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the available stock will last.

The social economic importance of the consumption of natural gas follows from the fact that its (social) costs are lower than those connected with the consumption of competing fuels. Part of this difference, depending on the price to be paid for the gas, takes the form of benefits to the consumers, here to be called consumers' surplus. The remaining part will accrue as net revenue to the sellers of the gas.

In this study mainly the social aspect has been considered, although this objective is still rather complex. It seems reasonable to adopt a preference function where the consumers' surplus and the Government share are weighted appropriately. In order to simplify matters the social importance of the profit accruing to the private exploiters has been neglected.

The model consists of 8 equations. The first equation states that the total stock of gas equals the accumulated annual sales during the period of exploitation. Annual sales are defined in equation 2 as total energy consumption multiplied by the product of the potential share of gas and density. The potential share of natural gas is a function of profit per m^3 , p , the difference between the equivalence price of natural gas and the total costs of production and distribution of natural gas. The (uniform) variable p may be conceived of as an action parameter in the model [eq. (3)]. Total energy consumption — defined as the maximum potential demand for gas — is assumed to increase at a constant rate of growth [eq. (4)]. The annual private profits and the consumers' surplus are defined in equations (5) and (6) respectively. Equation (7) represents the preference function, while the last one defines the present value of the stock in terms of the weighted national benefits. It is this quantity that has to be maximized by choosing an appropriate value of the variable p . In general no direct solution is possible and numerical methods have to be applied; there are, however, exceptions for special cases.

The outcomes of the model for optimal price, period of exploitation and value of the stock are heavily depending on the values to be attached to the weights in the preference function. Regardless of the true values of the weights the following general conclusions may be drawn from the model, *ceteris paribus*. When the stock is larger the optimum price tends to be lower. A higher rate of discount works in the same direction. A higher growth rate of potential demand for gas and an increased density will have an opposite effect on the optimal price.

It must be stressed here once more that the model analyzes the long-term aspects of the optimal price policy only. In the short run, other circumstances may also play a more or less important role.

¹The authors are stressing explicitly that this paper expresses their own opinions only.

Analytic Techniques for the Study of World Wide Air Line Competition, Harlan D. Mills, IBM

Computational game theoretic techniques have been developed and applied to route simulation models of world wide air line competition in order to provide information for U. S. government policy decisions in the development of advanced transport aircraft, particularly with respect to (1) supersonic

transports (up to 1800 miles per hour) (2) very large subsonic transports (up to 800 seats) (3) more modest extensions of current transports. The models use noncooperative (Cournot) equilibrium theory over a network of some 400 air routes to estimate the competitive behavior of some 30 airlines in varying degrees of competition with each other over their authorized routes and with varying motives ranging from pure economic to national prestige or national service. The objective of the models is to estimate the ultimate effects of cost and performance on aircraft demand in competition with other future aircraft, as this demand is reflected through aircraft procurements by airlines as they compete to anticipate and satisfy consumer demand for air travel.

The route simulation models require four principal types of information:

1. Demographic data underlying air passenger/freight demand between major world city pairs in period 1970-2000.
2. Engineering data underlying cost/performance of various future aircraft.
3. Airline data describing motivations/resources of international competing airlines.
4. Regulatory data regarding airline route authorizations, fare levels, etc.

With this information two major interacting phenomena are simulated, route by route:

1. Flight scheduling of various types of aircraft by authorized airlines to maximize their performance against competing services.
2. Passenger selection of flights, based on convenience, economy, airline image, etc.

Noncooperative (Cournot) equilibrium in airline behavior is determined by methods of fictitious play (iterative procedures), and route by route results are aggregated into airline system operations, passenger service levels, and worldwide aircraft requirements, by type, over the period of time in question.

AGGREGATION

Embodied Technical Change and the Existence of An Aggregate Capital Stock,
Franklin M. Fisher, Massachusetts Institute of Technology

This paper is concerned with the construction of aggregate production functions when labor is optimally allocated to different kinds of capital so as to maximize the output of an homogeneous product. The discussion is carried on in the context of Solow's model of embodied technical change but the results are applicable in a considerably wider context. In the embodied technical change context, the question becomes that of the necessary and sufficient characteristics of such change which permit the value of output when maximized to be written as a function of a capital aggregate and total labor.

We first examine the case in which each production function involves