as well as at the seasonal frequencies (that is, $\pi 2 = 0$, and $\pi 3 = \pi 4 = 0$). If individual t-tests show that $\pi 1$, $\pi 2$ are significantly different from zero, and a joint F-test reveals that either or both $\pi 3$ and $\pi 4$ are significantly different from zero, then there is no unit root at the zero frequency, and there are no unit roots at seasonal frequencies. Thus, the order of integration of the series is I(0,0) such that it is stationary.

However, if $\pi 1$ is not significantly different from zero, but $\pi 2$ and both $\pi 3$ and $\pi 4$ are significantly different from zero, then the order of integration is I(1,0). To accept the null hypothesis that I(1,1), the condition that H_0: $\pi 1 = \pi 2 = \pi 3 = \pi 4 = 0$ must be satisfied. HEGY presented a table which contains the critical values for testing for unit root at the zero frequency and unit roots at the seasonal frequencies (see Table B.2). If the series have unit roots only at the seasonal frequencies then the series may be seasonally cointegrated, and if the series have a unit root only at the zero frequency then the series are cointegrated at the zero frequency.

The results of the HEGY unit root tests for the series LQX_t and LRP_t are presented in Table B.1.

TABLE B.1

HEGY Tests for Unit Roots in the Data Series for LQX_t[a] and LRP_t[b]

Variable	Deterministic Component	t: π1	t: π2	F: π3 ∩ π4	Lags	DW	LM auto(4)
LQX_t	I	-0.51	-1.70	2.81	0	1.50	8.54
	I, SD	-0.59	-2.39	3.15	0	1.75	8.78
	I, SD, T	-1.81	-1.80	3.29	1	1.86	7.82
	I, T	-2.09	-2.24*	5.85*	2	1.69	1.76
LRP_t	I	-2.05	-4.03*	10.32*	0	1.98	1.72
	I, SD	-2.11	-4.09*	14.05*	0	1.84	4.76
	I, SD, T	-2.78	-4.16*	15.36*	0	1.87	2.53
	I, T	-2.52	-4.04*	10.60*	0	1.98	2.49

\+ Log of quantity supplied of exports.
++ Log of relative price of exports.
* Greater than the 5 per cent critical value (see Appendix Table B.2).

TABLE B.2

5 Per Cent Critical Values for HEGY Unit Root Tests[a]

Observations	Deterministic Component	t: π1	t: π2	F: π3 ∩ π4
48	I	-2.96	-1.95	3.04
100	I	-2.88	-1.95	3.08
48	I, SD	-3.08	-3.04	6.60
100	I, SD	-2.95	-2.94	6.57
48	I, SD, T	-3.71	-3.03	6.55
100	I, SD, T	-3.53	-2.94	6.60
48	I,T	-3.56	-1.91	2.95
100	I,T	-3.47	-1.94	2.98

[a] Source: HEGY (1990).