The Impacts of Food- and Oil Price Shocks on the Namibian Economy: the Role of Water Scarcity*

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Abstract

The recent increases in international food and oil prices have raised concerns about how these exogenous shocks will affect the economic activity as well as poverty in developing countries. In this paper, the effects of international food and oil price increases on the Namibian economy are studied by means of a Computable General Equilibrium model. As a corn and oil importing Sub-Saharan African country, Namibia is among the countries considered to be particularly vulnerable to these price shocks. Besides, since Namibia is also one of the driest Sub-Saharan countries, the role of water scarcity is explicitly addressed in this particular context. The results show that the Namibian economy will be negatively affected by the food and oil price increases. In the case where the supply of water is assumed to be constant, it is shown that there will be even less ability to adapt for the economy, thus resulting in a more significant decrease in GDP than in the case where additional water sources are assumed to be available.

Keywords: computable general equilibrium model; food prices; oil prices; water scarcity

JEL classification: D58; Q18; Q25

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1. Introduction

The recent increases in global food and oil prices have raised concerns about how such external shocks will affect developing countries, both in terms of overall economic activity and poverty.[1] The rising food prices have become one of the most important questions on the World Bank agenda, where the recent price increases are referred to as "the current food crisis". There is concern that this current food crisis might threaten the possibility of reaching the Millennium Development Goal that calls for halving the share of people suffering from extreme poverty and hunger by the year 2015.[2] The reason is that while net-food-exporting countries will most likely benefit from higher world market prices, for net-food-importing countries, which are often poor countries, the negative impacts of higher world market prices of food might outweigh the positive effect on agricultural production. Further, while the increased profitability of agricultural activities following from higher world market prices of food might create a chance for many developing countries of expanding and improving the effectiveness of their agricultural production, a conceivable constraint for agricultural expansion might be the rising world market prices of crude oil and petroleum products which are currently taking place along with the food price increases.[3] In oil-importing countries, the negative effects on overall economic activity of the oil-price increases might be significant[4] and these price increases might have an offsetting effect on the potential growth of the agricultural sectors, depending on how petroleum-intensive agricultural production is in relation to other economic activities.

The expected growth of agricultural production in many developing countries also raises further concerns about the sustainability of natural resources; in particular water resources. In developing countries, the agricultural sector's share of total national water consumption is often substantial and in water scarce regions, such as for example Sub-Saharan Africa, further agricultural expansion might lead to the depletion of water resources.[5] In other words, water

[1] A recent working paper on the likely responses of higher food and oil prices was prepared by the World Bank to be discussed by the world leaders at the G8 summit meeting held in Japan in July 2008; see World Bank (2008a).
[2] See World Bank (2008b).
[3] See World Bank (2008a).
[4] In an analysis of the global impacts of high oil prices, made by the International Energy Agency (IEA) 2004, Sub-Saharan African oil-importing countries are singled out as being particularly vulnerable to international oil price increases.
[5] See Von Braun et al. (2008).

scarcity might be an important constraint to the possibilities for agricultural sector growth in many poor countries.

In this paper, the likely economy-wide impacts of the recently observed increases in world market prices of food and oil on the Namibian economy are analysed by means of a Computable General Equilibrium (CGE) model. Since Namibia is a dry country, special focus is given to the importance of water scarcity for agricultural sector growth and thereby, the possibility for the economy of adapting to the exogenous world market price changes. The importance of water scarcity is analysed by comparing the outcome in the case where additional water resources are assumed to be available to the case where total water supply is assumed to be constant.

As the economy-wide effects of food- and oil price increases, respectively, will most likely differ, a general equilibrium analysis is particularly useful for analysing the effects of both price shocks in combination. Besides, the use of a CGE model, in combination with disaggregated household data, also allows for a household level impact analysis. In terms of poverty impacts, food prices are in general considered to be of greater concern than oil prices since food constitutes a larger share of the expenditures of poor households.[6] Existing analyses show that the poverty impacts of rising food prices are likely to be diverse; while the poorest people in general spend a larger share of their total income on food, farm households, which are often among the poorest groups in low-income countries, may experience a rise in income when there is an increase in commodity prices.[7] Although several studies show that the overall impact of higher food prices on poverty is generally negative[8], there is need for a careful examination at the household level, also including indirect effects, in order to examine whether changes in prices of food will benefit or harm the poor people in a specific region.[9]

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[6] While rising oil and petroleum prices will also have negative effects on household welfare, oil price increases are, in general, likely to mainly affect richer household groups. See World Bank (2008a).
[7] See, for example, Hertel (2006).
[8] Several studies have shown that, in general, there are more net food buyers than sellers among the poor. See, for example, Jayne et al. (2000), Warr (2005) and Byerlee et al. (2006).
[9] Despite a widespread concern about the likely negative impacts of higher food prices on poor people, little hard information appears to be available on actual impacts on poor people. Aksoy and Isik-Dikmelik (2008) suggest the need for a re-evaluation of the consensus on the adverse impact of food prices on poverty; further work on regional differences and second-order effects is necessary to answer these questions more exactly.

In previous CGE-based literature, the impacts of food and oil price shocks on developing countries are in general studied separately.[10] However, as many countries are actually facing both higher world market prices of food and oil at the same time, it is highly motivated to study these price increases in combination. Further, the existing literature on general equilibrium aspects of food price changes mainly focuses on specific national trade liberalisation policies and can therefore not provide any general conclusion about the likely impacts in developing countries in general, or Namibia in particular, of the recently observed increases in the world market prices of several food products.[11] The few recent studies more explicitly focusing on the currently observed international food price increases are, in general, partial equilibrium analyses.[12] Therefore, this paper contributes to the previous literature both by studying the general equilibrium effects of the currently observed international food price increases, and also taking into account the increase in oil prices which is currently taking place along with the food price increases.

Although the potential environmental impacts of expanded agricultural production are often mentioned in previous studies of food price changes, the magnitude of these impacts is generally not further analysed.[13] For that reason, the third important contribution of this paper is that the importance of water scarcity is explicitly added to the CGE-analysis. This is one of few studies in developing countries where water is explicitly studied in a general equilibrium framework. Besides, to my knowledge, it is the first study that analyses water scarcity in the context of increased food and oil prices. In the recent literature, where general equilibrium approaches are used for analysing water supply and demand, the way in which water is included in the analysis can be divided into two categories; it is either explicitly included as a factor of production[14] or it is approximated by, for example, agricultural productivity.[15] This analysis falls into the first category by including water as a factor in the production process.

[10] For general equilibrium analyses of food price changes, the literature on trade policy can provide some examples, see e.g. Warr (2005), Cororaton and Cockburn (2006), Boccanfuso and Savard (2008). See also Gelan (2007) for a CGE study on the effects of food aid in Ethiopia. For general equilibrium analyses on oil price shocks in developing countries, see e.g. McDonald and Schoor (2005) and Essama-Nssah et al. (2007). There are, to my knowledge, no existing CGE-analyses where oil- and food price increases are considered in combination.

[11] See the above mentioned studies (in footnote 10) on general equilibrium analyses focused on trade policy.

[12] Some recent partial equilibrium applications of increased food prices are, for example, Ravallion et al. (2004), Ivanic and Martin (2008) and Aksoy and Isik-Dikmelik (2008).

[13] See, for example, Ravallion (2004), where the problem of increased water scarcity in Morocco is omitted from the analysis of short-term welfare impacts of price changes of cereals.

[14] See, for example, Berrittella et al. (2007), Diao and Roe (2003) and Goodman (2000).

[15] See, for example, Horridge et al. (2005); agricultural productivity is modelled as a function of rain.

As agriculture is the most water intensive activity, this paper focuses on water use in the agricultural sectors.[16]

The paper is structured as follows: Section 2 provides some background information about the economic structure as well as the water situation in Namibia. In addition, the actual levels of the recently observed international price increases on food and oil products are described. In section 3, the model and the data are presented followed by a description of the simulation scenarios in section 4 and the simulation results in section 5. Section 6 provides the concluding remarks.

2. Background

Namibia is one of the driest countries in Sub-Saharan Africa and it is highly dependent on its natural resource base: mining, fishing, agriculture and wildlife based tourism. Namibia is, by definition, a middle income country with a per capita income of USD 3000 per year.[17] However, when it comes to income distribution and poverty, the picture is no longer that of a middle-income country. Namibia's official unemployment rate is approximately 35 per cent and it is estimated that 50 per cent of the population live below the poverty line. Besides, Namibia has one of the most inequitable income distributions in the world.[18]

2.1. Food and oil price increases – from a Namibian perspective

The recent rise in international food prices is mainly driven by increases in the world market prices of cereals (defined as wheat, course grains and rice) and oilseeds (seeds grown primarily for the production of edible, i.e. cooking, oils), which nearly doubled between 2005 and 2007. Dairy product prices have also been rising nearly as much during this period, while the price increases of meat have been more modest (about 20 per cent). Although the OECD-FAO Agricultural Outlook (2008) expects prices to come down again from the record levels of 2007 and early 2008, prices are not expected to return to the low historical levels, at least

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[16]A similar approach has also been taken in previous water-studies; see, for example, Goodman (2000) and Berittella et al. (2007).
[17] According to World Bank (2007), countries with a per capita income between USD 906 and USD 11 115 are defined as middle-income countries.
[18] The official number for the Gini coefficient is 0.7. Worldwide, Gini-coefficients, as a measure of inequality of income distribution, range between about 0.2 for countries with low inequality, e.g. Denmark and Sweden, to 0.7 for the most unequal country, Namibia.

not during the next decade.[19] This report projects that, on average over the next ten-year period (2008-2017), the real prices of cereals, rice and oilseeds will be 10 to 35 per cent higher than the average prices in the past decade. Although dairy prices are projected to decline from the current levels, these prices, together with meat prices, are also expected to remain above the current averages in the next decade.

In Namibia, agricultural production accounts for about 7 per cent of GDP. Agricultural production can be divided into commercial cereal production, commercial other crop production, commercial livestock production and traditional agriculture. Like in many Sub-Saharan countries, Namibia's domestic production of cereals is low and most of the domestic consumption of cereals is imported. The share of other crops[20] that is domestically produced is larger and although a significant amount of other crops is also imported, Namibia is a net-exporter of non-cereal commercial crops. When it comes to livestock production, this sector together with the meat processing industry constitute two of Namibia's most important export sectors after mining and fishing. Considering the other food processing industries, Namibia is a net importer of grains, beverages as well as other food products.

When it comes to energy, the world market prices of crude oil and petroleum products have been rising since 1999, with a sharp increase since 2003. The world market price of crude oil reached the new record level of 100 US$ a barrel at the beginning of 2008 and is still on a level just below 100 US$ at the time of writing. In real terms, this corresponds to a price increase of about 100 per cent since 2003. Even though some experts consider the present oil prices as unjustifiably high, a return to the low levels of the last two decades is not likely to be expected in the longer term.[21]

[19] There are reasons to believe that while some of the factors underlying the current high price levels are temporary, others are permanent and will most likely make prices remain above the historically low levels. For example, the supply of food will most likely be able to recover from the temporary adverse weather conditions in large grain producing regions in the last few years. However, the increased demand for biofuels is the largest source of new demand in decades and is a strong factor behind an upward shift in agricultural prices.

[20] Non-cereal crops produced in Namibia are, for example, vegetables, fruits, cotton and ground nuts, where the latter two are examples of oilseeds.

[21] See, for example, Kemfert and Horn (2005). According to the authors, and contrary to what is often emphasized, there is no shortage of crude oil at present. One reason for the very high current oil prices is that the high level of capacity utilisation in oil extraction creates risks that are reflected in rising prices on the forward markets. Although predictions of future prices are difficult, future prices are projected to be somewhere between 70 and 160 US$ a barrel.

Namibia has no crude oil or coal resources and the total consumption of petroleum products is therefore imported. This makes Namibia particularly sensitive to fluctuations in international crude oil and petroleum product prices. The sectors using most petroleum products in their production are the transport sector followed by fishing, mining and construction. According to the data on input costs among the agricultural sectors,[22] commercial cereal production is most petroleum-intensive, followed by livestock production, traditional agriculture and other crop production.

2.2. Namibia's water resources

Water is considered to be one of the main constraints to development in Namibia. One expression for the importance of water in Namibia is the establishment of a system of water accounts, which was first constructed already in the mid 1990's.[23] The post-independence renewed national water policy,[24] which especially emphasises the need to recognise the economic value of water and promote an economically efficient use of water, has further strengthened the role of water accounting as an important tool for sound water management. The Namibian water accounts mainly focus on the flow accounts (supply and use) because there is little data available for stock accounts. While complete physical accounts for supply and use of water have been established, only partial monetary accounts are available so far due to lack of data.[25]

2.2.1. Water supply and use

In this section, the main structure of the water accounts is described. A more detailed description of the Namibian water accounts can be found in Lange (2006). In the water flow accounts, three different sets of classifications are used; natural sources of water, supply agencies and end-users. The main natural sources of water include groundwater, perennial surface water (from perennial rivers along the northern and southern borders) and ephemeral

[22] This refers to the information about the cost-structure of the production sectors found in the main database used in this analysis, the Social Accounting Matrix. See section 3.2. for a further explanation of the data in the SAM.
[23] See Lange (1998).
[24] The new water policy is specified in the Water Resources and Management Act (2004).
[25] Namibia is one of few developing countries where water accounts are constructed following the UN framework for the System of Environmental and Economic Accounts (SEEA). By combining hydrological and economic information in a framework consistent with the System of National Accounting, SEEA for water resources allows for a more integrated analysis linked to macro-economic policies as opposed to merely sector-specific analysis.

surface water stored in dams (ephemeral rivers only flow after periods of heavy rainfall). The major water supply institution is *Namwater*, a state-owned corporation operating on commercial principles. Namwater abstracts water from the natural environment and then directly supplies some end-users as well as other water supply institutions. Other water supply institutions include *Municipalities*, *Rural Water Supply* and *Rural Communities*, which abstract some water but purchase most of the water from Namwater, and *Self-providers*, which include individuals and companies that abstract water for their own use, mainly within the agricultural sector. The classification of end-users (production sectors and households) for the water accounts can be matched to the industry classification of the Namibian Social Accounting Matrix (SAM).[26]

Groundwater is the single largest natural source of water in Namibia, accounting for about 40 per cent of the total water supply. By institution, Namwater and agricultural self-providers are the two largest suppliers, together accounting for about 85 per cent of the total water supply.

When it comes to water use, according to Lange (2006), total water use has been growing faster than both population and GDP in the last decade, mainly due to the growth of water-intensive sectors, largely crop irrigation. Agriculture is the major user of water and uses about 75 per cent of the total water supplied. Crop irrigation is the most water-demanding activity, accounting for about 54 per cent of the total agricultural water use compared to 21 per cent in the livestock sector. The second largest user of water, following agriculture, is households, especially urban households. Interesting to note is that in recent years, water use has grown most rapidly in the fishing sector, which traditionally uses modest amounts of freshwater. The reason is the emergence of aquaculture in some parts of the country, which is an activity considered to have a high growth potential but, at the same time, is as highly water intensive as irrigated crop production.[27]

Although the data is not sufficient for compiling water stock accounts, there is some concern that current water stocks might be declining. In a long-term perspective, there are estimations on water availability of up to twice the level used today[28], but these long-term figures should be taken with caution. Although total water use does not yet exceed water availability on a

[26] The SAM constitutes the major database on which the CGE-model is built; see section 3.2. for a further explanation of the SAM.
[27] Lange (2006).
[28] See Christelis and Struckmeyer (2001).

national level, there are regional differences in water resources and demand, implying that in some regions, water shortages are already a fact.[29] In addition, there is concern that in some cases, the use of water has been "locked in" in specific sectors through investment and infrastructure development. This might lead to an inefficient water use as it will be difficult to use the water for other purposes in a situation when competition for water increases.

2.2.2. Full cost recovery water policy

In the past, the governmental policy of subsidising water, especially irrigation water used in commercial agriculture, has contributed to an inefficient allocation of water. Namibia's water policy has changed during the last decade, however,[30] and according to Lange (2006), there has been some progress towards full cost recovery at the national level; except for some rural households and the commercial irrigated agricultural sectors, end-users do in general cover the full private costs of supply. While there is no official information on the marginal costs of supplying water, estimates of average supply costs are available. The average cost of supplying water varies by institution and natural source of water. The average cost of all water abstracted by Namwater is 2.01 N$ per cubic metre of water. For agricultural self-providers, there is only an estimate available for the average cost of abstracting groundwater, which is estimated to 4.18 N$ per cubic metre, but this figure is highly uncertain and there are no available estimates of the average cost of supply for other water sources abstracted by agricultural self-providers.[31]

3. The model and Data

3.1. The Model

The model used in this paper is based on a standard CGE-model, developed by the International Food Policy Research Institute (IFPRI). This model has previously been used for

[29] Lange (2006).

[30] The New Water Resources Management Act emphasises the need to recognise the economic value of water; water tariffs should reflect the full opportunity cost of water, including private costs of providing water as well as environmental impacts. See Water Resources Management Act No. 24: 2004.

[31] See Lange (2006). Concerning agricultural self providers, although actual data on costs is not available, farmers pay the full cost of supply for the water they abstract by themselves. It is the water bought from Namwater by the agricultural sectors that is subject to subsidies.

macroeconomic analysis in a number of developing countries[32] and it is based on the same standard principles of neoclassical modelling as are most often original general equilibrium models. The model is a set of simultaneous equations which define the behaviour of different actors. All production and consumption decisions are driven by maximization of profits and utility, respectively. To some extent, however, the model allows the user to depart from some of the typical neoclassical assumptions, for example concerning the functioning of factor markets. By allowing for factor immobility and/or wage rigidity, the model can sometimes better represent the real functioning of the economy in many countries, especially in developing countries. A full documentation of the original model is given in Löfgren et al. (2002)[33] and a detailed description of the production and consumption structure, as well as a full mathematical statement of the model equations, can be found in Sahlén (2008). The most important behavioural assumptions for the model agents as well as some of the system constraints are briefly described below.

3.1.1. Households

Households receive income from factors of production and transfers from other institutions. The remaining income after direct tax payments, savings and transfers to other institutions is used for consumption. Households are choosing the bundles of commodities in order to maximize utility subject to their budget constraints. The utility function is a Stone-Geary function, implying that for each household, a minimum level of each commodity must be consumed, irrespective of its price or household income. After subsistence has been achieved, the relative contribution of each commodity to utility can be considered. The utility function can be written

$$U = \prod_{c} \left(q_c - \gamma_c\right)^{\beta_c}, \tag{1}$$

where q_c is total consumption of commodity c, γ_c is subsistence consumption and β_c is the relative weight of utility that the consumer spends on commodity c. The first-order conditions resulting from the utility maximization are referred to as a linear expenditure system, since the expenditure on a specific commodity is a linear function of total consumption expenditures. Households consume both domestically produced and imported commodities. In the case when a commodity is both domestically produced and imported, household consumption is

[32] Examples of macro-policy studies in African countries where the generic IFPRI CGE-model is used; South Africa: Thurlow (2002) and Go et al. (2005), Tanzania: Eskola (2005), Ethiopia: Gelan (2006) and Namibia: Sahlén (2008).
[33] This study contains a manual of the standard CGE-model, which can be downloaded from IFPRI’s website.

measured in terms of a composite commodity, which constitutes an aggregate of domestically produced and imported goods. For the aggregation of domestically produced and imported commodities, the Armington Constant Elasticity of Substitution (CES) specification is used. The choice between domestically produced and imported variants of the same commodity is modelled by assuming that the demanders minimize the cost subject to imperfect substitutability between imports and domestic commodities. The Armington CES function is specified as

$$QQ_c = \alpha_c^q \cdot \left[\delta_c^q \cdot QM_c^{-\rho_c^q} + \left(1 - \delta_c^q\right) \cdot QD_c^{-\rho_c^q} \right]^{-\frac{1}{\rho_c^q}} . \qquad (2)$$

In equation 2, QQ_c is the total (composite) supply of a commodity, while QM_c is the imported quantity and QD_c the domestically produced quantity of the commodity. Further, α_c is the Armington shift parameter, δ_c is the share parameter and ρ_c the function exponent. It is assumed that international supplies are infinitely elastic at given world prices. The assumption of imperfect substitutability is made in order to prevent unrealistic import responses to policy changes as it allows for some independence between the domestic and the international price system. The use of the Armington function is standard in the CGE literature.

3.1.2. Production

The production decisions are guided by the assumption of profit maximization in a perfect competition setting. This implies that the firm takes the prices of output, production factors and other inputs as given, the level of production is such that the marginal cost of inputs is equal to their respective marginal revenue products and there are no pure profits. This implies that the production is characterized by constant returns to scale. In the production of domestically produced commodities, different factors are combined into value added via a Constant Elasticity of Substitution (CES) production function:

$$QVA_a = \alpha_a \cdot \left[\sum_{f=1}^{n} \delta_{fa} \cdot QF_{fa}^{-\rho_a} \right]^{-\frac{1}{\rho_a}} , \qquad (3)$$

where QVA is the value added output in each production sector, a. QF represents the quantity of production factors used in the production process, α_a is an efficiency parameter and ρ_a is the CES function exponent, which is calibrated using the elasticity of substitution.[34]

[34] The elasticity of substitution for the CES function is $\sigma = 1/(1+\rho_a)$.

The value added output produced in equation 3 is, in turn, combined with intermediate inputs using a Leontief specification, implying no substitutability between value added and intermediate inputs in production. Intermediate inputs are, in turn, bundles of composite commodities combined via a Leontief production function, implying that the model does not allow for substitution between different intermediate inputs.[35]

3.1.3. Other agents

Factor incomes from the factors of production are paid to the *factor owners*, which are *households* and *enterprises*. Enterprises do not consume and their incomes are allocated to direct taxes, savings and transfers to other institutions, mainly households.

Imported commodities are paid for to the *Rest of World* which also pays for domestically produced commodities that are exported. Domestic production is divided between domestic supply and exports based on suppliers' revenue maximization, subject to a Constant Elasticity of Transformation (CET) function. This implies that although the supply of exports is determined by the relative price of exports and domestic goods, producers' maximization of sales is subject to imperfect substitutability between exports and domestic sales. The CET function is written

$$QX_c = \alpha_c^t \cdot \left[\delta_c^t \cdot QE_c^{-\rho_c^t} + \left(1-\delta_c^t\right) \cdot QD_c^{\rho_c^t} \right]^{\frac{1}{\rho_c^t}}, \qquad (4)$$

where QX_c is total domestic output, QE_c is exports and QD_c is domestic sales of domestic output. The equation also includes shift and share parameters as well as a function exponent. The assumption of imperfect transformability is (just like the assumption of imperfect substitutability between domestic produced goods and imports), made to better reflect the empirical realities of most countries and is a standard component in CGE-models. Namibia is assumed to be a price-taker on all export markets, i.e. the country is assumed to be too small for its export or import volumes to significantly affect the world market prices of these goods.

Another important agent in the model is the *government*, which levies taxes on commodities, imports, production, factors, households and enterprises. The government consumes a bundle

[35] This implies that, in general, the model allows for greater substation on the consumption side than on the production side, which is a standard feature of most CGE-models.

of government goods and also makes transfer payments to other agents, mainly households and enterprises.

Households, enterprises, the government and the rest of world all save part of their income, which is accumulated in the Savings-Investment account from which investment commodities are purchased.

3.1.4. Model closure rules

Besides the behavioural specifications described above, the model also contains a set of constraints that must be satisfied for the model system as a whole, which are not necessarily considered by, and do not refer to, any individual actor. These include constraints for markets (factor and commodity markets) and macroeconomic aggregates (government and external balances as well as the savings-investment balance). These constraints are satisfied via the model closure rules, which means that the user determines which variables should be endogenous and exogenous.[36]

For factor markets, different closure rules (which represent mechanisms for equilibrating supply and demand) can be chosen for the different factors. In this paper, the capital stock in each sector, together with the mixed factor in agricultural production,[37] is assumed to be fixed. This is the standard way in which capital and land are modelled in static CGE-models in developing countries and it is motivated by a relatively short time horizon. For the labour market, a distinction is made between skilled and unskilled labour categories. Skilled labour is considered to be fully employed and mobile between sectors. Unskilled labour is also considered to be mobile between sectors, although the analysis allows for unemployment among the unskilled. The different closure rules for the two different labour categories are chosen in order to reflect the fact that a considerable amount of unskilled labour in Namibia is actually unemployed. Unemployment is achieved in the model by holding the real wage constant for this labour category.[38]

[36] See Appendix C for a specification of the different closure rules for factor markets and macroeconomic aggregates available.
[37] The mixed factor contains a capital as well as land component in the agricultural sectors. See section 3.2. for a clarification of the mixed factor.
[38] This assumption is standard in CGE models for countries where unemployment is high. See e.g. Thurlow (2002), van Heerden et al. (2006) and Gelan (2007).

Concerning water, different closure rules form the basis for three different model simulations; in the first scenario, water is assumed to be "unemployed", i.e. water supply is assumed to be perfectly elastic and, to a large extent, mobile between sectors. In the second and third scenarios, total water supply is fixed and the importance of factor mobility is tested by assuming a relatively high degree of mobility between sectors in scenario three, while in scenario two, the water is assumed to be sector specific.[39]

Concerning the macroeconomic balances, real government consumption as well as all tax rates are exogenous and thereby not assumed to be affected by the exogenous price changes. This implies that government savings are endogenous in order to maintain the government balance. When it comes to the savings-investment balance, real investment is assumed to be exogenous while savings are endogenous. In order to address the possible influences on exports and imports of the exogenous price increases simulated in this paper, foreign savings are assumed to be endogenous while the exchange rate is fixed. The model numeraire in all simulations is the Consumer Price Index (CPI).[40]

3.2. Data

In order to calibrate the model, a significant amount of data is needed, together with values of elasticities (see section 3.2.2.). The original SAM for Namibia from 2002[41] constitutes the main source of data on basis of which the model is calibrated. In the base case, the model equations ensure that the values in the original SAM are reproduced. The SAM divides the economy into 26 sectors of production, five factors of production and six household groups according to their main source of income. The household groups are: urban households who receive their income from wages and salaries, urban households involved in business activities, other urban households (mainly depending on pensions and gifts), rural households receiving income from wages and salaries, rural households within business activities and commercial farming and, finally, other rural households (mainly depending on subsistence farming, pensions and gifts). By combining the total income for each such group (provided in

[39] See section 4 for a detailed description of the simulations scenarios.
[40] As the model is a real model, only relative prices matter and a numeraire must be chosen. All simulated price changes are interpreted as changes in comparison to the numeraire price index. Therefore, there is no price inflation in the model. This does not reflect the view that inflation is unimportant in this particular context, only that the model does not take inflation into account.
[41] See Lange et al. (2004) for a full documentation of the construction of the 2002 SAM. The full original database can also be found in Sahlén (2008).

the SAM) with data on the actual number of households in each household group (provided in the preliminary report of the Namibian household income and expenditure survey 2003/2004), the average income per household within each household group can be estimated. These results show that the average income is lowest for the urban and rural household groups depending on pensions and other income, together with the rural household group that receives income from wages and salaries. The highest average incomes are found within urban and rural household groups involved in business and farming. This information is interesting when it comes to analysing the effects on the current income distribution, in particular because Namibia has one of the most unequal income distributions in the world.

The factors of production included in the original SAM are unskilled labour, skilled labour, capital, a mixed factor in the commercial agricultural sectors (representing a mix of farm owners' labour, capital and a land as well as a water component) and a mixed factor in the traditional agricultural sector (analogous to that in the commercial sectors, but with a negligible capital component). The reason for using the mixed factors in the database is that it is difficult to distinguish between different types of earnings of self-employed farmers; the surplus of sales revenue over input costs includes a payment for own labour, own capital input as well as land and water input. Therefore, their factor income is left as "mixed income" in the national accounts.

The original SAM needed some minor adjustments in order to fit the purpose of this study. First, in order to make the model easier to solve numerically, a number of smaller service sectors have been aggregated into a single sector when fed into the CGE-model. Some additional small adjustments concerning tourism and traditional agricultural data were also needed. In addition, improved fishing sector data, which was first used in an earlier study about the Namibian economy by Sahlén (2008), is also included in this paper. These minor adjustments are further described in Appendix B while in this section, the more important water data adjustments are further described.

3.2.1. Water data

In this section, the methodology for including water as a factor of production in the CGE model is described. A general feature of the model, which is standard in most CGE-models, is that it does not allow for substitution between intermediate inputs, only between the different factors of production. In the original data, water is included as an intermediate input into production, which implies that no substitution between water and other inputs or other factors of production is allowed.[42] Therefore, in order to allow for substitution possibilities between water and other factors of production in the analysis, water is transformed into a factor of production instead of an intermediate good in the production process. By treating water as a factor of production, the effects of increased water scarcity can be explicitly modelled by introducing restrictions on total water supply.

The water accounts for the flow and use of water constitute an important source of additional data. In traditional water accounts, a distinction is made between different natural sources of water; groundwater, perennial surface water and ephemeral surface water. In my model, however, no distinction is made between the different natural sources of water. The reason is mainly that as the monetary accounts are not complete, the potential benefits of dividing the water into different types of water would most likely be offset by the drawbacks associated with having to rely on a set of additional assumptions.[43] Further, although there are more than two water supply institutions in Namibia, only self-providers within the agricultural sectors as well as a water distribution service sector are modelled as water abstracting institutions. The water distribution service sector is supposed to mainly represent Namwater but also the smaller institutions mentioned in section 2.2.1. above.[44]

The part of water used in the agricultural sectors that is "self-provided" can, in the original data, be seen as a "hidden" factor of production, as it is represented by a fraction of the mixed factor used in the agricultural production sectors. In a similar way, part of the initial total capital factor in the water distribution service sector should be seen as a water factor. For the purpose of this study, the part of the mixed or capital factors that represent water needs to be explicitly modelled as a water factor in the agricultural sectors as well as in the water distribution service sector.

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[42] This follows from the fact that a Leontief technology is used for aggregating the different intermediate inputs as well as intermediate inputs and factors of production.

[43] The assumptions made concerning the value of water are further described below. In addition, since the costs for supplying different water sources also depend on regional differences, a regional instead of a national analysis should be carried out for a distinction between different sources of water to be meaningful. Specific regional data is not available at the moment and therefore, it was decided not to divide the water factor according to natural sources.

[44] In the original SAM, Namwater together with the smaller water supply institutions are aggregated into one water distribution sector, while the water provided by agricultural self-providers is basically omitted from the data. The inclusion of agricultural self providers in the analysis therefore constitutes an important development of the original data.

To identify the hidden water factor in the agricultural sector and water distribution service sector, respectively, additional data on the quantity of water used per sector (in cubic metres) as well as the value of water per cubic metre is required. Comprehensive data is available for the actual water use among the economic sectors in Namibia, but assumptions must be made concerning the value of water. One possible indicator of the value of water would be the marginal cost of supplying water to end-users, assuming that end-users actually pay the full cost for providing the water. As mentioned in section 2.2.2., while no estimates of the marginal costs of water supply exist, there are some estimations of the average cost of water supply available for the year 2001-02. This cost varies by type of natural water source and water supply institution but, on average, it lies within a range of 1- 4 N$ per cubic metre.[45] In the absence of other reliable estimations of the value of water, this unit price of water per cubic metre is used as a guideline for estimating the share of total factor income attributed to water in the agricultural as well as in the water distribution service sector. For the base case, the value of 2 N$ per cubic metre is used[46] but in order to shed some light on the sensitivity of these assumptions, a sensitivity analysis has been conducted for the case of a lower initial share of total factor income attributed to water (calculated using a water value of 1 N$ per m^3) as well as a higher total water income (calculated using a value of 3 N$ per m^3). See Appendix A for the results of this sensitivity analysis.[47]

While a water factor of production is only introduced in the agricultural and the water distribution service sectors as described above, the water distribution sector is then assumed to deliver water (as a commodity) to the rest of the economic sectors and households, mainly following the original structure in the SAM.[48] However, for the purposes of studying total

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[45] See Lange (2006) for these estimations.

[46] 2N$ per cubic metre is equal to the average cost of supply for all water abstracted by Namwater, which is the institution providing the most reliable data for the supply cost estimations.

[47] This approach to determining the size of total water income out of the mixed factor or capital factor in the agricultural and water distribution service sectors, respectively, was also used by Goodman (2000). In the dataset for the Southeastern Colorado economy used in his analysis, all factor income except labour (which was provided by labour income data) was aggregated into “other property income”. As his analysis includes labour, capital, land and water as factors, it was necessary to allocate other property income to income from land, water and capital.

[48] Some additional small adjustments have been made considering the data on household consumption of water. In the original SAM, rural households do not seem to consume much water. The reason is most likely that some of the rural households receive water as a benefit attached to their salary from the farms where they work, and for some of the poorest rural households, the water costs are completely subsidized by the government, explaining the high costs of water for the government registered in the original SAM data. For the purpose of this study, the part of the government expenses for water, which according to information from Lange (2006) is in fact distributed to rural households, needs to be transferred to rural household consumption in the database while, at the same time, these households are compensated via a lump-sum government transfer representing the subsidy of the water costs. Further, to adjust for the water received as a benefit attached to salaries in the

water demand in the agricultural sectors, the intermediate use of water in the agricultural sectors, which is represented in the original SAM as a commodity bought from the water distribution service sector, also needs to be transformed into a factor of production. In this case, the actual value presented in the SAM is assumed to represent the total cost of the amount of water bought from Namwater. The actual water costs for this part of the water in the agricultural sector reveal an exceptionally low price per cubic metre of water when combined with the actual water use quantity data in Lange (2006). One reason for this is that part of the water for agricultural use bought from Namwater is subsidised by the government. As a consequence, water productivity in agriculture (measured as the ratio of the value added from each sector divided by the water use in each sector) is significantly lower than in other economic sectors.

Considering the different uses of water as a factor, it is reasonable to assume that while the self-provided part of the agricultural water might be only transferable between the different agricultural sectors, the part that is originally provided by Namwater or other institutions should be considered to be exchangeable also between different uses, i.e. between the agricultural sectors and the water distribution service sector. The reason why not all water is considered to be mobile between agricultural and other water uses is that it is unlikely that the self-provided water in the agricultural sectors could be distributed to urban areas for urban use.[49] In the model, this restriction on mobility is explicitly modelled by dividing water into two different factors of production, where the first type of water (self provided) is only used in the agricultural sectors, while the second type of water can be used in the agricultural sectors as well as in the water distribution service sector. The initial allocation of self-provided water as well as other water between the different sectors can be seen in table 1 below.[50]

agricultural sectors, these sectors are allowed to produce an additional commodity, water, which they "sell" to the rural households that work on the farms. These households are compensated for their water costs via increased labour salaries. These small adjustments remove the misleading result that the rural households will not be at all affected by changes in the water prices as, according to the original SAM, they do not seem to consume any water at all. However, in terms of overall economy-wide effects, these minor changes are of negligible importance.

[49] The reason for this assumption is that a considerable amount of investment in water infrastructure is needed in order to transfer water from on-farm boreholes to other urban water uses. Although the water provided by water supply institutions might, to some extent, also be geographically constrained at the moment, it is reasonable to assume that this part of the water will, at least in the medium run, be more easily transferred between different uses.

[50] This implies that in the agricultural sector, the two types of water are not considered to be perfect substitutes in the production. This is a reasonable assumption. On each farm, either self-provided water or water bought from institutions is used, i.e. generally the two types of water are not used in combination. Farmers are either

Table 1. Initial use of the factor water by sector in the model

Water use, in million cubic metres*	Commercial cereal	Commercial other crop	Commercial livestock	Traditional Agriculture	Water distribuiton service sector
Self-provided Water	13 000 000	58 000 000	25 000 000	35 000 000	
Other water	9 000 000	39 000 000	1 000 000	29 000 000	16 000 000

*Quantities are based on the water use accounts from 2001-02: the total use of freshwater is about 225 million m^3. Losses from delivery to end-users are excluded from these figures.

3.2.2. Elasticities

In addition to the data provided in the SAM and the data on water factor quantities described in the above section, explicit values for elasticities are needed in order to calibrate the model. These include trade elasticities, substitution elasticities between factors of production and expenditure elasticities of market demand by households. Concerning the expenditure elasticities for household energy demand (more specifically petroleum and electricity), these values are taken from an empirical study of Namibian energy demand by De Vita et al. (2006).[51] Since, to my knowledge, there are no other available empirical estimates of the required elasticities in Namibia, all other elasticity values are taken from a CGE model of the South African economy by Thurlow (2004).[52] This is motivated by the fact that the structure of the Namibian economy is similar to that of the South African economy. See Sahlén (2008) for a further explanation of the elasticities needed in this model. In Appendix A, a sensitivity analysis is conducted for the trade elasticities as well as the substitution elasticities for factors of production used in this paper.

4. Simulation Scenarios

In the light of the observed increases in world market prices of food and oil described in section 2.1., the increases in world market prices simulated in this paper are the following; a

connected to the Namwater distribution system, or they are self-providers of water. The division of water into two different water factors do not appear to have any significant impact on the overall economy-wide results. If all water is considered to be one factor, a greater amount of water will be able to move between the agricultural and water distribution service sectors in case of water mobility which will, in general, only affect the possibility of expansion in the agricultural sectors following the exogenous price increases. This implies that by dividing water into two different factors, the desired realistic constraint on water mobility of the part of water that is self-provided can be achieved without causing any major changes in the results.

[51] De Vita et al. estimate income- and price-elasticities of the Namibian energy demand by end-users for the period 1980 to 2002.

[52] These are, in turn, mainly based on empirical estimates for the South African economy. See Thurlow (2004).

50 per cent increase in the prices of petroleum products,[53] a 30 per cent increase in the prices of cereals and grains (corresponding to cereal production and grain milling in the SAM-data), a 20 per cent price increase for other oil seeds (corresponding to other crop production; oil seeds only constitute part of the crops included in other crop production in the SAM data) and a 10 per cent price increase for meat products (corresponding to livestock production and meat processing in the SAM) and dairies (corresponding to other food and beverages production; dairies constitute part of this sector in the SAM).

To analyse the importance of water scarcity, these exogenous world market price changes are combined with three different assumptions about total supply of water as well as water mobility between sectors. These assumptions imply three different model scenarios. In scenario 1, the total supply of water is assumed to be perfectly elastic. As described in section 3.2.1., it is further assumed that self-provided water can only be used in agricultural sectors, while the water bought for agricultural use from Namwater can also be used in the water distribution service sector. In scenario 2, the total water supply is assumed to be fixed, and the water initially used in the different agricultural sectors as well as in the water distribution service sector is assumed to be sector specific (immobile). In scenario 3, the total supply of water is also assumed to be fixed, but water is now assumed to be mobile between the different agricultural sectors and, to some extent, also between the agricultural sectors and the water distribution sector (as described in section 3.2.1). These different assumptions will affect the outcome of the simulations; the results of the first scenario will indicate how much total water demand would actually increase following the expansion of agricultural production if total water supply could increase. Scenarios 2 and 3, on the other hand, will point out the importance of increased water scarcity and to what extent the different assumptions of water mobility will affect the results.

5. Simulation Results

The results presented here should be interpreted as the likely impacts of exogenous increases in the world market prices of food and oil only, assuming these to be the only exogenous

[53] As petroleum products are also produced from other sources than crude oil (like coal and gas), it is unlikely that the recently observed 100 per cent increase in crude oil prices is fully transferred to petroleum price increases. In South Africa, for example, crude oil constitutes about 50 per cent of the total costs in the petroleum production industry; see McDonald and van Schoor (2005).

changes affecting the economy.[54] The results for key variables are presented for all three scenarios in table 2 below.

Table 2. Simulation results.

Percentage change in variables	Scenario 1 - perfectly elastic water supply	Scenario 2 - constant water supply - water immobile	Scenario 3 - constant water supply - water mobile
GDP	-1.1	-1.3	-1.3
Total water consumed	20.7	-	-
Trade balance:			
- Exports	3.7	3.3	3.3
- Imports	-9.7	-9.7	-9.7
Production by sector:			
- Cereal production	4.9	0.9	-5.0
- Other crop producton	27.5	3.3	7.9
- Livestock production	0.9	0.7	0.3
- Traditional agriculture	6.2	3.6	3.3
- Fish production	0.1	0.1	0.1
- Fish processing	0.6	0.6	0.6
- Mining	0.4	0.5	0.5
- Meat processing	1.0	1.0	0.8
- Grain milling	-0.4	-0.5	-0.4
- Beverages and other food	0.3	0.3	0.3
- Textiles	-0.3	-0.3	-0.3
- Light manufacturing	-0.9	-0.9	-0.9
- Heavy manufacturing	-0.1	-0.1	-0.1
- Construction	-	0.1	0.1
- Water distribution service*	-2.8	-2.2	-3.3
- Electricity	-1.3	-1.4	-1.4
- Hotel and restaurant	-1.9	-1.9	-1.9
- Other private services	-0.3	-0.4	-0.4
- Transport	-8.7	-8.9	-9.0
- Governmental services	-0.5	-0.5	-0.5
Real household consumption:			
- Total (average)	-9.3	-9.4	-9.4
Distribution among households:			
- Urban hh, wage and salary	-9.0	-9.0	-9.0
- Urban hh, agr and business	-11.0	-11.0	-11.1
- Urban hh, pensions and other	-7.3	-7.2	-7.3
- Rural hh, wage and salary	-11.1	-11.1	-11.2
- Rural hh, agr and business	-8.0	-8.6	-8.8
- Rural hh, subs. agr. and other	-8.6	-8.8	-8.8

* Note that although total water demand for the *water factor* is increased through the expansion of the agricultural sectors, the demand for the water (as a commodity) distributed by the water distribution service sector to all households and sectors except agriculture decreases. When output in service and industrial sectors contracts, and when households' factor incomes decrease, the demand for water decreases. To adjust to the declining demand, there is a decrease in the supply of water distribution services.

[54] In a recent study by Reid et al. (2008) about the likely impact of climate change in Namibia, it is shown that agricultural production will most likely decrease due to an overall loss in agricultural productivity caused by climate change. If such impacts had been included here, it is likely that the agricultural expansion would have been more constrained. However, such aspects are not further considered in this paper.

5.1. Scenario 1 – Water supply is perfectly elastic

In this scenario, water supply is assumed to be perfectly elastic, meaning that water will not be a constraining factor for agricultural sector expansion. One interpretation of this scenario is that additional groundwater could always be pumped to satisfy increased demand.

5.1.1. Changes in production and water use

The effect on GDP of external world market price increases in food and petroleum products is negative; GDP decreases by 1.1 per cent. This is, to a large extent, due to the increase in the world market price of petroleum (0.8 per cent), but the total effect on GDP of the increase in international food prices alone is also negative. One reason for this is that the expansion of exports, especially in the livestock production and meat processing sectors, does not outweigh the negative effect on overall domestic production due to increased production costs. Increased world market prices also cause an increase in domestic prices, as prices on imported intermediates rise.[55] Increased production costs cause a general decline in production, especially in the non-exporting sectors (for example the service sectors) where exports are not an offsetting factor. There is a decline in total factor income when factor demand decreases and the unemployment of unskilled labour increases.

Turning to the sector-level changes in production, there is substantial growth in the agricultural production sectors. The other crop production sector grows by about 27 per cent, followed by the traditional agricultural sector (6.2 per cent), the cereal production sector (4.9 per cent) and the livestock sector with a nearly 1 per cent increase in production. The main reason why other crop production increases more than cereal production, despite the fact that the world market price of cereals increases more than that of other crops, is that other crops are exported, while cereals are not. This means that the other crop production sector is not only dependent on domestic demand, but can increase its production to sell the products at the new higher price directly on the world market. The reason why domestic cereal production increases, although cereals are not exported, is that the imports of cereals are becoming

[55] Intermediate inputs constitute a bundle of “composite commodities”, which are aggregates of domestically produced and imported goods. When the prices of imported goods increase, demand for domestically produced commodities increases and thereby, there is also an increase in domestic prices. As there is no domestic production of petroleum products in Namibia, the international price increase will translate into an equivalent price increase for the final commodity as well as for intermediate inputs of petroleum. The more expensive intermediate inputs can, in turn, not be substituted with other inputs due to the Leontief technology for intermediate inputs in production, which implies that increases in production costs will be a fact.

relatively more expensive than domestically produced cereals, so that domestic production increases and imports decrease.[56] Traditional agriculture mainly produces cereals, but also livestock products and other crops, and will also expand domestic production as imports of these products are becoming relatively more expensive. Cereal production is the most petroleum-intensive agricultural sector, followed by livestock production, implying that cereal and livestock production are more negatively affected by the rising petroleum prices than other agricultural production. Another reason why livestock production does not respond as much to the increased world market prices as crop production is that the world market price increase on products produced in the livestock production sector is lower than in the crop production sectors.

Concerning the structure of other production sectors, most industry and service sectors reduce their output, while fish production and processing, mining, meat processing, beverages and other food production expand. While the expansion of meat processing, beverages and other food production directly follows from the increased prices of their exported products,[57] it is interesting to note that also mining and fish industries increase production following the increased world market prices of agricultural and petroleum products. The reason is that these are important export sectors, thus implying that when increased costs of production cause domestic prices to increase, the negative effect on the domestic market can be offset by an increase in the exports of these products. In addition, since both mining and fishing industries are relatively skilled labour-intensive, these industries can also benefit from the general decrease in wages for this labour category, which follows from the contraction of the service sectors.

Turning to water use, the fact that the irrigated crop production sector is the most water intensive activity of all agricultural sectors implies that there is a significant increase in total water use. Water demand increases for all agricultural sectors, and total water use rises by slightly more than 20 per cent in this scenario. This amounts to more than 40 million m^3,

[56] Cereals serve, to a large extent, as intermediate inputs for other food production and are to a lesser extent directly consumed by households. Due to the limited substitution possibilities between intermediate inputs in the production process, there is an increase in the demand for cereals, notwithstanding the price, as other food production sectors increase their production.

[57] The reason why grain milling reduces its production is that these products are not being exported, thus implying that this sector cannot directly benefit from the increased world market price of the product. In addition, this industry suffers from highly increased production costs when the prices of cereals increase. Cereals constitute as much as 75 per cent of the total intermediate inputs in this sector and due to the use of a Leontief production function for intermediate inputs, there are no substitution possibilities between different inputs.

which is a significant amount of water. For example, it constitutes almost half the present use of water in the other crop production sector. The total water supply is adjusted to maintain the balance between demand and supply. It is interesting to note that if only food price increases were to be considered, the increase in total water demand would be about 22 per cent, implying that the increased petroleum prices only slightly dampen the expansion of the agricultural sectors and thereby also total demand for water.[58]

5.1.2. Changes in the distribution of real household consumption

At the household level, the real income effects of increased world market prices depend on how these exogenous changes translate into changes in the prices of goods and services consumed by households and changes in factor incomes. In this case, although the consumer price index is held constant, implying that any price increase on a specific good must be offset by a price decrease on other goods, household groups can be differently affected by price changes as their consumption pattern differs. Concerning changes in household factor income, these will differ across household groups according to the differences in the structure of factor ownership.

The total effect on real household consumption of the simulated changes in world market prices of food and petroleum products is negative. All household groups are negatively affected by the external price increases due to decreased factor incomes in the economy, and increased prices of food and petroleum products, which constitute significant shares of households' total consumption expenditures. It is interesting to note that if the price increases of petroleum products were disregarded, there is one household group for which welfare would actually increase. Rural households, which receive their income from agriculture and businesses, own a relatively large amount of the factors for which there is an increase in demand (mixed income and water) and is therefore the only household group actually benefiting from increased international food prices alone. On the other hand, this is also the household group that is most negatively affected by the increase in prices of petroleum products, which implies that when the food and petroleum price increases are combined, the overall effect on real income for this household group is negative. In general, the income

[58] The fact that fish production seems to be increasing together with other food production is interesting from the point of view of water use. Although, according to current data, agriculture is the most water intensive production sector, fish production is the sector where water use increases the most due to the expansion of the water intensive activity of aquaculture. There is a risk that any expansion in fish production would mainly be in the form of increased aquaculture and this will put further pressure on the water resources than what can be analysed in this model.

distribution is differently affected by the food and petroleum price increase, respectively; while the negative real consumption effects of petroleum price increases mainly fall on richer households; if food price increases are considered in isolation, the rural poor are most negatively affected.[59] The main reason is that food products constitute a larger share of total expenditures in poor households than in richer households. The real consumption of the rural household group that receives its income from wages and salaries, together with that of the urban households that receive their income from business activities, is negatively affected by both petroleum and food price increases. As is clear from table 3, these are thus the household groups that are hit the hardest in these simulations.[60]

5.2. Scenario 2 – Total water supply is fixed and water is immobile between sectors

One interpretation of scenario 2 is that the water use in Namibia is already at the sustainability constraint, and the government decides that groundwater should not be pumped at a faster rate than it is being replenished. The assumption of fixed total water supply is here combined with the assumption of water immobility; it is assumed that the water used in each specific sector cannot be used for other purposes, i.e. water is no longer assumed to be mobile between different agricultural sectors or between the agricultural sectors and the water distribution service sector. This might be the case if there are constraints associated with the transfer of water between different uses. There might, for example, be geographical constraints to the possibilities of transferring water between different activities, especially between agricultural production (mostly in rural areas) and other, urban, uses. In Namibia, which is a large and sparsely populated country with limited infrastructure for long-range transport of water, this is a problem.[61] Such constraints are here modelled by introducing sector-specific water resources. In the model, sector specific water means that increased (decreased) demand for water in one sector must be followed by a rise (fall) in the price of water, ensuring that demand in each sector always equals the initial supply.

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[59] Although the poor urban household group will be less negatively affected, these results are important for poverty analysis as poor rural households constitute more than 70 per cent of the total number of poor households in Namibia.

[60] Both these household groups consume a relatively large amount of petroleum products and will also suffer from higher food prices for different reasons; rural households partly due to reduced factor income, but also due to the increased prices of food while urban business households will mainly suffer because their factor income decreases substantially as there is a decrease in production in manufacturing and services.

[61] Other, non-geographical constraints are also possible. In some sectors, mainly traditional agriculture, a larger share of rain-fed agricultural livestock production is practised and it could easily be argued that rainwater provides a far too irregular source of water to be useful for any other purposes than livestock grazing; it is almost certainly not sufficient to use for commercial crop production.

5.2.1. Changes in production and water use

This scenario causes a loss in GDP of 1.3 per cent, which is slightly larger than the loss in scenario 1. This is intuitive as the constant water supply and the absence of water mobility between sectors constitute constraints on the ability for the economy to adapt. However, the implementation of constant water supply does not seem to be of any critical importance for the ability of the economy to adapt; the changes in overall production due to the restriction in constant water supply are relatively modest.[62] The increase in exports is lower than in scenario 1, while imports decrease as much as in scenario 1.

The increase in production in all agricultural sectors is significantly lower than in the previous scenario. Concerning the changes in production in non-agricultural sectors, the results are similar to those in scenario 1, except for the water distribution service sector where the contraction of production is smaller than in scenario 1. The reason is that water can no longer move from this sector into the expanding agricultural sectors. The fact that production other sectors do not change is intuitively reasonable as the only thing that is changed between the scenarios is the assumption about the supply and mobility of the water factor, which only directly affect the sectors using water as a factor of production.

5.2.2. Changes in the distribution of real household consumption

As concerns the distribution of real household consumption, the results differ somewhat from scenario 1. In general, rural households, especially those receiving their income from agriculture and businesses and households that mainly practise subsistence farming, are more negatively affected than in scenario 1. The reason is that rural households, to a large extent, depend on farm income and, as the expansion of agriculture is now less significant, there is a decrease in total farm income.

5.3. Scenario 3 – Total water supply is fixed and water is mobile between sectors

In this scenario, water supply is still assumed to be fixed, as in scenario 2, but water is now assumed to be exchangeable between the different agricultural uses and between agricultural

[62] It is important to note that in this paper, water scarcity is modelled as a constant water supply. It is possible that other definitions of water scarcity would lead to different results. For example, according to the fourth IPCC assessment report, one important impact of climate change in the Sub-Saharan African region will be intensified and more frequently occurring droughts. Therefore, there is some concern that the water supply might decrease in the future.

and other uses by allowing for mobility between the different agricultural sectors and, to some extent, also between agricultural sectors and the water distribution service sector. This implies that in case of an increase (decrease) in total water demand, the price of water will have to rise (fall) in order to sustain a balance between total supply and demand.[63] An interpretation is that the self-provided part of the water can easily be transferred to other agricultural activities but not to other (urban) uses. The water that is distributed by Namwater, however, can also be used in the water distribution service sector (and thereby in any other economic activity). As compared to the previous scenarios, although some flexibility is maintained due to water mobility, the agricultural sector expansion following the increased food prices is constrained due to water scarcity; an increase in the use of water in one sector must be offset by a corresponding decrease in water use in other sectors.

5.3.1. Changes in production and water use

The decrease in GDP is almost the same as in scenario 2.[64] Concerning the sector-specific production changes, the results show that while the non-cereal crop production sector increases its production by 7.9 per cent (as compared to only 3.3 per cent in scenario 2), this expansion comes at the cost of a smaller increase (compared to scenario 2) or even a decrease in the production in the other agricultural sectors as well as the water distribution service sector. The livestock and the traditional sectors still increase their production, but only by 0.3 and 3.3 per cent, respectively. Cereal production decreases by 5 per cent, however. The reason is that when the self-provided water is subject to fixed supply, while free to allocate between the agricultural sectors, the increase in water demand in the non-cereal crop production sector must be directly offset by a decrease in water demand in the other agricultural sectors. This implies that when the price of water increases, following from increased total demand, production sectors will, to some extent, substitute water for other, relatively cheaper, factors of production. Substitution is more difficult in the commercial crop production sectors as

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[63] In a mobile-factor scenario, there is a fixed factor price-distortion-factor that differs between sectors which ensures that any initial exogenous differences in the factor value between sectors is maintained. The economy-wide factor price is instead free to vary. If total demand for a factor increases, the economy-wide factor price will have to increase for that factor, thus implying that the factor price increase is the same in all sectors, independent of the pre-determined price differential which is maintained by the fixed price distortion factor.

[64] The decrease in GDP is actually slightly larger than in scenario 2 (although the difference is too small to be noticed in table 3 above). This might seem surprising, but the reason why this mobile water scenario results in a somewhat greater GDP loss than when water is sector specific is related to the inefficiency in water use that is built into the model. As the value of water (and thereby the productivity) is lower in agricultural sectors than in the water distribution service sector, the transfer of water into the agricultural sectors will contribute to a decrease in overall production. This inefficiency in water use becomes evident in the comparison of scenarios 2 and 3.

water constitutes a relatively large share of the total factors used in the production process. While the non-cereal crop production sector can afford to pay the higher water price as it directly benefits from increased export prices for the products, the cereal production sector, on the other hand, which does not export its good, will decrease its water consumption following the price increase. The decreased use of water translates into decreased production in this water intensive sector. In the other agricultural sectors, water can to a greater extent be substituted for other, relatively cheaper, factors of production, and production can increase despite less water being used.

Concerning the changes in production among other economic sectors, the results are very similar to the results for scenarios 1 and 2. However, it is worth mentioning that the expansion of the meat processing sector is constrained in scenario 3. This directly follows from the smaller increase of livestock production compared to the other scenarios, since meat processing relies heavily on livestock products as inputs to production. Exports do not increase as much as in scenario 1, while imports do. Concerning the distribution of real income between different household groups, the results are similar to those in scenario 2 but, in general, most household groups become somewhat less well off here than in scenario 2.[65]

6. Conclusions

In this paper, a CGE-model of the Namibian economy is used for analysing the likely impacts of the recently observed international food and oil price increases. As a cereal- and oil-importing country in Sub-Saharan Africa, Namibia is among the countries which are considered likely to be most negatively affected by these international price increases. The fact that Namibia is also one of the driest countries in Sub-Saharan Africa makes it interesting to include the role of water scarcity in the analysis. In this paper, water is included as a factor of production in the agricultural as well as the water distribution service sector by making use of the existing data on water supply and use provided by the Namibian water accounts.

The results show that the overall impacts on national production of increased world market prices of food and oil-products are negative; the GDP will decrease by more or less 1.1-1.3 per cent. The main reason is that the increased exports of primarily agricultural products will not offset the rise in overall production costs followed by the increased import prices of

[65] Once more, this is a consequence of the inefficiency of water use that is built into the model; see footnote 66.

petroleum and agricultural products. This causes a contraction of total national production. Agricultural production will increase as a result of the combined food and oil price increases. The agricultural sector that is benefiting the most is the commercial (non-cereal) crop production sector. Overall, there is a redistribution of production from non-exporting sectors (for example, textiles, manufacturing and the service sectors) into exporting sectors (commercial agriculture, fishing and mining). By coincidence, these exporting sectors are all natural resource abundant sectors, depending on land, water, fish and mining products like diamonds, uranium and gold, implying that this would make the Namibian economy even more dependent on its natural resources. This will require additional efforts to ensure a sustainable management of the resources.

The role of water scarcity is explicitly modelled. Since agricultural production uses about 75 per cent of the total water consumed in Namibia, water scarcity can become a constraining factor for the adaptation of the economy to the external price shocks simulated here. It is found that the level of agricultural growth will, to a large extent, depend on the availability of additional water resources. If water supply is assumed to be perfectly elastic, water use will increase by almost 20 per cent following the agricultural expansion. However, as there is concern that the current water use might already be near the sustainability constraint, it is interesting to analyse the effects if water supply were instead fixed at the current levels. The result from the scenarios where water supply is fixed shows that there is then less ability to adapt for the economy, thus resulting in a somewhat greater decrease in total GDP than in a case when additional water resources are available. The results indicate that due to the current policy of subsidizing part of the water used in agriculture, an additional constraint of water immobility between sectors, imposed in one of the scenarios, might actually lead to slightly less negative impacts than when water is mobile between sectors.

Concerning poverty impacts of the increased food and oil prices, while oil price increases alone mainly affect the richer household groups, food price increases make the poorest rural households significantly less well off in terms of real consumption. The reason is that poor households spend a relatively larger share of their total income on food products, while richer households spend more on petroleum products. The two poor rural household groups, including the group with mainly subsistence farm households, would be the two most negatively affected household groups if food price increases were considered in isolation. The reason why also subsistence farm households are negatively affected by the increased import prices of food is that the increase in farm incomes following from increased production is not sufficient to offset the negative effects of higher food prices. This analysis reinforces the general concern that poor subsistence farmers in developing countries might not necessarily gain from higher international food prices. However, in combination with the simultaneous petroleum price increases simulated in this paper, the changes in income will be more evenly distributed between urban and rural households; rural subsistence farmers might be less negatively affected than urban households, but the poor rural households that work on farms without owning any land will still be the household group suffering the most from higher petroleum and food prices.

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Appendix A – Sensitivity Analysis

Size of initial total water factor income

To shed some light on the sensitivity of the share of total factor income initially attributed to water in the agricultural and water distribution sectors, simulations have been conducted with a lower as well as a higher total water income as a starting point for the simulations.

Lower water income

When the initial total water income is lower,[66] this means that a smaller share of total factor income within the water using sectors is attributed to water. In scenario 1, where water supply is assumed to be perfectly elastic, the size of actual water income out of total factor income in each sector will be of importance for the magnitude of changes in water use and production among sectors. The agricultural sectors still grow, but less than in the original simulations. The reason is that water now constitutes a less significant share of the total mixed or capital factors (which are assumed to be sector specific), thus implying a lower rate of factor mobility between sectors. The GDP decreases slightly more than in the original simulations (-1.2 as compared to -1.1 per cent). However, the qualitative results do not change; the directions of the effects are the same. In the sectors not using water as a factor of production, the production changes are nearly identical to those of the original simulation. The same is true for the income distribution results.

In scenario 2, where water supply as well as current water use in each sector are fixed, the amount of water income out of total factor income in each sector is insignificant; there is no difference between the assumptions of the different factors; water, mixed income and the capital factor are treated the same and the results are therefore identical to the results in the original simulations.

In scenario 3, where water supply is assumed to be fixed, but water is still assumed to be mobile between sectors, the same reasoning as in scenario 1 holds; when total water income is lower, the share of mobile water out of the total factors in each sector is smaller and the

[66] The initial total water income is here calculated using the value of 1 N$ per m^3.

changes in water demand and production likewise. The effect on GDP is nearly identical to that in the original simulation.

Higher water income

For model scenarios 1 and 3, a higher value of total water income[67] will imply greater flexibility; in the case of perfectly elastic supply, agricultural production as well as total water demand will increase significantly more than in the original simulations. The negative effect on GDP, when water supply is perfectly elastic, is considerably smaller (only -0.5 per cent as compared to -1.1 in the original simulation), while in scenario 3 there is no significant change of the GDP effect in comparison with the original simulation. The production structure in all other sectors is not significantly affected by the level of water income and the results concerning the distribution of income are maintained. In scenario 2, where water supply is fixed and water is immobile, the level of water income is of no importance at all for the results.

Trade elasticities

As the results to a large extent depend on export and import patterns, a sensitivity analysis with respect to trade elasticities is highly motivated. As mentioned in section 3.2.2., most initial elasticity values are directly taken from a CGE-analysis of the South African economy by Thurlow (2004). Regarding trade elasticities, the elasticity of substitution between imports and domestic output in domestic demand (referred to as Armington in the table) as well as the elasticity of transformation between exports and domestic demand for domestic marketed output (referred to as CET in the table), the initial values, directly imported from the South African study, are presented in table 3 below.

[67] The initial total water income is here calculated using the unit water value of 3 N$ per m^3.

Table 3: Initial values of trade elasticities

	Armington	CET
Agriculultural products	1.596	2
Fish products	0.740	2
Mining	1.026	2
Other food products	0.740	2
Textiles	2.813	2
Manufacturing	0.946	2
Petroleum products	1.528	2
Electricity and water	0.500	2
Construction	0.500	2
Services	0.500	2
Governmental services	0.500	2

These values indicate that imported and domestically produced agricultural and petroleum products are, in general, considered to be closer substitutes than many other products. These values are based on empirical estimations by the Industrial Development Corporation in Pretoria and are well within the range of trade elasticities reported in other CGE-studies.[68] Concerning the elasticity of transformation between domestically produced products and exports, there are no empirical estimates available. It is assumed that export supply elasticities are in general higher than Armington elasticities.[69] However, a sensitivity analysis is performed where the value of trade elasticities is varied for the products of particular concern in this study; agricultural, food and petroleum products.

Simulations are run for varying levels of trade elasticities; Armington elasticities as well as CET elasticities are increased and decreased by up to 30 per cent, respectively, for agricultural, food and petroleum products. To isolate the effect of changed values of trade elasticities, everything else is held constant in these simulations. The overall qualitative results do not seem to be sensitive to changes in these parameters. In general, the higher is the Armington elasticities, the higher is the demand for domestic products and thereby there is a greater increase in agricultural production following the increased import prices of these products. Likewise, the higher the CET-elasticities, the more exports can increase following the changes in relative prices between exports and domestic production. However, the changes in overall GDP as well as the distribution of income between different household

[68] See Thurlow (2004) for a further discussion of these trade elasticities.
[69] This implies that following an increase in foreign prices, producers are more able to shift production towards the foreign market than consumers can shift their consumption patterns away from imported commodities. See Thurlow (2004).

groups are very small and the same reasoning as in the original simulation still holds concerning the differences between the three different scenarios.

Elasticities of substitution between factors of production

In the initial simulations, the elasticity of substitution between all factors of production is 0.5 in all production sectors. As the possibility of substitution, especially between water and other factors of production, is important for the results, a sensitivity analysis is conducted by testing the results for lower as well as higher substitution elasticities in the sectors using water. The results show that the higher is the substitution elasticity between factors of production, the greater is the ability to adapt for the economy, thus resulting in a greater increase in agricultural production and a less negative impact on total GDP. However, the changes in production are minor; an increase in the elasticity of substitution to 0.6 in the water using sectors results in a 0.03 per cent less negative effect on total GDP. If the elasticity of substitution is decreased to 0.4 in the water using sectors, the ability for the economy to adapt is only slightly lower, resulting in a 0.04 per cent greater decrease in GDP than in the original simulations.

Appendix B – Adjustments of the SAM-data

Agricultural sector data

Some small necessary adjustments in the SAM have been made for the traditional agricultural sector. In the original SAM, the traditional agricultural sector produces an "own" commodity called "traditional commodity", which can be described as "food for own consumption"; this is largely cereal crop production. However, for modelling purposes, it is important that the food produced in the traditional agricultural sector could be substituted for food purchased from elsewhere. Therefore, the "traditional commodity" has been redefined; it is assumed that the traditional sector produces crops (mainly cereals) that are substitutable either for crops produced elsewhere in the country or for imported crops.[70] In addition, some adjustments

[70] If these changes are not made, the traditional agricultural sector will be significantly negatively affected by the exogenous price increases, as the commodity produced in the traditional agricultural sector will be treated as a completely different product than the other agricultural and food products produced in other agricultural sectors. Although it can be discussed how subsistence farmers would actually behave in the case of increasing prices of their products, it would be highly unrealistic to assume that their products would not be substitutable with other agricultural products. Subsistence farmers should have incentives to increase their production for the domestic

have been made with regard to the distribution of factor income in the traditional agricultural sector. In the traditional agricultural sector, the mixed factor category includes land rents and income generated by labour supplied by people informally employed in the sector. By recognizing the approximate number of informal workers in the subsistence agricultural sector (see Angula and Sherbourne 2003) together with an estimate of the mean rural informal wage (see Humavindu 2007), part of total mixed income in the traditional sector can be transformed into factor income for unskilled workers. For the purposes of this study, this small adjustment represents a better way of modelling the factor income distribution in the traditional agricultural sector.

Tourism data

Due to lack of data, a full representation of tourism was not possible at the time of development of the SAM. Therefore, tourism is treated as a "dummy sector" in the current SAM, which is a way of pointing out the importance of an activity which does not correspond to an actual industry. This dummy sector corresponds to the total value of "the purchase of products in the Namibian economy by non-residents", which was found in the national accounts.[71] However, in the CGE-model, activities without factor inputs are not allowed, so this dummy sector had to be eliminated from the original SAM for the data to fit the model. This was simply done by treating the values of purchases by foreign tourists for each commodity directly as "exports".

Fish data

By making use of the resource rent (as factor income distributed to different households etc.) estimated through the Natural Resource Accounts (NRA) methods for fish,[72] fish is included as a factor of production in the fish and fish processing sectors. This adjustment was made in a previous study by Sahlén (2008) to capture the likely effects of an increased share of the fish rent captured by the government. As this adjustment provides an improvement of the fish sector data in the original SAM, it is also used in the present paper, although this is not necessary for the analysis. As the fish factor is treated in the same way as capital (i.e. assumed to be sector specific), this adjustment will not affect the results of the current analysis at all.

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market when the prices of their products increase. Therefore, for the purpose of this analysis, it was decided to transform the traditional commodity into cereals, other crops and livestock products.

[71] Lange et al (2004).

[72] The Namibian fisheries accounts are based on the UN System of Integrated Environmental and Economic Accounts (SEEA). See Lange (2005) for a detailed description of the methodology for fish-rent calculations.

Appendix C – Model Closure Rules

In table 4 below, the available factor and macro closure rules for the IFPRI standard CGE-model are presented. For a further explanation of the available macro-closure rules, see Sahlén (2008).

Table 4. Available closure rules in the standard CGE-model

Factor Market	Government	Rest of World	Savings-Investment
FAC-1 Fixed factor supply; flexible wages; mobile factors	**GOV-1** Flexible government savings; fixed direct tax rates	**ROW-1** Fixed foreign savings; flexible real exchange rate	**SI-1** Fixed capital formation; uniform MPS point change for selected institutions
FAC-2 Flexible factor supply; fixed wages; mobile factors	**GOV-2** Fixed government savings; uniform direct tax rate, point change for selected institutions	**ROW-2** Flexible foreign savings; fixed real exchange rate	**SI-2** Fixed capital formation; scaled MPS for selected institutions
FAC-3 Fixed factor supply; fixed wages; immobile factors (activity specific)	**GOV-3** Fixed government savings; scaled direct tax rates for selected institutions		**SI-3** Flexible capital formation; fixed MPS for all non-gov. institutions
			SI-4 Fixed investment and gov. consumption absorption shares (flexible quantities); uniform MPS point change for selected institutions
			SI-5 Fixed investment and gov. consumption absorption shares (flexible quantities); scaled MPS for selected institutions