DE ECONOMIST 130, NR. 1, 1982

THE EXPLOITATION OF DUTCH NATURAL GAS: AN ALTERNATIVE APPROACH**

BY

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1 INTRODUCTION

The 1973 oil crisis was an annoying incentive for a reconsideration of the role of energy in the economy. This reflection has extended to many areas, among which are economic theory and economic policy. In economic theory Hotelling's (1931) classic work on the economics of exhaustible resources enjoyed a great revival, comparable to the renewed attention for Ramsey's (1928) contribution on growth economics in the 1960s. With respect to economic policy, governments woke up to the fact that it had become necessary to develop a strong energy policy. Many international organizations were founded to coordinate the actions taken by member countries.

In the present paper we shall discuss government policy. Inasfar as practical recommendations are concerned, we shall restrict ourselves to the Netherlands, although the analysis could be applied to other (small) countries as well.

Dutch energy policy is based on the 'Nota energiebeleid' by the Minister of Economic Affairs (1979). A large part of this report is devoted to an analysis of the international and domestic energy situation. Many recommendations concerning the conservation of energy are made. The central objective of energy policy is defined to be the reduction of oil dependence. An appendix to the report briefly describes a model designed by the Central Planning Bureau to aid energy policy.

In section 2 we shall go into this model and its results are examined.

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** I am indebted to J.S. Cramer, R. Ramer, and C. Weddepohl for helpful comments and to A. Stokman and T. v.d. Mey who assisted in the calculations. All remaining errors are mine.

Section 3 is devoted to some critical comments on the model used. In section 4 an alternative model, which is in our opinion better suited for designing energy policy, is constructed by way of example. In section 5 some exercises are performed with the model, and section 6 contains the conclusions.

2 THE CENTRAL PLANNING BUREAU SCENARIOS

In this section we will try to describe the model developed by the Central Planning Bureau (C.P.B.) in support of Dutch energy policy. The description is short and rather imperfect, as the report on energy policy does not contain more information.

As is usual in long-term models, it is assumed that no disasters or technological breakthroughs will occur. The main point of departure is that gross national product grows by some given percentage annually. In one version the growth rate is set equal to 2% (the so-called low scenario); in an alternative version it is 3% (the so-called high scenario). These growth rates do not apply uniformly to the different sectors of the economy but the distribution over four large sectors is as shown in Table 1.

TABLE 1 – GROWTH RATES OF PRODUCTION IN FOUR SECTORS OF THE ECONOMY

	High scenario			Low scenario		
	1977/85	1985/90	1990/2000	1977/85	1985/90	1990/2000
Agriculture	3	3	3	3	3	2.5
Industry	4.5	4.5	5	3.5	3	3.5
Construction	2	0.5	0.5	1.5	0	0
Services	3.5	3	3	3	2	2
Natural gas	−1.9	−3.2	−5.3	−1.9	−3.2	−5.3
Total	3.5	3	3.5	3	2	2

Source: 'Report on Energy Policy.'

There is some argument underlying this distribution, which will be presented below. The causes of the overall growth rates are not given. From the growth rates specified above, exports and imports by firms are derived in a way which is not described. Figures for energy demand by households and firms are presented next. These are based on the expected number of houses, the penetration rate of central heating and on the expected number of private cars, among other things. Moreover, it is assumed that demand for some products such as electrical equipment is reaching a satiation level. Another assumption is that the real oil price, which also influences energy demand, will increase by 1% annually from 1977 to 1990 and by 2% afterwards. Demand by firms depends on output through the energy-intensity per sector. Demand figures are given in Table 2.

TABLE 2 – DEMAND FOR ENERGY IN P JOULES

	1977	1985 High	Low	1990 High	Low	2000 High	Low
Housholds + government							
– Heating	376.8	554.3	544.3	607.1	607.1	703.4	703.4
– Transport	92.1	113.0	108.9	121.4	113.0	129.5	117.2
– Other	188.4	217.7	217.7	238.7	238.7	268.0	268.0
Total	657.4	875.1	870.9	967.2	958.8	1101.2	1088.6
Firms:							
– Industry	904.4	1478.0	1281.2	1825.5	1486.4	3056.5	2106.1
– Services	205.2	284.7	276.3	322.4	305.7	443.8	381.0
– Agriculture	108.9	142.4	142.4	167.5	163.3	226.1	213.5
– Construction	37.7	41.9	41.9	46.1	41.9	46.1	41.9
– Transport	242.8	330.8	314.0	385.0	364.3	540.1	489.9
Total	1498.9	2277.7	2055.8	2763.7	2361.5	4312.6	3232.4
Final domestic use	2156.3	3152.8	2926.7	3713.9	3320.3	5413.8	4321.0
Energy sector	494.1	640.6	762.0	762.0	669.9	1130.5	896.0
Total domestic use	2650.4	3793.4	4475.9	4475.9	3990.2	6544.3	5217.0

Source: 'Report on Energy Policy.'

In the 'Report on Energy Policy' a large number of recommendations is made in order to save energy. We shall not go into the measures proposed. If the recommendations are succesfully implemented the picture drastically alters (Table 3). Demand has to be met by coal, oil, natural gas, nuclear energy and other sources of energy. With respect to *natural gas*, the Slochteren deposit occupies a special position, as it constitutes a reliable component in the Dutch energy supply. Elsewhere in the report it is stated that this deposit can fulfil three functions: it can be used in critical situations, during peak demand, and as a reserve for future generations. Policy is directed towards letting it fulfil these requirements as long as possible. More concrete supply figures can be found in the annual plans of sales of natural gas by Gasunie.[1] These figures indicate that about half of the 1975 reserves

1 Gasunie is a semi-governmental firm, buying, selling and distributing natural gas.

will remain after 2000. This policy will require large efforts to obtain natural gas on the world market and in exploration activities, since apart from the objective defined above, households and advanced industrial applications will continue to be supplied by natural gas. The use of natural gas by electricity plants will not be expanded for the time being. The contribution of *coal* will increase: all electricity plants which are to be build before 1990 will use coal as input, and the share of coal in industrial applications will become more substantial. Electricity plants which will be constructed after 1990 will use *uranium* as input in one version and coal in an alternative version. The contribution of non-conventional energy remains moderate. Finally, oil equilibriates the energy account (Table 4). A large part of this energy will have to be imported and therefore one could expect that the current account of the balance of payments would deteriorate seriously. But the growth figures in Table 1 are chosen such that this will not occur. Neither will there be excessive unemployment nor a too large budgetary deficit.

TABLE 3 – DEMAND FOR ENERGY IN P JOULES

	1977	1985 High	1985 Low	1990 High	1990 Low	2000 High	2000 Low
Housholds + government							
– Heating	376.8	460.6	460.6	443.8	443.8	418.7	418.7
– Transport	92.1	108.8	104.7	108.6	104.6	113.1	100.5
– Other	188.4	213.6	213.5	213.6	213.6	213.6	213.6
Total	657.4	783.0	778.8	766.2	762.0	732.6	732.8
Firms:							
– Industry	904.4	1360.8	1197.5	1591.0	1323.1	2294.5	1679.0
– Services	205.2	251.2	247.0	259.6	251.3	305.6	268.0
– Agriculture	108.9	125.7	125.7	134.0	129.8	154.9	146.5
– Construction	37.7	41.9	41.9	46.1	41.9	46.1	41.9
– Transport	242.8	326.6	309.8	372.6	351.1	502.4	456.4
Total	1498.9	2106.2	1921.9	2420.3	2097.8	3303.5	2591.8
Final domestic use	2156.3	2889.0	2700.7	3186.5	2859.8	4036.1	3324.6
Energy sector	494.1	607.1	577.8	674.1	602.9	875.1	716.0
Total domestic use	2650.2	3496.1	3278.5	3843.7	3462.7	4923.9	4040.6

Source: 'Report on Energy Policy.'

TABLE 4 –TOTAL USE OF ENERGY-BEARERS IN P JOULES

High scenario	Coal	Oil	Gas	Nuclear	Other	Total
1977	134.0	1067.7	1394.2	46.1	8.4	2650.4
1985	297.3	1741.7	1406.8	41.9	8.4	3496.1
1990	481.5	1896.7	1415.2	41.9	8.4	3843.7
2000	1117.9–531.7	2411.7	1277.0	41.9–628.1	75.4	4923.9

Low scenario	Coal	Oil	Gas	Nuclear	Other	Total
1977	134.0	1067.7	1394.2	46.1	8.4	2650.4
1985	297.3	1524.1	1406.8	41.9	8.4	3278.5
1990	376.8	1620.4	1415.2	41.9	8.4	3462.7
2000	858.3–389.4	1787.8	1277.0	41.9–510.8	75.4	4040.4

Source: 'Report on Energy Policy.'

3 SOME COMMENTS

In this section we briefly comment on the way energy policy described above is established and suggest an alternative approach to the problem at hand. Since the model used has not been made public and since not all outcomes are given, we are left with two scenarios which are feasible, in the sense that they obviously satisfy the constraints imposed by the model, and which seem to be acceptable to policy makers: the outcomes given above imply a certain rate of unemployment, some deficit on the government's budget, some surplus or deficit on the current account, and a certain growth rate of non-energy consumption, conditions which are satisfactory from the point of view of the policy makers. The public, however, does not know the values of these variables, despite the fact that these may be more important to it than the figures representing the use of energy. The report gives only two possible long-term courses for the Dutch economy, whereas alternatives are not discussed.

Secondly, the question arises whether the outcomes *are* satisfactory. There are five accepted objectives of social economic policy: full employment, stable prices, a fair income distribution, a satisfactory growth of per capita welfare and a steady course of the balance of payments. The main objective of energy policy is formulated as the reduction of oil dependence.

Confronting this aim with the results which would be reached as a consequence of this policy (Table 4), we easily see that the share of oil in total energy supply increases from 40% in 1977 to almost 50% in 2000 in the high scenario and to 45% in the low scenario. Hence the aim is not reached. Another point is that large energy imports have to be compensated by large non-energy exports. Given the relatively small growth rates for output this probably does not leave much for non-energy consumption, which could conflict with an objective of social economic policy, *viz.* the one which refers to the course of per capita welfare. Therefore we conclude that energy policy does not adequately take into account the social economic framework, and that it may render results which are inconsistent or may conflict with macroeconomic objectives.

Finally, one would think that energy policy would also *develop* a policy related to exploitation of energy. However, exploitation policy is based on the plans of sales of natural gas by Gasunie, which hardly take into account the macroeconomic ideas underlying the C.P.B. model.

In our view, a better way to tackle the problem is to specify *a priori* the general objectives of social-economic policy, either as constraints in the model or as targets and to derive from them the actions to be taken by the government concerning exploitation and energy savings. In the following we shall present such a model by way of example. Emphasis will be put on exploitation. In particular, it will be shown that in the context of the model, the rate of exploitation is a consequence of social-economic policy and cannot be determined from outside the model.

4 THE MODEL

The model gives a strongly aggregated picture of possible long-term time paths of the Dutch economy. Apart from labour, which is assumed to be homogeneous, there are two commodities: energy and the aggregate of other commodities, which we shall call 'good 1.' Energy presents itself in several forms. Therefore, some adjustments of the data are necessary in order to define an aggregate. The thermal value of the primary energy consumption is known: this is the thermal value of domestic exploitation of natural gas and crude oil plus imports of crude oil mainly, minus exports of natural gas and oil products. In converting primary energy into energy in its final form, some energy is lost. We assume that the conversion loss per final calorie is the same for all final uses. All final use can be expressed in thermal values embodied in the primary sources of energy. For details we refer to Appendix A.

In the model, five sectors are distinguished: households; government; the energy sector; the other firms; and the other countries. Households supply labour and demand energy and good 1. The government demands labour, energy and good 1. The energy sector consists of the oil products industry, the exploitation of natural gas, and public utilities. This sector produces natural gas, converts primary energy and imports and exports energy. The foreign countries import and export good 1 and energy. The other firms produce good 1 and demand labour and energy.

The basic ideas of the model can now be easily presented. The supply of labour is exogenous. It is assumed that employment in firms is constant and that the government 'absorbs' the remaining part. Good 1 is produced according to a C.E.S. production function having labour and capital as inputs and possibly exhibiting technical progress. Output is allocated to households, government, the foreign sector (exogenously), and to gross investment. The existing capital stock plus investment determine next year's output. Imports of good 1 are a constant proportion of output. Producing good 1 also requires energy; the necessary amount is not a function of output, as is usually assumed, but we assume that the capital stock is productive only if energy is allocated to it. This assumption not only facilitates the exercises but it is also in some respects in accordance with the findings of Magnus (1979). Non-energy consumption by households and the government induces their demand for energy. This demand and the demand by firms can be influenced by the given relative world market price of primary energy. A given fraction of non-energy consumption has to be imported. When we assume that the surplus on the current account of the balance of payments in terms of net national income is constant, then the amount of energy to be imported or exported follows. Given the domestic use of energy, the necessary exploitation of domestic natural gas reserves can then be calculated.

By $C(t)$ we denote the consumption of good 1 by households and the government in year t. These consumption goods originate partly from domestic production ($C_f(t)$) and partly from the foreign sector ($C_m(t)$):

$$C(t) = C_f(t) + C_m(t). \tag{1}$$

We assume that imports of good 1 for consumption purposes are a constant fraction δ of total consumption (hence substitution effects are assumed away):

$$C_m(t) = \delta\, C(t). \tag{2}$$

The consumption of energy by households and government is denoted by $E_g(t)$. It is assumed that this is a function of the consumption of good 1 and of the relative world market price of energy (P).

$$E_g(t) = \beta C^{\theta}(t) P^{\pi}(t), \tag{3}$$

where $\beta > 0$, $\theta > 0$, $\pi < 0$. A higher relative price of energy may induce households to consume less and it may also induce the energy sector to convert more efficiently. The dependence of energy use on consumption seems rather plausible: private cars require gasoline, refrigerators require electricity, etc. The households supply labour to the government and to the producers of good 1, but not to the energy sector nor the foreign sector. The total supply of labour is exogenous as well as the supply of labour to firms (L_f). Let a bar above a variable indicate that it is exogenous. Then we may write:

$$L_f(t) = \bar{L}_f(t). \tag{4}$$

We now give an outline of the non-energy production sector. This sector produces good 1. Output ($Q(t)$) is allocated to households and government ($C_f(t)$), investments ($K(t+1) - K(t) + \mu K(t)$) and exports ($X_f(t)$). μ is the constant rate of depreciation. Exports are considered exogenous.

$$Q(t) = C_f(t) + \bar{X}_f(t) + K(t+1) - K(t) + \mu K(t). \tag{5}$$

There are four factors of production: capital (K), labour (L_f), imports (M_f) and energy (E_f). We assume that imports are in fixed proportion to production. For the Netherlands there is some evidence (see Magnus (1979)) that energy and capital are complements. As in the case of household demand, we assume that some savings can be induced by an increasing relative price of energy. We do accept substitutability between labour and capital. We assume a C.E.S. production function that possibly exhibits technological progress. Hence:

$$Q(t) = (1+\chi)^t A[\alpha((1+\zeta)^t K(t))^{-\rho} + (1-\alpha)((1+\xi)^t L_f(t))^{-\rho}]^{-1/\rho}, \tag{6}$$

$$E_f(t) = \phi K^{\sigma}(t) P^{\eta}(t), \tag{7}$$

$$M_f(t) = \epsilon Q(t), \tag{8}$$

where χ, ζ, ξ, α, ρ, ϕ, ϵ and A are positive constants and η is a negative constant.

The energy sector can now be considered. The final use of energy is defined as the energy consumption by households, the government and the good 1 producing firms (E_g (t) + E_f (t)). Domestic final use plus exports (E_x (t)) must equal the exploitation of energy (E_b (t)) plus imports (E_m (t)):

$$E_f(t) + E_g(t) + E_x(t) = E_b(t) + E_m(t). \tag{9}$$

The energy sector is engaged in exploitation. Let $R(t)$ be the pool of energy and let the initial pool be given; we then have:

$$R(t+1) - R(t) = -E_b(t), \quad R(0) = \overline{Ro}. \tag{10}$$

For the Dutch situation, one must distinguish between energy exports according to long-term contracts, which were made at the beginning of the 1970s, and other energy exports. The difference is important because the price of the 'contractual' exports is much lower.

$$E_x(t) = E_x'(t) + \overline{E}_a(t), \tag{11}$$

where $\overline{E}_a(t)$ is exports of energy on long-term contracts. These exports are exogenous. E_x' (t) denotes the other energy exports.

For good 1 and energy there are world markets. The prices that come about on these markets are considered given to our economy. Good 1 is chosen to be the *numéraire* and its price is set equal to 1. The price of contractual exports is denoted by P_a (t). It is taken to be exogenous.

$$P(t) = \overline{P}(t), \tag{12}$$

$$P_a(t) = \overline{P}_a(t). \tag{13}$$

We ignore income transfers from and to the foreign sector and governmental exports. Let $S(t)$ denote the surplus or the current account of the balance of payments, then:

$$S(t) = \overline{X}_f(t) - C_m(t) - M_f(t) + P(t)\,(E_x'(t) - E_m(t)) + P_a(t)\overline{E}_a(t). \tag{14}$$

We now define net national income in world market prices ($Y(t)$):

$$Y(t) = C(t) + C_o(t) + K(t+1) - K(t) + \overline{X}_f(t) - M_f(t) - C_m(t) + P(t)(E_x(t) - E_m(t)) + \overline{P}_g(t)E_g(t) + P_a(t)\overline{E}_a(t). \quad (15)$$

Here C_o is the non-material government consumption. $\overline{P}_g(t)$ is the price of household and government energy demand. In the calculations that follow, it differs from $P(t)$ since the data do not allow us to distinguish between the pure energy part and the rents of heating equipment, etc. For simplicity we assume that non-material government consumption is a constant proportion of net national income:

$$C_o(t) = \psi\, Y(t). \quad (16)$$

For $S(t)$ we assume that development aid requires a fraction ν of net national income:

$$S(t) = \nu\, Y(t). \quad (17)$$

This is the model. It is easy to show how the model can be used for designing energy scenarios. Let us therefore consider again the central and accepted objectives of economic policy: full employment, stable prices, a steady course of the balance of payments, a fair income distribution, and a satisfactory growth of per capita national income. If one agrees that a steady course of the balance of payments is reflected when a surplus exists on the current account amounting to a certain constant proportion of net national income, when the objective of having stable prices implies that domestic prices follow world market prices which are given to the economy, when full employment is conceived in such a way that this aim is satisfactorily realised if employment in firms remains constant, then the model is capable of indicating how the economy (the energy sector included) will develop in time when the final objective is formulated as a certain annual growth rate of non-energy consumption (the income distribution does not enter into the model). As will be shown below, the model contains only one degree of freedom and the growth rate of non-energy consumption determines the time path of all variables. The rate of exploitation of natural gas reserves is also endogeneous. We can also examine the sensitivity of the outcomes to variations in the parameters of the model. On the basis of such an analysis, an energy policy might be designed which, for example, emphasizes influencing price elasticities.

Admittedly the merits of such exercises (which will be performed in the next section) should not be overestimated. The model is largely technical in nature and is rather primitive, and the coefficients used are highly uncertain. Moreover, if one should wish to implement the outcomes of some scenario, large difficulties may arise. However, many of these objections apply to all existing long-term models. Furthermore, our model is meant to be a first attempt to tackle the problem in a consistent way.

5 THE SIMULATION

5.1 *Introduction*

In this section, the results of some simulations will be given. For convenience' sake, we reproduce the model first, after elimination of a number of identities. Please recall that barred variables like $\overline{P}$ are exogenous.

$$C = C_f + C_m, \tag{1}$$

$$C_m = \delta C, \tag{2}$$

$$E_g = \beta C^{\theta} P^{\pi}, \tag{3}$$

$$Q = C_f + \overline{X}_f + K(t+1) - K(t) + \mu K(t), \tag{4}$$

$$Q = (1+\chi)^t A\,[\alpha((1+\zeta)^t K)^{-\rho} + (1-\alpha)\,((1+\xi)^t \overline{L}_f)^{-\rho}]^{-1/\rho}, \tag{5}$$

$$E_f = \phi K^{\sigma} \overline{P}^{\eta}, \tag{6}$$

$$M_f = \epsilon Q, \tag{7}$$

$$E_b = E_f + E_g + (E_x' - E_m) + \overline{E}_a, \tag{8}$$

$$R(t+1) - R(t) = -E_b, \tag{9}$$

$$S = \overline{X}_f - C_m - M_f + \overline{P}(E_x' - E_m) + \overline{P}_a \overline{E}_a, \tag{10}$$

$$Y = C + C_o + K(t+1) - K(t) + \overline{X}_f - M_f - C_m + \overline{P}_g E_g + \overline{P}(E_x' - E_m) + \overline{P}_a \overline{E}_a, \tag{11}$$

$$C_o = \psi Y, \tag{12}$$

$$S = \nu Y. \tag{13}$$

Altogether there are 13 equations and 15 endogenous variables *viz.*

C	E_g	E_x'	Q	S
C_f	E_f	E_b	K	Y
C_m	E_m	R	M_f	C_o.

Since no distinction can be made between imports of energy and 'free' exports of energy, we may determine the behaviour of the economy as described by the model for the given initial values and the given course of the exogenous variables provided only one further variable is set in advance. We select total consumption (C) to this end and extrapolate it by applying a 2% growth rate to the known initial value. We may then calculate a simulated path of the economy over, for example, the forty years following the base year 1975, proceeding as follows. From K (o) we are able to calculate the output of good 1 (5). From (4) the new stock of capital can be derived because by (1) and (2), C_f is known. It is then easy to calculate the use of energy by households and firms (E_g and E_f) from (3) and (6). Also the imports of good 1 by firms (7) and households (2) are known. Then it is necessary to find Y. (10)–(13) imply that

$$Y = (C + K(t+1) - K(t) + \overline{P}_g E_g) \,/\, (1 - \nu - \psi),$$

as can be verified by straightforward calculations. Then S follows from (13). $E_x' - E_m$ will be known as soon as S is known. Finally, using this result and (8) the exploitation (E_b) can be calculated as well as the new pool of energy.

In order to understand the results without going through Appendix A, it is useful to give the course of some important exogenous variables and parameters. The relative world market price of energy is assumed to increase by 8% annually in the first 5 years. In these years, the price of energy consumption by households increases by 5% annually and the price of contractual natural gas exports by 10%. For the remaining part of the simulation period, these growth rates are 2%, 1.5% and 4% annually. The price of contractual exports is not allowed to overtake the world market price. The growth rate of non-energy exports is set equal to 3% per annum. Hicks-neutral technical progress amounts to 2% annually. Price elasticities of energy demand by households and firms are -0.4. This is roughly in accordance with the figures used in the report (see p. 62). The surplus on the current account assumes its 1975 value and amounts to approximately 4%.

5.2 *The Results of the Simulations*

5.2.1 The basic scenario

A description will be given below of the so-called basic scenario in which the annual growth rate of private non-energy consumption is 2%. A complete numerical description is found in Appendix B. The stock of capital is monotonically increasing from 380 to 1210 in 2015. Its growth rate is, however, very moderate. This is caused by the small technical progress. Net investments tend to decrease. The use of energy by households initially decreases as a consequence of the large price increases of energy; after 1981 it slowly increases. In the forty years we are considering energy demand increases by 50%. Also the use of energy by firms shows a very low growth rate. Net national income grows steadily (to about double) which implies that the surplus on the current account of the balance of payments should grow in a moderate way. But as non-energy exports grow by 3% annually, this implies that imports of energy can be relatively high. This effect causes a decreasing rate of exploitation. Heuristically and rather informally, the reasoning is as follows: The annual growth rates of non-energy consumption and non-energy exports do not leave much room for net investment, given 2% technical progress. Hence non-energy output increases by approximately 2% per annum, as do non-energy imports. Hence the gap between non-energy exports and imports grows rather rapidly. Since net national income cannot grow much faster than by 2% per annum (see equation 14), the surplus on the current account should only grow moderately. In our case, this implies that the volume of energy imports should increase. Given the rather minor increase of energy use by households and firms, this implies that the rate of exploitation can decrease. In our case, exploitation becomes negative in 2009 – which means that energy is accumulated! Of course, this is not feasible, but the problem can be easily solved by relaxing the constraint that non-energy consumption is in fixed proportion to domestic non-energy production and by increasing the prescribed growth rate of non-energy consumption.

If one would look forward only until 2000, then in this model about 1/3 of the initial pool of natural gas would remain at that time. This is less than in the 'Report on Energy Policy,' but one should be aware that after 2000, less and less will be exploited. From this basic scenario we conclude that under our assumptions, a 2% annual growth rate of non-energy consumption can be attained by the Dutch economy.

A final remark: the model does not provide any reason to advocate non-conventional energy. Dutch natural gas reserves and our assumption on the growth rate of non-energy exports are sufficient to guarantee the attainability of 2% annual growth rate of non-energy consumption.

5.2.2 A sensitivity analysis

The parameters of the model are $\alpha, \beta, \delta, \eta, \theta, \zeta, \mu, \nu, \pi, \rho, \sigma, \phi, \psi, \chi, \xi$ and A. The exogenous variables are P_e, P_g, X_f, E_a and C. Some of these parameters or exogenous variables might be subject to government policy, others might not. The autonomous exports of natural gas can hardly be manipulated. The same goes for the world market price of energy. Furthermore, for the time being, it seems very hard to model the parameters referring to the technology endogeneously. It would therefore seem that it is useless to investigate the sensitivity of the outcomes of the model for variations in these parameters and exogenous variables. In our case, however, this is not true. The estimates of these parameters bear much uncertainty and it therefore makes sense to find out how the model would operate if we had made mistakes in the estimation. It is also interesting to see the impact of, for example, smaller price increases. Other parameters and exogenous variables can be influenced directly or indirectly. Exports, for example, might be stimulated to some degree, or the government might aim at increasing the sensitivity for energy prices. In these cases errors might also have been made in the estimation. We will consider the latter group first. Unless it is explicitly stated, the parameters and exogenous variables will take the value which they had in the basic scenario.

– The growth rate of non-energy consumption.

The first simulation refers to changes in the growth rate of non-energy consumption. The 2% growth we have postulated before was a possible concrete formulation of one objective of economic policy. But one could as well try to set the target at a higher level or be satisfied with less consumption. It turns out that *ceteris paribus* a 2% growth rate should be considered as a maximal long-term growth rate since when we put it equal to 3% or 4%, the stock of capital would become negative in 2011 or 1998 respectively. Apparently the technology does not allow 3% growth of consumption *and* of non-energy exports.

If the growth rate is set equal to 0% or 1%, we have the reverse effect. There is very fast accumulation of capital. Obviously, this result is absurd in the sense that society would never choose such a course for its economy, as the accumulation of capital as such does not serve any goal. Therefore we have made a side-step which seems to be interesting. We have investigated the effects of reducing the labour time by 1% annually, given stationary non-energy consumption. The results are striking. If there is no reduction of labour time, the final stock of capital would be 2323 in 2015, but if labour time is reduced by 1% annually it is only 424.

There are some other effects. In the former case, national income keeps growing since there are net investments; in the latter case it decreases. This implies that development aid funds diminish, but we also see an enormous accumulation of energy (from 1988 on) because of the balance of payments condition. We therefore conclude that in the case of labour time reduction the balance of payments condition deserves closer examination: first, since the accumulation of energy is useless in the long run; second, because development aid is reduced, which cannot have been the intention when the objective concerned was formulated.

– The growth rate of non-energy exports.
In the basic scenario, exports grow by 3% annually. If the growth rate would be 4%, keeping the other growth rates in the model constant, there will be less capacity for investment and in fact the stock of capital will become negative in 2007. Obviously, this outcome will never occur. If, on the other hand, the growth rate is lower than 3%, say 2%, there will be a rapid accumulation of capital. Then energy demand by firms will grow rapidly as well as net national income, since net investments increase. This latter effect causes the necessity of a larger surplus on the current account, which has to be accomplished through decreased energy imports. In fact, the Netherlands would have to become a net exporter of energy, which implies in this case that the pool of natural gas will be depleted in 1996. It follows that in the model the growth rate of non-energy exports plays a crucial part. Exporting more than in the basic scenario does not seem feasible in view of the productive capacity; exporting less leads to fast depletion.

– Domestic demand for energy.
There are several parameters influencing domestic demand for energy: price elasticities of demand (η and π), non-energy and capital elasticities with respect to energy demand (θ and σ), and the coefficients β and ϕ. In the basic scenario the price elasticities were simultaneously set equal to -0.4. It turns out that variations in these parameters are rather important for the rate of exploitation. Let us consider the case where the price elasticities are -0.2. Non-energy output is not affected and hence the stock of capital remains the same. However, the demand for energy by households and firms sharply increases. Net national income is slightly larger because of the larger energy demand by households, and therefore less energy can be imported in view of

the balance of payments condition. In fact, the pool of natural gas will be depleted in 2012. In the case of price elasticities equal to –0.6, the effect is the opposite. We may conclude that the sensitivity of the public to energy price increases is very important with respect to energy policy.

The government might try to provide incentives to use equipment requiring less energy and could thereby influence the capital elasticity (σ) and the consumption elasticity (θ) with respect to energy demand. The impact of such a policy is far less impressive than the case we considered above, although of course it is difficult to compare variations in different elasticities. The basic σ was 0.9 and the remaining pool of natural gas was 5000 approximately. If $\sigma = 0.8$ the remaining pool is 6600. The impact of a variation of θ (in the basic scenario equal to 1) is of the same order of magnitude.

Finally, we considered the cases where β and ϕ were reduced by ½%, 1% or 2% annually in terms of themselves. This process might be called autonomous savings. In the case of savings in household demand, the effect is modest. If savings amount to 2%, which seems rather optimistic, the final pool of energy rises from 5000 to 8000 approximately. Autonomous savings in firms demand are more important. When they are 2%, the final pool becomes 12000 approximately.

– Non-energy imports.

The import share of non-energy consumption (δ) and of non-energy output (ϵ) are rather important parameters. We have decreased them by ½%, 1% or 2% annually in terms of their own value. In the case of imports by firms, the stock of capital is not affected nor is national income. Hence less imports by firms ought to be compensated entirely by importing more energy because of the balance of payments condition. This effect is very important. Some results are listed below.

Savings in ϵ	0%	½%	1%	2%
Final pool	5000	15000	24000	40000

We may therefore conclude that in this case as well the target concerning the growth rate of non-energy consumption can be set higher (after relaxing the import equation for non-energy consumption) or that some reduction of labour time is possible.

Reducing the import share of non-energy consumption (δ) lowers net investments because more non-energy output has to be used for consumption purposes. This induces less energy demand by firms. Also national income is smaller which causes more imports of energy in view of the balance of payments condition. The results are less striking than in the case of ϵ.

Savings in δ	0%	½%	1%	2%
Final pool	5000	8700	12000	18000

– ψ, ν.
Variations in the percentage of national income the government claims (ψ) are not of notable influence. Relaxing the balance of payments condition by putting ν equal to its 1975 value minus 1% is not very effective either.

Variations in exogenous variables and parameters which we do not consider as policy instruments will be discussed below.

– The growth rate of the world market price of energy.
In the basic scenario we have assumed that the world market price of energy increases by 8% annually for the first five years and by 2% annually thereafter. This prediction might be too optimistic. Therefore the case in which the price increase amounts to 8% annually over the total period has been considered as well. The stock of capital and non-energy consumption remain unchanged. In view of sharp price increases, firms and households demand less energy; however, national income is slightly larger because the value of household energy consumption is increased. Therefore the value of energy imports should be less, which leads to far fewer energy imports. Savings in domestic demand do not outweigh fewer imports and hence more of the pool of natural gas will be exploited. The final pool in 2005 is 1900 which seems to be enough for another eight years.

– Technical parameters.
In the basic simulation the *elasticity of substitution* ($1/1+\rho$) between labour and capital was set equal to 1/3. Making capital and labour closer substitutes by postulating ρ to be equal to 1 causes rapid growth of the stock of capital, inducing a high demand for energy and also large non-energy imports. With non-energy exports remaining unchanged and national income growing fatter, fewer energy imports are allowed because of the balance of payments condition. In fact, the pool of natural gas will be exhausted in 2005. Putting the elasticity of substitution at 1/4 we are left with a final pool of energy of 9500. From this we conclude that the substitutability between labour and capital is an important factor.

This also holds for the *weight α in the production function* attached to capital. It is easily seen that as soon as $K > L$ output increases as α increases. Indeed when $\alpha = 0.4$ (instead of 0.27) a rapid accumulation of capital results (to 2000 in 2015). Exhaustion takes place in 1997. If $\alpha = 0.2$ the final stock of capital is 857 and the final pool of natural gas is 13000.

The influence of *technical progress* is striking. If *Hicks-neutral technical progress* (χ) would be 1% instead of 2%, the stock of capital would start to decrease in 1985 and would become negative in 1997. In this case it would thus be impossible to maintain the prescribed growth in consumption. But if technical progress of the Hicks type were 3%, the stock of capital would grow extremely rapidly. National income grows very fast as well. Hence much less energy can be imported. In fact, the pool of natural gas would be depleted in 1993. In several years the economy would be a net exporter of energy, apart from contractual exports.

If in addition to 2% Hicks technical progress, *Harrod-neutral technical progress* is introduced there is also fast exhaustion of the pool of natural gas. The reasoning presented above also applies to this case.

The effect of introducing *Solow-neutral technical progress* is far less important. This is caused by the fact that marginal product of capital decreases in the original programme relative to marginal product of labour. Hence the impact of Harrod-neutral technical progress, which is labour augmenting, is considerably larger. Below some results are listed.

Harrod t.p.	1%	2%	3%
Depletion year	1994	1991	1988
Capital in depl. year	1443	1477	1362
Solow t.p.	1%	2%	3%
Depletion year	*	*	2006
Capital in depl. year			1287

* Means no depletion within 40 years.

Variations in the *rate of depreciation* (μ) are important. If μ is low at a 3% level instead of 5.6% the stock of capital grows rapidly to 1521 in 2001, the depletion year. If $\mu = 0.10$ the stock of capital becomes negative in 1997.

From the previous analysis we must unfortunately conclude that the parameters referring to the pre-supposed technology are rather influential. The stock of capital either becomes negative or it grows very fast, causing exhaustion of the pool of natural gas within 25 years or so. If these parameters indeed differ from our original estimation, then in the former case non-energy consumption cannot grow at a 2% rate, and/or non-energy exports should be reduced. The latter case looks serious too. Before discussing it, we should first remark that the model does not contain the possibility of discovering new energy deposits as a consequence of increased willingness to search due to price increases. This process will lengthen the lifetime of Dutch energy reserves. It is, however, hard to model such a process, and furthermore no data are available. Nonetheless, exploration activities should not be neglected. Second, in this case the growth rate of consumption can be maintained and the depletion year can be postponed by attaching more value to leisure, thereby reducing output and the growth of capital. As we remarked before, the balance of payments condition then deserves re-examination.

6 CONCLUSIONS

In this paper we have briefly reviewed the energy policy to be conducted by the Dutch government. It has been shown that the basic objective of this policy will not be accomplished and furthermore that it may lead to macroeconomic inconsistencies. More general objectives of economic policy are not taken into account in a satisfactory way. No exploitation policy is developed. These observations emphasize the need for a model which is macroeconomic in nature and provides the opportunity to incorporate energy policy into general economic policy. By way of example, such a model is presented in section 4. The main features of the model are complementarity between capital and energy and between non-energy consumption and energy, substitutability between capital and labour, a fixed supply of labour, and exogenous exports. In some way the objectives of economic policy are taken into account as well. Subsequently a non-energy consumption growth rate of two percent (from 1975 on) is chosen and the course of the economy considered, given this growth rate. The main outcome of this so-called basic scenario is that the resulting course of the economy is feasible. Moreover, the final stocks of capital and natural gas seem acceptable. Furthermore a sensitivity analysis is performed with respect to the parameters of the model. Some results are listed below. We wish to emphasize that they hold *ceteris paribus.*

- It is not possible to have more than 2% growth in non-energy consumption.
- Zero growth leads to absurd outcomes unless it is accompanied with labour time reduction and revision of the balance of payments condition.
- More exports are not feasible; fewer exports lead to fast depletion.
- The role of price elasticities is very important, as is the role of import shares.
- Increases in the world market price of energy do not dramatically affect the course of the Dutch economy.
- Unfortunately the values of technical parameters, of which we know little, are rather influential.

One should bear in mind that these results originate from a very simple and imperfect model. The following are among the weaknesses of the model. First, extraction costs are neglected as well as the possibility of exploration. Since we have assumed that world market price increases of energy are considerable, it is likely that exploration activities will be stimulated, thereby possibly extending the lifetime of the resource of natural gas. Moreover the price increases by themselves increase the so-called proven reserves. The aggregation level should also be mentioned, as should the fact that the model is highly technical in nature and therefore does not clearly indicate how a scenario can be realized. The model presented here does not pretend to give concrete and definite answers to energy problems but it is rather intended to give an indication of an alternative approach. Nonetheless, we do have some policy recommendations to make:

- Energy policy should be embedded in general economic policy.
- In designing energy policy, attention should be paid to the economy's technology in its broad sense.

APPENDIX A

PARAMETERS, EXOGENOUS VARIABLES AND INITIAL VALUES

A.1 INTRODUCTION

The model in section 4 contains far too many parameters to permit a purely analytical investigation of its properties. We must therefore attribute numerical values to its parameters, set initial values and – since we wish to simulate a number of time-paths of the economy – also establish the course of the exogenous variables. These values should moreover be 'realistic' in the sense that they should not be completely at variance with the known characteristics of the Dutch economy. In general, parameter values have been selected rather arbitrarily on the basis of prevailing views, and we have not obtained them by econometric estimation. We have, however, ensured a certain degree of consistency by calibrating all numerical values to the known macroeconomic data of 1975. This is our base year: all prices are index numbers with 1975=1, and most volume variables are expressed in billions of guilders at the 1975 price level. Energy volumes are, however, expressed in 10^{15} calories.

A.2 THE INPUT-OUTPUT TABLE

Much information has been derived from the input-output table for 1975 produced by C.B.S. (1977). The input-output table is compressed first. A distinction is made between 'oil industry' (including oil- and natural gas-exploitation) and 'public utilities' on the one hand and the other sectors on the other. We identify the first sectors with the energy sector. As far as costs are concerned we only distinguish between imports, wages and salaries, indirect taxes and other income. See Table 1.

This input-output table must be modified further in order to yield the base values required by the model. The main problem is caused by indirect taxes. We want to express most of the variables in world market prices.

In the following we denote by $[x,y]$ the entry in row x and column y. We assume that imports are in world market prices, which implies that we neglect import duties. Now we deal with column 4 first. We wish to neglect indirect taxes on exports, *i.e.* to reduce [6,4] to zero. 0.3 is small compared to 109.5. Quite arbitrarily we break 0.3 down into 0.2 added to [6,1] and [1,4] and 0.1 added to [6,2] and [2,4]. The new [6,1] is then distributed proportionally over [1,5], [1,6], [1,7] and [1,8]. This implies:

83.9	:=	81.0	[1,5],
5.6	:=	5.4	[1,6],
22.3	:=	21.5	[1,7],
7.0	:=	6.8	[1,8].

So indirect taxes on final expenditures for good 1 are removed from the production side and from row 1. A new row is then added called indirect taxes on good 1 such that the old column sums are maintained in colums 4 to 9. The same procedure is applied to [6,2]. In dividing, however, and in the following [2,7] will be neglected. This is taken care of by subtracting it from [7,2]. Now we have the result depicted in Table 2.

Four other modifications are made (see Table 3):
- wages for investment purposes of the government are considered wages for consumption,
- Imports of capital goods [4,7] and [4,8] are treated as imports by firms and supplied by firms to final investments,
- We aggregate material private and public consumption as well as private and public investments,

TABLE 1

	1 Firms	2 Energy	3 1+2	4 Exports	5 Pr. cons.	6 Pu. cons.	7 Pr. inv.	8 Pu. inv.	9 4–8	10 3+9
1) Firms	93.5	1.7	95.2	89.4	83.9	5.6	22.3	7.0	208.2	303.4
2) Energy	9.3	6.9	16.2	14.0	6.9	1.0	0.1	0	22.0	38.2
3) 1+2	102.8	8.6	111.4	103.4	90.8	6.6	22.4	7.0	230.2	341.6
4) Imports	51.4	13.3	64.7	5.8	20.7	0.7	10.1	0.1	37.4	102.1
5) Wages	75.7	2.0	77.7	0	0	28.3	0	0.2	28.5	106.2
6) Ind. taxes	3.9	2.3	6.2	0.3	9.2	0.9	2.4	1.2	14.0	20.2
7) Other income	69.6	12.0	81.6	0	0	1.7	0	0	1.7	83.3
8) Total 4–7	200.6	29.6	230.2	6.1	29.9	31.6	12.5	1.5	81.6	311.8
9) 3+8	303.3	38.2	341.6	109.5	120.7	38.2	34.9	8.5	311.8	653.4

TABLE 2

	1 Firms	2 Energy	3 Total	4 Exports	5 Pr. con.	6 Pr. con.	7 Pr. inv.	8 Pu. inv.	9 4–8	10 3+9
1) Firms	93.5	1.7	95.2	89.6	81.0	5.4	21.5	6.8	204.3	299.5
2) Energy	9.3	6.9	16.2	14.1	4.8	0.7	0	0	19.6	35.8
3) 1+2	102.8	8.6	111.4	103.7	85.8	6.1	21.5	6.8	223.9	335.3
4) Imports	51.4	13.3	64.7	5.8	20.7	0.7	10.1	0.1	37.4	102.1
5) Wages	75.7	2.0	77.7	0	0	28.3	0	0.2	28.5	106.2
6) Ind. taxes	0	0	0	0	9.2	0.9	2.4	1.2	13.7	13.7
7) Ind. taxes en.	0	0	0	0	2.1	0.3	0	0	2.4	2.4
8) Ind. taxes 1	0	0	0	0	2.9	0.2	0.8	0.2	4.1	4.1
9) Other income	69.6	11.9	81.5	0	0	1.7	0	0	1.7	83.2
10) Total 4–9	196.7	27.2	223.9	5.8	34.9	32.1	13.3	1.7	87.8	311.7
11) 3+10	299.5	35.8	335.3	109.5	120.7	38.2	34.8	8.5	311.7	647.0

TABLE 3

	1 Firms	2 Energy	3 Total	4 Exports	5 Cons.	6 Inv.	7 4–6	8 3+7
1) Firms	93.5	1.7	95.2	95.4	86.4	38.5	220.3	315.5
2) Energy	9.3	6.9	16.2	14.1	5.5	0	19.6	35.8
3) 1+2	102.8	8.6	111.4	109.5	91.9	38.5	239.9	351.3
4) Imports	67.4	13.3	80.7	0	21.4	0	21.4	102.1
5) Wages	75.7	2.0	77.7	0	28.5	0	28.5	106.2
6) Ind. taxes	0	0	0	0	15.6	4.6	20.2	20.2
7) Other income	69.6	11.9	81.5	0	1.7	0	1.7	83.2
8) Total 4–7	212.7	27.2	239.9	0	67.2	4.6	71.8	311.7
9) 3+8	315.5	35.8	351.3	109.5	159.1	43.1	311.7	663.0

– [4,4] is considered as imports by firms which are exported immediately. This procedure results in the following table:

From Table 3 we have for 1975:

$$X_f = 95.4 \qquad K_{t+1} - K_t + \mu K_t = 38.5 \qquad C_o = 30.2$$

$$C_f = 86.4 \qquad M_f = 67.4 \qquad \overline{P}_e E_m = 13.3$$

$$C_m = 21.4 \qquad Q = 220.3 \qquad \overline{P}_e E_x' + \overline{P}_e \overline{E}_a = 14.1$$

$$\overline{P}_g E_g = 5.5$$

$$S = 7.4$$

From the original table it follows that depreciation is 19.8. Then $Y = 169.6$. ψ and ν can now easily be derived.

1975 BALANCE OF ENERGY (in 10^{15} CALORIES)

Production of primary energy	+	712.9
Imports	+	679.3
Exports	–	718.0
Bunkering	–	113.1
Stock decrease	+	8.5
Gross primary consumption		569,6
Results from conversion	–	69.2
Own use energy-bearers	–	37.6
Distrib. and transp. losses	+	2.0
Use of non-energetic appl.	–	48.3
Stat. differences	–	0.4
Final use		416.1
Of which Industry		146.8
Transportation		65.6
Households		113.2
Other final users		90.5

A.3 THE ENERGY SECTOR

We now collect data on the energy sector. The point of departure is the energy balance sheet for 1975 from *'De Nederlandse energiehuishouding,'* C.B.S. (1976).

From this table it follows that:

$$E_b = 712.9,$$

$$E_m = 679.3,$$

$$E_x = 821.0 \quad \text{(bunkering is treated as exports).}$$

We now have to split up the final use of energy over the sectors, firms and households. The number of liters of gasoline that has been sold in 1975 is equal to $4{,}674 * 10^6$; see CBS (1978). This corresponds with $39.3 * 10^{15}$ calories. Magnus (1978) gives a series until 1974 for: number of kilometers for private use/total number of kilometers by cars.

Extrapolating this fraction we get 0.69 for 1975. Transportation is thus broken down into 27.1 for households and 38.5 for firms. Government expenditure on energy is 1.2 in 1975, CBS (1977); that of private households 8.6 in 1975. Assuming that the composition of the use of energy by the government is approximately the same as that of the private households, assuming that the average price is also the same, and knowing that the 8.6 corresponds to a volume of energy equal to 140.3, we may put government use at 19.6.

We now have:

$$E_g = 159.9,$$

$$E_f = 256.9,$$

where E_g and E_f are measured in final use calories. The domestic need for energy in terms of primary calories equals imports plus exploitation minus exports: 561.1. Assuming that the conversion loss for household energy as a proportion of the primary energy is equal to the loss for firm energy we have:

$$E_g = 215.9,$$

$$E_f = 345.2.$$

Combining the balance of energy and the input-output table we have for the world market price of energy 0.0195. But the price of exports is lower: 14.1/ 831.1 = 0.0170. The difference may arise from two causes: import duties and the different composition of exports and imports. Import duties are neglected in this paper and they cannot be very important. Therefore the difference in the price is attributed completely to the different composition. Indeed the contractual exports can be assumed much cheaper than the 'free' exports of energy.

From Gasunie (1977) we can derive E_a:

E_a

1975	378	1982	336	1989	294	1996	210
1976	420	1983	336	1990	294	1997	210
1977	420	1984	336	1991	252	1998	210
1978	378	1985	336	1992	252	1999	126
1979	378	1986	294	1993	252	2000	84
1980	378	1987	294	1994	252	>2000	0
1981	336	1988	294	1995	210		

For the exports of energy we have:

$$E_x = E_x' + E_a.$$

The value of the exports is equal to 14.1. The price of the 'free' exports is the world market price for energy. The free exports are 831.1 − 378 = 453.1. Then it is easy to calculate the price of contractual exports.

We recall the equations for the demand for energy by households and firms:

$$E_g = \beta C^\theta \overline{P}^\pi,$$

$$E_f = \phi K^\sigma \overline{P}^\eta,$$

η and π will be assumed to be equal to -0.4. θ and σ will be chosen 1.0 and 0.9. These choises are rather arbitrary, but this is due to the lack of data. As explained below, K is estimated at 380. Then it is easy to find β and ϕ, because all other variables and parameters are known.

From Gasunie's annual report (1977), the pool of natural gas in 1975 can be derived. At the beginning of 1978 it is 1650 billion m^3. The sales in 1975, 1976 and 1977 were 89, 84 and 94 billion m^3. It is expected that an additional stock of 500 billion m^3 will be found by exploration. For the beginning of 1975, one could say that the stock equals 2427 billion m^3. This corresponds to $R(0) = 20{,}387$.

A.4 THE TECHNOLOGY

We recall the production function of the model:

$$Q = (1+\chi)^t A[\alpha\,((1+\zeta)^t K)^{-\rho} + (1-\alpha)\,((1+\xi)^t L_f)^{-\rho}]^{-1/\rho}.$$

For 1975 (where t=0) we have:

$$Q = A[\alpha K^{-\rho} + (1-\alpha)\,L_f^{-\rho}]^{-1/\rho}.$$

To determine A, α and ρ the following procedure is applied. For ρ a value of 2 seems reasonable. It implies an elasticity of substitution between capital and labour that equals 1/3. Then estimates are made for the stock of capital in 1975 and of labour in 1975. Next it is assumed that the share of labour in the value added amounts to 0.7. In the case of profit maximizing this share is equal to

$$\frac{WL}{PQ} = \frac{(1-\alpha)\,L_f^{-\rho}}{(1-\alpha)\,L_f^{-\rho} + \alpha K^{-\rho}}.$$

From this equation α can be derived. Knowing all 1975 parameters and variables it is now easy to calculate A.

It is very difficult to find a good estimate of the initial stock of capital. There have been some studies by Den Hartog and Tjan (1974) and Magnus (1978). Very arbitrarily we assume it is equal to 380. This can be defended in a rather crude way by the following argument. Hartog and Tjan calculated the capital stock in 1973 in 1963 prices. Without taking into account buildings, they arrive at 114.3. According to Magnus it is 86.0. We shall take the average. According to Magnus the stock in buildings was 49.0. Assume that the governmental stock of capital compared with the private stock is proportional to investments (7/32.5). Then for K in 1973 we have approximately 180 in 1963 prices. For 1975 the price index (1963=100) is 1.8. Then it follows:

$$K(1975) = 324 + \text{investments in 1973 and 1974.}$$

Investments in 1973 and 1974 can be found in C.B.S. (1977). In this way we reach 380 approximately. It is obvious that this estimate is very crude. The Central Planning Bureau (1978) gives figures about L_f. We shall assume that government demand for labour is such that the available number of labourers for firms is constant and equals 410 (in ten thousands). Now we can find α. It is equal to 0.27.

Finally we are left with the depreciation rate μ. In Magnus (1978) the average depreciation rate is found to be 5.6 percent. Here we adopt this estimate.

In the simulations we put χ, Hicks-neutral technical progress at 2%. Solow and Harrod-neutral technical progress are put 0%. The annual growth rate of non-energy exports is taken to be 3%. Some support for this can be found in C.P.B. (1976).

APPENDIX B

THE BASIC SCENARIO

This appendix contains a full description of the basic scenario. Recall that 1975 is the base year.

K : stock of capital (in billion guilders),
S : surplus on the current account,
E_b : exploitation (in 10^{15} calories),
R : pool of natural gas,
E_g : energy use households,
E_f : energy use firms,
E_x'-E_m : free energy exports minus energy imports.

Year	K	S	E_b	R	E_g	E_f	$E'_x - E_m$
0	380.0	7.3	708.7	20387.0	215.9	345.2	−230.4
1	397.2	7.5	715.5	19678.3	213.5	348.4	−266.4
2	416.2	7.8	710.1	18962.8	211.2	352.3	−273.4
3	437.0	8.0	693.4	18252.7	208.9	356.9	−250.4
4	459.4	8.2	686.8	17559.2	206.6	362.1	−259.9
5	483.5	8.5	678.5	16872.5	204.4	367.6	−271.5
6	509.0	8.7	659.6	16194.0	202.1	373.3	−251.9
7	535.7	8.9	661.5	15534.4	204.5	387.9	−266.9
8	563.6	9.1	660.8	14783.0	207.0	402.7	−284.9
9	592.2	9.3	657.5	14212.1	209.5	417.8	−305.8
10	621.6	9.5	645.1	13554.7	212.0	432.9	−293.8
11	651.3	9.6	636.8	12909.6	214.5	448.0	−319.7
12	681.3	9.8	625.9	12272.7	217.1	462.9	−398.0
13	711.4	10.0	612.3	11646.8	219.7	477.4	−378.8
14	741.4	10.1	546.2	11034.5	222.3	491.5	−411.7
15	771.1	10.3	575.1	10438.4	224.9	505.2	−407.1
16	800.4	10.4	555.1	9863.3	227.6	518.4	−442.9
17	829.3	10.6	532.8	9308.2	230.4	530.9	−480.5
18	857.5	10.7	508.5	8775.4	233.1	542.8	−519.5
19	885.0	10.9	486.0	8266.9	235.9	554.1	−514.0
20	911.8	11.0	462.8	7780.9	238.7	564.7	−550.6
21	937.7	11.1	437.9	7318.1	241.6	574.5	−588.2
22	962.7	11.3	411.3	6880.2	244.5	583.7	−626.8
23	986.8	11.4	383.0	6468.9	247.4	592.1	−582.4
24	1009.8	11.6	353.3	6085.9	250.3	599.7	−596.8
25	1031.8	11.7	322.0	5732.6	253.3	606.6	−638.0
26	1052.8	11.9	289.2	5410.6	256.4	612.8	−579.9
27	1072.5	12.0	255.1	5121.4	259.4	618.3	−622.6
28	1091.2	12.2	219.5	4866.3	262.5	623.0	−666.0
29	1108.6	12.4	182.5	4646.8	265.7	626.9	−710.1
30	1124.8	12.5	144.2	4464.3	268.8	630.1	−754.8
31	1139.7	12.7	104.6	4320.1	272.0	632.6	−800.1
32	1153.3	12.9	63.6	4215.5	275.3	634.4	−846.1
33	1165.6	13.0	21.3	4151.9	278.6	635.4	−892.7
34	1176.5	13.2	−22.3	4130.6	281.9	635.7	−939.9
35	1186.0	13.4	−67.2	4152.9	285.3	635.3	−987.7
36	1194.0	13.6	−113.4	4220.1	288.7	634.1	−1036.1
37	1200.5	13.7	−160.9	4333.4	292.1	632.2	−1085.2
38	1205.5	13.9	−209.7	4494.3	295.6	629.5	−1134.8
39	1208.9	14.1	−259.8	4704.0	299.2	626.2	−1185.1
40	1210.7	14.3	−311.2	4963.7	302.7	622.0	−1236.0

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Summary

THE EXPLOITATION OF DUTCH NATURAL GAS: AN ALTERNATIVE APPROACH

Dutch energy policy is briefly reviewed and an alternative approach is suggested. A very simple model of the Dutch economy is presented which enables us to simulate the course of some macro-variables and of the pool of natural gas. Subsequently a sensitivity analysis is performed with respect to the parameters of the model.