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A DYNAMIC ANALYSIS OF MARKETING ORDERS, VOTING, AND WELFARE

by

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A Dynamic Analysis of Marketing Orders, Voting, and Welfare

Peter Berck and Jeffrey M. Perloff

An evaluation of the profit and welfare effects of marketing orders requires explicit recognition of the gains to be made during the transition from a competitive equilibrium to a regulated equilibrium. This paper presents a dynamic model of how profit-maximizing farmers would vote on marketing order rules, given new firms will enter based on rational expectations (perfect foresight) about the path profits follow. Most previous studies are static and have contrasted the competitive long-run equilibrium with the regulated long-run equilibrium.[1]/ Since the adjustment period for many crops lasts for years, such static analyses may be largely irrelevant.

We consider two types of price-enhancing marketing order policies: allocating the crop between the fresh and processed markets and destroying part of the crop (an extreme form of allocation). Instead of just looking at the steady-state solution, we examine how owners of farms of varying quality would vote on the two rules at every moment in time.

The two key questions we answer are: 1) do owners of farms of different quality agree on how the crop should be allocated and 2) should the allocation rules be set so that profits are below the short-run maximizing levels to deter entry? In a reasonably general specification, we show that all farmers who have perfect information about future entry will agree on setting the

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[1]Virtually all of the studies on fruit and vegetable marketing orders are surveyed in Heifner, Arbruster, Jesse, Nelson, and Shafer; while essentially all the studies on milk orders are surveyed by Dahlgran.

allocation rules so that short-run profits are maximized. That is, farmers who maximize the present discounted value of profits ignore the effect of high short-run profits on entry. These conclusions do not change when there are barriers to entry.

It is entirely possible for producers to have a positive present value of profits from an order which increases prices even though over time, "...larger and larger quantities of the commodity must be isolated from the market to maintain the enhanced price and total income."[2/] When the order starts, profits are very high. The profits then fall to zero as entry occurs, so that the present discounted value of profits is strictly positive.

The failure to consider the dynamic adjustment path has led to serious biases in the estimates of welfare losses or producer gains by comparing the competitive long-run equilibrium to the long-run equilibrium under an order.[3/] For example, LaFrance and de Gorter find that it takes over 10 years for the dairy industry to adjust, so that "the average annual dynamic welfare change is three times the static estimate."[4/] Similarly, Thor and Jesse find that it takes 4 to 7 years for the orange industry to adjust.[5/]

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[2]Farrell.

[3]For example, consider the otherwise excellent studies of Minami, French, and King; Masson, Masson, and Harris; and Ippolito and Masson which present only static, long-run welfare loss estimates. See also many of the papers on fruits and vegetables surveyed by Heifner, Arbruster, Jesse, Nelson, and Shafer or those on milk surveyed by Dahlgran.

[4]Michael G. Baumann and Joseph P. Kalt have used dynamic models to calculate consumer surplus over time from freezing natural gas prices. They conclude that the inappropriate static analysis overestimates the present value of such a program by 15 percent ($12 billion).

[5]The adjustment period is probably lengthy for those crops which have a long nonbearing period after planting. In calculating bearing acreage, the California Crop and Livestock Reporting Service (1982 California Fruit and Nut Acreage) uses years-to-bearing estimates of three or more years for all fruit and nut crops: almonds have 4 nonbearing years, apples 7, apricots 4, avocados 3-5, cherries 6, chestnuts 8, dates 6, figs 4-7, grapefruit 5, grapes 3, kiwi-

The next section of this paper discusses the types of allocation rules used across crops. The following section analyzes voting and the long-run effects of these allocation rules in a static model (i.e., when entry is instantaneous). The model is then extended to the dynamic case where firms enter slowly based on rational expectations. The welfare implications of these profit-maximizing policies follow. The paper ends with a summary and conclusions.

Marketing Orders

Marketing orders for milk, and many vegetables, fruits, nuts, and horticultural specialties provide for quantity controls, quality controls, and market support activities.[6]/ While many different market control and enhancement instruments have been used in the various programs, in this section we will concentrate on price discrimination and output restrictions. The optimal choice of these instruments to maximize profits will be studied below.

Price Discrimination Programs

First, many marketing orders have provisions which result in market subdivisions and price discrimination. These classification/price discrimination schemes use either quantity or quality controls. Market flow regulations and

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fruit 4, lemons and limes 5-6, macadamia nuts 7, nectarines 4, olives 7, oranges 5-6, peaches 4, pears 6, pecans 8, persimmons 5, pistachio nuts 6, plums 4, prunes 6, tangelos and tangerines 5-6, walnuts 6-9.

[6]This section relies on Garoyan and Youde; USDA Farmer Cooperative Service; USDA Agricultural Marketing Service; Ippolito and Masson; Jesse and Johnson; Heifner, Armbruster, Jesse, Nelson, and Shafer; and Armbruster and Jesse.

volume or sales management are the two basic types of quantity control which are permitted.[7]/

There are three types of volume management tactics which are used to reduce the quantity sold in one or more submarket: production limitations (which will be discussed in more detail below), market allocation restrictions, or diversions of some of the product to a reserve pool. Market allocations explicitly lead to price discrimination. These programs dictate the percent of output which can be sold in two or more different market outlets for a basic commodity.

Some programs allocate between domestic and export markets while others allocate between fresh and processed markets. The amount sold in the primary (relatively low elasticity, high price) market is restricted so that the "surplus" is sold in the secondary (relatively high elasticity, low price) market.

For example, milk orders typically employ a price discrimination scheme where the price for raw grade A milk designated for fluid uses (Class I) is higher than the price paid for milk designated for manufacturing uses (Class II). In contrast, grade B milk, which is not regulated, passes lower sanitation standards and may only be used for manufactured products.[8]/ Similarly Federal marketing orders for California almonds, cranberries (10

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[7]Market flow regulations control the within-season pattern of sales which allows for price discrimination over time. See Jesse and Johnson for a discussion of handler prorates and shipping holidays. As we will not deal with price discrimination over seasons in this paper, we will concentrate on volume or sales management programs in this survey.

[8]Ippolito and Masson.

states), Oregon-Washington filberts, Pacific Coast walnuts, California dates, and California raisins allocate markets.[9]

A reserve pool program (which is often used in conjunction with producer allotment programs) is very similar to a market allocation program. The only distinction is that the quantity not sold in the primary market reserve is held in a reserve pool rather than immediately diverted to a secondary market. Later in a marketing year, some of the pool may be sold in the primary market if demand increases. Alternatively, the reserve may be stored for the following marketing year, diverted to secondary markets, or sold for nonfood uses. California almonds, tart cherries (8 states), California raisins, California-Idaho-Oregon-Washington hops, Far West spearmint oil, Pacific Coast walnuts, and California prunes have marketing orders which provide for a reserve pool.

Further, a number of State marketing orders provide or have provided in the past for either market allocations or reserve pools. These include Georgia sweet potatoes, fresh peaches, and fresh apples; South Carolina fresh market cucumbers; Colorado fresh potatoes and fresh peaches; and Utah fresh apples.[10]

Quality restrictions may also lead to market allocations and price discrimination. Common quality regulations include minimum grades, sizes, and maturi-

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[9]See Armbruster and Jesse and Jesse and Johnson. These crops set a "free percentage" and a "restricted percentage" before the harvest. Handlers then uses the "free percentage" to determine the amount that may be marketed without restriction (i.e., sold in the primary market). The rest must be sold in other outlets such as export, manufactured products, oil, or livestock feed. The "free percentage" may be increased during a marketing season if the demand in the primary market is unexpectedly great; however, the "free percentage" cannot be lowered during a marketing season.

[10]See Garoyan and Youde, p. 9. They note that California marketing orders provide for stabilization pools. At the time of their study, no commodity used this type of provision.

ties. These regulations are enforced through mandatory Federal inspection programs. While in most cases, the specified standard remain unchanged from one marketing year to another; in a few cases, the standard are changed frequently (sometimes even within a shipping season). In these latter cases, the quality regulations are presumably being used to restrict output to the primary market.[11]/

Output Restrictions

Some marketing orders permit producer allotments. Historical sales levels are generally used to determine an aggregate quota and quotas for individual

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[11]See Jesse and Johnson. They note (p. 13): "Thirty-seven of the 47 fruit and vegetable marketing orders use both grade and size regulations, 2 use only grade regulations, and 3 use only size regulations. Two orders, cranberries and tart cherries, apply grade and size standards only to the restricted portion of the crop. The two Florida orders for grapefruit use neither type of regulation, but eligible production under these orders is also covered under the Florida citrus order, which does regulate size and grade."

Garoyan and Youde note that quality standards are set by several State marketing orders as well (pp. 7 and 11). These include California dry beans, eggs, dried figs, desert grapefruit, desert grapes, grower cling peaches, fresh peaches, fresh Bartlett pears, processing strawberries, and processing pears; Georgia sweet potatoes, fresh peaches, and fresh apples; South Carolina fresh market cucumbers and sweet potatoes; Utah fresh apples and sweet cherries; and Colorado fresh potatoes and fresh peaches (Mesa Co.).

producers. A marketing order administrative committee, based on its market conditions expectations, then determines the percent of the quota which may be sold. The excess may be placed in a reserve pool. These allotments may prevent new entry. Allotment provisions are found in the cranberries, Florida celery, hops, and Far West spearmint oil marketing orders. Tree removal, "green dropping," and culls from processing which are dumped produce the same effect. These latter three methods were all used in cling peaches.[12]/

The Basic Model

Suppose farms vary in land quality (or farmers vary in ability or entrepreneurial skill). Let farms be indexed by θ^i, where θ^i is the farm's minimum average cost. For simplicity, we assumed that each farm, if unrestricted, produces one unit of output.[13]/ If relatively high quality (low average cost) firms enter the industry first, industry output is $F(\theta)$, where θ is the quality of the marginal farm.

Suppose that the industry was initially in competitive equilibrium when the government institutes a marketing order which allows a majority of the currently operating firms 1) to determine a market allocation or "splitting rule," and 2) to pick a percentage of the harvested crop to be destroyed.[14]/

The splitting rule allocates λ share of output to the primary (fresh food, relatively low elasticity) market and $[1-\lambda]$ share to the secondary (processed

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[12]See Minami, French, and King, p. 3.

[13]Relaxing this assumption complicates the mathematics without changing any of the major results reported below.

[14]The use of allotments as a barrier to entry is discussed below. Until then, we assume allotments or green dropping are used only to destroy a share of the crop.

food, relatively high elasticity) market. The percent destroyed, δ, affects revenues, but not costs. The marketing order is assumed to have universal coverage.[15]

Instantaneous Adjustment

If each farm sells λ share of its output in the primary market and $(1-\lambda)$ share in the secondary market, that is equivalent to selling all the output at a blend price, where the blend price is defined as

$$p \equiv \lambda p_1(\lambda\delta F(\theta)) + [1 - \lambda]p_2([1 - \lambda]\delta F(\theta)), \tag{1}$$

where p_1 is the inverse demand for the product in the primary (fresh) market, p_2 is the inverse demand for the product in the secondary (processed) market, $\lambda\delta F(\theta)$ is the output in the primary market, and $[1-\lambda]\delta F(\theta)$ is output in the

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[15] If coverage is not universal, then the problem becomes one of a dominant firm with a competitive fringe. For an analysis of the dynamics of an analogous problem, see Gaskins. Where marketing orders do not cover all production, the rules discussed above only apply to covered producers. Coverage is nearly universal in many markets, however. Federal regulations cover about 78 percent of the grade A milk, while state regulations cover an additional 18 percent (Ippolito and Masson). According to Jesse and Johnson all the production of tree nuts, dried fruits, hops, tart cherries, olives, and cranberries are covered by Federal orders. Ninety-five percent of total fresh citrus fruit is marketed through nine separate Federal orders. All oranges, lemons, limes, tangelos, and temples and nearly all fresh grapefruit and two-thirds of tangerines are marketed under Federal orders. When processing use is included in the calculations, however, marketing order coverage of citrus drops to only one-fourth. Only about 10 percent of total noncitrus fruit tonnage is regulated by Federal order. Federal orders only cover fresh potato sales, so that only about 70 percent of the fall potato crop is covered. Federal marketing orders cover less than 50 percent of other vegetables; while coverage averages 13 percent of fresh market vegetables.

secondary market.[16] Thus, the blend price, $p = p(\theta,\lambda,\delta)$, is a function of θ, λ, and δ.

If there are no barriers to entry and firms can enter instantaneously, we would expect a static equilibrium in which firms enter until the marginal firm makes zero profits. That is firms enter until, for the marginal firm, (average) revenue, $p\delta$, equals (average) cost, θ:[17]

$$p(\theta,\lambda,\delta)\ \delta = \theta. \tag{2}$$

This entry condition implies that we can write $\theta = \theta(\lambda,\delta)$. That is, the choice of the vector of control variables, (λ,δ), determines the marginal firm's characteristics; industry output, $\delta F(\theta(\lambda,\delta))$; and the blend price, $p = p(\theta(\lambda,\delta),\lambda,\delta)$.

Voting

How then are λ and δ (the market allocation and share of crop destroyed) chosen? The marketing order requires a majority vote of firms in the industry (given the assumptions above, there is no distinction between farms and units

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[16]The total output which is sold in either market is the share, δ, of the total output, $F(\theta)$, which is not destroyed, $\delta F(\theta)$. Since the share of that output which is sold in the primary market is λ, $\lambda\delta F(\theta)$ units of output are sold in that market. Similarly, $[1-\lambda]\delta F(\theta)$ units are sold in the secondary market.

[17]We assume that each farm bears the cost of producing one unit of output, but that it is only allowed to sell $0 < \delta < 1$ units. We also assume that disposal of the $1 - \delta$ units is costless. This form of modelling is appropriate where the crop is destroyed after harvesting. Where green dropping is used, the costs may be an increasing function of δ.

sold). In order to determine how a majority of firms would vote, we first consider how a single firm which has an average cost of θ^i would choose λ and δ given a free hand. Based on that information, we will be able to determine how the majority of farms will vote.[18]

The instantaneous profits of a farm of quality θ^i are $\pi^i = p(\theta(\lambda,\delta),\lambda,\delta)\delta - \theta^i$. This farm would choose the control variables (λ and δ) to maximize its profits. The first order conditions (for an interior maximum) are:

$$\frac{\partial \pi^i}{\partial \lambda} = [p_\theta \theta_\lambda + p_\lambda]\ \delta = 0, \tag{3}$$

$$\frac{\partial \pi^i}{\partial \delta} = [p_\theta \theta_\delta + p_\delta]\ \delta + p = 0, \tag{4}$$

where a subscript on p or θ indicates a partial derivative with respect to the subscripted variable.

Neither of these conditions depends on θ^i. They depend only on θ (the quality of the marginal firm) and the control variables. As a result, each farm currently in operation would choose the same levels of each of the control

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[18] In many markets, the key voting issue concerns differences between processors and growers. By assuming that the processors are competitive, we can disregard their voting preferences in the current analysis.

variables. This unanimity eliminates the need to examine the voting decision in greater detail.[19]

If $\delta > 0$, the first order condition (3) states that farms should chose λ such that $p_\theta \theta_\lambda + p_\lambda = 0$. This condition says that output should be allocated between the markets until the last unit will have the same effect on the blend price (revenues) regardless in which market it is sold, taking entry into account.

Equilibrium

By writing the entry condition, equation (2), in implicit function form and totally differentiation (holding δ constant), we find that $d\theta/d\lambda = p_\lambda/[1 - p_\theta]$. Making this substitution into (3) for θ_λ, we obtain $p_\lambda/[1 - p_\theta] = 0$. Thus, since $p_\theta < 0$, the equilibrium condition may be expressed as $p_\lambda = 0$.[20] That is, the share of output going into the primary market should be increased until any further increase would lower the blend price.

That is, it is not necessary to take account of the entry condition to determine λ, since it "washes out." The marketing order board, if it wants to

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[19]This unanimity result (and the one obtained below in the dynamic model) would be lost if the destruction rule were changed so that costs were also a function of the share destroyed. For example, if destroying part of the crop occurred early on so that some labor and other costs of harvesting were avoided, then costs could be written as $c(\theta^i, \delta)$. In this case, equation (4) would depend on θ^i so that firms would differ on their optimal policy according to their relative efficiency.

[20]From (1), $p_\theta = \delta F'(\theta)\ (\lambda^2 p_1' + [1 - \lambda]^2 p_2') < 0$, since all terms are positive except p_1' and p_2' which are negative (since demand curves slope down). That is, a rise in θ indicates that more firms have entered (the cost of the marginal firm has risen), so $F(\theta)$, total output, increases, which increases output in both markets (holding λ constant), which lowers prices in both markets, which lowers the blend price, p.

maximize farmers' incomes, should chose λ to maximize profits as a discriminating monopolist would, ignoring entry.

The other condition is also quite straight-forward. Condition (4) states that crops should be destroyed until the marginal benefit taking account of entry, $[p_\theta\theta_\delta + p_\delta]\delta$, equals the marginal cost, p. Using the entry equation (2) as above, we can rewrite this condition as $[p + p_\delta\delta]/[p_\theta\delta - 1] = 0$. Since $p_\theta < 0$, this condition becomes $p + p_\delta\delta = 0$. Again, the marketing order board should set δ as a monopolist would, ignoring entry.

Gradual Entry with Rational Expectations

We now assume that rather than enter instantaneously, firms enter gradually at some rate which depends on expected profits. In particular, we assume that the rate of entry at time t is a function of the present value of expected profits, y(t):

$$\dot{\theta}(t) = ky(t), \tag{5}$$

where

$$y(t) = \int_t^\infty \pi^e(s)\, e^{-r(s - t)}\, ds, \tag{6}$$

and where k is a positive constant, $\dot{\theta} = d\theta/dt$ is the rate of change (time derivative) of the marginal firm (and hence of output) and $\pi^e(t)$ is expected profits at time t.[21] If the potential marginal entrant at time t, $\theta(t)$, can perfectly predict the path of prices, then we can rewrite (6) as

$$y(t) = \int_t^\infty [p(\theta(s),\lambda(s),\delta(s))\delta(s) - \theta(t)]\, e^{-r(s-t)}\, ds, \tag{7}$$

where the term in the brackets is the marginal firm's profit's (and where all variables are shown as functions of s or t to indicate whether they change over time or are set as of a particular time). The time derivative of y is:

$$\dot{y}(t) = y(t)\left(\frac{r^2 - k}{r}\right) + \theta(t) - p(\theta(t),\lambda(t),\delta(t))\,\delta(t). \tag{8}$$

Again, we will examine how an individual firm i would choose the control variables, which will indicate how these variables would be chosen by all firms collectively. Firm i would want to maximize the functional

$$V^i = \int_0^\infty [p(\theta,\lambda,\delta)\delta - \theta_i]\, e^{-rt}\, dt, \tag{9}$$

where the term in brackets is profits at time t (the control variables, λ and δ, and the state variable, θ, are a function of time with the time argument suppressed), so V^i is present discounted profits. This functional is maximized subject to (5) and (8).

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[21]Our results below would not change in an important way if we wrote, more generally, that entry was a function $k(\theta,y)$. We use this simple specification for clarity only. This assumption has been made in Gaskins and many other papers. Our model, however, uses rational expectations unlike Gaskins's and other such models which use myopic (adaptive) expectations.

The Hamiltonian is:

$$H = [p(\theta,\lambda,\delta)\delta - \theta^{i}]e^{-rt} + z(t)ky + v(t)[y\left(\frac{r^{2} - k}{r}\right) + \theta - p\delta], \qquad (11)$$

where z(t) and v(t) are the costate variables corresponding to the state variables θ and y respectively.

Necessary Conditions

The necessary conditions are equations (5), (8), and

$$\dot{z} = - H_{\theta} = - p_{\theta}\delta e^{-rt} - v\ (1 - p_{\theta}\delta), \qquad (12)$$

$$\dot{v} = - H \ = -[zk + v\left(\frac{r^{2} - k}{r}\right)], \qquad (13)$$

$$H_{\lambda} = p_{\lambda}\delta\ [e^{-rt} - v] = 0, \qquad (14)$$

$$H_{\delta} = [p_{\delta}\delta + p]\ [e^{-rt} - v] = 0, \qquad (15)$$

by the maximum principle.

Since $[e^{-rt} - v] \neq 0$ is nonzero on any open time interval (as shown in the Appendix), we can rewrite equations (14) and (15) as

$$p_{\lambda} = 0, \qquad (14')$$

$$[p_{\delta}\delta + p] = 0, \qquad (15')$$

which are the same conditions we obtained in the instantaneous entry model above. Since $p = p(\theta,\lambda,\delta)$, however, p, p_λ, and $[p_\delta\delta + p]$ will evolve over time. The splitting rule, λ, and the destruction rule, δ, will be the same as in the instantaneous entry model only when θ has the same value as in that model. As shown below, θ in this model equals the θ in the instantaneous entry model only at the equilibrium. For the entire (possibly very long) adjustment period, θ, λ, and δ will differ from the the static equilibrium values.

Voting

Since equations (14') and (15') do not depend on θ^i, all firms actually in the market would vote for the same λ and δ. That is, all firms want to set the control variables to maximize instantaneous profits. These results show that firms should ignore entry when voting on λ and δ.

Equilibrium

If an equilibrium (θ^*,y^*) is given by $\dot{\theta} = 0$ and $\dot{y} = 0$. Solving $\dot{\theta} = ky^* = 0$, gives $y^* = 0$. Solving $\dot{y} = y^*([r^2 - k]/r) + \theta^* - p\delta = 0$, gives $p(\theta^*,\lambda(\theta^*),\delta(\theta^*))\ \delta(\theta^*) = \theta^*$, which determines θ^*.

From equations (14') and (15'), we can write $\lambda = \lambda(\theta)$ and $\delta = \delta(\theta)$. Given an initial value for θ, $\theta(0) = \theta^0$, we have $\lambda^0 = \lambda(\theta^0)$ and $\delta^0 = \delta(\theta^0)$, from which we can calculate $p^0 = p(\theta^0,\lambda^0,\delta^0)$. Further, if we can determine $\theta(t)$, we also can determine $\lambda(t)$ and $\delta(t)$, from which we can infer $p(t) = p_\theta\theta + p_\lambda\lambda + p_\delta\delta = p_\theta\theta + p_\delta\delta$, which tells us everything we need to know about the adjustment path.

The nature of the equilibrium can be determined by finding the eigenvalues of a linearized version of the system (5) and (8) about the equilibrium, (θ^*, y^*).[22]

$$\begin{pmatrix} \dot{\Delta\theta} \\ \dot{\Delta y} \end{pmatrix} = \begin{pmatrix} 0 & k \\ 1 - \delta p_\theta & \frac{r^2 - k}{r} \end{pmatrix} \begin{pmatrix} \Delta\theta \\ \Delta y \end{pmatrix}, \qquad (16)$$

where $\Delta\theta = \theta - \theta^*$ and $\Delta y = y - y^* = y$. This differential system is subject to the initial condition that θ^0 is given and a transversality condition which is discussed below. The characteristic polynomial corresponding to the Jacobian matrix in equation (15) is $\mu^2 - ([r^2 - k]/r) - k + \delta p_\theta = 0$. The eigenvalues of this linearized system are:

$$\mu = \frac{\frac{r^2 - k}{r} \pm \sqrt{\left(\frac{r^2 - k}{r}\right)^2 + 4k(1 - \delta p_\theta)}}{2}. \qquad (17)$$

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[22]Note, $d(p\delta)/d\theta = p\delta_\theta + \delta(p_\theta + p_\lambda\lambda_\theta + p_\delta\delta_\theta) = \delta p_\theta$, using equations (14') and (15').

The eigenvalues have opposite signs: $\mu_1 < 0 < \mu_2$, so the dynamic system has a saddle point.[23] That the system has a saddle point is also shown by the phase space analysis below.

We can now fully describe $\theta(t)$ and $y(t)$ in a neighberhood of the equilibrium:

$$\theta(t) = a_1 e^{\mu_1 t} + a_2 e^{\mu_2 t} + \theta^*, \tag{18}$$

$$y(t) = b_1 e^{\mu_1 t} + b_2 e^{\mu_2 t} . \tag{19}$$

Since there must be a finite maximum blend price, p (i.e., the primary and secondary market demand curves must hit the price axes at some finite price), y has a finite maximum. Thus, b_2 must equal 0. It therefore follows that $a_2 = 0$, as well.[24]

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[23] We have a solution which meets the necessary conditions. If

$$\begin{pmatrix} V^i_{\lambda\lambda} & V^i_{\lambda\delta} \\ V^i_{\delta\lambda} & V^i_{\delta\delta} \end{pmatrix}$$

is negative definite, then there is only one solution.

[24] We can rewrite equations (17) and (18) in matrix form as

$$\begin{pmatrix} \theta(t) \\ y(t) \end{pmatrix} = C \begin{pmatrix} 1 \\ c \end{pmatrix} e^{\mu_1 t} + D \begin{pmatrix} 1 \\ d \end{pmatrix} e^{\mu_2 t} + \begin{pmatrix} \theta^* \\ 0 \end{pmatrix},$$

where c, d $\neq$ 0 (otherwise, the vectors are not eigenvectors). Thus, if b_2 ($\equiv$ Dd) = 0, then D must be zero. It therefore follows that $a_2 = 1 \cdot D = 0$.

Using (18), we know that at $t = 0$, $\theta^0 = a_1 + \theta^*$. Thus, we can rewrite equation (18) as

$$\theta(t) = (\theta^0 - \theta^*)\, e^{\mu_1 t} + \theta^*. \tag{18'}$$

After some algebraic manipulation, we can similarly rewrite equation (19) as

$$y(t) = \frac{\mu_1(\theta^0 - \theta^*)}{k}\, e^{\mu_1 t}. \tag{19'}$$

Phase Space

A phase diagram can be used to illustrate the path of adjustment. Figure 1 shows the phase space where $r^2 > k$. Where $r^2 < k$, $\dot{\theta} = 0$ is the same, but $\dot{y} = 0$ is reflected around the θ axis so that the phase space is the mirror image of Figure 1. In either case, the approach paths are qualitatively the same.

The saddle point is the same as the instantaneous entry equilibrium point. In both models, in equilibrium, the marginal firm must earn zero profits (or else entry would continue). That is, $y^* = 0$. Since the λ and δ necessary conditions are the same for both models and, in the limit, the entry condition is the same, then θ^*, $\lambda^* = \lambda(\theta^*)$, and $\delta^* = \delta(\theta^*)$ must be the same.

Along the adjustment path which approaches the equilibrium from below, the number of firms (which is a function of θ) is constantly increasing while the blend price is constantly decreasing. When the marketing order is first introduced, the blend price will instantaneously increase substantially. From then on, gradual entry of new firms will increase supply and force the price down continuously. Thus, the lowest level of consumer surplus and the highest profits occur when the marketing order first goes into effect.

Although the marketing board adjusts the splitting rule to achieve the maximum profits at each instant in time, it is not able to offset the steady flow of new firms into the industry. Eventually (and eventually may be a very long time), the number of firms increases to the point where no further firms find it profitable to enter the market.

If, as in the model we discuss here, new entrants have higher costs of production, then in the long run, the order does increase prices and is advantageous to the efficient firms. On the other hand, if all firms have the same cost structure, then in the long run, no firm earns economic profits.

Barriers to Entry

Some marketing orders have rules such as allotments or other forms of entitlements which are used as barriers to entry. Our model is little changed in this case. Entry occurs up until the constraint is reached, and then stops.[25] As a result, all firms in the industry can make positive profits in the long run and consumers are hurt since prices remain relatively high ("an undue price enhancement").

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[25] Formally, a state constraint is added to the maximum problem: $\theta \leq \underline{\theta}$. See Jacobson, Lele, and Speyer for a discussion of this problem. The necessary conditions obtained above hold until the constraint is hit. The control variables are continuous across the boundary, so θ increases continuously up to $\underline{\theta}$.

Comparative Dynamics

Changes in the interest rate, r, and the entry rate, k, affect the path of adjustment to steady state, but not the steady state itself. Since consumer surplus and profits are highest during the early stages of the transition period to the steady state, it is important to know how entry rates and interest rates affect profits and consumer surplus along this path.

In this section, we determine how changes in r and k affect profits and surplus. The first result holds for all values of θ while the other results come from the linear approximation to the differential equation system and only hold near the equilibrium.

To show that the present value of profits decreases when r increases, we differentiate equations (4) and (7) with respect to r:

$$\frac{d\dot{\theta}}{dr} = 0, \tag{20}$$

$$\frac{d\dot{y}}{dr} = y\ (1 + \frac{k}{r^2}). \tag{21}$$

As shown in Figure 1, The relevant portion of an optimal adjustment path in the (θ,y) plane approaches the steady state, (θ*,0), from below. Since as r increases, y increases everywhere while θ remains constant, an optimal path with a higher r must lie everywhere below one with a lower r. Otherwise, the path would eventually lie above the old path and therefore not intersect the y-axis at θ* (the steady state). Since the path with a higher r lies everywhere below, the y associated with any given θ is smaller. Thus increasing r decreases the present value of profits for each new entrant and therefore it decreases the aggregate value of profits.[26]

The effect of an increase in r on consumer welfare can only be determined in the neighborhood of the steady state. Along the linear approximation to the optimal path near the equilibrium given by equations (17') and (18'),[27]

$$\frac{d\theta}{dr} = t(\theta - \theta^*)\frac{d\mu_1}{dr} \tag{22}$$

$$\frac{dy}{dr} = \left[\left(\frac{\theta^0 - \theta^*}{k}\right)\frac{d\mu_1}{dr} + \mu_1 t\right] e^{\mu_1 t} \tag{23}$$

where,

$$\frac{d\mu_1}{dr} = -\left(1 + \frac{k}{r^2}\right)\frac{\mu_1}{\sqrt{\left(\frac{r^2 - k}{r}\right)^2 + 4k(1 - p_\theta \delta)}} \tag{24}$$

The last derivative, $d\mu_1/dr$, is positive since μ_1 is negative and all the other terms are positive. Since θ is always less than θ*, dθ/dr is less than or equal to zero. Thus, for every t not equal zero, increasing r results in a lower θ, lower supply, and higher price. Increased interest rates make con-

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[26]The present value of profits of a θ^i farm which is producing at time t is $y(t) + (\theta^i - \theta)$. That is, the present value of that farm's profits differ from y by a constant $(\theta^i - \theta)$. Thus, y(t) contains all the necessary information about profits of all farms that are producing.

[27]From (17') we can write:

$$(\theta - \theta^*) = (\theta^0 - \theta^*)\, e^{\mu_1 t} .$$

sumer surplus lower. It is also possible to show that dy/dr is negative.[28] A higher interest rate decreases the present value of profits to be made from entering the market and therefore deters entry.

The effects of increasing the rate of entry parameter, k, can only be determined near the equilibrium. From the linear approximation to the optimal path described by (17') and (18'):

$$\frac{d\theta}{dk} = (\theta - \theta^*)\, t\, \frac{d\mu_1}{dk} \quad , \tag{25}$$

$$\frac{dy}{dk} = \frac{\theta - \theta^*}{k} \; \frac{d\mu_1}{dk} \; (1 + \mu_1 t) - \frac{\mu_1}{k} \quad , \tag{26}$$

where,

$$\frac{d\mu_1}{dk} = \frac{\dfrac{\mu_1}{2r} - (1 - \delta p_\theta)}{\sqrt{\left(\dfrac{r^2 - k}{r}\right)^2 + 4k(1 - p_\theta \delta)}} \tag{27}$$

Since $d\mu_1/dk$ is negative (the numerator is negative and the denominator is positive), $d\theta/dk$ is nonnegative. Increasing the rate of entry, k, therefore, increases supply, which lowers price, and makes consumers better off. The sign of dy/dk even at t = 0 is indeterminate. A higher k may increase or decrease profits. Heuristically, an increase in k corresponds to "faster" entry which makes producers worse off; but since entry is perfectly antici-

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[28]The sign of $d\mu_1/dr$ is positive, the sign of $(\theta_0 - \theta^*)$ is negative, and at t = 0, the sum of the terms in the brackets is positive. Since the linear approximation to the optimal path is linear in (θ, y) space, if y is initially smaller, it must be everywhere smaller, for given θ.

pated, it may not actually occur. With some effort, it can be shown that where r is very small, an increase in k increases profits ($dy/dk > 0$) and when r is very large, an increase in k decreases profits.

Summary and Conclusions

Immediately after a marketing order which allocates a crop between two markets (price discriminates) or destroys part of the crop is instituted, firms in the industry receive substantial, positive economic profits and consumers suffer substantial welfare losses. The higher profits attract new, less efficient firms into the industry. The additional output drives down prices, aiding consumers and reducing profits of firms already in the industry. Thus, the increase in profits is greatest when the order is started and the additional profits diminish over time.

Given that entry reduces profits, the marketing board has a strong incentive to discourage entry. Nevertheless, it is not optimal to use the splitting or crop destruction rules to discourage entry. The board's optimal policy from the producers' point of view, is to choose the policy that maximizes profits at each moment of time without regard to the entry these profits engender. This policy is optimal for producers even though entry decisions are based on rational expectations.

Where the new entrants are not as efficient as existing firms, the long-run, steady-state equilibrium has (compared to the original competitive equilibrium) a higher price in the primary market, a lower price in the secondary market, more total output, lower consumer surplus, more profits for firms originally in the market, and zero profits for the marginal producer (the last entrant).

The lower the interest rate or more responsive entrants are to profits (the larger the rate of entry coefficient), the greater is consumer welfare at every moment. Producers operating under a market order are harmed by a higher interest rate.

Since the welfare of consumers and producers adjust continuously over time, the present discounted value of welfare varies substantially from the traditional short-run and long-run welfare triangle calculations which ignore dyamics. Recent empirical studies show that dynamic welfare measures can be several times larger (or smaller) than the usual static measures.

Earlier empirical studies which used static models, while miscalculating the welfare loss and the increase in profits, could have derived the long-run, profit-maximizing marketing order rules since the static results are the same as the steady-state levels in our dynamic model. Had voting been considered in these static models, the same unanimity results obtained in our dynamic model could have been derived.

Appendix

Costate Variables and Transversality Conditions

We can linearize near the equilibrium so that we can examine the behavior of the costate variables there:

$$\begin{pmatrix} \Delta\dot{z} \\ \\ \Delta\dot{v} \end{pmatrix} = \begin{pmatrix} 0 & p_\theta\delta - 1 \\ \\ -k & \dfrac{r^2 - k}{r} \end{pmatrix} \begin{pmatrix} \Delta\theta \\ \\ \Delta y \end{pmatrix} + \begin{pmatrix} -p_\theta\delta e^{-rt} \\ \\ 0 \end{pmatrix}.$$

The corresponding eigenvalues are

$$\zeta = \frac{\dfrac{r^2 - k}{r} \pm \sqrt{\left(\dfrac{r^2 - k}{r}\right)^2 + 4k(1 - \delta p_\theta)}}{2},$$

where the eigenvalues have opposite signs: $\zeta_1 < 0 < \zeta_2$. The costate variables may be written as:

$$z(t) = \alpha_1 e^{\zeta_1 t} + \alpha_2 e^{\zeta_2 t} + \frac{p_\theta\delta\, e^{-rt}}{r}$$

$$v(t) = \beta_1 e^{\zeta_1 t} + \beta_2 e^{\zeta_2 t}.$$

In addition to the necessary conditions identified above, the transversality conditions must also be met. Since $y^* = 0$, one transversality condition is certainly met, $\lim_{t\to\infty} vy = 0$. Since $\lim_{t\to\infty} \theta = \theta^* > 0$, the other transversality condition, $\lim_{t\to\infty} z\theta = 0$ implies $\lim_{t\to\infty} z = 0$. Thus, α_2 must equal zero (as must β_2). It is obvious from inspection that $v(t) \neq e^{-rt}$ in general.

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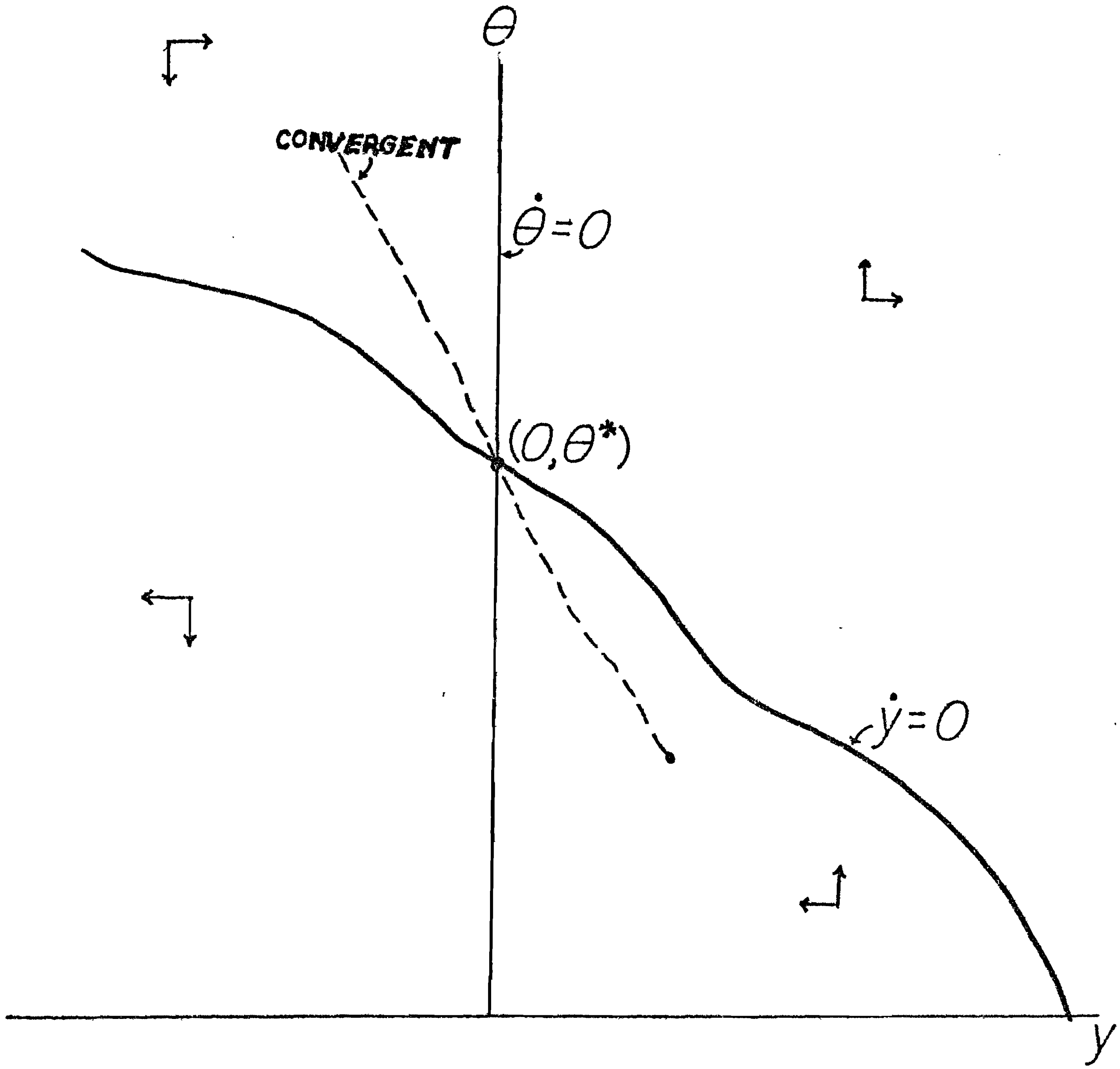

PHASE SPACE WHEN $r^2>k$

FIGURE 1