# A CITRUS SYSTEM DYNAMIC MODEL OF JAPAN

by

Hiroshi Yamauchi *

and

Yuichi Kishimoto **

* Professor, University of Hawaii

** Associate Professor, St Andrews University; and Research Associate, Kyoto University Institute of Economic Research.

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## ABSTRACT

Midterm effects of alternative quota adjustments on production, prices, and orchard retirements are simulated taking into account interseasonal effects between early and late varieties. Real world corroboration is accomplished through institutional and technical feedbacks and the recent agreement to expand quotas by 11,000 metric tons per year for the next 4 years.

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## I. INTRODUCTION

The purpose of this paper is to present a new citrus system dynamic model of Japan which is designed to simulate the likely midterm effects of alternative options for expanding import quotas to the U.S. The model is a refinement of an earlier effort of a Citrus Issue Project Group (1982) consisting of independent university researchers with broad support from both private and public sectors in Japan.

## II. CITRUS SYSTEM DYNAMIC MODEL OF JAPAN

In Japan, citrus varieties are generally classified into two groups. The first is the traditional early varieties most typically represented by the mandarin orange (unshu mikan) which is harvested in the late fall and winter seasons and shipped to the market up to as late as March. The second is the midseason and late citrus varieties which are harvested in the midwinter and spring seasons and shipped to the market up to as late as June. These oranges include the navel, regular and sweet natsukans, hassaku, and iyokan. For convenience we shall refer to these two citrus groups as simply early and late varieties.

The principal methods used in the construction of this model are first, the Forrester System Dynamic method (1968), and second, the method of deriving a system of demand equations based on the theory of dual utility function by Samuelson (1965) and subsequent empirical applications by Heien (1974) in the U.S. and by Kishimoto (1982) in Japan. The overall structure of the model including the domestic supply and demand sectors (both endogenous) and the international trade sector (exogenous) is shown in Fig. 1. There are two markets, one for fresh fruits and the other for processed juice. In the fresh fruit market, the different varieties of domestically produced citruses

and imported oranges are separately handled. At the distribution stage, the imported fresh oranges and domestic navels are combined. In the juice market, the domestically processed mandarins are combined with the imported juices. The model is designed for annual data.

There are two important differences between this model and an earlier 1982 effort by Fujitani and Takebe. In their model all the late summer varieties were aggregated into a single subsector and a loglinear demand function was specified for the whole lot. In this new model the late summer varieties are disaggregated into separate subsectors and for each, simple linear demand functions are specified. Such simple linear demand functions according to varieties guard against the possibility of underestimating an aggregate price flexibility for all late summer varieties in the event of import liberalization. In the range where quota adjustments are expected to occur, the loglinear demand function is increasingly flatter than the simple linear demand function.

The underlying assumptions of the model are: (i) There is a large number of average-sized homogeneous citrus farms and an even larger population of homogeneous consumers. This means that the behaviors of producers and consumers are not differentiated by scale factors. (ii) In the fresh fruit market, the behavior of wholesalers generally reflects the behavior of consumers, i.e., the consumer demand curve at the retail level is a parallel shift out from the wholesale demand curve. (iii) In the juice market, consumer behavior is generally reflected in the prices paid to farmers by the Ehime Fresh Fruit Growers Cooperative. (iv) At the international level, the world prices for citrus fruits and juices are not affected by the amount of imports into Japan. This "small country" assumption will need to be empirically tested in the future since Japan is currently one of the major importers of citrus products from the U.S.

determined by the yields per 10 ares (0.1 hectare) which have been previously corrected for two year fluctuations in yields typical of citrus production in Japan.

To obtain the wholesale prices, the distribution system of fruits must be sorted out. The distribution ratio of each fruit variety is applied to its total harvested quantity to get the distribution of domestically harvested fruits. The consumption of fresh fruits is obtained by applying the consumption ratio of fresh fruits to the quantity of domestic fruits distributed. The sum of domestic fruits distributed and orange imports under the quota is the total amount of oranges in the subsector distributed. Finally, the wholesale price is determined by the total amount of oranges distributed from the subsector and the variables specified in the variety demand function.

## III. SIMULATING THE MIDTERM EFFECTS OF RELAXING QUOTA RESTRICTIONS

To measure the effects of relaxing quota restrictions, it is necessary to forecast future changes in certain exogenous variables, namely the consumer price index and the household consumption expenditures in nominal terms, and to select alternative options for relaxing import quotas on both fresh fruits and processed juice. It is also necessary to simulate the response of farmers to large falls in wholesale fruit prices.

To forecast consumer price indices CP(t) and nominal household expenditures YN(t), it is useful for our purposes, to assume a stable economic growth path for the five year forecast period. To do this, it is sufficient to select two recent stable years (1980 and 1981) after the second "oil shock" which occurred in 1979, compute the average of annual changes for these two variables, and use them in simple exponential trend equations to obtain the customary averaging rates (i.e., geometric means) as follows.

$$CPI(t) = CPI(0) * a$$

where, $CPI(0) = 1.372$
$a = [(1.080 + 1.049)/2] = 1.064$

$$YN(t) = YN(0) * b$$

where, $YN(0) = 238.1$, (in ¥1000)
$b = [(1.071 + 1.055)/2] = 1.063$

Import quotas for fresh oranges and processed juice are policy control variables whose simulated impacts can be computed by the model. For fresh fruits, a reasonable design of alternative quotas based on recent negotiations is as follows. In option I, it was assumed that domestic farmers would be successful in holding the quota constant at the 1983 level for the next five years, in essence a status quo option. Option II assumed an annual incremental rate of increase in quotas of 6.1%. This is close to the five year trend prior to 1981. Options III and IV assumed higher annual increases of 10% and 20% respectively, the latter approximating complete liberalization. For juice, it was assumed that the five year trend prior to 1981 would continue to prevail. During this period, 20% juice concentrates increased at an annual rate of 500 metric tons per year.

The sensitivity of wholesale prices to shifts in market supply and the subsequent adjustments in producing orchards have been clearly demonstrated in Japan. In 1972, the Japanese citrus industry experienced a large drop in prices due to an over production of mandarins. At that time, the average annual wholesale price of mandarins fell to about two-thirds of the previous year's average. The farmers' response over the next five years was to reduce bearing orchard squares by about 10%. Thus, the effects of large quota expansions on prices and production are of important concern. These hypothetical effects are estimated by the model taking into account the differential substitution effects among the six varieties.

The simulated results of the alternative quota options are discussed in terms of their relative midterm effects on harvested quantities, prices, and orchard squares. The status quo option I is used as the baseline from which to measure the relative effects of the different levels of liberalization. Thus in Table 1, the baseline results are in absolute values and the alternative options II, III and IV are in terms of percentage changes from the baseline. The sequence of simulation in each case is the lagged cutback in bearing orchards, decline in harvested quantities, and fall in prices.

The effects on prices are in all cases greater than on harvested quantities and on orchard squares retirements. The effects on these latter two are about the same percentagewise. This is explained by the cost minimizing behavior of farmers who try to offset the price effects by maintaining high levels of harvests and delaying orchard retirements until after the productivity is depleted and as much of their sunk costs are recovered. The interseasonal effects on the early variety mandarins are clearly evident. In terms of the percentage changes in production and orchard retirements, the interseasonal effects on mandarins are about equal to the strongest effects on the late varieties, sweet natsukan and hassaku.

The effects of full liberalization are approximated by option IV (20% annual rate of quota expansions) at the bottom of the table. Price reduction effects at the end of the period range from about 17% (mandarins) to 67% (sweet natsukan). The production and orchard retirement effects are lower, ranging from 0% (regular natsukan) to around 6-7% (sweet natsukan, hassaku, and mandarins). However, these are only 5 year effects, and the rapid rate of increase in these effects clearly point to more severe long term effects and adjustment problems for the industry.

The effects of increasing the rate of partial liberalization can be seen from options II and III. As we stated earlier, option II would maintain the

able 1. Simulated Results of Alternative Quota Options

| Options | Year | Production | | | | | | Prices | | | | | | Orchard Squares | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | UQP | NQP | RQP | SQP | HQP | IQP | UWPF | OWPF | RWPF | SWPF | HWPF | IWPF | UOSQ | NOSQ | ROSQ | SOGQ | HOSQ | IOSQ |
| | | 1000 metric tons | | | | | | ¥/kgm | | | | | | 1000 ha | | | | | |
| Baseline | 1984 | 2568 | 51.6 | 32.6 | 263.1 | 235.3 | 169.2 | 200 | 429 | 110 | 130 | 199 | 404 | 108.2 | 3.23 | 1.95 | 9.45 | 8.92 | 7.70 |
| Option I | 1985 | 2288 | 54.9 | 25.1 | 223.5 | 222.7 | 211.0 | 228 | 460 | 119 | 124 | 196 | 480 | 103.6 | 3.32 | 1.50 | 8.73 | 8.89 | 8.40 |
| (no increase | 1986 | 2360 | 54.6 | 17.6 | 230.7 | 236.9 | 199.0 | 236 | 498 | 130 | 137 | 224 | 490 | 99.4 | 3.42 | 1.05 | 8.29 | 8.98 | 9.10 |
| in quota) | 1987 | 2110 | 60.7 | 10.0 | 196.2 | 225.5 | 246.2 | 263 | 532 | 140 | 135 | 223 | 575 | 95.6 | 3.54 | 0.60 | 7.67 | 9.00 | 9.80 |
| | 1988 | 2178 | 58.4 | 2.5 | 200.5 | 239.8 | 230.7 | 272 | 575 | 153 | 150 | 252 | 581 | 91.7 | 3.66 | 0.15 | 7.18 | 9.09 | 10.50 |
| | | Percentage Changes From Option I Baseline | | | | | | | | | | | | | | | | | |
| Option II | 1984 | 0 | 0 | 0 | 0 | 0 | 0 | -1.00 | -0.93 | -0.91 | -3.08 | -3.02 | -1.98 | 0 | 0 | 0 | 0 | 0 | 0 |
| (6.1% increase | 1985 | -0.09 | -0.07 | 0 | -0.09 | -0.09 | 0 | -2.19 | -2.17 | -1.68 | -7.26 | -7.14 | -3.54 | -0.10 | -0.06 | 0 | 0 | -0.09 | 0 |
| in quota) | 1986 | -0.42 | -0.20 | 0 | -0.39 | -0.38 | 0 | -2.97 | -3.01 | -3.08 | -8.76 | -9.82 | -5.51 | -0.40 | -0.20 | 0 | -0.36 | -0.38 | 0 |
| | 1987 | -0.90 | -0.40 | 0 | -1.02 | -0.84 | 0 | -3.42 | -3.57 | -4.29 | -14.1 | -13.4 | -6.26 | -0.94 | -0.40 | 0 | -0.78 | -0.86 | 0 |
| | 1988 | -1.47 | -0.45 | 0 | -1.50 | -1.50 | 0 | -4.04 | -4.35 | -4.58 | -16.7 | -15.5 | -7.92 | -1.42 | -0.38 | 0 | -1.25 | -1.51 | 0 |
| Option III | 1984 | 0 | 0 | 0 | 0 | 0 | 0 | -2.00 | -1.63 | -1.82 | -4.62 | -5.02 | -3.22 | 0 | 0 | 0 | 0 | 0 | 0 |
| (10% increase | 1985 | -0.17 | -0.11 | 0 | -0.13 | -0.13 | 0 | -3.07 | -3.26 | -3.36 | -10.5 | -10.7 | -5.42 | -0.10 | -0.09 | 0 | -0.11 | -0.15 | 0 |
| in quota) | 1986 | -0.64 | -0.31 | 0 | -0.52 | -0.59 | 0 | -5.08 | -4.62 | -4.62 | -14.6 | -15.2 | -8.57 | -0.60 | -0.32 | 0 | -0.80 | -0.60 | 0 |
| | 1987 | -1.47 | -0.62 | 0 | -1.27 | -1.33 | 0 | -5.70 | -6.01 | -6.43 | -23.0 | -22.0 | -10.3 | -1.57 | -0.62 | 0 | -1.30 | -1.37 | 0 |
| | 1988 | -2.48 | -0.67 | 0 | -2.59 | -2.42 | 0 | -6.98 | -7.48 | -8.50 | -27.3 | -26.2 | -13.4 | -2.40 | -0.60 | 0 | -2.37 | -2.43 | -0.02 |
| Option IV | 1984 | 0 | 0 | 0 | 0 | 0 | 0 | -3.50 | -3.26 | -2.73 | -9.23 | -9.55 | -6.19 | 0 | 0 | 0 | 0 | 0 | 0 |
| (20% increase | 1985 | -0.35 | -0.21 | 0 | -0.22 | -0.27 | 0 | -7.02 | -6.74 | -6.72 | -22.6 | -23.0 | -11.7 | -0.29 | -0.18 | 0 | -0.23 | -0.29 | 0 |
| in quota) | 1986 | -1.36 | -0.66 | 0 | -1.04 | -1.22 | 0 | -11.0 | -10.2 | -10.0 | -33.6 | -33.9 | -19.0 | -1.31 | -0.64 | 0 | -1.09 | -1.26 | 0 |
| | 1987 | -3.22 | -1.68 | 0 | -2.70 | -2.93 | 0 | -13.7 | -14.1 | -15.0 | -52.6 | -50.7 | -23.8 | -3.24 | -1.35 | 0 | -1.74 | -2.94 | 0 |
| | 1988 | -6.24 | -1.88 | 0 | -7.28 | -5.71 | -0.74 | -16.9 | -18.1 | -20.3 | -66.7 | -63.1 | -33.0 | -6.22 | -1.88 | 0 | -7.10 | -5.32 | -0.72 |

Note: First letters of each variable name signify citrus variety, U = Unshu Mandarin, N = Navel, R = Regular Natsukan, S = Sweet Natsukan, H = Hassaku, I = Iyokan, O = domestic Navel plus imported oranges.

annual rate of quota expansions at the 6.1% level of the recent past. At the end of the period, the range of price effects reaches 4-7%. Harvest and orchard retirement effects are lower at 0-1.5%. Raising the liberalization rate to 10% (option III) increases the range of price effects to 7-27%. The range of harvest and orchard retirement effects remain relatively low at 0-2.6%.

The possibility for further liberalization must consider additional information on longer term dynamic factors which are not taken into account in the model. For example, the present increasing demand for iyokan explains the relative price impacts of 7.9% to 13.4%, and at the same time, negligible impacts on orchard squares and quantities harvested. However, this increasing demand for iyokan is expected to reach a saturation point sometime in the near future, and at that time a greater impact will be felt.

Another important factor is the recent tendency toward adapting greenhouse technology to growing high yielding citrus ("house mikans"). The regulation of temperature, moisture, and other environmental factors through such technology is not only increasing yields but also extending the harvesting and shipping seasons for the early mandarin varieties to June, July and August. The seasonal distinction between early and late varieties is thereby being removed by this greenhouse technology. Because of the high capital intensiveness of production and the high value fruits that are involved, the relative impacts are expected to considerable on the innovating farmers.

## IV. SUMMARY AND CONCLUSIONS

In recent years, internal resistance from agricultural producers in Japan have effectively countered external pressures for immediate and full liberalization of imports. Economic impact studies have thus become an important part of trade negotiation process to find alternative positive adjustments in quotas. The citrus dynamic model of Japan is a useful analy-

tical tool in this respect. Refinements in its structural design and simulations with high quality data made possible through institutional support and feedbacks from the relevant decision levels have resulted in close corroboration with the actual operating system. Such corroboration is not only in terms of statistical fits of historical patterns and trends, but also in terms of the recently negotiated bilateral trade agreement between the U.S. and Japan.

The agreement which took effect on April 1, 1984 took about 18 months to reach. The initial negotiations opened in October 1982 with the U.S. demanding complete decontrol of beef and citrus imports from the U.S., and the Japanese flatly rejecting it as being neither politically nor economically feasible. The talks collapsed and subsequently reopened a year later, in Sept 1983, with the U.S. proposing a "phased-in liberalization" through 30% annual increases in citrus quotas and a 5-year deadline for complete decontrol of imports. Again, the Japanese flatly rejected the proposal considering it to be de facto full liberalization. A month later, in Oct. 1983, the U.S. proposal was lowered to 25% annual quota increases with the same 5-year deadline for complete decontrol. This time the Japanese countered with quota increases of 7,000 metric tons per year over 4 years. This was close to our option II rate which the U.S. rejected as insufficient. In January 1984, Japan raised its offer to 11,500 metric tons increase for the first year and 8,500 metric tons per years over the next 3 years. This worked out to be close to our option III rate of 10%. The U.S. countered with 15,000 metric tons per year over 4 years, equivalent to average annual rate of 18.3%, and for the first time below our option V rate of 20%. The final agreement reached in April 1984 was for quota increases of 11,000 metric tons per year for 4 years, which works out to an average annual rate of 13.4% and a little

over our option III level.

The initial pressures from the U.S. for full and immediate liberalization took over a year to come to grips with the economic realities for reasonable positive adjustment potentials. Final settlement took another six months. The model offers a quick and efficient means of analyzing alternative options for reasonable adjustments toward trade liberalization over time. Institutional as well as technical feedbacks are essential to improving its performance and utility. More open exchange of information and testing of conditions such as the "small country" assumption can help improve future trade relations between the two countries.

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