Testing for Efficiency: A Policy Analysis with Probability Distributions

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Contribution appeared in Arfini, F. (Ed.) (2005) "Modelling Agricultural Policies: State of the Art and New Challenges", proceedings of the 89th EAAE Seminar, pp. 222 - 232

February 2-5, 2005

Parma, Italy

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Abstract

The study evaluates the efficiency of government intervention using a vertically-structured model including imperfectly competitive agricultural input markets, a bread grain market, and an imperfectly competitive food industry. An actually observed bread grain policy is compared to a hypothetical efficient policy. Computer-intensive simulation procedures and surface response functions are utilized to account for the sensitivity of model results with respect to 10,000 normal distributed parameter sets.

Key words: efficient policy, statistical policy analysis.

1. Introduction

As a rule, governments defend their policies as efficiently meeting stated objectives. The aim of this study is to take this to an empirical test. In particular, it is analyzed if the market interventions of the Austrian bread grain market before the EU accession (1991-1993) were designed to efficiently meet the main stated objectives. To do so, the actually observed policy is compared to a hypothetical optimal policy, which fulfills stated objectives at minimum social cost.

The paper is organized as follows. In the next section, the official objectives relevant to the bread gain policy in Austria and the policy instruments are reviewed. In section 3, a vertically-structured model including imperfectly competitive agricultural input markets, the bread grain market, and the imperfectly competitive food industry is developed. Since the results crucially depend on the model parameters, a range rather than (one or a few) specific values are derived for each model parameter. Section 4 presents some empirical analysis. First, we define "avoidable social cost" as the difference between the actual policy and a hypothetical optimal

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policy. Second, we present some model results. Third, we utilize different types of surface response functions to undertake a thorough sensitivity analysis. Section 5 provides a summary and discussion.

2. Objectives and instruments of Austrian bread grain policy

Official objectives of farm policy as stated in national agricultural legislation are manifold. It also appears that there is a high degree of unanimity about the goals of agricultural policy among developed countries. Following Winters (1987, 1990) in analyzing the objectives of agricultural support in OECD countries one may identify four categories of farm policy goals: i) support and stabilization of farm income; ii) self-sufficiency with agricultural (food) products; iii) regional, community and family farm aspects; iv) the environment. There is not much doubt among agricultural policy analysts that farm income support has been the most important goal over the last decades (Josling, 1974; Gardner, 1992).

In general, Austrian agricultural legislation in 1993 was not different from other developed countries. The overall goals of agricultural policy are stated in paragraph 1 of the "Landwirtschaftsgesetz" (Agricultural Status) (see Gatterbauer et al. 1993, Ortner, 1997) and perfectly fit in the four categories mentioned above.

The particular objectives of bread grain market interventions are stated in the "Marktordnungsgesetz" and can be summarized as (Astl, 1989: 88; Mannert, 1991: 74): i) safeguarding domestic production, ii) stabilizing flour and bread prices; and iii) securing a sufficient supply and quality of bread grain, bread grain products and animal feedstuffs.

Utilized policy instruments to meet stated policy objectives can be illustrated by means of figure 1 with D_{fo} being the domestic demand for bread grain for food production, and D being the total domestic demand for bread grain including demand for feeding purposes. Initial domestic supply is represented by S and supply including a fertilizer tax by S_t. World market price is assumed to be perfectly elastic at P_w for a small country like Austria. Farmers obtain a higher floor price P_D for a specific contracted quantity (or quota) Q_Q. Since farmers have to pay a co-responsibility levy CL_{PD} the net producer price is P_D - CL_{PD}. Quantities, which exceed the quota, can be delivered at a reduced price P_E. Again, farmers' net floor price is P_E - CL_{PE}, with CL_{PE} being the co-responsibility levy for bread grain beyond the quota. Food processors have to buy bread grain at the higher price P_D, while the price of bread grain for feeding purposes is P_E. Therefore, domestic demand for bread grain in food production is Q_D, domestic demand for feeding purposes is $Q_E - Q_D$, total domestic demand is Q_E, and exports are $Q_X = Q_S - Q_E$.

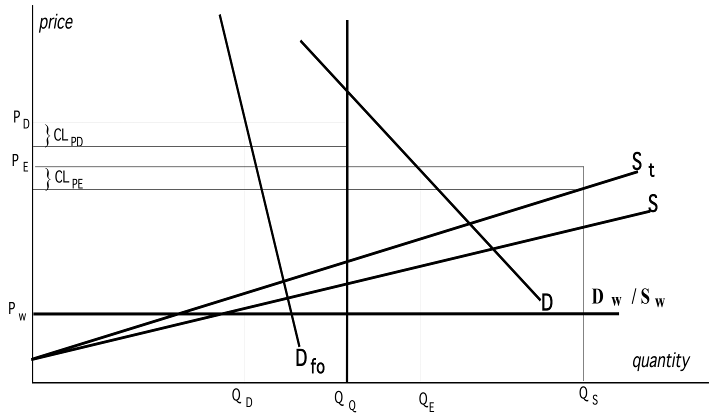

Figure 1. Bread grain market and policy

3. The model

The Austrian agribusiness of bread grain is modeled by a log-linear, three-stage, vertically-structured model (Salhofer and Schmid, 2004), as illustrated in figure 2. The first stage includes four markets of input factors used for bread grain production: land, labor, durable investment goods (e.g. machinery and buildings), and operating inputs (e.g. fertilizer, seeds). Since 95% of farmland is owned by farmers and 86% of labor in the agricultural sector is self-employed, land and labor are assumed to be factors offered solely by farmers in perfectly competitive markets. On the contrary, investment goods, and operating inputs are supplied by upstream industries, which are assumed to have some market power to set the prices above marginal cost. Export and import of input factors are not considered. Hence, it is assumed that domestic consumption of input factors equals domestic production. This seems to be appropriate for land and agricultural labor and is also likely for important industrially produced input factors (e.g. tractors, fertilizer).

At the second stage, input factors of the first stage are used to produce bread grain. The first and the second stage are linked by the assumption that bread grain producers maximize their profits. The produced quantity of bread grain is used for food production, animal feed, and exports.

The third stage represents firms which process and distribute bread grain such as wholesale buyers, mills, exporters, and foodstuffs' producers. Bread grain along with other input factors of labor, and capital (which is a residual of including all other inputs) is combined to produce food (bread grain products like flour, bread, noodles). The downstream industry is assumed to have some market power to set the prices above marginal cost. Export and import of input factors are not considered since import and export of processed bread grain do not play an important role in Austria. According to Astl (1991), the ratio of imports to total consumption of bread and baker's ware is less than 7%. According to Raab (1994), exports of flour and flour products increased but were still only 4% of domestically processed bread grain in 1993.

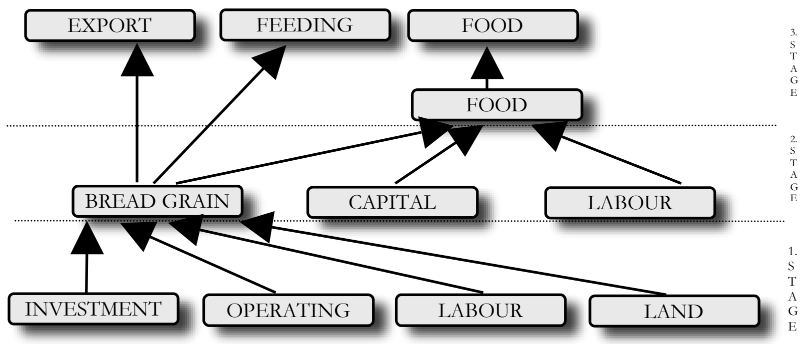

Figure 2. Three-stage vertically-structured model of Austrian bread grain market

Table 1. Upper and Lower Limits of Model Parameters

Model parameters	Symbol	Upper limit (*u*)	Lower limit (*l*)
Supply elasticities of agricultural input factors			
Land	ε_A	0.10	0.40
Labour	ε_B	0.20	1.00
Durable investments	ε_G	1.00	5.00
Operating inputs	ε_H	1.00	5.00
Supply elasticities of food industry input factors			
Labour	ε_J	0.20	1.40
Capital	ε_K	1.00	5.00
Cost shares of agricultural input factors			
Land	α_A	0.06	0.10
Labour	α_B	0.29	0.39
Durable investments	α_G	0.11	0.19
Cost shares of food industry input factors			
Labour	α_J	0.27	0.37
Substitution elasticity of bread grain production	σ_S	0.10	0.90
Substitution elasticity of food production	σ_F	0.50	1.50
Demand elasticity of bread grain for feeding	η_E	–0.50	–1.50
Demand elasticity of bread grain at the consumer level	η_F	–0.10	–0.60
Lerner indices			
Operating inputs industry	L_F	0.00	0.20
Agricultural investment goods industry	L_G	0.00	0.20
Food industry	L_H	0.00	0.20
Agricultural share of expenditures for bread grain products	λ	0.07	0.09
Cost of public funds	MCF	0.10	0.40

The model is calibrated to fit the price and quantity averages from the period 1991- 1993. To run the model 32 parameter values are necessary. While 13 values of these 32 parameters are endogenously derived in the calibration process, 19 specific parameter values have to be assumed.

In contrast to most empirical studies of this kind we do not assume one (or a few) specific value(s) for each parameter, but rather assume each parameter to be in a plausible range. The upper (*a*) and lower (*b*) bounds of these ranges are based on extensive literature and data analysis (Salhofer, 2001; Salhofer et al., 2001)) and are presented in table 1. We assume a symmetric normal distribution $N(\mu, \sigma,)$ with $\mu = (a+b)/2$ and $\sigma = (\mu-a)/1.96$, which is truncated at *a* and *b*, between the upper and lower bounds. Hence, 10,000 independent draws are taken for every single parameter. Consequently, we derive 10,000 parameter sets including 19 elements. These parameter sets are used to derive 10.000 welfare measures.

4. Empirical analysis

4.1 Optimal policy and avoidable social cost

As discussed above, the main objective of agricultural policy in Austria, as in most developed countries, was to support farm income. Beside income redistribution, securing a sufficient supply and quality of bread grain products and animal feedstuffs was the most important goal of Austria's bread grain policy in particular (Mannert, 1991). Given this, we may simplify government's decision problem as trying to maximize social welfare given a socially demanded level of farmer's welfare and self-sufficiency. (Alternatively, one could describe government's decision problem as minimizing social cost, given a certain amount of income transfers to farmers and self-sufficiency). Assuming that the socially demanded transfer level is reflected in the actually observed transfer level, self-sufficiency is given when domestic supply is greater or equal domestic demand, and the policy instruments available to government are the actually used instruments, government's decision problem can be formalized as:

$$\max_{P_{QD}, P_E, CL_{PQD}, CL_{PE}, Q_Q} W \quad s.t.\, U_{BF} \geq U_{BF}^{A},\, Q_s - Q_E \geq 0 \tag{1}$$

where U_{BF}^{A} is the actually observed welfare level of bread grain farmers. We us standard Marshallian producer and consumer surplus areas as well as market power rectangles (defined as (price − marginal cost) × quantity) to estimate bread grain farmers' welfare and total welfare (Salhofer and Schmid, 2004)

The official goal of introducing a tax on fertilizer was soil protection and hence environmentally motivated. For simplicity, it is assumed that this environmental goal is separable from other goals and optimally met by the current level of fertilizer tax. Hence, government can freely choose the levels of five policy instruments (P_E, CL_{PE}, P_{QD}, CL_{PQD}, Q_Q) to maximize welfare under given constraints.

Utilizing the described simulation model, assumed distributions of parameter values, and standard welfare measures, the nonlinear optimization problem (1) is solved numerically for 2 times 10,000 alternative parameter sets utilizing GAMS software (Brooke et al., 1988). As a result, two alternative distributions of the optimal welfare levels as well as the optimal policy instrument levels and combinations are derived.

Utilizing the same model, parameter sets, and welfare measures, but taking the world market price of bread grain one can simulate a hypothetical non-intervention scenarios. Thus, the social cost of the optimal policy are measured as

$$SC^{*}=W^{*}-W^{W}, \tag{2}$$

where W^* and W^W are the welfare level in the optimal situation and in the world market price situation, respectively. Similarly, plugging in the actually observed prices into the simulation model one could calculate the social cost of the actual observed policy as

$$SC^{A}=W^{A}-W^{W}, \tag{3}$$

where W^A is the actual welfare level. Finally, subtracting the social cost of the hypothetical optimal policy fro the social cost of the actual policy provides a measure of avoidable social cost (ASC):

$$ASC=SC^{A}-SC^{*}=W^{A}-W^{*}. \tag{4}$$

ASC gives the social cost that could be avoided by a policy that fulfills all policy objectives at minimum social cost.

4.2 Empirical results

Some empirical results are summarized in table 2. At the mean, the social cost of the actually policy are estimated to be € 159 million (about 42% of the value of bread grain production) with a standard deviation of € 23 million. In 95% (9,500 cases) of our 10,000 simulations the social cost are in a range of € 116 million to € 205 million. The 75% probability interval is between € 132 million € 186 million. In the case of the optimal policy the social cost are significantly smaller with a mean of € 68 million, a standard deviation of € 6 million, a 95% probability interval between € 58 million and € 82 million, and a 75% interval between € 61 million and € 75 million. Therefore, government could have avoided social cost by € 91 million on average with a 95% (75%) probability between € 45 (63) million and € 138 (119) million, if the same instruments are used at different levels.

Table 2. Social cost of actual and optimal policy

	Mean	Median	Std. Dev.	95% Probability interval From	to	75% Probability interval from	to
Social cost of actual policy	158.7	157.9	23.1	115.8	205.3	132.1	186.1
Social cost of optimal policy	67.8	67.1	6.2	57.6	81.8	61.1	74.7
Avoidable social Cost	90.9	90.8	23.9	44.8	138.1	62.9	118.8

4.3 Sensitivity analysis

To analyze the sensitivity of the *ASC* with respect to the model parameters, surface response functions are utilized (Zhao et al. 2000). The nonlinear relationships between *ASC* and model parameters can be described by first-order approximations – either in linear (Horan, Claassen and Howe, 2001) or log-linear form (Salhofer, 2001) – or by a second order approximation (Zhao et al. 2000; Salhofer and Schmid, 2004). Here we apply all three forms and compare the results:

First-order linear:
$$ASC = c_0 + \sum_{i=1}^{19} c_i b_i + e \qquad (5)$$

First-order log-linear:
$$\ln(ASC) = c_0 + \sum_{i=1}^{19} c_i \ln(b_i) + e \qquad (6)$$

Second-order:
$$ASC = c_0 + \sum_{i=1}^{19} c_i b_i + \sum_{\substack{i,j=1 \\ i \le j}}^{19} d_{ij} b_i b_j + e \qquad (7)$$

with b_i being the 19 model parameters, and c_0, c_i, and d_{ij} being regression coefficients, and e an error term.

Utilizing these regression results on can derive sensitivity elasticities $\varepsilon_{ASC,b_i} = \frac{\partial ASC}{\partial b_i}\frac{b_i}{ASC}$, i.e. how sensitive *ASC* is to changes of a specific model parameter. These elasticities for the three different surface response functions are calculated in the following way:

First-order linear:
$$\varepsilon_{ASC,b_i} = c_i \frac{b_i}{ASC} \qquad (8)$$

First-order log-linear:
$$\varepsilon_{ASC,b_i} = c_i \qquad (9)$$

Second-order

$$ASC = c_0 + \sum_{i=1}^{19} c_i b_i + \sum_{\substack{i,j=1 \\ i \leq j}}^{19} d_{ij} b_i b_j + e \tag{10}$$

Equations (5)-(7) are estimated using the 10,000 parameter sets and the implied *ASC*-values. The R^2s are 0.986 (linear), 0.954 (log-linear), and 0.999 (second-order). In the linear case, all 20 coefficients are significant at least at the 99% level. In the log-linear case, 18 out of 20 coefficients are significant at least at the 99% level and one coefficient is significant at the 95% level. In the second-order approximation, 155 out of 210 are significant at least at the 95% level and 165 at least at the 90% level.

Derived Sensitivity elasticities are presented in table 4. In the case of the log-linear response function, the mean is the estimated coefficient and the standard deviation is its standard error. In the case of the linear first-order and the trans-log second-order approximation, the mean and the standard deviation are calculated from 10,000 values derived from the 10,000 normal distributed parameter sets and equations (9) and (10). Therefore, the standard errors of the log-linear regressions and the standard deviations from the other two cases have to be compared with some caution. The elasticities derived with these three different methods all have the same signs. For most cases the values are relatively similar between the log-linear and the linear approximation. The elasticities derived from the second-order approximation are in most cases larger than those derived from the two alternative first-order approximations. However, they are also in a wider range and therefore statistically less often significantly different from zero. All three approaches identify the Lerner index for the operating inputs industry and the agricultural share of expenditures for bread grain products as the parameters with the most significant influence on the results.

Table 4. Sensitivity elasticities

Model parameters	Symbol	Log-linear	Linear	Second-order
Supply elasticities of agricultural input factors				
Land	ε_A	**0.015**	**0.018**	**0.021**
Labour	ε_B	**0.099**	**0.107**	**0.129**
Durable investments	ε_G	**0.040**	**0.044**	**0.081**
Operating inputs	ε_H	**0.106**	**0.111**	**0.196**
Supply elasticities of food industry input factors				
Labour	ε_J	**0.017**	*0.020*	0.030
Capital	ε_K	**0.030**	**0.032**	*0.060*
Cost shares of agricultural input factors				
Land	α_A	**-0.023**	**-0.024**	-0.027
Labour	α_B	-0.013	**-0.015**	-0.036
Durable investments	α_G	**0.030**	**0.026**	0.029
Cost shares of food industry input factors				
Labour	α_J	**-0.020**	**-0.025**	-0.017
Substitution elasticity of bread grain production	σ_S	**0.009**	*0.008*	0.009
Substitution elasticity of food production	σ_F	**0.921**	**0.919**	**0.955**

Demand elasticity of bread grain for feeding	η_E	**0.405**	**0.431**	**0.252**
Demand elasticity of bread grain at the consumer level	η_F	**0.175**	**0.189**	**0.216**
Lerner indices				
Operating inputs industry	L_F	**1.739**	**1.745**	**2.123**
Agricultural investment goods industry	L_G	**0.212**	**0.209**	**0.348**
Food industry	L_H	**0.525**	**0.525**	**1.120**
Agricultural share of expenditures for bread grain products	λ	**1.909**	**1.897**	**2.376**
Cost of public funds	MCF	**0.012**	**0.026**	0.033

Bold values indicate a significant difference from zero at the 95% (90%) level

5. Discussion

In general, governments defend their policy as efficient in common political statements. Utilizing a three-stage vertically-structured model including upstream and downstream industries it is shown over a wide range of possible model parameter values that the Austrian bread grain policy in 1991 to 1993 was quite inefficient in meeting its two main objectives, namely supporting farm income and self-sufficiency. In fact, the social cost could have been reduced on average by more than 57% by using the same policy instruments, but at optimal levels.

Observing that government was inefficient in achieving the main explicitly stated objectives requires some rationalization. Five rationales are given here:

1) <u>Uncertainty about demand and supply:</u> Demand, but especially supply of agricultural products is influenced by changes in exogenous factors which government can not fully anticipate. An efficient policy in one year, might be inefficient (to some extent) in another year with some unexpected exogenous shock. However, in the case of the Austrian bread grain market before EU accession no such extreme exogenous shift in demand or supply appeared and changing weather conditions are controlled to some extent by taking three year averages.
2) <u>Uncertainty about policy effects:</u> Government can not perfectly anticipate how a change in policy will influences the behavior of individuals and firms. Hence, the actually observed policy will never exactly match with the ex-post algebraically optimal policy. However, the large estimated difference in social cost between the actual and the optimal policy outcome raises the question if this rational is the only (main) sources of observed inefficiencies.
3) <u>Policy inertia:</u> The static analysis carried out in this study neglects that government can not only choose the type and levels of policy instruments, but also the point in time at which a policy is changed. Therefore, at each point in time government has to decide if the cost of changing a policy are higher or lower as the cost of having a suboptimal policy in place. Only if the latter is true government will change its policy.
4) <u>Path dependency:</u> Today's policy depends to some extent on yesterday's policy (Koester, 1997). In addition, smaller reforms are usually easier realized than

large ones. The floor price policy observed in many agricultural markets of developed countries were born and breed from food shortage after World War II. Higher producer prices have stimulated investments and production and a supply shift. The same is true for the case of bread grain in Austria. From the end of the 70's supply exceeded demand and production surplus and expenses for export subsidies increased. However, at that time producers were used to and consumers were no longer aware of the high prices of agricultural products and government tried to tame the increasing surplus production by minor adjustments like the introduction of the co-responsibility levy in 1979 or the change to a two-price plan (a higher floor price for a certain amount of bread grain under a quota and a lower floor price for the rest) rather than a radical change in the support system.

5) Implicit policy objectives: From a political economy point of view, government does not act like a benevolent dictator, but rather tries to maximize its probability to stay in power. Hence, instead of (or in addition to) following the explicit (official) objectives, it also has implicit (not officially mentioned) policy objectives. For example, Salhofer, Hofreither and Sinabell (2000) discuss that beside farmers, upstream and downstream industries had considerable formal (institutionalized) and informal influence in the agricultural policy decision-making process in Austria. Moreover, they confirm that upstream and downstream industries clearly benefited from the existing policy. Therefore, one could argue from a political economy point of view that support of upstream and downstream industries were never an explicit official goal of farm policy, however, political pressure from this group has made it to an implicit policy objective.

The results derived in this study are based on relatively new and computer intensive simulation and sensitivity-analysis techniques which obviously become more important in policy analysis. Ranges of parameter values, rather than a few specific values are computed. Therefore, instead of producing one (or a few) specific but highly uncertain number(s) about the effect of a policy, we are able to give a plausible range as well as a mean. Although this is clearly an improvement from the academic point of few, it might be a challenge to sell such results in policy consulting. We show the importance of parameter values on model results as well as the degree of uncertainty that remains given the uncertainty about parameter values. For example, we estimate the 75% probability interval of the avoidable social cost between € 63 million and € 119 million.

We also use surface response functions to identify those parameters with the strongest influence on our results. So far, three different forms of such surface response functions have been used in the literature: log-linear and linear first-order approximations as well as a second-order trans-log approximation of the nonlinear relation between model parameters and derived policy measure. We have shown that the utilized surface response function can significantly influence the derived sensitivity elasticities. This is definitely an area of future research.

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