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MEASUREMENT OF ALLOCATIVE BIASES OF PRODUCTION CONTROL POLICIES

Robert D. Weaver

Because of growing stocks of grain and the reinstitution of production controls, the question of what allocative impacts such controls imply is once again relevant. The prospect that restrictions on land use may initiate an intensification in the use of substitute inputs such as fertilizer, which are already high in price, is discouraging. Although the issue is an old one, empirical evidence on the extent of these effects is incomplete.[1] The purpose of this article is to derive a convenient means of measuring the allocative effects of changes in input restrictions. As an example of empirical application, results are presented which indicate the impact of acreage restrictions during the marketing quota years in North and South Dakota.

Given that government acreage control policies place restrictions on land use, does such policy lead to changes in the mix of outputs or inputs and, if so, to what extent? These questions can be addressed by means of a concept based on a generalization of Hicks' measure of the bias of technical change. Just as technical change may shift isoquants in many different ways, the changes in the level of any restricted or fixed input will shift isoquants which trace optimal combinations of variable inputs. In either case, shifts in isoquants may result in a change in the combination of resources employed. Similarly, in a multiple output situation, changes in technology or fixed factors may shift production possibility curves and lead to changes in the choice of outputs.

Following Hicks' terminology, one can measure the impact of policy-imposed input restrictions in terms of the biases they introduce in resource allocation. If the land restrictions led to no change in the relative use of pairs of inputs or in the relative production of pairs of outputs, one can conclude that the restrictions were "neutral" in their impact on input and output mixes. If the policy led to changes in these mixes, then in Hicks' terminology one can conclude that resource allocation was changed, or "biased," toward the increased relative use of various inputs or production of various outputs. By quantifying the extent of this bias, one can determine exactly how relative utilization or production changed.

Suppose producers employ a wide variety of inputs ($X_1, X_2 \ldots X_n$) which can be adjusted as desired by purchasing more at market prices ($r_1, r_2 \ldots r_n$). Also, suppose producers use inputs ($\Theta_1, \Theta_2 \ldots \Theta_q$) whose services are fixed or restricted for any number of reasons: the absence of rental markets, lags in adjustments, or government restrictions announced through various regulations. The state of technology, T, may also be a constraint of this type. Finally, all these inputs are used to produce a variety of outputs ($Y_1, Y_2 \ldots Y_m$) which may be sold at expected prices ($P_1, P_2 \ldots P_m$).

If the producers formulate their production plans in an attempt to maximize expected profits, it is convenient to describe the relation between these choices and their determinants by a set of output supply and input demand functions.

$$(1) \qquad Y_i^* = Y_i(P_1 \ldots P_m, r_1 \ldots r_n, \Theta_1 \ldots \Theta_q) \qquad i = 1, \ldots m$$

$$(2) \qquad X_h^* = X_h(P_1 \ldots P_m, r_1 \ldots r_n\, \Theta_1 \ldots \Theta_q) \qquad h = 1, \ldots n$$

Does the shift in isoquants or production possibility frontiers result in a change in optimal relative choices although all relative prices have been held constant? Figure 1 shows graphically that if an increase in a fixed factor leads to a parallel shift of isoproduct curves so that the optimal choice for the indicated price ratios remains along the ray A, the impact of the change could be said to be Hicks neutral. If the change leads to a new optimal choice which is to the right of A, e.g., point b, then the impact has been X_h saving in relation to X_k. If

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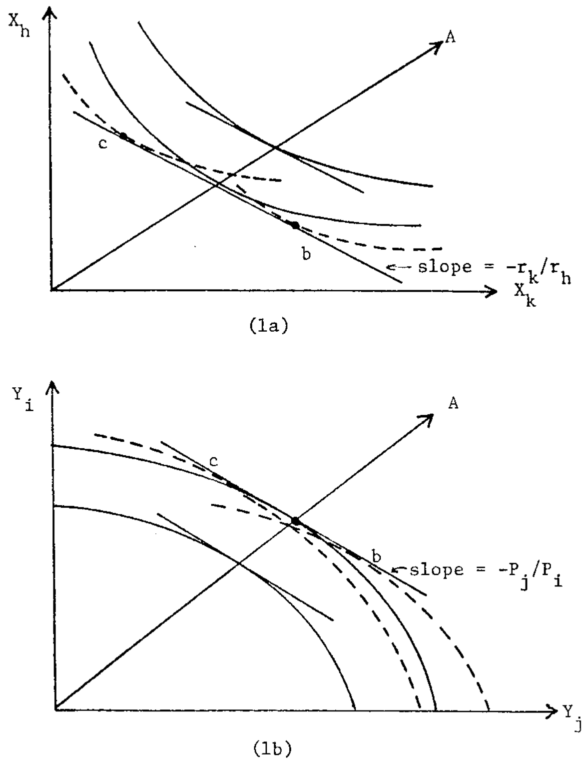
[1]An example of evidence available on this subject is given by Christensen and Aines [3], who conclude that fertilizer intensification accounted for more than 40 percent of the increase in yields between 1940 and 1960.

FIGURE 1. IMPACT OF AN INCREASE IN FIXED FACTOR ON PRODUCTION DECISIONS.



the new optimal choice is to the left of A, at say point c, the change may be said to have been X_h using in relation to X_k. These conditions can be summarized conveniently with the following rule.[2]

A change in a fixed factor (Θ_r) has been

$$(3)\quad X_h \begin{Bmatrix} \text{saving} \\ \text{neutral} \\ \text{using} \end{Bmatrix} \text{relative to } X_k \text{ as } \frac{dX_h^*}{X_h^*} - \frac{dX_k^*}{X_k^*} \lesseqgtr 0$$

$$h \neq k = 1, \ldots n.$$

By the same logic an increase in a fixed factor would lead to an outward shift in the production possibilities frontier as in Figure 1b. Does this change lead, *ceteris paribus*, to a change in output mix away from ray A? The impact of such a change on output mix can be described by the following rule.

The change in a fixed factor (Θ_r) has led to

$$(4)\quad \begin{Bmatrix} \text{an increase} \\ \text{no change} \\ \text{a decrease} \end{Bmatrix} \text{in } Y_i^* \text{ relative to } Y_j^* \text{ as } \frac{dY_i^*}{Y_i^*} - \frac{dY_j^*}{Y_j^*} \gtreqless 0$$

$$i \neq j = 1, \ldots m.$$

Multiplying the left side of the inequality relation in equation 3 by the reciprocal of the proportion of change in Θ_r gives:

$$(5)\quad B_{hk} = \frac{\Theta_r}{d\Theta_r}\frac{dX_h^*}{X_h^*} - \frac{\Theta_r}{d\Theta_r}\frac{dX_k^*}{X_k^*}$$

$$H \neq k = 1, \ldots n$$

where B_{hk} is the measure of bias in allocative impact of a change in Θ_r. On an intuitive level, it is nothing more than the difference between appropriate elasticities of choice with regard to changes in the fixed factor (Θ_r). Similarly, one can rewrite the left side of equation 4 as

$$(6)\quad B_{ij} = \frac{\Theta_r}{d\Theta_r}\frac{dY_i^*}{Y_i^*} - \frac{\Theta_r}{d\Theta_r}\frac{dY_j^*}{Y_j^*}$$

$$i \neq j = 1, \ldots m.$$

One complication with this measure should be noted. Although the rules 3 and 4 upon which 5 and 6 are based are not influenced by direction of the change of the fixed factor (Θ_r), the definitions 5 and 6 are influenced. This effect follows from the fact that the direction of the change of Θ_r determines the sign of $d\Theta_r$. Therefore, one could define rules identical to 3 and 4 using the bias concepts 5 and 6 for positive changes in $d\Theta_r$; however, for negative changes the inequality signs would be reversed. Because it is more interesting to determine the impact of a tightening of input restrictions, the following rules relate to decreases in restricted inputs (or "tightening" of restrictions).

A tightening of restrictions (decrease in Θ_r) has been

$$(7)\quad X_h \begin{Bmatrix} \text{saving} \\ \text{neutral} \\ \text{using} \end{Bmatrix} \text{relative to } X_k \text{ as } B_{hk} \gtrless 0$$

$$\forall\, h \neq k = 1, \ldots n.$$

[2]For measurement of the impact, $d\left\{\frac{X_h^*}{X_k^*}\right\}$

A Hicks neutral or X_h saving or using impact in relation to X_k is indicated by this total differential being equal to, greater than, or less than zero.

A tightening of restrictions (decrease in Θ_r) has led to

$$(8)\quad \left.\begin{array}{l}\text{an increase}\\ \text{no change}\\ \text{a decrease}\end{array}\right\} \text{ in the supply of } Y_i^* \text{ relative to } Y_j^* \text{ as } B_{ij} \lesseqgtr 0 \quad \forall i \neq j = 1, \ldots m.$$

Note that by simple arithmetic

(9)

$$B_{hk} = \frac{\Theta_r}{d\Theta_r}\frac{dX_h^*}{X_h^*} - \frac{\Theta_r}{d\Theta_r}\frac{dX_k^*}{X_k} = -B_{kh} = -\frac{\Theta_r}{d\Theta_r}\frac{dX_k^*}{X_k} + \frac{\Theta_r}{d\Theta_r}\frac{dX_h^*}{X_h^*}$$

and similarly,

$$B_{ij} = -B_{ji}$$

Elasticities required to determine B_{hk} and B_{ij} can be obtained from estimates of output supply and input demand functions similar to those in equations 1 and 2. However, to study the effects of restrictions on input use on all choices, the entire set of such choice functions must be estimated to provide measures of all elasticities required in equations 5 and 6.

AN APPLICATION

During 1950 and from 1954 to 1964, restrictions were placed on the number of acres that could be planted to wheat and feed grains, and were enforced by a system of penalties which would be imposed on producers who marketed grain in excess of the normal production of the allotted acreage. This allotted acreage was intended to be a policy instrument which would set a limit on the acreage a producer could plant. When allotted acreages were set at levels which required the producer to reduce planted acreage, the policy imposed a constraint on the firm's decision and the levels of the constraint represent a type of fixed factor for the firm.[3] Given this interpretation, one can use the foregoing methodology to investigate the nature of allocative biases which may have resulted from acreage controls during the quota years. Specifically, the problem is to obtain estimates of the elasticities involved in equations 5 and 6.

In work reported elsewhere, Weaver [13] presents estimates of all required elasticities based on a postwar (1948-1970) sample of state-level aggregate data from North and South Dakota.[4] A complete set of output supply and input demand functions were estimated which were consistent with the hypothesis that producers attempted to maximize expected profits. In addition, a functional form was employed which is consistent with the possibility that technology faced by producers may be joint in outputs or non-homogeneous. Specifically, the equations were derived from a translog functional form [4] and their parameters were restricted to satify all implications of the hypothesis of expected profit maximization (e.g., linear homogeneity in prices, and symmetry) [15]. With these restrictions imposed the equations were estimated by an iterative Zellner procedure[5] to take into account cross-equation correlation in the error terms. Variable inputs and outputs were aggregated in the following groups: labor (LAB), capital services (building and machinery) (CAP), fertilizer (FERT), petroleum products (PET), materials (MAT), wheat (W), feed grains (FG), and livestock (LTK). Fixed factors were defined as including the state of technology (measured by a time trend) (T), total farmland available for cultivation (LLDI), preseason precipitation (R), wheat allotment (A), and feed grain base (B). Futures prices were used as measures of expected output prices after extensive study of the information content of past series of prices. As concluded by Weaver [13], if one maintains the hypothesis that information is readily available, and if futures markets are efficient [see 7], then futures price will reflect all information which is useful in improving the accuracy of price forecasting. However, as shown by Weaver [13], this is not generally the case for adaptive extrapolations of past prices as used by Nerlove [11] and others. Furthermore, under these conditions the hypothesis of expected profit maximization implies that all producers hold the same expectations. This assumption has been relied upon since Nerlove's [11] work with adaptive expectations. These assumptions lead one to

[3]Research by the author [13, 14] has failed to reject the hypothesis that acreage controls during the quota years in these states placed binding constraints on acreage utilization.

[4]A complete description of the sample is given in [13]. State-level aggregate data were chosen in the absence of farm-level time series. After extensive review of census data describing the distribution of farm expenses and product mixes, it was concluded that North and South Dakota were sufficiently homogeneous in type and design of farm to allow results based on aggregate data to be of interest. Certainly, any heterogeneity in the present sample is much less severe than that found in typical supply studies, e.g., Nerlove [11], Houck and Ryan [10], Griliches [6], Gardner [5]. Data employed relied heavily on USDA price, expense, and revenue series. Expenses were obtained from unpublished records of USDA, *Farm Income Situation*, and *Changes in Production and Efficiency*. Revenues were gathered from *Agricultural Statistics* and various state publications. Input price aggregates were constructed from detailed price data reported in state publications and expenditure weights reported in *Major Statistical Series and How They Are Constructed*. Futures prices were employed as measures of price expectations for crops with the exception of those hay and forage crops which are not traded on futures markets. For such crops and for livestock, one period lagged prices obtained from *Agricultural Statistics* and state publications were employed.

[5]See Zellner [16].

expect that observations of futures prices of harvest contracts during the production planning period will serve as accurate approximations of producer expectations.

Measures of biases for particular input and output pairs were calculated as in equations 5 and 6 by using estimates of the elasticities of choices with respect to wheat allotments and with respect to feed grain base restrictions presented by Weaver [13]. Because the reported measures of biases involve a nonlinear combination of normally distributed parameters, the distribution of the bias measures is not normal and is difficult to characterize. Confidence intervals therefore are not reported. Table 1 reports the measures of bias introduced by wheat allotments in North and South Dakota. Table 2 reports bias of feed grain restrictions. Because the estimates are based on choice functions which were not restricted to be consistent with homogeneity, or any other *a priori* restriction on technology, they are expected to vary over points of observation, time, and cross-section. This expectation follows from the fact that the derivatives of the production function that lie behind the choice elasticities were allowed to change between different points on the production surface. The point estimates reported in Table 1 indicate that although allotments were not neutral in their impact on decisions (i.e., $\beta \neq 0$), the magnitudes of their allocative effects were small.[6] A reduction in the wheat allotment was found to result in fertilizer (FERT) being substituted for all other variable inputs. For example, one sees from Table 1 that fertilizer was substituted for capital services in both North and South Dakota. That is, if input h is fertilizer (FERT) and input k is capital (CAP), $\beta_{FERT,CAP}$ is $-.006$ and $-.0091$ for North and South Dakota, respectively. Using rule 7, one sees that this implies the acreage restrictions were fertilizer using in relation to capital services. In other words, the negative elasticity of fertilizer utilization with respect to a change in the allotment exceeded that of capital utilization. The same effect is seen for fertilizer use in relation to materials (MAT) and petroleum products (PET). For the impact of fertilizer use in relation to labor, $\beta_{LAB,FERT}$ is .023 and .027 in North and South Dakota, respectively. Recalling from equation 9 that $\beta_{LAB,FERT} = -\beta_{FERT,LAB}$, one finds that $\beta_{FERT,LAB}$ was $-.023$ and $-.027$ in the two states. That is, the allotments led to an increase in fertilizer use in relation to labor. Similarly, Table 1 indicates a shift into capital and materials use in relation to petroleum products. By the rule in equation 9, allotments led to a saving of capital in relation to materials. These nonzero effects are of small magnitude. One can conclude from these results that although wheat acreage controls led to changes in the relative choices of inputs, those changes were not strongly biased toward the use of a particular input (e.g., fertilizer).

As illustrated in Table 2, feed grain bases on the whole had very different effects on resource allocation, although the magnitudes of changes in relative factor utilizations were very small as in the case of wheat allotments. Using equation 7 as a basis for interpretation of feed grains, one finds labor utilization was increased in relation to all other inputs (with

TABLE 1. BIASES (β_{hk},β_{ij}) OF WHEAT ACREAGE ALLOTMENTS ON PROVISIONAL PRODUCTION DECISIONS: 1950, 1954-1964.

		β_{ij}	
Product i	Product j	North Dakota	South Dakota
Wheat	Feed Grains	.0006	.0327
Wheat	Livestock	-.0081	-.0044
Feed Grains	Livestock	-.0084	-.0112
		β_{hk}	
Input h	Input k	North Dakota	South Dakota
Labor	Fertilizer	.02319	.0275
Labor	Capital	.0172	.0185
Labor	Materials	.0188	.0248
Labor	Petroleum Products	.0115	.0091
Fertilizer	Capital	-.006	-.0091
Fertilizer	Materials	-.0044	-.0028
Fertilizer	Petroleum Products	-.0117	-.0185
Capital	Materials	.0015	.0063
Capital	Petroleum Products	-.0057	-.0094
Materials	Petroleum Products	-.0073	-.0157

TABLE 2. BIASES $[\beta_{hk},\beta_{ij})$ OF FEED GRAIN ALLOTMENTS (BASES) ON PROVISIONAL PRODUCTION DECISIONS: 1950, 1954-1964.

		β_{ij}	
Product i	Product j	North Dakota	South Dakota
Wheat	Feed Grains	-.0155	-.0030
Wheat	Livestock	-.0056	.0141
Feed Grains	Livestock	.0099	.0902
		β_{hk}	
Input h	Input k	North Dakota	South Dakota
Labor	Fertilizer	-.0260	.0039
Labor	Capital	-.0132	-.0110
Labor	Materials	-.0170	-.0259
Labor	Petroleum Products	-.0154	-.0137
Fertilizer	Capital	.0128	-.0149
Fertilizer	Materials	.0090	-.0299
Fertilizer	Petroleum Products	.0106	-.0176
Capital	Materials	-.0038	-.0149
Capital	Petroleum Products	-.0022	-.0027
Materials	Petroleum Products	.0016	.0123

[6]Weaver [13] statistically tested the hypothesis that acreage controls during the quota years were Hicks neutral. By appropriate F-tests of parameter restrictions which are sufficient conditions for Hicks neutrality, the hypothesis was rejected for the current sample.

the exception of a nearly zero effect in South Dakota for the change in labor relative to fertilizer use). All other inputs were substituted for fertilizer in North Dakota, whereas in South Dakota fertilizer was substituted for all other inputs. Capital was found to be substituted for materials and petroleum and the latter was found to be substituted for materials.

On the output side, as seen in Table 1, a reduction in allotments was found with few exceptions to have allocative effects which averaged only about a 1 percent change in one output over another. Exceptions to this pattern were found for the wheat allotment in South Dakota where a reduction in the allotment resulted in a 3 percent greater reduction in wheat than increase in feed grains in both states. In the case of feed grains bases, reductions in the base acreage resulted in the expected substitution of wheat and livestock production. The strongest change in mix occurred in South Dakota where the percentage increase in livestock exceeded that of the decrease in feed grains by 9 percent.

The results indicate that although input controls may cause a reallocation of resources, the extent of that effect may be inconsequential and depends on the nature of production possibilities. Although the results are specific to the sample, the methodology is readily adaptable for application to alternative samples, types of diversified farms or businesses, and alternative government regulations which effectively restrict input utilization or output supply.

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