The Soviet Grain Import Decision

As a Short Term Control Problem

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1. Introduction

Over the last several decades, the Soviet Union has played a major role in world grain markets as a major grain importer and exporter. Because of the large impact of Soviet grain market behavior on the welfare of American and Canadian farmers and because that behavior appears difficult to predict, the Soviet agricultural situation has sparked much research. The studies to date (e.g., Carey and Havelka; CIA; Desai; Johnson; Johnson and Brooks; USDA; Wyzan) have focused on five primary facets of Soviet agriculture: (1) the role of weather in determining crop yields, (2) crop and livestock production functions, (3) the industrial organization of Soviet agriculture and its integration into the Soviet economy, (4) the effects of the U.S. grain embargo on Soviet imports, and (5) the actual Soviet import/export decision process. It is on this last facet that our knowledge is the most unsatisfactory.

A number of hypotheses have been proposed about Soviet import/export behavior with regard to agricultural products. There are two main thrust to these hypotheses: (1) Soviet imports are primarily a trend phenomena with a weather influenced production component (Desai), and (2) Soviet imports are primarily a function of a hard currency constraint (Jones; Jones and Hamilton). In its extreme form, the first hypothesis assumes that the Soviets decide on a total quantity of grain to import without consideration of price while the second assumes that the Soviets allocate a given amount of hard currency to grain import and import the largest quantity possible subject to the hard currency constraint. If the Soviets use price expectations when setting the hard currency budget, these two hypotheses may not be that much in conflict. There is, however, a distinct difference in emphasis between the fixed quantity and fixed hard currency constraint approaches. The fixed

quantity approach emphasizes Soviet production possibilities in the manner pioneered by D. Gale Johnson, while the hard currency constraint approach has its basis in work done in international economics on the trade of centralized economies. One group sees Soviet consumption of agricultural products constrained by internal production, and the other by the Soviets' inability to generate sufficient foreign exchange earnings. Both of these approaches emphasize elasticities: Desai estimates show grain price elasticity to be insignificantly different from zero supporting the fixed quantity hypothesis while Jones and Hamilton's estimates place the price elasticity at close to minus one supporting their argument of a fixed amount of revenue for the Soviets to spend on grain imports.

Both approaches are too simplistic. These models allow for little or no responsiveness in Soviet import decisions to changing world market conditions. Furthermore, both models fail to show how the grain production problem and the grain importation decision fit together in the Soviet planning framework.

2. The Soviet Control Problem

The entire Soviet agricultural situation can be placed in in an optimal control framework with short and long run components.[1] The general problem facing the Soviets is,

$$F_t(A_t, X_t, U_{t-i}, V_t) = 0 \qquad (1)$$

where A_t is a matrix representing the Soviet criterion function, X_t the constraint or state matrix, U_{t-i} a matrix of control (policy) instruments

1/Chow examines the entire Soviet economy within a control framework, but does not consider grain imports explicitly.

influencing the function F_t at time t, and V_t is a matrix of stochastic terms.[2] This is a very general control problem of the form found in most standard reference books on the topic (Kamien and Schwartz; Rausser and Hochman). To put more structure on the problem, define the time period, t, so that the Soviet grain crop planted at time t - 1 is available for use in time period t. Thus controls exercised at, t, have no effect on the size of the available grain crop, G_t, since it was planted and harvested during the period t - 1.

Assume, also, that the Soviets have some targeted level of grain production, TG_t, based upon their consumption goals for each t.[3] When faced with a shortfall in grain production, $(TG_t - G_t > 0)$, the Soviets must exercise control instruments which influence $(TG_t - G_t)$ and since controls exercised at t do not influence G_t, these controls must take the form of augmenting G_t or reducing TG_t. The Soviets can thus be seen to have a short term control problem, how to minimize $(TG_t - G_t)$, and a long term control problem, how to increase G_t. If one assumes that the stochastic terms affecting the short term and long term control problems are independent,[4] and that the Soviets recognize any effects of exercising U_{jt} on A_{t+i}, then the short term control problem is decomposable and can be estimated independently of the long term control problem.

2/Space limitations prevent a detailed derivation and justification of the control formulation used. More information is available from the authors.

3/In any time period t, planned consumption equals planned production plus planned imports minus planned exports. It is assumed here that there are no planned imports. The implications of this assumption are discussed in a later section.

4/In the sense that if v_t is the realization of the stochastic process influencing the short term control problem at t and w_t likewise for the long term problem, $E(v_t' w_t)=0$.

The long term control problem consist of decisions such as how many tractors to build, how much fertilizer to produce, how much land to bring into production, and what and when to plant. The long term problem is considered in detail in Johnson and Brooks and is not discussed further. The short term control problem may be written as,

$$J_t(A_t, G_t, Z_t, U_{jt}, U_{kt}, W_t) = 0, \tag{2}$$

where Z_t is a submatrix of X_t, and the control variables are divided into groups j and k. If the matrices A_t, G_t, Z_t, U_{jt}, and U_{kt} are observed and all derivatives are continuous in the relevant regions, then the implicit function theorem may be used to solve for the conditions under which a particular control U_{jt} is used so that

$$U_{jt} = J_{t*}(A_t, G_t, Z_t, U_{kt}, W_{t*}), \tag{3}$$

where * represents the transformations of the function J and the stochastic process W necessary for equations (2) and (3) to be equivalent.[5] The next step is to specify the variables in each of the matrices in equation (3) and to specify a functional form.

The simplest representation of the criterion function, A_t, in the short term control problem consists minimizing the difference between planned and realized grain production, $TG_t - G_t$, and some trade off, R, between what the Soviets are willing to give up in other parts of the economy in time t or t + i in order to reduce $TG_t - G_t$. G_t is a major constraint on Soviet behavior.[6]

5/It is important to keep in mind that it is not the optimal use of a control instrument which is being estimated but the condition under which the Soviets choose to import grain as a control.

6/The notion that the Soviets use imports to make up for their production shortfalls is of course not new, and is implicit but not operationalized in the agricultural economics work. Turpin tests this hypothesis using a simple correlation framework and finds support for it with respect to agriculture and a number of other commodity groups.

The matrix Z_t consist of other constraint variables and includes foreign exchange availability, EXPN, and world prices for Soviet grain imports P_{it}. The control instruments available to the Soviet Union are net imports of grain, NI_t, the difference between planned and actual livestock slaughter, SDIF, the importation of grain substitutes, S_t, and choosing to accept a change in TG_t.

The simplest representation of equation (3) is the linear form,

$$NI=a_0 + a_1(TG-G) + a_2R + a_3EXPN + a_4P_i + \ldots + a_kp_k + a_1SDIF + a_mS + W^*, \quad (4)$$

where the t subscript has been dropped to avoid notational clutter. It is also convenient to assume that W* is distributed normally with mean zero.

The hypothesized comparative static results are as follows: (1) $\partial NI/\partial(TG - G) > 0$ so that larger shortfalls between actual and planned production result in greater levels of net imports, (2) $\partial NI/\partial R < 0$ so that as the unconstrained expenditures on grain imports increases relative to available foreign exchange net grain imports decline, (3) $\partial NI/\partial EXPN > 0$ so that as availability of foreign exchange increases NI increases, (4) $\partial NI/\partial P_i < 0$ so that as the price of grains increase net imports go down, (5) $\partial NI/\partial SDIF > 0$ is so that as the difference between planned and actual meat consumption becomes larger the Soviets have to import more grain to feed the livestock which were not slaughtered (meat production is a control variable which increases the consumption of agricultural products other than grain by Soviet citizens and decreases need to feed livestock in period t), and (6) $\partial NI/\partial S < 0$ so that as the imports of grain substitutes rise net imports of grain fall.

At this point, the optimal control framework may seem unnecessary. Equation (4) is seemly not that different from a single period optimization

problem.. However, the optimal control framework is useful since it clearly illustrates the importance of Soviet consumption targets and the dynamic nature of the Soviet decision process concerning agricultural consumption targets. These dynamics come from the fact that the allocation of future resources to the Soviet agricultural sector is strongly influenced by the current magnitude and cost of the Western grain purchased to reduce the diffence between the planned and actual consumption. This relationship is described by Johnson and Brooks but is difficult to model since it has changed significantly over time. A more comprehensive model should included these linkages explicitly since it is only the strong assumptions about independence of the error processes that allows the model to be estimated in the simple framework present here.

3. Data and Empirical Estimation

The data used for the empirical estimation are annual observations from 1955-1982 (1956 after lags), a period which corresponds to the post Stalin era in the Soviet Union.[7] Estimates of Soviet grain production, G_t, are taken from the latest USDA estimates and are generally the official Soviet numbers. The quality of the data series varies. The Soviet grain production targets used are generally the last available Soviet targets which were announced before G_t was planted. Note that these target numbers are frequently quite different than those overly optimistic targets announced at the beginning of the five/seven year plans. These target numbers were obtained from a wide variety of sources and those from 1960 to 1965 had to be inferred from more general

7/The reader is forewarned about both the poor and variable quality of data which any estimation of Soviet activities out of necessity entails using.

Soviet revisions of the seven year plan beginning in 1958. Livestock estimates, L, actual meat production, M, and meat production targets, TM, are official Soviet statistics in terms of cattle equivalents and 1000s of metric tons respectively. The same caveats apply to the meat production targets as for the grain targets. SDIF is the difference between TM and M. Exports of grain are USDA estimates in millions of metric tons while Soviet hard currency earnings (in millions of U.S. dollars) are those estimated by the CIA. All grain prices are U.S. gulf export prices per metric ton, soybean prices are average Chicago cash prices per metric ton. The Commerce Department's GNP deflater (normalized at 1972) was used to deflate all prices and expenditures.

To economize on notation, the quantity $(TG_t - G_t)$ is denoted by LDIF where, in terms of calendar year production statistics, LDIF is the difference between planned and actual grain production reported for the previous year (i.e., that grain available for use in t.) Net imports, NI, is defined as the difference between Soviet grain imports and grain exports. Wheat and corn prices are highly collinear so there are two options: (1) use a single price or (2) use a weighted average of the two prices. The wheat price, PW, was chosen, again for simplicity, since results appeared to be insensitive to the choice. Direct estimates of grain substitutes, soybeans, milk, poultry, live cattle, and boxed beef are generally unavailable especially for early periods. The price of soybeans, PS, is used as a proxy for the cost of exercising the control instrument of importing substitutes. A reasonable way to operationalize, R, the tradeoff between agricultural and other forms of consumption is to use the ratio of the cost of importing enough grain to set LDIF to zero to the total amount of foreign exchange available. This new variable is called RATIO and is calculated as [(PW * LDIF)/EXPN].

The estimated equation is,

$$NI = \beta_0 + \beta_1 LDIF + \beta_2 RATIO + \beta_3 EXPN + \beta_4 PW + \beta_5 SDIF + \beta_6 PS + w. \quad (5)$$

The estimated parameters of the equation above are presented in equation (I) below along with the elasticities evaluated at the means,

Variable	Parameter	t-value	Elasticity
INTERCEPT	-14.061	-3.13	
LDIF	.312	5.82	1.00
RATIO	- 3.799	-2.36	- .39
EXPN	.181	5.86	1.47
PW	-12.808	-2.79	-2.12
SDIF	1.859	1.46	.08
PS	13.666	3.68	3.54

The adjusted R^2 for this regression is .92 and the Durbin-Watson statistic is 1.85 (with RHO = .064) indicating no problem with auto-correlation. Note that RATIO is a function of LDIF, EXPN, and PW so for the entire equation the estimated elasticities at the means are LDIF (.75), EXPN (1.72), and PW (-2.371).[8]

The difference between planned and actual slaughter is not highly significant and RATIO is a function of three of the variables in the equation (LDIF, PW, and EXPN). It is of interest to see how the parameters change when these two variables are dropped from the estimation. The results from estimation of this equation (II) are,

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8/PW and PS may not be strictly exogenous variables since the Soviets in some years have had an influence on those prices. However, an equation was estimated using barley prices as an instrument for the wheat price and almost identical results were obtained. Given dirty data and possible specification errors, the OLS results should be more robust.

Variable	Parameter	t-value	Elasticity
INTERCEPT	-14.731	-3.07	
LDIF	.218	5.94	.70
EXPN	.233	9.86	1.88
PW	-11.820	-2.41	-1.96
PS	11.868	3.03	3.07

The adjusted R^2 for this equation is .91, the Durbin-Watson statistic, 1.69, and RHO, .165.

The residual plots show outliers which correspond to known exogenous shocks on Soviet trade. The first of these shocks occurred in 1972 and 1973 when the prices of gold and oil, two of the Soviet Union's major exports, more than tripled. The second shock occurred in 1980 and 1981 when a very similar phenomena occurred. These shocks are not accurately reflected in hard currency exports due to the stockpiling/reserve nature of these exhaustible resources and the relevance of these assets for obtaining Western bank credit. The third shock was the 1980 U.S. embargo on Soviet grain imports.

These shocks can be accounted for by two dummy variables, one for the embargo (EMBARGO) and one for the four years where Soviet assests under went a massive revaluation (GLDOILD). These new variables are included in Equation (III),

Variable	Parameter	t-value	Elasticity
INTERCEPT	-14.479	-4.58	
LDIF	.220	5.14	.70
RATIO	- 1.905	-1.59	- .19
EXPN	.194	8.40	1.57
PW	- 6.098	-1.73	-1.01
SDIF	1.415	1.57	.06
PS	8.879	3.18	2.30
GLDOILD	8.474	4.39	
EMBARGO	-10.068	-3.09	

The adjusted R^2 for this equation was .96, while the Durbin-Watson statistic was 1.92 and the estimate of RHO -.013.

4. Discussion

It is noteworthy that three fairly different specifications yield results that are quite similar. However, equation I is maybe preferred since it is theoretically the most complete equation. Equation II requires less data if used for predictive purposes and gives similar results. Equation III explains the existing data best but relies on two dummy variables for shocks that are hard to envision a priori, but such a specification may be useful if such shocks occur again in the future. The similarity in the estimated coefficients and elasticities among the three equations indicate that the results of the empirical models are robust.

Using the estimated partial derviatives for LDIF (directly and through RATIO) from equations I, II, and III, the Soviets, on average, import 75%, 70%, or 58%, respectively, of any shortfall in planned grain production. The elasticities evaluated at the means for hard currency foreign exchange earnings are 1.72, 1.88, or 1.70 for equations I through III and indicate that the hard currency income elasticity of grain import demand is fairy high. The price elasticities for wheat and soybeans with respect to grain imports are moderately high indicating that a good deal of substitution takes place between grain imports and grain import substitutes.

The fixed quantity and fixed foreign exchange allocation hypotheses fare poorly in comparison to the results presented here. Desai estimated three import demand equations using observations from 1950-1979, ([i] $GI = \theta_0 + \theta_1 G + \theta_2 time + \theta_3 D71$, [ii] $GI = \theta_0 + \theta_1 G + \theta_2 M + \theta_3 D71$, and [iii] $GI = \theta_0 + \theta_1 G + \theta_2 L + \theta_3 D71$) where GI is gross imports and D71 is a dummy variable which is zero for observations before 1971 and one after. These equations were estimated using NI instead of GI and observations from 1956-1982. The

adjusted R^2's were around .70, the same as Desai's. The increased in adjusted R^2's from .70 to .90 in the equations presented in the earlier sections represents a large increase in predictive ability. Furthermore, the Desai type model got progressively worse in predicting the observations of the mid 1970's to 1982. In contrast, even equation (II) predicts fairly uniformly over the entire time period and in particular predicts correctly a fairly complicated series of sign changes in the net import pattern. The primary difference between Desai type equations and the ones presented here are the incorporation of Soviet targets, foreign exchange availability, and the prices they face.

The finding of significant coefficients on the LDIF variable along with a price elasticity of -2.12 for PW in equation (I) does not support Jones' hypothesis of an allocation of foreign exchange for grain purchases without reference to the size of LDIF. There is however, a very clean way to test this hypothesis. If foreign exchange is allocated independently, the expectation of expenditures should be independent of LDIF, $E([PW * NI]_t \mid LDIF_t) = E[PW * NI]$. This can be tested by computing the correlation coefficient between these two variables if a linear relationship is assumed. The correlation coefficient of .65 is quite large and significantly different from zero. This suggests that EXPN and RATIO do have significant effects on Soviet behavior.

The estimated models have several interesting policy implications. First, the high net import elasticity of demand with respect to foreign exchange earnings implies that increases in Soviet oil sales to Western Europe should result in substantial increases in world grain demand. Furthermore, any U.S. attempts to constrain Soviet hard currency earnings may have direct detrimental effects on U.S. farm income. Second, the estimated price

elasticities indicate that the Soviets are quite willing and able to substitute away from grain imports toward soybean (and perhaps meat) imports when grains become over valued. Supplemental analysis not presented here suggests that this price sensitive and willingness to substitute have increased over time within the larger agricultural commodity group, although there are signs that total agricultural imports are still inelastic,[9] and there is some support for Jones' hypothesis of a fixed allotment of foreign exchange if total agricultural imports are examined. Therefore, any policies aimed at extracting higher economic rents from the Soviets in the fashion of Schmitz et al. must include export restrictions on all relevant grains and grain substitutes in order to be effective. Third, at least in the very short run (one or two years) the Soviets tend to follow their announced plans and import grain when their actual production falls short of their planned production. Thus, announced Soviet plans may provide policy makers with useful information if timely estimates of the Soviet grain harvest can be obtained.10 However, in the long run the question remains of how successful the Soviets will be in meeting their production goals and therefore how much they will import.

9/Gardner specifically suggests that the Soviets became much more flexible in foreign purchases after 1978.

10/The Soviet Union did not announce their target for 1983 although it would appear that U.S. intelligence services should be able to obtain or infer what this number is since so many visible Soviet decisions hinge on it. The large gap between the 1984 Soviet target and USDA estimates of Soviet production suggests record or close to record Soviet grain purchases from Western countries.

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