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The Century Model

- on the Long Term Sustainability of the Saudi Arabian Economy

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Abstract:
This report gives a documentation of the Century Model, developed by the Research Department of Statistics Norway (the Oslo Group) as part of the construction of a system of macroeconomic models for the use of the Ministry of Planning in connection with the preparation and monitoring of the five-year Development Plans. The assignment is an integral part of the UNDP Project SAU/94/001/A/01/01 Support for Economic Planning, Modelling and Management Information Systems Development under the contract TCD CON 4/95 with Statistics Norway. The Project is intended to assist the Government of Saudi Arabia in designing and implementing an interlinked system of macroeconomic models and will also support the development of an integrated information system in the Ministry of Planning directed at assisting the model development exercise and attaining closer coordination of plan formulation and execution processes.

Keywords: Saudi Arabia, Sustainability.

JEL classification: O53, O11, Q32.

Acknowledgement: The model has been prepared in consultation with the Ministry of Planning and UNDP experts and has benefited substantially from written comments to earlier drafts from a committee chaired by Director Mohammed Al-Ghanimi, Ministry of Planning, from Mr. Peter Gudgeon, UN/DDMS, and from discussions (incl. written comments) in January - February from Drs. Abdul Mohsen, Abdul Aal, El Sayed Esmat and UNDP Expert/Shief Technical Advisor Hashim A-Shami. Financial support from United Nations contract TCD CON 4/95 SAU/94/001 Macroeconomic Modelling, is gratefully acknowlegded.

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1 Introduction

The Saudi Arabian economy is highly dependant upon non-renewable natural resources, mainly oil and water. Revenues from exports of crude oil and oil products are the major sources of income for the government and for the economy as a whole. The sharp decline in the world price of oil in 1986 and relatively bleak prospects for increases in prices and volume of Saudi Arabian oil exports have created a challenge for the continued growth of the Saudi Arabian economy. The high dependence upon non-renewable water reserves is of fairly recent origin, and a consequense of the vast expansion of a commercial agricultural sector. The scarcity of water may be harder felt in the future.

Ample oil revenues have allowed industries and services of Saudi Arabia to expand considerably over the last decades. This has induced a need for extra labour, and the low labour participation rate add to this need. Much of the labour input in the economy is imported from abroad.

The annual population growth in Saudi Arabia is currently more than 3%. A continued population growth will imply that the oil revenues should be shared by more people, but also that the Saudi Arabian labour supply will increase, and reduce the need for expatriate labour.

To study these issues in the long run, the Century model focuses on the long run development in the national wealth. National wealth consists of real capital, net foreign assets, human capital, and natural resources (although only real capital and net foreign assets enter when national wealth is conventionally measured). The prime purpose of the *Century Model* is to study the long-run sustainability of the Saudi Arabian economy. In stock terms this problem can be formulated as the management of national wealth.

Although Saudi Arabia has several depletable natural resources only those on which the future of the country really depends are included in the *Century Model*, i.e. petroleum, but also water. Water is ultimately the more important resource, and the drawing down of depletable water reservoirs at a high rate calls for the inclusion of water supply in the long-run perspective.

For the important issue of the sustainability of the Saudi Arabian economy, a longer time horizon is needed than the five-year horizon of the Development Plans. A proper perspective on the gradual transition from an oil-dependent economy to a viable industrial structure, when the petroleum resources no longer can serve as an engine of growth and transformation, requires a time perspective at least some decades ahead. The *Century Model* is a first attempt at developing an analytical tool that can serve in this regard.

Targets for the long run development in Saudi Arabia can be adapted from those given prominent attention in the Fifth and Sixth Development Plans, such as (1) Economic growth and social development, (2) Diversification away from oil dependence, (3) Privatization, i.e. a reduced role for the public sector, (4) Rationalization and increased cost awareness in public spending, and (5) Saudiization of the labour market. Hence, these targets serve as a guide for the issues to be addressed in the *Century Model*.

The dependence of the Saudi economy upon petroleum and water makes it reasonable to add optimal petroleum management and optimal water management as additional overall targets. The high capacity to import and the ample government finances of the Saudi economy has implied that neither the balance of payments nor the government budget has been severe constraints on the spending patterns. Bleaker outlook for future oil revenues in the decades to come may imply that the balance of payments and the government budget gradually become more binding constraints.

The *Century Model* shed light on the possibility space for simultaneous fulfilments of such overall targets in a long-term perspective, although a fully satisfactory treatment will require a further development of the model. Economic growth is an obvious concern for a country which has chosen modernization and development. The average growth over the past two decades has been high, but in the longer perspectiveit may be hard to keep this high growth rate. Diversification is taken to mean the promotion of non-oil based industry to support the balance of payments through exports or replacement of imports and to become a future source of growth. The results with regard to diversification over the last two decades are not too encouraging. The difficulties in achieving substantial diversification may be more due to social and institutional factors than to economic constraints. Results with regard to diversification is, however, a *sine qua non* for sustainable growth. Privatization seems to express primarily a need to reduce the burden on the government budget by shifting responsibility to the private sector. This can be done in alternative ways and may include shifts in expenditures as well as changes in prices of government services and introduction of new taxes. Rationalization in public spending amounts to reducing the burden by other means, primarily by avoiding waste and inefficient allocations. Saudiization of the labour market means primarily achievement of a higher participation ratio of the Saudi labour force, which is very low, indeed, by international comparison.The interaction and trade-offs of these targets can be studied by macroeconomic models addressing the issues. The *Century Model* is constructed for this purpose, although not all of the issues can be studied by means of the fairly simple first version of the model developed within the current project.

In the *Century Model* the links between the economy and the natural environment are depicted in very simple terms. The same is true about the purely economic relationship. It is believed, however, that an approach towards an analytic study of the important and vital issues related to the long-run sustainability of the Saudi Arabian economy in a planning context may benefit from trying to model the basic relationships and stylized facts in as transparent terms as possible before proceeding towards more elaborate modelling efforts. The *Century Model* has been launched as a limited effort in this direction.

Section 2 below gives a brief presentation of the main content and suggested use of the *Century Model*. Section 3 gives a more precise description of the content by setting out the equations and variables in the model. Various methodological issues and data needs are discussed in chapter 4, while section 5 deals with the data and calibration of the *Century Model*. Section 6 presents scenarios constructed with the model, while section 7 sketches some ideas on future refinements.

2 An outline of the structure and use of the *Century Model*

The *Century Model* may be considered as an intertemporal accounting framework. The model is oriented towards considering the long run consequences of economic policy choices. It is developed as a simulation model that may be operated in different modes by an interchange of exogenous and endogenous variables.

2.1 The structure of the *Century Model*

The stock variables of the model are capital, energy reserves, water reserves, labour supply, treasury and foreign assets. Besides keeping account of the changes in stock variables, the model will also describe the functioning of the economy within each year. In the model it is assumed that firms in the private sector are profit maximizers, implying that production and factor inputs are chosen to maximize profit. This assumption will determine the private sector's responses to changes in policy.

In the standard mode of the model capital formation is exogenous and together with the capital stock given at the end of the previous year, this determines the capital stock year by year. From profit maximizing once the capital stock is given, the optimal production will be determined. Simultaneously, the firms also choose other factor use to minimize the production costs.

As an alternative to assuming exogenous capital formation, we may assume that the amount of expatriate labour is exogenous. In this mode of the model we may determine the consequence of a reduced use of expatriate labour, by letting the amount of available labour determine the optimal production level. The capital stock, and hence also the capital formation is then chosen to minimize the cost of producing this output, while in the standard mode the need for expatriate labour depends upon the capital formation.

The model assumes that the private sector produces only one commodity, hereafter referred to as the macro commodity. This commodity will thus be an aggregate of a large variety of different commodities (not including energy and water). The value of different commodities are weighed together in the macro commodity according to their value, as in the national accounts.

The model does not at this stage attempt to explain the household behaviour. Instead it can be used to investigate whether current consumption in the long run is consistent with income. Assumptions may be entered about the future per capita consumption, and the model can be used to corroborate the long run consequences of population growth. Demand for the macro commodity will be derived from the assumptions made about the consumption development.

Population growth will increase the labour force, as well as the demand for the macro commodity and for energy and water. An increased labour force may also make a larger private sector more profitable (when expatriate labour is exogenous). Thus population growth will contribute to increased demand for water and energy from the private sector.

In addition to consumption the macro commodity will also be demanded for capital formation. Total production, determined as stated above, will usually not coincide with domestic demand. An excess of production over demand will be exported, a deficit imported.

The oil revenues are exogenous, and so is the price of energy. This is natural since the oil price is determined in the world market. On the other hand, the opportunity cost of energy need not be equivalent to the world price on oil. Saudi Arabia is such a large producer on the world oil market, that its production has an impact on the world price on oil. At the same time, increased domestic use of oil has negligible effects on the price. Hence the opportunity cost (shadow price) of oil may be different from the world market price. Both oil revenues and shadow prices are exogenous and has to be specified by the model user.

The demand for energy from household and government is simply assumed to be proportional to the respective demand for the macro commodity. Parameters representing energy economizing efforts should be considered for inclusion in the model. In the current mode of the model, the export of oil is exogenous, and extraction is determined as the amount exported and used domestically.

The development in the stock of foreign bonds is determined by the cumulative effects of the current account of the balance of payments.

2.2 The use of the *Century Model*

The *Century Model* is not designed to fit into the format of the Development Plan preparation and implementation in the same way as the *Implementation Model* and the *Selection Model,* see Johansen et al. (1996), Cappelen et.al. (1996) and Bjerkholt (1993). Its longer time horizon and more aggregate structure suggests a use more suited for providing a background for the development perspectives prior to the Development Plan preparation. Perhaps it would not be unreasonable to introduce a *Perspective Plan* representing the longer time horizon. The model may, of course, be used also on a more ad hoc basis as an easily available tool for studying longer term perspectives.

It is difficult to come by "hard facts" relating to the longer term development. Even scientifically bases estimates as those of the depletable stocks of petroleum and water tend to have a rather limited duration. Also many of the other estimates used in the model, such as the growth of the Saudi population, the propensities to use energy and water, etc. may in a longer perspective turn out to be loosely founded. Hence, the forecasts of the *Century Model* ought to be viewed as very conditional, indeed, and the answers it provide as tentative summaries of current available information.

The model is a instrument to allow the planning administration to become better acquainted with the interrelations of the long-term trends influencing the Saudi economy, such as depletion rates, population growth, oil price trends etc. Although the results from the model for decades ahead may seem remote from the short-term agenda, this is not necessarily so. The long-term trends dealt with in the *Century Model* concern very vital issues for the Saudi economy, and accordingly, early detection of future problems ought to be of great importance for the modification of policy.

On the other hand the *Century Model* as set out below is - admittedly - a quite crude tool. The reliability of the model's estimates may be improved by more detailed specifications and more corroborated data.

3 The formal model: equations and variables

3.1 Private sector factor demand

Production in the private sector is described by a Cobb-Douglas production function in capital, labour, and energy

$$YPA = aKP^{\alpha} EP^{\beta} ED_Y^{\eta}$$

where α, β, and η, are parameters. (A complete list of variables and parameters is given in section 3.7.) Each firm in the private sector is supposed to maximize profits. Normalizing the price of the macro commodity to 1, the profit is

$$YPA - p_K(1+\tau_K)KP - w(1+\tau_L)EP - p_{ED}(1+\tau_E)ED_Y.$$

The first order condition for profit maximization, gives the following factor demand equation for the private industry.

(1) $p_K KP(1+\tau_K) = \alpha YPA$

(2) $wEP(1+\tau_L) = \beta YPA$

(3) $p_{ED} ED_Y(1+\tau_E) = \eta YPA$

3.2 Labour market

The model distinguishes Saudi Arabian labour supply from that of expatriates. The Saudi labour supply is given as a parametric share (λ) of the labour force. Labour force is related to the total population through the dependency ratio (σ).

(4) $ES + EN = E$

(5) $E = EP + EG$

(6) $ES = \lambda LS$

(7) $POP_{SA} = \sigma LS$

3.3 Energy demand

Energy is given as a depletable stock. The energy demand from households, government and desalination are assumed to be determined by constant propensities (relative to the level of consumption including expatriate consumption, governmental expenditure and desalination, respectively). The market clearing equation for energy balances supply and demand.

(8) $R_E^{-1} - R_E = EE + \varepsilon_{RE}$

(9) $ED_C = a_{EC}(CPR_S + CPR_N)$

(10) $ED_G = a_{EG}(CG + JG)$

(11) $ED_D = a_{ED} D$

(12) $EE = ED_Y + ED_C + ED_G + ED_D + A_E + \varepsilon_{EE}$

(13) $CPR_N = (1 - S_{EX})wEN$

3.4 Water demand

Water is given as a depletable stock. Water consumption in households is assumed to be proportional to consumption of the macro commodity. The market clearing equation for water balances supply and demand.

(14) $R_W^{-1} - R_W = W_{NR}$

(15) $WD_C = a_{WC}\left(CPR_S + CPR_N\right)$

(16) $W_{NR} + D + W_O = WD_C + WD_A + WD_Y$

3.5 Capital accumulation

The user cost of capital is constituted by the sum of the interest rate (r) and the annual rate of depreciation (δ). Capital formation adds to the the stock of capital.

(17) $p_K = (r + \delta)$

(18) $JP = KP - KP_{-1} + \delta KP_{-1}$

3.6 Balance of payments, market clearing and the government budget surplus

The current account of the balance of payments equals the value of exports plus interest on foreign assets less the value of imports and remittances. The net value of the current account is added to the foreign assets. The market clearing equation for the macro commodity, energy and water balances supply and demand. The government budget surplus (net financial investment) is added up from energy export revenues, taxes on capital formation, domestic energy use, labour income, and interest on net claims, less government expenditures. The surplus adds to net claims. This equation needs further consideration, e.g. to incorporate the running cost of desalination and the cost of investing in desalination capacity.

(19) $p_E A_E + XXCPN - M - s_{EX} wEN + rZ_{cum}{}^{-1} = Z_{cum} - Z_{cum}{}^{-1} + \varepsilon_Z$

(20) $M + YPA + YG + YID = \left(CPR_S + CPR_N\right) + CG + JG + JP + XXCPN + \varepsilon_{Y_s}$

(21) $T - T^{-1} = rT^{-1} + p_E A_E + \tau_K JP + \tau_E p_{ED}(EE - A_E) + \tau_L wE - (CG + JG) - ED_G p_{ED} + \varepsilon$

(22) $EG = a_{YE} YG$

(23) $YG = a_{YG}(CG + JG)$

3.7 Variables and parameters

A description of the varibles in the model is given below. Data for all varibles are given in the appendix.

KP	- Capital
YPA	- Production
M	- Import
$CPR_{S,N}$	- Private consumption
YG	- Public production
YID	- Import duties

CG	- Government saudis and non saudis consumption
JG	- Governmental investment
JP	- Capital formation
XXCPN	- Export
R_E	- Energy reserves
EE	- Energy extraction
ED_Y	- Energy demand, Private sector
ED_D	- Energy demand, Desalination
ED_C	- Energy demand, Households
ED_G	- Energy demand, Government
A_E	- Energy export

R_W	- Water reserves, non-renewable
W_{NR}	- Water extraction, non-renewable sources
D	- Water supply, Desalination
W_O	- Water supply, other sources (renewable and recirculated.)
WD_C	- Water demand, households
WD_A	- Water demand, agriculture
WD_Y	- Water demand, private

ES	- Labour supply, Saudi Arabian
EN	- Labour supply, Expatriates
E	- Total labour.
EP	- Labour demand from private industries
EG	- Labour demand from the government

LS	- Saudi Arabians in working ages
POP_{SA}	- Population
T	- Treasury
Z_{cum}	- Foreign assets

p_K	- Userprice of capital
p_E	- Energy price, world market
p_{ED}	- Energy price, domestic
w	- Wages
r	- Interest rate

τ_K	- Taxes on capital
τ_L	- Taxes on labour
τ_E	- Taxes on energy

α, β, η	- parameters of the Cobb-Douglas production function
λ	- participation ratio
σ	- dependency ratio
δ	- rate of depreciation
s_{EX}	- savings rate, expatriates
a_{EC}	- energy demand in private sector relative to total private consumption
a_{EG}	- energy demand in government sector relative to total government consumption

a_{ED} - energy demand for desalination relative to the level of desalination
a_{WC} - water demand in household sector relative to total private consumption
a_{YE} - energy demand public sector relative to public production
a_{YG} - Public production relative to public expenditure
ε_x - residuals, x=RE,EE,Y,Z,T

4 Methodological issues

4.1 Technical progress

The production function is not specified as a part of the model. The exogenous investments determines the level of capital. The total production level is then determined by the factor demand for capital, as the production level that makes the actual capital stock optimal. Since the production function is not included in the model, (actually it would be redundant in this model) technical progress cannot be specified through the production function. How, then should technical progress be introduced?

The underlying assumption, which makes the production function redundant, is that both wages and interest rates are determined at the world market. Since we have calibrated the model to give constant returns to scale, that implies that the technology is identical in all countries, otherwise we could not have an equilibrium, since the country with best technology would attract all the labour. Technical progress thus affects the national economy only indirectly through the world market prices, e.g. as increasing wage rates at the world market.

4.2 Simulation vs. optimization

In the first sketch of the *Century Model* in Bjerkholt (1993) an optimizing mode of the model was mentioned as a possibility after corroboration of the specification and proper estimation and calibration of parameters. In general the choice between optimization and simulation as the mode of operation depends on the intended use of the model. It is possible to specify target variables as exogenous and a corresponding number of "instruments" as endogenous in a simulation model, and hence use the model to indicate how to reach these targets. This is known in the literature as target-setting or the target-instrument approach, see e.g. Tinbergen (1992). An optimization model, on the other hand, can be used not only to determine how to reach a target, but what the target should be. An example may help to clarify the difference.

In the section 2.1, it was indicated that expatriate labour, in an alternative mode of the model, could be defined as an exogenous variable. This would require that one variable that is exogenous in the standard mode, is made endogenous. It was indicated in the discussion above that investment in this case would be made endogenous. The simulation model would then determine the size of the private sector compatible with the given target of expatriate labour.

If the model user also wants to specify targets for the growth rate of the private sector, he would run into problems of feasibility, except if taxes on labour is introduced. For a given tax rate on labour, the size of a profit maximizing private sector will be determined by the amount of available labour. A tax on labour will make labour a more expensive production factor and hence reduce labour demand. With an exogenous labour supply in Saudi Arabia, this will reduce the need for expatriate labour. Thus with an endogenous tax rate, the model will determine the tax rate that is required to reach both the required growth rate and the amount of expatriate labour.

An optimization model is most useful when the targets are inconsistent, e.g. it will be impossible to meet a simultaneous targets on growth rate, taxes and expatriate labour. An optimization model can be used to determine a consistent set of targets that are best suited for reaching some clearly defined overall objectives. Typically, the overall objective will be stated in the form of some welfare function, where the total welfare in the economy is some function of total consumption of the macro commodity, of energy and water. Furthermore, it has to be stated how the welfare of the present generation should be weighted against the welfare of future generations.

The output from an optimization model will not only be a policy that determines how to reach certain targets, but also what these targets should be. A optimization model would thus tell the decision maker what the rate of Saudiization should be, how large the growth rate should be, and what tax rate he should set as a target. In short a simulation model is used to analyse how to reach a given target, while an optimization model can be used to determine what the target should be.

Our experience is that a real life decision maker often hesitates to accept the targets determined by an optimization model. If he at the outset believed that the use of expatriate labour should be decreased, he may be very skeptical to an optimization model that suggests an increase. Of course, the results of an optimization model are not objective facts, but depends on how the welfare function is specified. It may be easier to comprehend a target in terms of economic growth than to comprehend the meaning of the parameters in a particular welfare function.

Furthermore, there may be important aspects of the choice of targets that are not represented in an economic model. Reduction in the expatriate labour supply may be set as a target for political or cultural non-economic reasons. These will not be reflected in the suggestions from an economic optimization model.

An optimization mode is an extension of the simulation mode. The welfare function is essential in an optimization model, and should reflect the view of the decision maker. The implementation of an optimization mode, thus requires a dialogue with the model users about the objective function, preferably after the users are familiar with the model. Our suggestion is thus that such an extension should be considered as a potential further development after this project is completed and the Ministry users have had some time to get familiar with it.

5 Data and Calibration

Much of the basic economic data needed for the *Century Model* are derived from data already obtained for the *Implementation Model*, and from data files prepared for the *Oil Model*. Additional data have been supplied by the Ministry of Planning. The data sources and values for all variables are given in an appendix. See also the Technical Documentation report of the *Century Model*.

The model is calibrated so that all equations are satisfied by observed data in the base year 1989. To achieve this we had to introduce some residuals at the equations for energy reserves and extraction, and in the market clearing condition for the macro commodity. Finally, residuals are included both the governmental and national budget equation.

The technology is assumed to have constant return to scale, hence $\alpha + \beta + \eta = 1$. This condition implies that if the use of labour, capital and income is increased by a common factor (e.g. doubled) then the production is increased by the same factor (doubled).

6 Simulation Results

6.1 Reference scenario

In this reference scenario we make the following assumptions about the exogenous variables.

Variable	Explanation	Assumption
XXCPN	Export	Constant
POP_{SA}	Population	3% growth until 2010, then 2%
CPR_S	Consumption	3% growth until 2010, then 2%
CG, JG	Public expenditures	Constant
EG	Employment government	Constant
JP	Investment	3% growth until 2010 then 4%
PED	Energy prices, domestic	20 SR/barrel, constant until 2000, then 2% growth
PE	Energy prices	63.75 SR/barrel, constant until 2000, then 2% growth
AE	Export of energy	Constant
r	Interest rate	5%
w	Wages	2% growth
WDA	Water demand agriculture	Starts at 16 400 million m^3, decreasing to 11 000 million m^3 and thereafter constant.
WDY	Water demand industry	Constant
D	Desalination	Start at 714, increasing to 1150 mill. m^3 in 1999, then increasing by 4%.
WO	Water from other sources (Renewable and recycled)	Starting at 2650, increasing to 3310 mill m^3 in 1999, growing 0.5% per year thereafter.

XXCPN: The model determines the net export, that is the difference between export and import. To determine each of them, one has to be set exogenous. In this case we have assumed constant import.

POP_{SA}, CPR_S: The population growth is currently about 3-4% per year, so we have set the growth to 3%, in the beginning of the period, and assumed that the growth will decline later.

We further assume that the per capita consumption is kept constant, to see if the policy is sustainable, that is whether a constant per capita consumption is feasible in the long run.

JG, CG, EG: In spite of the population growth, we assume that the governmental expenditures are constant in the simulation period, to reflect the plans to reduce public expenditures.

JP: Investments are assumed to grows at a rate higher the population growth. As a consequence the capital stock per capita will increase.

PE, PED, AE: Energy prices, that is mainly oil prices are assumed to grow at a rate of 2% per year from year 2000. Export are assumed constant. We assume that Saudi Arabia cannot export more oil without pressing prices down, thus the alternative value of the energy price consumed domestically is less than the world market price. As a consequence we assume that domestic prices are lower than world market prices. Note also that when export are exogenous, the production will be endogenously determined to cover both the export and the domestic demand.

r: Even though the interest rate on the world financial market has varied in the past, there are no clear and strong trends, and hence we assume that the interest rate will be constant.
w: We assume that wages start at 23.87 thousand SR per year, which is about the current average in the economy. Wages are in the Century Model assumed to be given from the world market. Technical progress in the region will result in increased wages in the region. We have assumed that wages are growing at a rate of 2% per year, which correspond to about 1% technological progress.

WDA: The reference scenario assumes that water demand from agriculture is cut more than what is assumed in the Sixth Development Plan, where demand from agriculture in 1999 is 14 700 millions cubic meters, compared to 11 000 million cubic meters in the reference scenario.

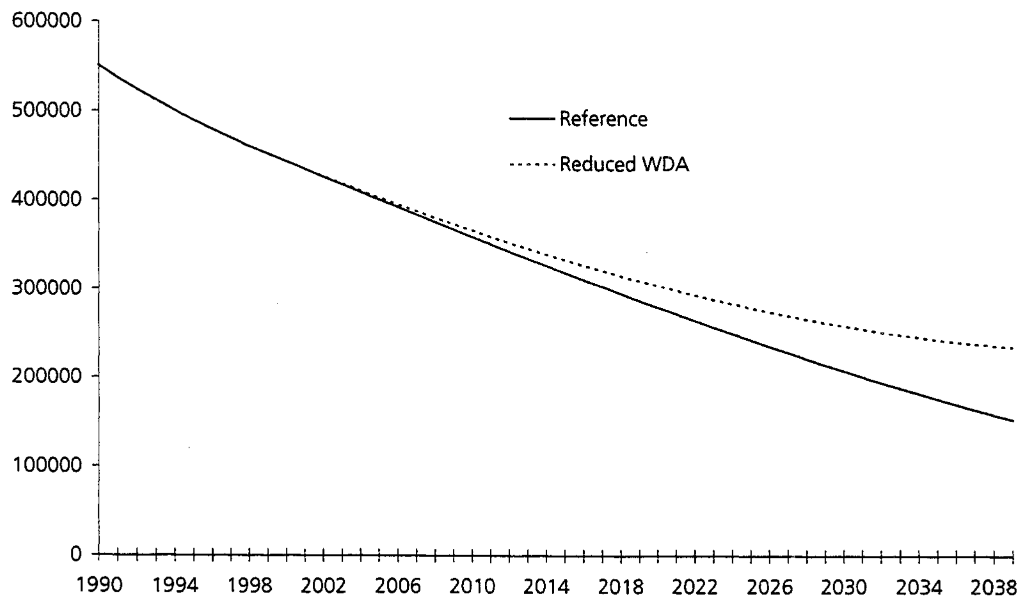
D: To 1999 according to plan, thereafter we assume that desalination increases more than the population growth.

WO: Water supply from other sources consists of renewable and recycled water. Recycled water is currently about 10% of WO, and is assumed to grow at 3% like the population, while renewable is assumed to be constant. This gives a total growth of about 0.5 %.

6.2 Water

About 80% of current water supply is taken from non-renewable sources. In the long run, such extraction have to be reduced, since the reserves are limited. To study the long-run development of Saudi Arabia it is thus natural to consider the development of remaining water reserves. The water reserves in the reference scenario is given in figure 1. The initial reserve estimate is the probable reserves of 565 billion m^3 above 300 meters depth . The accumulated extraction during the 50 years of simulation is about 400 billion m^3. The slope of the line is rather constant, and remaining reserves continues to decline at the end of the simulation period.

Figure 1. Remaining water reserves. Billion cubic meters



The reference scenario is based on the Sixth Development Plan and assumes that the demand from agriculture is 16.4 billion m3 in 1991 (the base year for the simulations) declining to 14,7 billion m3 in 1999, and constant thereafter. In a more optimistic scenario the water use for agriculture continues to decline with 1% per year, otherwise the assumptions are as in the reference scenario. Note that with 1% decline in water use in agriculture and 2-3% growth in the population, we would expect an increasing import of agricultural products. The water reserves in this scenario is also illustrated in figure 1. The remaining reserves are about 100 billions higher than in the reference scenario at the end of the simulation period. Moreover, remaining reserves are declining much slower at the end of the simulation period. The scenario assumptions pay no attentions to potentially water supply enhancing policies, e.g. import of water and sophisticated water saving technology.

6.3 Accumulated surplus or deficits

The model computes the development in both national and governmental wealth. The total national wealth should also include the petroleum wealth, which is the present value of future petroleum rent. Using petroleum income as a proxy for the rent, the wealth is 2-4 000 billion SR in 1991 depending upon assumed future oil prices. The wealth will decrease during the simulation period, due to extraction, but since the extraction period extends far beyond the simulation period, the wealth will only decrease slightly. To maintain the total wealth, the financial wealth should thus be slightly increasing during the simulation period.

The development in financial wealth, which is the net foreign assets held by Saudi Arabians, is presented in figure 2, while figure 3 shows the governmental wealth (the solid lines).

We lack numbers of the wealth in the base year 1989, but have tried to construct an estimate from past balance of account, back to 1969. According to this estimate the initial wealth was + 690 billion SR. An alternative estimate can be derived as the stock that would give the net property income received from abroad in the national account. With a 5% interest rate this would give an estimate of 270 billion SR. Due to the interest payment during the simulation period, an error of 100 billion SR in the initial wealth estimate, will multiply to about 1000 billion SR in 2040.

Figure 2. Foreign assets. Million SR

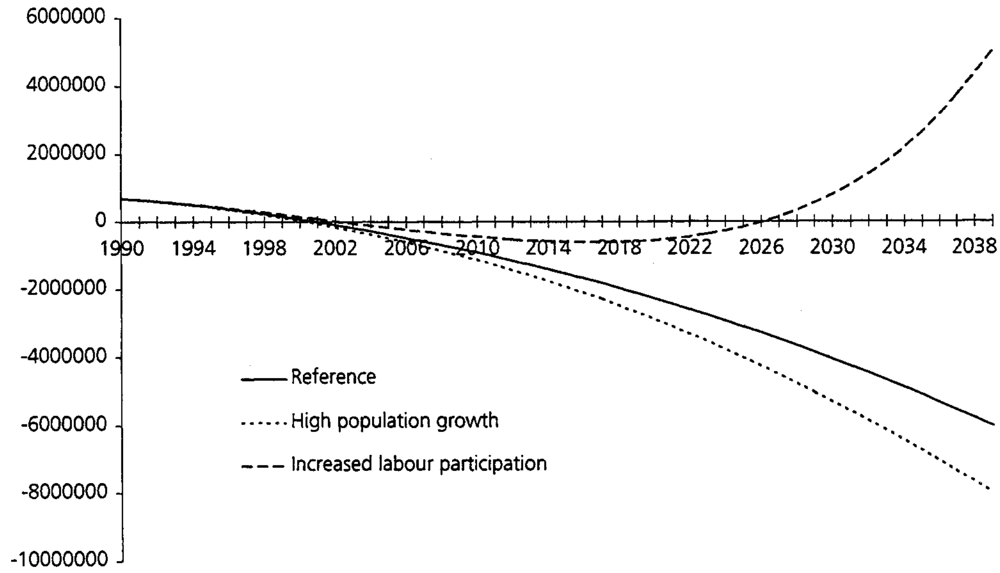
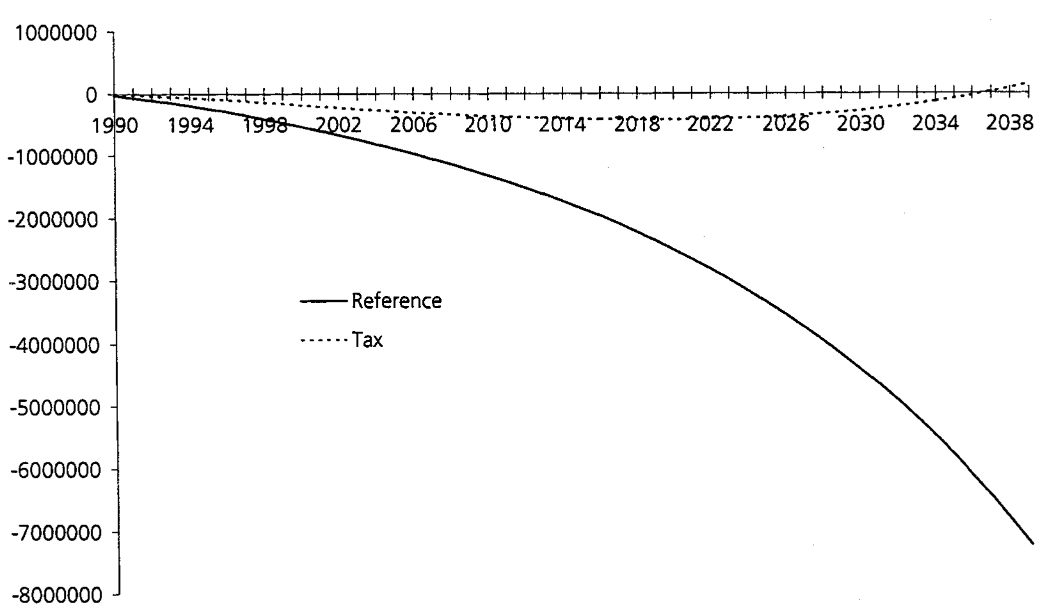


Figure 3. Treasuries. Million SR



We note that the foreign assests are declining and reaching a national debt of 6000 billion SR in 2039. If we assume a higher population growth 3.8% until 2005 and then by 3%, the debt becomes 8000 billion SR. Note however that if the labour participation rate is eincreased gradually from about 30% in 1985 to 65% in 2040, then the foreign assets eventually increases and reaches about 5000 billion SR in 2040.

The treasury (governmental wealth) is decreasing in the reference scenario as shown in figure 3, reaching a debt of 7000 billion SR in 2039. As above we have estimated initial debt from past deficits. This gives an estimate of -154 billion SR in 1991. Any initial error will multiply as above. To improve the development a scenario with a 20% tax on labour income is considered. The result is presented in the dotted line in figure 3. In this case, the government debt ends at 150 billion SR in 2031.

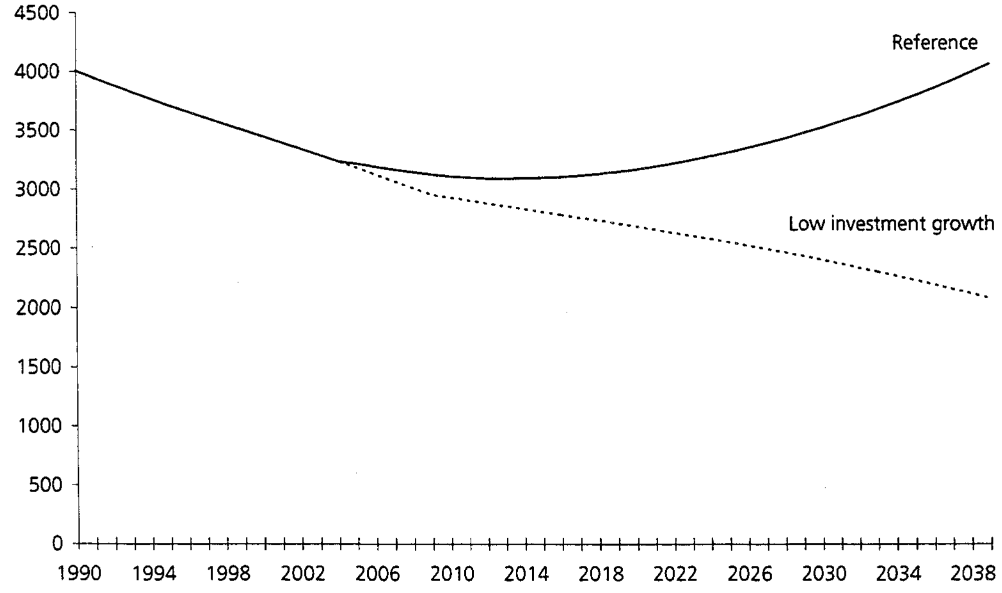
Note that in the reference scenario, the governmental expenditures are constant, while the population is increasing, thus the expenditures per capita are assumed to be declining.

6.4 Expatriate labour

The demand for expatriate labour in the reference scenario is shown in figure 4. The demand is steadily declining until 2010. The reasons for this is that, we have assumed technological progress in the area in form of increased wage rates. Thus will induce a substitution of capital for labour in the private sector and reduce the demand for labour. From 2010 however the investment rate is increasing faster than the population, this increases the per capita capital stock in the private sector, and hence also the demand for labour. Note however that the Saudi-population in 2040 is more than 3 times as large as in 1990. The alternative scenarios presented in this note will not significantly affect the demand for expatriate labour.

Figure 4 further presents a simulation where the investment growth is kept constant at 3% throughout the simulation period. In this scenario the employment of non-saudis declines to 2000 in 2040.

Figure 4. Employment non-Saudis



7 Future work

The *Century Model* is a highly aggregate model, and further disaggregation may be found advantageous. A more disaggregated model can be used to make more precise assumptions and take more factors into account. On the other hand, the advantage of an aggregate model is its transparency. An aggregate model is easier to comprehend, and get familiar with. Hence, we recommend that the aggregate model is explored to get acquainted with the Century Model approach before further disaggregation.

We will consider some points where more details would enchance the model: First, the model has only one type of labour. In fact there are different kinds of labour, depending on the skills of the employee, an unskilled person cannot take a job that requires higher education. The use of expatriate labour may be different for different kind of labour. Perhaps few Saudi Arabians will be attracted to low paid jobs as unskilled workers. A division of the labour market into different kinds of labour may thus be important to understand the demand for expatriate labour, and how it can be influenced. This would also open for an explicit consideration of human capital as part of the natural wealth.

Secondly, there is only one commodity apart from energy and water. This makes it difficult to analyse the aspects related to specific industries, e.g. the agricultural sector with its intensive use of non-renewable water. A separation of the agricultural sector will enchance the study of water use.

Another stylized feature of the current version is the exogeneity of the demand side of the economy. The consumption of water and energy is determined by a constant ratio to the consumption of the macro commodity. It will be necessary to endogenize this ratio to allow the study of instruments e.g. to reduce water consumption.

Finally, a potential extension is to develop an optimization mode of the model. Adding uncertainty would be a further extension of an optimization mode.

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Appendix. List of variables with 1989 values and sources

Variable	*Data source*		
XXCPN	IM	21089.99	mill. S.R
B		182842	mill. S.R
EE		3370.85	mill. barrels
CG		164995.2	mill. S.R
JG		45200.7	mill. S.R
		210195.9	mill. S.R
YPA		175073.54	mill. S.R
CPR		168746.76	mill. S.R
JP		36803.7	mill. S.R
KP		1990: 532796	mill. S.R
		1991: 634021	mill. S.R
E		5352.6	1000 persons
ES		2133.6	1000 persons
EN		3219	1000 persons
EP		4558.7	1000 persons
EG		793.9	1000 persons
POP_{SA}	OPEC's annual stat. bull.	15584	1000 persons
PE		63.75 = 17$/barrel * 3.75	S.R
PED		20	S.R
LS		6948.42	1000 persons
RW	Sixth dev. plan	1990: 579836	mill. m^3
		1991: 565000	mill. m^3
AE		2685	mill. barrels
D		714	mill. m^3
R		0.05	
T	T = T(-1) + GRTOT - GETOT T(1969) = 0, timeseries from IM	1990: -48759.1 1991: 154329.1	mill. S.R mill. S.R
Z	$Z = (1 + R)\,Z(-1) + Z_{IM}$ Z(1969) = 0, R = 0.05	1990: -755226.12 1991: - 689194.43	mill. S.R mill. S.R
WDA		16400	mill. m^3
EDD		71.4	mill. fat
RE		1990: oil 260004 + gas 5443.2	mill. barrels
		1991: oil 260936 + gas 5449.4	mill. barrels
WDC	Sixth dev. plan	1240	mill. m^3
WD	Sixth dev. plan	714	mill. m^3
WDA	Sixth dev. plan	16400	mill. m^3
WDY	Sixth dev. plan	560	mill. m^3
WO		2650	mill. m^3
W		18.27	thousand SR
		109.55	
EDY		0.25 * 780 = 195	mill. barrels
EDG		0.25 * 780 = 195	mill. barrels
EDC		0.5 * 780 =390	mill. barrels
PK		0.15	
REST			
RESZ			
RESE			

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ISSN 0805-9411

Statistics Norway