Macro-economic impacts of large scale Jatropha cultivation and biodiesel production in Tanzania

Master Thesis

By Anna Sophia Scharschmidt

Supervisor:

Dr. M. Sanders

Second Supervisor:

Dr. R. Bailis

School of Economics

Utrecht University

13.08.2010

Table of Contents

Summary

Tanzania's strong dependency on petroleum product imports in the face of increasing oil prices and high price volatilities continues to pressurize the inflation rate, retards growth and development and destabilizes the economy. For this reason the National Energy Policy (Ministry of Energy and Minerals 2003) strives to substitute conventional fossil fuels with alternative fuels originating from Tanzania itself. One of these options is bio-diesel made from Jatropha oil seeds, which would not only offer an opportunity to alleviate Tanzania's dependency on petroleum product imports, but also for more agricultural employment and thus poverty reduction in rural areas.

While the economic viability of Jatropha plantations has been assessed extensively such as in Wahl (2009) and GTZ (2009), the discussion on its macro-economic impacts remains vague. Positive effects with respect to rural development and a weakening dependency on petroleum product imports are emphasized by Brittaine and Lutaladio (2010) and Mulugetta (2009) respectively. The present study strives to contribute to the existing literature by giving more precise insights focusing in particular on GDP, employment effects and the impacts on the trade balance.

The analysis is based on an Input-Output framework assuming Leontief production functions (see Miller and Blair 2009). This standard Input-Output analysis, however, does not allow for macro-economically important feedback effects and substitution between production factors at the aggregate level. Therefore, one major contribution of this study lies in the development of an extended technique based on Cobb-Douglas production functions. Thus, Cobb-Douglas production functions and their associated supply-side elasticities are estimated in a cross-section data set comprising of Input-Output tables from Kenya, Uganda and Tanzania. These results are then used to simulate a market response to the rising demand for primary and intermediate inputs, brought about by an increased production of Jatropha oil seeds and bio-diesel.

In order to assess a variety of Jatropha management systems and implementation schemes, the construction of several scenarios differentiates between smallholder settings and large-scale plantations.

In general, the results under Leontief production functions reveal that the production of bio-diesel from Jatropha oil seeds has positive effects on Tanzania's economy.

When assuming a 20% diesel blending target with bio-diesel from Jatropha oil, GDP and wage sum rise while imports decrease by 0.3%, 0.62% and -1.26% respectively in the smallholder scenario and by 0.24%, 0.36% and -1.01% respectively in the large-scale plantations scenario. This demonstrates that the smallholder setting has stronger positive impacts on Tanzania's economy.

In an extended scenario where 10% of Tanzania's lands are planted with Jatropha and surplus bio-diesel production is exported, GDP, wage sum and imports increase by 10.5%, 15.95% and 11.3%

respectively. However, the question remains whether this scenario is realistic considering its magnitude.

The comparison of those results computed by assuming Cobb-Douglas production functions versus Leontief production functions reveals that the market response under Cobb-Douglas smoothes out the results under Leontief production functions. The latter consequently overestimates structural changes. Again differences between both production functions are marginal assuming a 20% blending target (e.g. the increase in wage sum ranges between [0.37%; 0.64%]) and become non-negligible in large shocks such as the extended scenario (e.g. the increase in wage sum ranges between: [9.7%; 16.64%].

1. Introduction

1.1. Bio-energy and Jatropha in Tanzania

To assess the macro-economic effects of an increased production of bio-diesel from Jatropha oil in Sub-Saharan Africa, the relatively good availability of data on the Tanzanian economy predestines the country for a case study. In addition, its political stability, market oriented economy and agro-economic characteristics have given grounds for several studies on the production of Jatropha oil in Tanzania (see for instance Wahl et. al. 2009).

The country is a major consumer of petroleum products in East Africa. However, its demand is fully met by imports. In 2005, 40% of the countries' foreign currency spending was directed to petroleum product imports (GTZ 2005). Thus Tanzania is mostly representative for those countries which cannot extract oil from own sources[1]. This "… over-reliance on imported petroleum fuels" (Mulugetta 2009) causes a strong dependency of the economy on world market prices and thus has negative side effects:

1. In the face of an increasing worldwide demand for petroleum products in the past and future, prices are bound to increase in the long run. This will put further pressure on the inflation rate in Tanzania. In addition, according to Mulugetta (2009) transport and thus fuel consumption and GDP have grown in a parallel relationship in the past. Following this argument, increasing oil prices are thus likely to have reverse effects on GDP.
2. The high price volatility of fossil fuels has destabilizing effects on Tanzania's economy.

Blending fossil fuels with bio-fuels could thus alleviate Tanzania's extreme dependency. In addition, since fossil oil is a finite source, the production of fuels originating from Tanzania is a cornerstone in the National Energy Policy (Ministry of Energy and Minerals 2003). Thus, one main objective of its framework is to "Promote (a) fuel switch from petroleum to other alternative environmentally friendly fuels." Wahl et. al. (2009) associates this strategy with several positive effects:

1. Reduction of costly fuel imports, positive effects on the trade balance, less volatile petrol and diesel prices
2. Energy security
3. Employment opportunities for farmers and skilled engineers (strong improvements in the livelihood of subsistence farmers)

[11]This study is not representative for countries where large oil deposits have been found. Most importantly this excludes the top net oil exporters Nigeria, Libya, Algeria, Angola, Egypt, Gabon, Congo and Cameroon. East Africa is the only net-importing region in Africa and therefore Tanzania is strongly representative for this region. (see http://www.eia.doe.gov/emeu/cabs/chapter4.html for more detailed information on oil exploration in Africa)

4. New export commodity
5. Reduction of greenhouse gases (whether this holds for the whole production life cycle is yet to be assessed (GTZ 2009))

Despite these advantages, the general perception of energy crops is mixed amongst Tanzania's population and NGOs. Critics claim that the preservation of biodiversity is endangered when giving additional land to the production of energy crops. Gordon-Maclean et. al. (2009) are convinced that there is an urgent need for more studies on the biodiversity of each side before plantations are established.

Another hotly debated subject is food security, assuming that the cultivation of energy crops will replace food crops and thus endanger the livelihoods of the rural population. This certainly depends on the implementation scheme of each bio-energy project (GTZ 2009), which should be set up carefully. An in depth discussion of environmental and social impacts associated with an increased cultivation of energy crops and bio-fuel production in Tanzania is beyond the scope of this study. Extensive assessments can be found in Gordon-Maclean et. al. (2009), GTZ (2005) and Loos (2009) for instance.

For the purpose of this study the energy crop Jatropha was chosen to be further examined. Overall, Jatropha is a highly controversial energy crop plant which has received much attention throughout the last decade since it is claimed to have high prospects for the production of biodiesel. According to Openshaw (2000), Jatropha is susceptible to very few pests and diseases, is relatively easy to establish, grows under a wide range of rainfall regimes, is drought tolerant and grows quickly. Besides these positive properties Jatopha is useful for controlling or preventing erosion. With these attributes it is often seen as a crop which does not threaten food production and needs only very little if any irrigation.

However, these seemingly miraculous characteristics, have provoked further investigations and most of them were proven to be "…specious at best." (GTZ 2009) Naturally, if Jatropha crops are grown on marginal lands, their yield is much lower. In addition, like for any other plant, irrigation increases its productivity. In sum, all these positive characteristics are not necessarily incorrect, but not always achievable at the same time. (Wahl et al. 2009)

Since much effort has been put into the agricultural and agro-economic investigation of Jatropha plants with contradictory results, an inquiry into the macro-economic effects of large scale cultivations leading to the production of biofuels could add further insights into the contribution of Jatropha cultivation for development in East-African countries.

1.2. Objectives and research question

There are many questions associated with the introduction of a significant cultivation of Jatropha and the production of bio-diesel in Tanzania. While several studies so far have discussed social and environmental issues extensively, this study is the first that aims to reveal what the macro-economic impacts of biodiesel production from domestically grown Jatropha seeds in Tanzania are. A thorough analysis in this field will help to quantify what the economic benefits/ losses are and under which circumstances they are being optimized/ minimized. Special interest will hereby be focused on GDP, net-exports and employment effects. Since macro-economic impacts are likely to vary depending on implementations schemes, the analysis will be based on several scenarios differentiating between smallholder farmers and large-scale plantations.
In addition, this study aims to assess two methodological approaches. The foundation for the first will be a common Input-Output analysis based on Leontief production functions. This is a commonly applied but rather inflexible setting, as it is based on constant input shares. For this reason a more advanced second technique with Input-Output tables based on Cobb-Douglas production functions is introduced, which assumes that production is based on more flexible production functions that allow for substitution between input factors. For modeling a shock such as an additional industry introduced to Tanzania's economy, this methodology is intuitively more apprealing because it takes market mechanisms such as price variations of input factors and according demand shifts for intermediate inputs into account. The Input-Output table, however, will remain to be demand driven and thus final demand is kept exogenous. How this approach relates to the existing literature will be discussed in more detail in the next sub-section.
The basic question to be answered with respect to these methodological issues is whether the more flexible approach constructed in this study generates results which are significantly different from the common analysis and if so under which circumstances this is the case.

To sum up, this study is to inquire into the following two research questions:

1. What are the macro-economic effects of introducing a significant Jatropha cultivation and biodiesel production industry into Tanzania's economy?
2. Does the application of more flexible production functions in Input-Output analysis lead to different outcomes than in common analyses and under which circumstances are these significant?

1.3. Literature review

For assessing macro-economic effects of an extended biodiesel production in Tanznia, the micro-economic viability of the former is an essential prerequisite. If the cultivation of Jatropha was per se unprofitable, the analysis on the macro level would be rendered unnecessary.

Wahl (2009) examines the economic viability of Jatropha oil seed production in northern Tanzania by using a cost benefit analysis. He finds that the Net Present Value (NPV) of a five-year investment in plantations is only slightly positive, if yields are expected to be as high as 3000kg $ha^{-1}year^{-1}$. The GTZ (2009) for instance finds a maximum yield of approximately 1766kg $ha^{-1}year^{-1}$ in an extensive field study and reality check in Kenya. In addition, Wahl claims that Jatropha is not competitive with other crops on fertile land and thus recommends allocating fertile land to the production of other crops. Jatropha hedges and fences on the contrary, which bear only low opportunity costs, are found to be profitable, forming an additional source of income for subsistence farmers. Van Eijck et. al. (2010) supports similar results with respect to a low and intermediate input system in a smallholder setting in Tanzania. Likewise, increasing inputs into the production of Jatropha oil seeds do not lead to a higher NPV. In sum, the economic viability of Jatropha is not impossible; however, it is strongly dependent on field management and input systems. Overall, fewer inputs and fencing tend to be more profitable.

Macroeconomic impacts of a large-scale bio-energy production with respect to GDP, trade balance and employment have been assessed for the case of Argentina in Wicke et. al. (2009). The foundation of this study is a common Input-Output framework applied in a scenario approach. Energy crops are in theory cultivated on surplus land only, which is gained by an agricultural intensification throughout the entire farming sector. By assuming that freed land is fully dedicated to the cultivation of energy crops, the authors circumvent necessary modeling of the market for land and presuppose that energy crops are competitive with other plantings. In this way about 10% of the total Argentinean area is employed in the production of energy crops, affecting an increase in GDP by 25% through the production of Fischer-Tropsch fuel from eucalyptus. Since an Input-Output table assumes constant input shares, not allowing for substitution between input factors, the large size of the new bio-energy industry introduced to the Argentinean economy directly causes a huge increase in GDP. As Berck and Hoffmann (2002) put it: " I-O … models provide an upper bound on employment impacts because their Leontief production functions do not allow for adjustment through factor substitution." Therefore these models simulate very short run results, which are demand driven.

The seminal literature on Computable General Equilibrium (CGE) models overcomes the critiques mentioned above by allowing for substitution among goods in consumption and inputs in production associated with changes in relative prices, thereby representing the "… lower bound on possible aggregate employment effects…" (Berck and Hoffmann 2002) and long-run equilibria. The major drawback of CGE models however, as underlined by Wing (2007), is the required data intensity, since time series of observations for quantities and prices are needed for all inputs and outputs of each industry. In addition, along with market clearance, income balance and zero profit conditions household utility functions are to be assumed and optimized. This requires additional data on consumer preferences, which can be rather complicated to collect.

An attempt to develop a CGE model for assessing macroeconomic impacts of an extended bio-fuel production in Mozambique was performed in Channing et.al. (2009). Applying a dynamic CGE model with a 12 year simulation horizon and a series of dynamic equations, which vary parameters along time, the author finds that biofuel investments lead to poverty reduction and economic growth although some food plantings are replaced by energy crops. Interestingly, a comparison between large-scale plantations and an outgrower set up reveals that smallholder production more effectively reduces rural poverty by making greater use of unskilled labor.

Since common Input-Output analysis is highly inflexible and fails to model market mechanisms, while CGE models achieve a very high degree of accuracy on the cost of intense data requirements, the model constructed for the subsequent analysis draws close to the class of so called Variable Input-Output models (VIO). These are also described as partial CGE models (Liew 1999) in the sense that they incorporate a price sensitivity of intermediate inputs while being demand driven with no utility maximization of household consumption. Given the data availability on Tanzanian markets and consumers behavior, VIO models seem to be the approach which strives to elicit optimal results under the given circumstances and data limitations.

In section 2 the theoretical framework of common Input-Output analysis and the modifications made in this study will be discussed. Furthermore this section will shed some light on how to include a new industry into an Input-Output table. Subsequently section 3 continues with a description of the data used and the methodological approach towards the estimation of Cobb-Douglas production functions and supply side elasticities. Thereafter, in section 4 different scenarios are discussed which could possibly be realistic frameworks for a significant bio-diesel implementation scheme in Tanzania. Results are presented in section 5 and 6. While the former merely introduces those results which stem from common Input-Output analysis only, section 6 continues with further results generated under the assumption of Cobb-Douglas production functions. In order to imitate the approach chosen by Wicke et. al. (2009), section 7 will present results stemming from a large shock, assuming that 10% of all Tanzanian lands are planted with Jatropha. Final conclusions and discussions follow in section 8.

2. Theory

2.1. Input- Output Analysis

Input-Output tables and their manipulation will be a stepping stone for this study. The following sub-section is therefore devoted to the general functional framework of Input-Output analysis and its mathematical techniques and can be skipped without a loss by readers who are already familiar with these techniques.

The data structured in an Input-Output table typically stems from a particular economic area and a certain time interval. In our case this will be Tanzania in 2001. Basically, Input-Output tables separate economic activity into several industries or sectors and summarize flows of products between these entities and to final consumption. Mostly quantities are measured in monetary values in order to consistently incorporate different products and services. Otherwise problems would occur as soon as there are industries producing more than one good. On the other hand, price fluctuations may bias the data as they do not reflect changes in quantities. However, as long as the period under consideration is short, price changes are limited and input-output tables thus provide a snapshot of the economy.

In general, total output of an industry can be decomposed into intermediate inputs (flows of goods and services from one industry to all other industries) and final demand. Altogether this leads to a system of n linear equations with n unknowns (see equations 2.1.-1). The notation throughout this study terms intermediate inputs from industry i to industry j as x_{ij}. Total output of industry i is given by Y_i and final demand for goods and services from industry i is f_i. Commonly final demand is composed of household consumption, governmental expenditures, exports and savings and investment.

(2.1.-1) $$Y_1 = x_{11} + \dots + x_{1j} + \dots + x_{1n} + f_1 = \sum_{j=1}^{n} x_{1j} + f_1$$

.....

$$Y_i = x_{i1} + \dots + x_{ij} + \dots + x_{in} + f_i = \sum_{j=1}^{n} x_{ij} + f_i$$

.....

$$Y_n = x_{n1} + \dots + x_{nj} + \dots + x_{nn} + f_n = \sum_{j=1}^{n} x_{nj} + f_n$$

The same system of linear equations may be summarized in matrix notation (see 2.1.-2). This will serve the straightforwardness of the subsequent derivations. Throughout the subsequent analysis lower case letters will be used for vectors, while upper case letters stand for matrices.

$$\boldsymbol{y} = \begin{bmatrix} Y_1 \\ \vdots \\ Y_i \\ \vdots \\ Y_n \end{bmatrix} \qquad \boldsymbol{X} = \begin{bmatrix} x_{11} & \cdots & x_{1j} & \cdots & x_{1n} \\ \vdots & & \vdots & & \vdots \\ x_{i1} & \cdots & x_{ij} & \cdots & x_{in} \\ \vdots & & \vdots & & \vdots \\ x_{n1} & \cdots & x_{nj} & \cdots & x_{nn} \end{bmatrix} \qquad \boldsymbol{\iota} = \begin{bmatrix} 1 \\ \vdots \\ 1 \\ \vdots \\ 1 \end{bmatrix} \qquad \boldsymbol{f} = \begin{bmatrix} f_1 \\ \vdots \\ f_i \\ \vdots \\ f_n \end{bmatrix}$$

(2.1.-2) $$\boldsymbol{y} = \boldsymbol{X}\boldsymbol{\iota} + \boldsymbol{f}$$

Input-Output tables add a further dimension to this framework, as they comprise not only the decomposition of total output into intermediate deliveries and final demand, but also the input structure of each industry. This relates to intermediate goods from other industries and to primary inputs (e.g. labor). In addition, some sectors may import intermediate inputs from other economic areas or countries. Figure 2.1 poses an example of such a table. Here primary inputs are interchangeably called value added (v) which comprises inputs such as labor, land, capital, government services and entrepreneurship. Together with all imports (m) this is commonly referred to as the payments sector. Final demand is separated into household consumption (c), savings and investments (i), government expenditures (g) and exports (e), with vector **f** being the sum of all these final demand entries. Columns represent each industry's inputs, while rows represent each industry's deliveries to final demand and other industries. In addition, intra-industry deliveries of intermediate inputs are also accounted for in the diagonal of the industries' matrix in figure 2.1.

Figure 2.1: Framework of an Input-Output table

		Industries					**Final Demand**				**Total**
		1	…	j	…	n	c	i	g	e	
Intermediate Inputs	1	x_{11}	…	x_{1j}	…	x_{1n}	c_1	i_1	g_1	e_1	Y_1
	⋮	⋮		⋮		⋮	⋮	⋮	⋮	⋮	⋮
	i	x_{i1}	…	x_{ij}	…	x_{in}	c_i	i_i	g_i	e_i	Y_i
	⋮	⋮		⋮		⋮	⋮	⋮	⋮	⋮	⋮
	n	x_{n1}	…	x_{nj}	…	x_{nn}	c_n	i_n	g_n	e_n	Y_n
Value Added	v	v_1	…	v_j	…	v_n	v_c	v_i	v_g	v_e	V
Imports	m	m_1	…	m_j	…	m_n	m_c	m_i	m_g	m_e	M
Total		Y_1	…	Y_j	…	Y_n	C	I	G	E	

Row and column entries in an Input-Output table are balanced in two ways. Firstly, total inputs in every industry equal its total output:

(2.1.-3) $Y_i = Y_j$ and thus $\sum_{i=1}^{n} Y_i = \sum_{j=1}^{n} Y_j$

Secondly, total consumption of goods and services in an economic area or country, in table 2.1 this is termed final demand, is equal to the total remuneration of all primary inputs and total imports:

(2.1.-4) $$V = C + I + G + (E - M)$$

Put differently:

$$Gross\ National\ Income = Gross\ National\ Product$$

When manipulating an Input-Output table these two assumptions should apply to any transformed table as well. To ensure this, input shares are generally assumed to stay constant. Consequently, the quantity of any intermediate or primary input is a fixed share of total output and thus assumed to be endogenous to the latter. As total output is endogenously driven by deliveries of intermediate inputs to other sectors and exogenously driven by final demand, input quantities and total output can be determined as soon as final demand and input shares are known. The following matrix algebra allows for the derivation of the endogenous total output (see also Miller & Blair 2009). This standard procedure is fundamental to the manipulation of any Input-Output table.

Fixed input shares are commonly referred to as technical coefficients:

(2.1.-5) $$a_{ij} = {}^{x_{ij}}/_{Y_i}$$

Naturally the column sum of all input shares adds up to one.
Like intermediate inputs technical coefficients constitute a matrix (***A***). Thus equation (2.1.-5) may be rewritten in matrix notation:

(2.1-6) $$\boldsymbol{A} = \boldsymbol{X} * \hat{\boldsymbol{y}}^{-1}$$

with:

$$\boldsymbol{A} = \begin{bmatrix} a_{11} & \cdots & a_{1j} & \cdots & a_{1n} \\ \vdots & & \vdots & & \vdots \\ a_{i1} & \cdots & a_{ij} & \cdots & a_{in} \\ \vdots & & \vdots & & \vdots \\ a_{n1} & \cdots & a_{nj} & \cdots & a_{nn} \end{bmatrix} \quad \text{and} \quad \hat{\boldsymbol{y}} = \begin{bmatrix} Y_1 & \cdots & 1 & \cdots & 1 \\ \vdots & & \vdots & & \vdots \\ 1 & \cdots & Y_i & \cdots & 1 \\ \vdots & & \vdots & & \vdots \\ 1 & \cdots & 1 & \cdots & Y_n \end{bmatrix}$$

Similarly equation (2.1.-2) may be rewritten employing technical coefficients instead of absolute quantities:

(2.1.-7) $$y = A * y + f$$

Solving this equation for ***y***:

(2.1.-8) $$(I - A)y = f$$

(2.1.-9) $$y = (I - A)^{-1} * f$$

Equation (2.1.-9) defines total output of all industries depending on final demand and the matrix of technical coefficients. In order to simulate a shock such as the introduction of a new industry to the economy, both, final demand and the technical coefficients matrix, have to be manipulated. How this is done to derive a new equilibrium by applying equation (2.1.-9) will be discussed in subsection 2.2.

Throughout the introduction to this study it was argued that the type of production function underlying each sector is constrained by relatively strong assumptions which are hardly realistic in the medium and long run and for simulating large economic changes. This is mainly the case because the technical approach towards Input-Output analysis is built upon constant input shares. This characteristic is embedded in the so called Leontief production function. The fundamentals of this production function render substitution between input factors impossible. With a zero elasticity of substitution, the Leontief production function is a special case within the class of constant elasticity production functions (CES). In addition it neglects possible economies of scale. The formal notation of this kind of production function is the following:

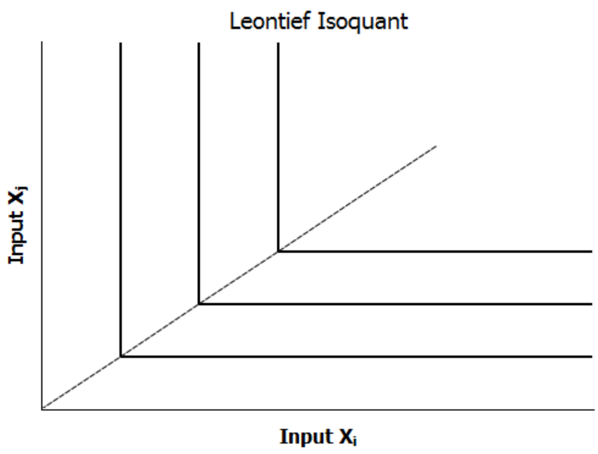
(2.1.-10) $$Y_n = f(a_{1n}x_{1n} \dots a_{tn}x_{tn} \dots a_{nn}x_{nn})$$

Where the Leontief is specified as:

(2.1.-11) $$Y_n = \min\left[\frac{x_{1n}}{a_{1n}} \dots \frac{x_{tn}}{a_{tn}} \dots \frac{x_{nn}}{a_{nn}}\right]$$

In (2.1.-11) and figure 2.2 it becomes clear that as soon as one input is not fully available, total output will decrease. Substitution of any missing input by other factors is not possible.

Figure 2.2:



In order to circumvent these rather inflexible properties, sub-section 2.3 discusses a less restricted production function, the Cobb-Douglas production function.

2.2. Introduction of a new industry to the economy

One major objective of this study is to assess the macro-economic impacts of a new industry added to Tanzania's economy and thus to the initial Input-Output table. This new industry will cover the production of biodiesel. In the resulting Input-Output table (see figure 2.3) industry n+1 stands for this additional industry. Because the inclusion of a new industry will disturb the initially balanced Input-Output table, the resulting table has to be adjusted to a new equilibrium. In order to do so it is most convenient to employ equation (2.1.-9), which determines new total output of each industry depending on the manipulated technical coefficients matrix ($\boldsymbol{A}'$) comprising the additional industry and the vector of final demands ($\boldsymbol{f}'$). Once total output is given, one can calculate all new entries to the Input-Output table using equation (2.1.-6) solved for $\boldsymbol{X}$.

Firstly, it is legitimate to assume that biodiesel is, to a certain extent, a perfect substitute for fossil diesel. Therefore it is obvious that there is a constant share γ to be subtracted from the production of industry *n* and added to the new industry's *n*+1 production. γ can thus be understood as a blending target. The same holds for the new technical coefficients matrix and the vector of final demands. The reader should realize that this applies to the respective row only as demonstrated in (2.2.-1) and (2.2.-4).

Secondly, in addition to these adjustments to the Input-Output tables' rows, there is to be a new column added to the matrix of technical coefficients. This comprises all intermediate inputs needed for the production of one unit of industry *n*+1's product. In the technical coefficients matrix (2.2.-1) this new column has already been included. In section 4 on the scenario build up, the construction of these column vectors will be discussed with respect to several assumptions.

(2.2.-1)
$$A' = \begin{bmatrix} a_{11} & \cdots & a_{1j} & \cdots & a_{1n} & a'_{1\,n+1} \\ \vdots & & \vdots & & \vdots & \vdots \\ a_{i1} & \cdots & a_{ij} & \cdots & a_{in} & a'_{i\,n+1} \\ \vdots & & \vdots & & \vdots & \vdots \\ a'_{n1} & \cdots & a'_{nj} & \cdots & a'_{nn} & a'_{n\,n+1} \\ a'_{n+1\,1} & \cdots & a'_{n+1\,j} & \cdots & a'_{n+1\,n} & a'_{n+1\,n+1} \end{bmatrix}$$

with

(2.2. -2)
$$a'_{nj} + a'_{n+1\,j} = a_{nj}$$

and

(2.2.-3)
$$a'_{nj} = (1-\gamma) * a_{nj} \quad ; \qquad a'_{n+1\,j} = \gamma * a_{nj}$$

The same break down applies to the entries of final demand.

(2.2.-4)
$$f' = \begin{bmatrix} f_1 \\ \vdots \\ f_i \\ \vdots \\ f'_n \\ f'_{n+1} \end{bmatrix}$$

with

(2.2-5)
$$f'_n + f'_{n+1} = f_n$$

and

(2.2.-6) $$f'_n = (1-\gamma) \cdot f_n \quad ; \quad f'_{n+1} = \gamma \cdot f_n$$

Having constructed a new vector of final demands and a new technical coefficients matrix, one can employ equation (2.1.-9) and (2.1.-6) in order to construct a new Input-Output table as in figure 2.3.

Figure 2.3: Framework of an Input-Output table with additional industry

		Industries						Final Demand				Total
		1	…	j	…	n	n+1	c	i	g	e	
Intermediate Inputs	1	x_{11}'	…	x_{1j}'	…	x_{1n}'	$x_{1\,(n+1)}'$	c_1	i_1	g_1	e_1	Y_1'
	⋮	⋮		⋮		⋮	⋮	⋮	⋮	⋮	⋮	⋮
	i	x_{i1}'	…	x_{ij}'	…	x_{in}'	$x_{i\,(n+1)}'$	c_i	i_i	g_i	e_i	Y_i'
	⋮	⋮		⋮		⋮	⋮	⋮	⋮	⋮	⋮	⋮
	n	x_{n1}'	…	x_{nj}'	…	x_{nn}'	$x_{n\,(n+1)}'$	c_n'	i_n'	g_n'	e_n'	Y_n'
	n+1	$x_{(n+1)1}'$	…	$x_{(n+1)\,j}'$	…	$x_{(n+1)\,n}'$	$x_{(n+1)\,n}'$	c_{n+1}'	i_{n+1}'	g_{n+1}'	e_{n+1}'	Y_{n+1}'
Value Added	v	v_1'	…	v_j'	…	v_n'	v_{n+1}'	v_c	v_i	v_g	v_e	V‘
Imports	m	m_1'	…	m_j'	…	m_n'	m_{n+1}'	m_c	m_i	m_g	m_e	M‘
Total		Y_1'	…	Y_j'	…	Y_n'	Y_{n+1}'	C‘	I‘	G‘	E‘	

Changes in this new table mostly depend on the input structure of the additional industry. Total value added tends to increase, if the new sector employs more primary inputs and less imports from other countries and vice versa. The results of this manipulation applied to the Input-Output table for Tanzania in 2001 will be discussed in section 5.

2.3. The market response

The main critique with regard to common Input-Output analyses in subsection 2.1 is that it is based on Leontief production functions and fixed shares of intermediate and factor inputs. Therefore, one objective of this study is to avoid these rather inflexible mechanisms by assuming a production function for each sector which supports the substitution between different inputs in response to demand shocks and price variations. Another simplified CES production function which covers substitution and yet is still fairly reasonable to be estimated even in smaller sample sizes is the Cobb-Douglas production function (as in 2.3.-1). Characteristically this production function leads to a constant elasticity of substitution.

(2.3.-1) $$Y = A * \prod_{k=1}^{K} X_k^{\alpha_k}$$

Y being total output,

A a constant[2],

α_k Cobb-Douglas coefficient k

and X_k input k

A market response to the inclusion of an additional industry into the initial Input-Output table basically mirrors a changing demand for intermediate inputs and primary factors. Intuitively, this will affect input prices, which in turn will induce sectors to change their input structure by substituting relatively more expensive inputs for cheaper ones. Throughout this sub-section this intuition will be formalized in three steps.

1. Determination of the optimal input structure for each sector with input quantities being endogenous to input prices.
2. Based on step one, supply side elasticities for intermediate inputs are to be derived. These will quantify how market prices change in correspondence to a variation of demand for intermediate inputs and primary inputs[3] following the inclusion of a new industry.
3. Based on step one the change in input quantities depending on price variations according to step two is to be calculated for each entry in the new Input-Output table.

Put differently, step one to three embrace the change in prices in response to a demand shock such as the introduction of a new industry and the corresponding change in input quantities, resulting from this change in prices. Intuitively it is clear, that market equilibrium is not yet reached. On the contrary, new input structures will induce prices to change again and these in turn are prone to affect optimal

[2] Non-bold A's do not refer to the matrix of technical coefficients in sub-section 2.1. and 2.2.
[3] The lack in supply-side elasticities for primary inputs will be discussed in sub-section 3.3.

input structures yet again. Thus the mechanisms in step two and three are to be repeated until an equilibrium is re-established.

In step one the optimal input structure for each sector is derived by minimizing production costs under a predetermined level of total output.

(2.3.-2) Production function: $$Y = A * \prod_{k=1}^{K} X_k^{\alpha_k}$$

(2.3.-3) Cost function: $$C = \sum_{k=1}^{K} c_k X_k$$

with c_k being the price of input k and C total production cost

This is commonly done by employing Lagrangian multipliers. The techniques are common textbook knowledge (see for instance Griffiths & Wall 2000) and were thus moved to Appendix A.
The resulting optimal input quantities are as follows:

(2.3.-4) $$X_k = Y^{\frac{1}{\pi}} * A^{\frac{-1}{\pi}} * \left(\frac{\alpha_k}{c_k}\right)^{\frac{\pi-\alpha_k}{\pi}} * \prod_{k'=1,k'\neq k}^{K} \left(\frac{c_{k'}}{\alpha_{k'}}\right)^{\frac{\alpha_{k'}}{\pi}}$$ with $$\pi = \sum_{k=1}^{K} \alpha_k$$

In step two one can determine supply side elasticities for each sector by employing the optimal input structure as given in equation (2.3.-4). Assuming that there is perfect competition in place along with zero profits for companies, the following relation holds:

(2.3.-5) $$P * Y = \sum_{k=1}^{K} c_k X_k$$ with P being the market price for outputs

When considering a high level of aggregation in the Input-Output table, such as in section 3, with at most a few industries within each sector operating under oligopolistic conditions, these assumptions referring to competitive markets surely are reasonable. Thus for simplicity price markups in oligopolistic markets are not considered.
Again the derivation is standard and moved to the Appendix A. The resulting supply side elasticity of each sector k is given by:

(2.3.-6) $\varepsilon_Y = -\frac{\pi}{\pi - 1}$ with $\varepsilon_Y = \frac{dY}{dP} * \frac{P}{Y}$

with: $\varepsilon_Y > 0$ for $0 < \pi < 1$

and: $\varepsilon_Y > 1$ for $0.5 < \pi < 1$

Since equation (2.3.-5) assumes perfect competition along with zero profits in companies, the above given derivation primarily holds for non-oligopolistic companies and industries. Positive supply-side elasticities should thus follow, such that industries increase their output in the face of rising prices. Consequently, for this condition to hold the sum of all Cobb-Douglas coefficients should be smaller than one, implying the absence of increasing returns to scale.

In addition, in order to simulate a new market equilibrium by iteratively calculating adjusted prices and quantities, each supply-side elasticity should be larger than one. Otherwise a small demand shock results in a somewhat stronger price variation which in turn will lead to an even larger change in quantities. Thus the system would become unstable and oscillate until at some point it reaches an unrealistic result with negative quantities[4]. Therefore, in order to ensure convergence, only supply-side elasticities larger than one are to be applied.

At this point the reader should be aware that supply-side elasticities can only be derived for intermediate inputs. This is because the optimal input structure of each sector, constructed in step one, was employed in step two. Since primary factors such as land, labor and capital are not being included in the industry matrix within the initial Input-Output table, but mainly provided by households and entrepreneurs, their respective elasticities cannot be derived numerically. Section 3.3.2 discusses how to circumvent this lack in supply-side elasticities for primary factors for the case of Tanzania.

In step three the variation of input quantities associated with a change in prices is to be determined. The procedure is similar for each entry in the Input-Output table. First some variables ought to be known for the derivation. This is the total output (Y_k)of each sector *k* after the introduction of a new industry. The latter is given in table 2.3 in sub-section 2.2 with $(Y_1' \dots Y_k' \dots Y_n')$. In addition, this is the price variation (Δ_k), which can be obtained using the supply-side elasticities in equation (2.3.-6). In the following this is demonstrated for output *k*.

[4] This is similar to a cobweb with divergent fluctuations. Here the assumption is that future supply is determined considering present demand and market prices. If the elasticity of supply is greater than the elasticity of demand, prices and quantities oscillate. (see Ezekiel 1938)

(2.3.-7) $$\varepsilon_{Yk} = \frac{\frac{dY_k}{Y_k}}{\frac{dP_k}{P_k}} = \frac{\frac{dY_k}{Y_k}}{\Lambda_k}$$ and $$\Delta_k = -\frac{\frac{dY_k}{Y_k}}{\frac{\pi}{\pi - 1}}$$

Given that Y_k and Δ are known, it is possible to derive the accompanying relative changes in optimal input quantities of intermediate inputs. Therefore it is assumed that the market price for each output is equivalent to the price of the respective input from the same industry. The following derivation is exemplary for intermediate input X_1 and may be similarly conducted for all other intermediate inputs. The optimal input quantity of X_k under the initial prices c_1 to c_k is given in (2.3.-4).

(2.3.-8) $$X_1 = Y^{\frac{1}{\pi}} * A^{\frac{-1}{\pi}} * \left(\frac{\alpha_1}{c_1}\right)^{\frac{\pi - \alpha_1}{\pi}} * \left(\frac{c_2}{\alpha_2}\right)^{\frac{\alpha_2}{\pi}} * \ldots * \left(\frac{c_K}{\alpha_K}\right)^{\frac{\alpha_K}{\pi}}$$

The formula for X_1^{new} changes only with respect to input prices and total output of the respective sector:

(2.3.-9) $$X_1^{new} = Y^{new\frac{1}{\pi}} * A^{\frac{-1}{\pi}} * \left(\frac{\alpha_1}{c_1 + \Delta_1 c_1}\right)^{\frac{\pi - \alpha_1}{\pi}} * \left(\frac{c_2 + \Lambda_2 c_2}{\alpha_2}\right)^{\frac{\alpha_2}{\pi}} * \ldots * \left(\frac{c_K + \Lambda_K c_K}{\alpha_K}\right)^{\frac{\alpha_K}{\pi}}$$

with $$c_1^{new} = c_1 + \Delta_1 c_1$$

Dividing X_1^{new} by X_1 delivers the change in input quantity relative to the initial input quantity.

(2.3.-10) $$\frac{X_1^{new}}{X_1} = \left(\frac{1}{1 + \Delta_1}\right)^{\frac{\pi - \alpha_1}{\pi}} * \left(\frac{1 + \Delta_2}{1}\right)^{\frac{\alpha_2}{\pi}} * \cdots * \left(\frac{1 + \Delta_3}{1}\right)^{\frac{\alpha_K}{\pi}} * \left(\frac{Y^{new}}{Y}\right)^{\frac{1}{\pi}}$$

X_1 and Y however, are not given in the Input-Output table, but only Ψ_1 and Y which represent monetary values:

(2.3.-11) $$X_1 * c_1 = \Psi_1 \quad ; \quad X_1^{new} * c_1 = \Psi_1^{new}$$

and $$Y * c_1 = \mathrm{Y} \quad ; \quad Y^{new} * c_1 = \mathrm{Y}^{new}$$

Inserting (2.3.-11) into (2.3.-10) leads to the final equation for the change in optimal input quantities:

(2.3.-12) $$\frac{\Psi_1^{new}}{\Psi_1} = \left(\frac{1}{1+\Delta_1}\right)^{\frac{\pi-\alpha_1}{\pi}} * \left(\frac{1+\Delta_2}{1}\right)^{\frac{\alpha_2}{\pi}} * \cdots * \left(\frac{1+\Delta_3}{1}\right)^{\frac{\alpha_K}{\pi}} * \left(\frac{Y^{new}}{Y}\right)^{\frac{1}{\pi}}$$

Thus monetary values of new input quantities and total output are still based on the initial set of prices. The only right-hand side unknown in the above given equation is Y^{new}. This is because total output times market price of one sector depends on intermediate inputs of the respective good in all other sectors. Therefore the above constructed equation cannot be solved analytically. However it is possible to approximate the result for Ψ_1^{new} by setting $Y^{new} - Y$ in a first step. Thereafter all intermediate inputs and final demands are to be summed up to the next Y^{new} , which in turn enables a new calculation of intermediate inputs. These steps can be repeated until the system is in equilibrium.

To sum up, the theoretical approach discussed in this sub-section allows to simulate a market response to the demand shock of a new industry introduced to the economy and sub-section 2.2 delivered an intermediate result only by deriving new equilibrium entries in the Input-Output table which are based on constant input shares. In sub-section 2.3 the former change in total output induces a market response with changing input prices and changing optimal input structures. Results are then obtained by an iterative procedure which includes the successive calculation of prices and quantities until the equilibrium is reached. This procedure, however, does not require extensive data on quantities and prices. How it can be applied to Tanzania's economy with a significant production of biofuels will be illustrated throughout the following two sections.

3. Data and empirical methodology

3.1. The Input-Output table for Tanzania

The initial Input-Output table has been aggregated from a Social Accounting Matrix (SAM) for Tanzania in 2001, compiled by the International Food Policy Research Institute (IFPRI). By comprising monetary flows between all institutions in an economy (e.g. households and the government), a SAM is a consistent framework capturing more information than an Input-Output table. A SAM does not only equate row and column sums of all industries, but also all other entries such as factor inputs, households and taxes are balanced. Data is largely taken from national accounts, labor force surveys, household budgets, foreign trade statistics, balance of payments and government budgets (see Thurlow 2003).

For the purpose of this study several entries in the Social Accounting Matrix had to be aggregated. These shall be discussed throughout this section. In the subsequent analysis single entries in the SAM shall be named industries, while the aggregation of these in the Input-Output table will be termed sectors.

Firstly, the SAM differentiates between 'Activities' and 'Commodities'. The former are those entities that carry out production. Goods are either directly delivered to 'Households' and thus final consumption, or they are put on the market. In that case they turn into 'Commodities' and are distributed to either 'Households' or the 'Rest of the World', 'Savings and Investment' and the 'Government'. This distinction has proven its application to be justified for developing countries, as a large share of the population, especially in rural areas, is engaged in subsistence production. However, for the benefit of this study they were added up to a single matrix of industries and intermediate inputs. This produces slightly inexact results, as it combines market and producer prices. Nevertheless, in order to apply the theoretical framework as laid out in section 2 it is necessary to compile one matrix of intermediate inputs.

Factor inputs in the SAM basically consist of 'Land', 'Labor' and Capital, with the latter being subdivided into 'Agricultural Capital' and 'Non-Agricultural Capital'. In addition, there is one input called 'Subsistence Factor' which accounts for the production of own household consumption (Thurlow 2003). In section 3.2 it becomes clear, that there is hardly a way of estimating a Cobb-Douglas coefficient for this 'Subsistence Factor'. Therefore it was split up and added to the other factor inputs according to their share in total factor input. The sum of all factor inputs constitutes the reimbursement of labor, land and capital in Tanzania. Together with taxes they add up to total value added and thus GDP.

Imports were basically transferred without any change. Interestingly, according to Thurlow (2003) 12.14% of total imports to Tanzania are petroleum products[5].

'Final Demand' in the Input-Output table comprises several entries in the SAM: 'Households', 'Government', 'Rest of the World' which is interchangeably used for exports, 'Savings and Investments' and 'Marketing Margins' which constitute demand for services from the trading sector only.

Table 3.1: Aggregated Input-Output table 2001 in billion of Tanzanian Shilling[6]

	Farming	Cash-crops	Manufacturing 1	Manufacturing 2	Services	Petro	Final demand	Total output
Farming	247.2	8.1	1.0	748.1	89.4	0.0	2,779.3	3,873.1
Cash-crops	0.0	49.9	0.0	294.6	0.3	0.0	358.2	702.9
Manufacturing 1	33.6	34.1	202.9	14.2	401.6	8.6	952.3	1,647.4
Manufacturing 2	25.5	9.1	8.8	90.3	151.3	0.3	2,298.7	2,584.0
Services	144.0	77.7	104.4	230.3	3,412.2	3.3	3,692.4	7,664.4
Petro	9.1	8.1	12.4	4.2	33.8	1.7	219.9	289.2

[5] According to WDI provided by the World bank group this share rises to 30% in 2007.

[6] US dollar exchange rate in December 2001: 1USD = 950.14 TSZ (see: http://www.oanda.com/lang/de/currency/historical-rates)

Labor	1,610.0	188.0	41.9	227.7	1,093.9	3.7
Agricultural capital	1,065.2	129.2	0.0	0.0	0.0	0.0
Non-agricultural capital	0.0	0.0	224.0	516.0	1,961.4	9.8
Land	456.2	55.4	0.0	0.0	0.0	0.0
Total imports	68.8	50.6	887.1	253.7	507.0	241.8
Tax	213.3	92.7	164.8	204.9	13.6	20.0
Total	3,873.1	702.9	1,647.4	2,584.0	7,664.4	289.2

All industries in the SAM have been aggregated to five sectors: Farming, Cash-crops, Manufacturing 1, Manufacturing 2 and Services. Petro was the only industry directly transferred to the Input-Output table, as it constitutes those intermediate inputs, which are to a certain extent to be substituted by biodiesel. All industries were aggregated with regard to their respective input structures and deliveries to 'Final Demand'. See Appendix 3 for a full list[7] of all industries in each sector. 'Manufacturing 1' for instance comprises industries such as metals and chemical products which are mostly utilized as intermediate inputs in other industries. 'Manufacturing 2' on the contrary primarily consists of food processing industries and household goods. Consequently a large share directly satisfies final demand by households. A significant share of 'Cash-crops' is exported. Industries in this category produce goods such as cotton, coffee and tobacco. The 'Farming' sector on the other hand comprises all industries involved in the production of food crops and livestock as well as hunting and forestry. Thus it foremost serves local demand. Unsurprisingly for a developing country like Tanzania, in 2001 46.3% of the total GDP at factor cost was generated within agricultural industries. Manufacturing accounted for 11.9% only. The balance was contributed by secondary industries and the services sectors (Thurlow 2003).

3.2. Estimation of Cobb-Douglas coefficients for intermediate inputs

This study deepens common approaches towards Input-Output analysis by assuming a Cobb-Douglas production function for each of Tanzania's sectors. Input shares are therefore not assumed to stay constant in response to a demand shock. On the contrary, since varying demand for inputs will affect prices, sectors are expected to substitute. These mechanisms depend on the optimal input structure derived in sub-section 2.3 and thus, substitution between input factors is not only determined by relative prices, but also by Cobb-Douglas coefficients.

In order to estimate Cobb-Douglas production functions comprising of Cobb-Douglas coefficients for each of Tanzania's sectors, one would ideally collect data on input-output relations for each sector over several years. Time series of this kind, however, are not available. Input-output relations in the

[7]The petroleum industry remains a part of 'Manufacturing 1' in this table, as it will be added to the 'Manufacturing 1' sector in the subsequent estimation of production functions.

SAMs for Tanzania from 1998-2001 compiled by the IFPRI institute are kept constant, stemming from one single data analysis in 1992. Therefore an alternative strategy had to be applied, employing the input-output structure of each industry in the 2001 SAM as one observation for its respective sector. Theoretically this implies a fundamental assumption, namely that all industries within the same sector produce a homogeneous good by using the same technology. However, this does also lead to a conceptual advantage. While the degree of substitution in a single industry is rather limited, its scope in the respective sector is much larger. See Appendix B for a full list of all industries in each sector. In addition, this approach renders any transformation of monetary values as applied in the original tables into pure quantities unnecessary. This is because estimation in values leads to the same estimates for all Cobb-Douglas coefficients as estimation in quantities. Only the intercept differs (see Appendix B).

To increase the number of observations, SAMs from Kenya (2001 and 2003) and Uganda (1999) were also used. This incurs the assumptions that firstly, similar industries across these countries have equivalent technologies and production functions and secondly that relative prices for similar goods are equal across counties. The latter condition is necessary, since otherwise quantities standing behind monetary values are not comparable. These assumptions allow us to increase the number of degrees of freedom and do not seem overly restrictive in the case of these neighboring countries. Nevertheless, while relative prices should be equivalent due to trade between neighboring countries, the assumption of similar techniques and production functions may bias the results.

The following function was estimated for each sector separately[8]:

(3.3.-1) $$Y = A * X_1^{\alpha_1} \dots X_K^{\alpha_K} * U$$

with Y being total Output and X_K input K
X is assumed to be non-stochastic with no exact dependence between $X_1 \dots X_K$
u is the disturbance term
successive disturbances are assumed to be mutually independent with $U = e^u$ and $u \sim N(0, \sigma^2)$
A is a constant

The reader should be aware that the usual approach of estimating (3.3.-1) in logarithms implicitly leads to estimating the conditional median function (3.3.-3) and not the conditional mean function (3.3.-2) as is commonly done.

(3.3.-2) $$E(Y|X) = A * X_1^{\alpha_1} \dots X_K^{\alpha_K} * E(U) \quad \text{and} \quad E(U) = e^{\frac{1}{2}\sigma^2}$$

[8] Strictly speaking the production function was estimated using monetary values from the Input-Output tables. However this doesn't change the estimates for the Cobb-Douglas coefficients. See Appendix B.

(3.3.-3) $M(Y|X) = A \cdot X_1^{\alpha_1} \dots X_K^{\alpha_K} \cdot M(U)$ and $M(U) = 1$

This is because in the conditional mean function $E(U) \neq 1$ and consequently its logarithm is not equivalent to zero, which is a necessary precondition for any unbiased linear regression. However, "The two central tendency functions differ in level, although not in shape." (Goldberger 1968). Thus, estimating either of both won't change the estimators $(a_1 \dots a_K)$ for $\alpha_1 \dots \alpha_K$. Only the estimator (a) for the intercept A will differ.

Taking logarithms of equation (3.3.-1) leads to the following regression equation:

(3.3.-4) $$y_t = \alpha + \sum_{k=1}^{K} \alpha_k x_{tk} + u_t$$

$y = \ln Y$

$x_k = \ln X_k$

$\alpha = \ln A$

$u = \ln U$

For the purpose of this study, it is adequate to estimate (3.3.-4). The intercept, which does differ between conditional mean and median function is not further needed throughout the subsequent analysis. Complicated adjustments of the regression equation are therefore not necessary and $a_1 \dots a_K$ are unbiased estimates for $\alpha_1 \dots \alpha_K$ with a minimal variance amongst all linear estimators.

OLS regression results for (3.3.-4) are given in table 3.2.

Table 3.2: Regression results for Cobb-Douglas coefficients (OLS, un-weighted)

	Farming	Cash-crops	Manufac turing 1	Manufac turing 2	Services[9]
Farming	0.058	0.024	-0.103	0.070	-0.023
	(0.07)	(0.06)	(0.14)	(0.04)	(0.05)
Cash-crops	-	0.043	-	**0.123***	-
		(0.05)		(0.06)	
Manufacturing 1	0.049	-0.056	**0.612***	0.009	0.086
	(0.06)	(0.06)	(0.32)	(0.05)	(0.09)
Manufacturing 2	0.037	-0.053	0.024	-0.175**	**0.078*****
	(0.05)	(0.04)	(0.16)	(0.06)	(0.04)
Services	0.083	**0.278***	0.018	**0.629*****	**0.336****
	(0.09)	(0.09)	(0.28)	(0.15)	(0.08)

[9] According to the Breusch-Pagan test the disturbances in the 'Services' sector are heteroskedastic (p=0.008). For this reason table 3.2 contains robust standard errors in the respective column.

Petro	0.082	0.068	0.108	**0.276***	0.003
	(0.08)	(0.09)	(0.15)	(0.14)	(0.04)
Labor	0.215	-0.048	-0.075	-0.019	0.106
	(0.18)	(0.34)	(0.45)	(0.23)	(0.12)
Agricultural capital	**0.383****	**0.386**[10]	-	-	-
	(0.14)	(0.18)			
Non-agricultural capital	-	-	**0.346***	0.131	0.116
			(0.17)	(0.18)	(0.07)
Land	**0.151***	**0.438**	-	-	-
	(0.09)	(0.20)			
Constant	2.122	2.036	1.913	3.039	3.395
	(0.23)	(0.29)	(0.56)	(0.35)	(0.44)
DF	22	2	9	5	15
Adj. R-squared	0.935	0.993	0.816	0.929	0.836
CRS	not rejected	not rejected	not rejected	not rejected	rejected

(*** - significant at the 1% level; ** - significant at the 5% level; * - significant at the 10% level)
(Standard Errors are given in parenthesis.)

Except for the case of 'Manufacturing 2' where own intermediate inputs have a negative coefficient, negative estimates are insignificant. Hence, the hypothesis that these coefficients are different from zero cannot be rejected at a confidence level of 10% and below. However, a theoretical value of zero, implying that a certain input is not needed at all, is not feasible as well, as it wouldn't correspond to the initial Input-Output table where inputs, which turn out to have negative Cobb-Douglas coefficients, are also used in the production process. Therefore, as negative coefficients unrealistically imply that production volumes decrease with increasing respective inputs, these coefficients will be set to an infinitesimal positive value. In this way they can be interpreted as inputs which contribute to total output to a very limited extent only. Overall, negative coefficients could point to the underemployment of some factors as is quite common in developing countries.

The uncommonly high adjusted R^2 cannot be associated with a high quality of the regression analysis, since the samples compiled for all five sectors have very few degrees of freedom only. Therefore, regression results were merely constructed rather than estimated which they would not be if they were based on a bigger sample size. The compilation of a larger data set could thus improve regressions fundamentally. However, data is scarce and especially the consistency of several SAMs in Sub Saharan Africa initiates problems for the compilation of larger sample sizes.
Interestingly, in all five sectors 'Labor' is highly and positively correlated to total output. However, estimates for 'Labor' turn out to be insignificant in all columns and in three out of five cases they are

[10] A high correlation of 'Labor' with 'Land' and 'Agricultural Capital' distorts the significance of the latter two. A Wald test for joint significance leads to the conclusion that both factor inputs should be treated as significant coefficients in the subsequent analysis with p=0.0202.

negative. The primary reason for this is probably the low marginal productivity of labor in Tanzania. In sub-section 3.3.2 it is argued that there is a lot of so-called labor slack to be found. This is mostly subsistence labor in small family businesses or on family owned lands or underemployment and unskilled labor in the manufacturing and services industries, which could be used more effectively for other purposes. Hence the additional employment in many sectors does not significantly add to total output, which is why 'Labor' turns out to be insignificant in all regressions.

In addition to the un-weighted regressions as discussed previously, one could also argue that larger industries within each sector should have more influence on the estimation of the respective production function than smaller industries. After all, large industries have a higher share in total output and thus it could be justified if these industries held a higher share in sample sizes too. In an un-weighted regression however, every industry has the same statistical weight on the estimation of a production function. In addition, the Ugandan GDP amounts to about two third of Tanzania's and Kenya's GDP. Thus Ugandan industries are on average smaller than the industries in the rest of the sample, which should be taken into account. In order to do so, all regressions were additionally conducted in a weighted form. See Appendix B for weighted regression results. It is apparent, that the magnitude of the estimates hardly changes however their significance improves strongly. Nevertheless, estimates stemming from weighted regressions were not employed in the subsequent analysis. This is primarily because the significance of weighted estimates is artificially boosted by assumed larger sample sizes in accordance to the weight of total output in each industry. In addition, the sums of all significant coefficients imply strongly increasing returns to scale, which is rather unrealistic for Tanzania's economy. Thus, these results are not only constructed rather than estimated, but their value is also low from an economic point of view. Nevertheless, the weighted regressions reveal that there are no large differences in production functions between larger and smaller industries and thus an un-weighted regression is reasonable to be applied.

The estimation of Cobb-Douglas production functions for each sector in sub-section 3.2 does now provide the grounds for the calculation of a supply-side elasticity for each sector in sub-section 3.3.

3.3. Approach towards supply-side elasticities

3.3.1. Intermediate inputs

For determining supply-side elasticities for each intermediate input, Cobb-Douglas coefficients are to be employed as derived in the Theory section such that:

(3.3.-5) $$\varepsilon = -\frac{\sum_{k=1}^{K} \alpha_k}{\sum_{k=1}^{K} \alpha_k - 1}$$ with ε being the elasticity and α_k the Cobb-Douglas coefficient for input *k*

This is equivalent to equation (2.3.-6).

In order to widen the analysis and allow some insights into the sensitivity of all macro-economic indicators to different supply side elasticities, the use of Cobb-Douglas coefficients at several confidence intervals seems to be promising.

All sums of Cobb-Douglas coefficients are summarized in table 3.3. Into each sum were only those coefficients added, which were significantly different from zero. Cells with a 'null' stand for those sums, where the lower bound of all confidence intervals was negative and thus assumed to be infinitesimal. All other cells which are grey, will lead to negative elasticities in table 3.4, because their sums are larger than one.

Table 3.3: Sum of all significant coefficients at several Confidence Intervals in each sector

	Farming	Cash-crops	Manufacturing 1	Manufacturing 2	Services
Lower Bound 95% CI	0.086	null	null	null	0.164
Lower Bound 90% CI	0.140	0.014	0.053	0.341	0.208
Lower Bound 80% CI	0.231	0.211	0.275	0.525	0.256
Coefficient	0.534	1.102	0.957	1.029	0.413
Upper Bound 80% CI	0.838	1.994	1.640	1.533	0.570
Upper Bound 90% CI	0.929	2.482	1.862	1.717	0.618
Upper Bound 95% CI	1.011	3.136	2.074	1.906	0.663

Table 3.4: Supply-side elasticities at several Confidence Intervals in each sector

	Farming	Cash-crops	Manufacturing 1	Manufacturing 2	Services
Lower Bound 95% CI	0.094	null	null	null	0.196
Lower Bound 90% CI	0.163	0.014	0.056	0.518	0.263
Lower Bound 80% CI	0.301	0.268	0.379	1.105	0.345
Coefficient	**1.148**	**-10.767**	**22.498**	**-35.752**	**0.704**
Upper Bound 80% CI	**5.162**	**-2.006**	**-2.563**	**-2.878**	**1.327**
Upper Bound 90% CI	13.012	-1.675	-2.160	-2.396	1.621
Upper Bound 95% CI	-95.677	-1.468	-1.931	-2.104	1.965

Negative elasticities are set to infinity and in the simulation they were substituted by sufficiently large values. In general, a larger sum of coefficients implies a higher respective elasticity. Only if a sum is above one, elasticities abruptly turn negative. From a theoretical point of view increasing returns to scale are only to be found in monopolies and oligopolies which, in order to maximize profits, decrease their total output. The same behavior in widely aggregated sectors such as 'Services' or 'Manufacturing 1' however is highly unlikely. Therefore, sums larger than one should be taken as an indication for returns to scale, which are close to one. These imply very high elasticities and thus flat supply curves with quantities responding strongly to only slightly increasing prices. In developing countries where free capacities are nothing unusual this surely is realistic.

The two sets of elasticities in bold in table 3.4 are the sets employed in the simulation. The first set stems from the original estimation results. Here the elasticity for the 'Services' sector was set to a value marginally above one in order to assure convergence as discussed in the Theory section. The second set is the one next to the original set with all elasticities above one.

Overall, a higher data quality with resulting elasticities of above one in all sectors would be desirable. However, under the given difficulties of compiling a coherent dataset the compromises made in this study are inevitable.

3.3.2. Factor inputs

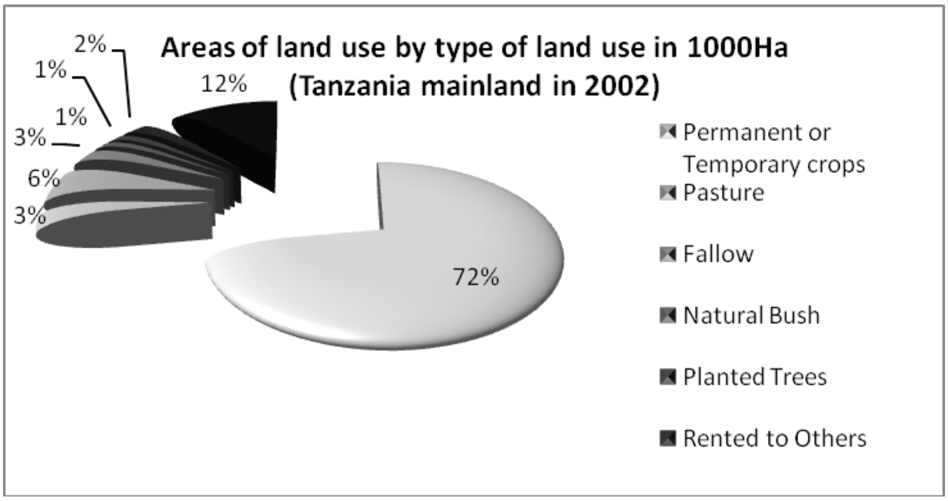
Naturally there are no production functions and Cobb-Douglas coefficients available for determining supply-side elasticities of factor inputs. Nevertheless, from the relevant literature and statistics on factor markets it is feasible to narrow down the magnitude of the elasticities for land and labor. Additional information on the capital market is hardly available, as capital may have very different applications and manifestations in each sector. In addition, as loans are rarely available for the majority of all businesses and interest rates are strongly biased by credits from development banks, it is of little help to rely on the market for capital. However, final results will show that the supply-side elasticity of capital has only marginal impacts on macroeconomic indicators after all.

Throughout the final simulation it is then possible to conduct sensitivity analyses with respect to the supply-side elasticities of land, labor and capital. This will allow to further determine, which elasticities are likely to materialize strong impacts on macroeconomic indicators and whether there are some elasticities, which hardly affect these indicators at all.

Land

From the macro- perspective the market for land in Tanzania is rather tight. About 72% of all unsettled areas are under permanent or temporary crops (see fig 3.5). Only 12% is uncultivated and usable according to the Ministry of Agriculture and Food Security. Nevertheless, this unused land is likely to be dry, it is scattered across the country and it should be understood as free nature. It will hardly be desirable for the country to cultivate land wherever possible, especially with respect to the preservation of biodiversity and water security. Naturally these constraints pose difficulties on the acquirement of big plots for agricultural purpose as aimed for in 'large-scale' scenarios.

Figure 3.5:



Source: Ministry of Agriculture and Food Security and Cooperatives (CountrySTAT United Republic of Tanzania)

In addition, there are several governmental institutions involved in the process of acquiring major sites. Overall the market for land in Tanzania is strongly regulated in 'The Land Act' and 'The Village Land Act' from 1999. Especially foreign companies, which constitute the majority of investments into large-scale plantations, find themselves in a complicated web of regulations and responsibilities.
In sum these considerations support a non-competitive view on the market for land, in which supply side elasticities are obsolete. Nevertheless they are not dispensable in this analysis, as they are needed to simulate a pricing response to an increased demand for land. Thus the most realistic way of modeling the tight market for land with respect to large plot sizes is, to assume a steep supply curve and hence a low elasticity. In the subsequent simulation this will imply, that firms are inclined to substitute additional demand for land by other input factors such as labor or agricultural capital.

The perspective of smallholder farmers is somewhat different. According to CountrySTAT about 58% of all households employed in the agricultural sector have land occupied by customary right. Only 21% of all households hold a certificate of ownership. Therefore large areas of land are under the authority of village councils. Under these circumstances farmers are often in the position to claim additional small areas of land for growing Jatropha attached to their own fields and patches. A study about the socio-economic impacts of a Jatropha-project with smallholder farmers in Mpanda revealed that approximately 55% of all farmers grow Jatropha on new land or as additional crop on their own empty lands. In contrast, 45% of all outgrowers replaced other crops with Jatropha (Loos 2009).
Additional demand for land in smallholder scenarios is thus likely to have a very small impact on the prices for land, if any, as long as farmers have unproblematic access to additional lands. To model this situation it is best to assume a very flat supply curve for land and consequently a large elasticity.

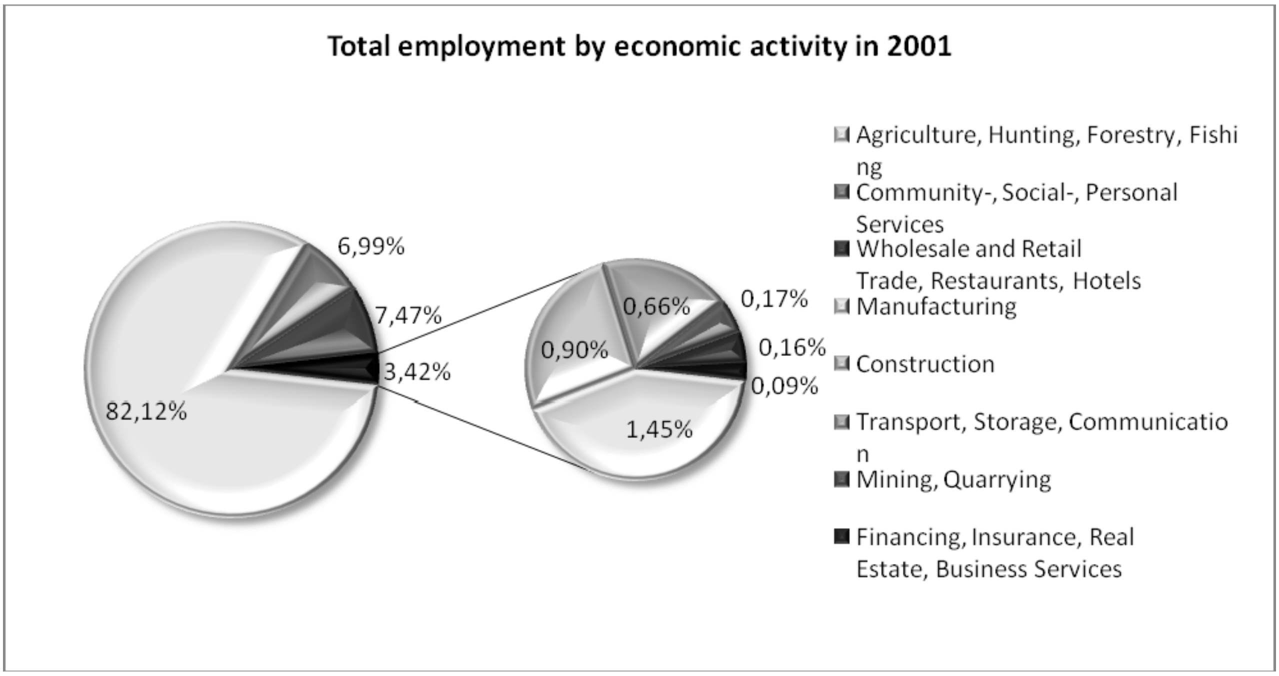
Labor

In order to model market mechanisms resulting from the introduction of a jatropha and bio-diesel industry to Tanzania's economy, it is necessary to anticipate how wages will react to an increasing demand for labor.

Commonly the line of argument for developing countries is that with a fixed availability of arable land and an unproportionally large, non-commercialized or traditional sector a surplus of labor is at hand. Because there is too much labor employed on limited lands, the marginal product of labor in the agricultural sector is very low. Therefore wages in the neoclassical sense are commonly too low to satisfy subsistence levels. For this reason institutional wages[11] are paid, which are higher than marginal productivity. (Ranis 1997) This leads to nearly constant wages in the presence of increasing demand for labor, as long as the marginal product of labor is below the institutional wage.

To a large extent this theory also applies to the case of Tanzania's labor market, where 82% of the total economically active population is employed in the agricultural sector. In contrast, the commercialized or modern sector is rather small with 18% of total employment only (see figure 3.6). However, as has previously been discussed, availability of land is not entirely fixed in Tanzania. On the contrary, field studies have shown that farmers are able to marginally extend their lands for additional planting. For this reason it is more appropriate to assume that labor is fully employed. Figure 3.7 mostly confirms this view. Apparently unemployment in rural areas amounts to 1% only.

Figure 3.6:

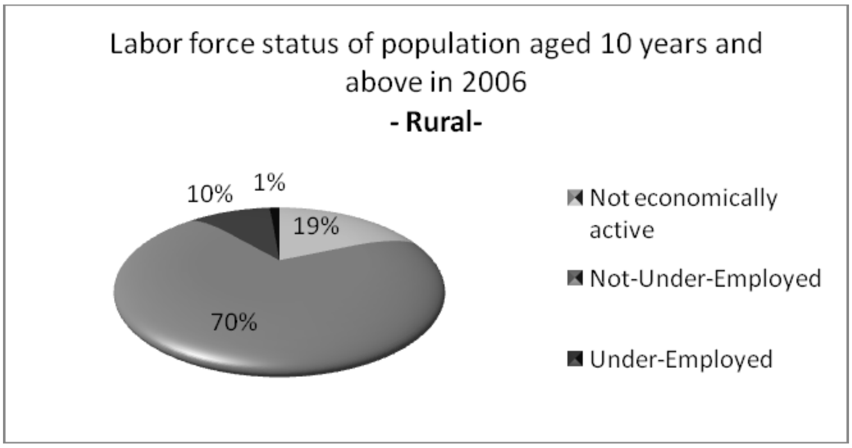


Source: ILO LABORSTA

[11] Institutional wages are more or less equal to the average product of labor as opposed to the marginal product of labor and consequently they represent a sharing value rather than an efficient allocation of labor.

Despite full employment, however, it seems appropriate to assume a flat labor supply curve and consequently a high elasticity of labor supply, because, even though there might not be a large labor surplus, there certainly is labor 'slack'. This is for three reasons as discussed in Reynolds (1969). Firstly, as is the case of Tanzania, there is open unemployment of approximately 9% in urban areas resulting from strong rural-urban migration (see figure B4 in Appendix B).

Figure 3.7 :



Source: National Bureau of Statistics Tanzania: Statistical Abstract 2006

Secondly, a large share of the population works less than any reasonable concept of full time and could be persuaded to work for the prevailing wage, which would consequently not or only marginally increase. Thirdly, additional demand for employment usually repays opportunity costs for labor only and stays relatively constant as long as self-employed subsistence workers are present. Indeed figure 3.7 comes up with an underemployment of 10% in the rural population.

4. Scenarios

4.1. Implementing biofuels into Tanzania's current fossil fuel market

Tanzania has no natural resources of crude petroleum oil and until 1997 the sector was heavily regulated. Tanzania's only refinery plant TIPER processed crude petroleum oil to meet around 50% of national requirements. The balance was imported by the Tanzania Petroleum Development Corporation (TPDC). Following continuous efforts of modernization since 1991, in 1999 the refinery plant was closed down and imports of crude oil for refinery were stopped. Today petroleum products are not being processed within the country.

In 1997 downstream markets for petroleum products were liberalized to enhance competition and reduce prices. Within short time 70 companies registered as oil marketing companies. These are organized under the Tanzania Association of Oil Marketing Companies (TAOMC) with the main players being BP, TOTAL, ORYX, ENGEN, GAPCO, GAPOIL, OILCOM, NATOIL and KOBIL. Despite these efforts a study by the German Technical Cooperation (GTZ 2005) claims that the market for petroleum products in Tanzania is inefficient due to its oligopolistic structure.

According to the 2001 SAM, total consumption of petroleum products in Tanzania added up to a monetary value of 289 billion TZS. While 83.6% (242 billion TZS) was accounted for by actual imports, only 16.4% were added within the economy for instance by transportation, additional labor costs and taxes. Households and thus final demand hold a share of 76% in total consumption. Only 24% of all petroleum products are used as intermediate inputs.

There are two reasons for which consumers could be willing to substitute fossil diesel by biodiesel that could be used to include the new bio-diesel industry into the technical coefficients matrix: the competitiveness of bio-diesel prices and a policy induced blending target. Firstly, the competitiveness of prices could induce increased demand for biodiesel. According to van Eijck (2010), biodiesel made of Jatropha oil could be competitive with the average fossil diesel price in 2006 and 2008 of around 1.15$ per liter, if there were no government taxes such as road toll and excise duty on biodiesel and if the price for Jatropha seeds did not exceed a maximum of 0.17$ kg^{-1} . According to her estimations in a smallholder setting, a price of 0.14$ kg^{-1} is feasible and thus competitiveness possible. In addition, the GTZ (2005) underlines possible efficiency improvements, 'learning by doing' effects and economies of scale as production volumes increase. However, it is hard to tell what the exact prices for Jatropha seeds, straight vegetable oil and consequently biodiesel will turn out to be. Amongst others, they strongly depend on the input systems and methods of management e.g. fencing, intercropping and monoculture. In addition, scale effects as well as related policies are likely to influence price schemes strongly.

For technical reasons and in order to treat fossil diesel and bio-diesel as perfect substitutes in the initial Input-Output table, which is based on monetary values, it is necessary to assume that both have the same market price (see section 2.2.). Otherwise differing prices would mistakenly lead to a variation in quantities. Therefore, the competitiveness of biodiesel is no feasible option to include a 'Jatropha cultivation and bio-diesel industry' into the initial Input-Output table. It is rather a theoretical assumption, which is necessary to hold in the first place.

The second reason for a substantial increase in biodiesel consumption could be a corresponding policy framework stipulating a certain blending target. According to the REN21 (2009) binding obligations for blending targets are already at place or aimed at within determined time intervals in 24 countries around the world. In Tanzania however, there are no conclusive regulations in place at present. This lack in a clear legal framework has led to a climate of uncertainty amongst investors. In a draft version of the *'Guidelines for sustainable development of liquid biofuels and co-generation in Tanzania'* issued by the Ministry of Energy and Minerals in 2008 it was stated that "Tanzania has already realized the need to promote biofuels". However no clear regulations were announced, nor are any blending objectives given. While the document calls for thorough examinations of environmental and social issues, such as the allocation of land or food security, it alienates biofuel stakeholders in Tanzania.

Table 4.1: Petroleum products consumption in Tanzania in 2001

Type of product	metric tonnes
Liquified petroleum gas	20,009
Petrol	130,756
Diesel	350,176
Industrial diesel	21,360
Fuel Oil[12]	96,382
Jetfuel	49,598
Paraffin	104,252
Total	**772,533**

Source: GTZ, 2005

Despite these obscurities a policy induced blending target depicts a neat way of implementing biodiesel into the initial Input-Output table from 2001. In order to do so, it is necessary to determine the share of petrol-diesel that shall be substituted by bio-diesel products, as there are no blending targets stipulated in policy documents yet. In the nearer future demand for bio-diesel will foremost be limited by technical restraints, as older vehicles can only run on a (at maximum) 20% blend without modifying the engine. This maximum blend will thus be the basis for all four scenarios.

Since diesel is only one out of several petrol products comprised within the same industry in the Input-Output tables, it is necessary to determine what a 20% blend of diesel with biodiesel is equivalent to with respect to total consumption of petrol products.

Diesel consumption in Tanzania accounts for almost half of total petroleum product imports in terms of weight (see table 4.1). In 2001 about 470 Mio l diesel were imported to the country, with a retail price amounting to 703.10 TZS[13] per liter and a CIF price of 319.63 TZS[14] per liter. Thus, considering CIF prices which are net of taxes, total consumption of diesel products adds up to a value of 150.24 billion TZS with the 20% share being 30.05 billion TZS. Relative to the total value of petroleum product imports in the SAM, which amounted to 241.8 billion TZS, this is a ratio of 12.42%. Thus, in

[12] The term fuel oil is used to indicate the heaviest commercial fuel that can be obtained from crude oil, heavier than gasoline and naphta (GTZ 2005). It is commonly used by industry as boiler fuel.

[13] According to GTZ (2005) the diesel retail price in Tanzania in 2001 was 74 US$ cents per liter, with an exchange rate of: 1USD = 950.14 TZS (see www.oanda. com)

[14] CIF prices are wholesale market prices including 'cost, insurance and freight'. According to the 'Petroleum Fuel Price Build-up' by the GTZ (2005) the ratio of CIF/retail price is approximated to be 0.45.

the Input-Output table a share of 12.42% of total petroleum product consumption in each sector will be substituted by bio-diesel.

4.2. The Scenario buildup

At present there are mostly two different approaches towards the cultivation of Jatropha and the fabrication of straight vegetable oil (SVO) and biodiesel discussed. One is a set up in which companies contract outgrowers, who plant Jatropha trees on their own fields and patches, often as boundary crops and live fences, and harvest the seeds. These are then sold to the contracting company, which processes the seeds and produces SVO and /or biodiesel. The other approach is conducted by companies that cultivate and harvest Jatropha on their own large-scale plantations in order to produce SVO and /or biodiesel. In addition, according to GEXSI (2008) the combination of both is also common. In these cases outgrowers are employed in combination with a managed plantation. In Africa this approach is equally important as the pure outgrower scheme.

Outgrower and large-scale plantations apply different methods of field management for growing Jatropha. Firstly fencing is a widely used approach typically applied by smallholder farmers who grow Jatropha in hedges, bordering their fields. These have the advantage of taking up very little land, which usually doesn't replace food crops, and protecting other food crops from animals. Secondly, Jatropha trees may also be intercropped with other plants in order to benefit soil fertility. Like fencing this method is typically applied by smallholders. However, in this case Jatropha trees are likely to substitute food crops more often, particularly as shrubs grow and the canopy closes, shading out other crops. A third approach is the cultivation of Jatropha trees in monocultures. Either small- holders may plant Jatropha trees in monoculture on small patches on their own land or companies cultivate Jatropha on large-scale plantations. The following scenarios are designed to distinguish small-holder farmers from large-scale plantations. While the former apply all three methods of field management in a low respectively intermediate input system, the latter typically make use of monoculture plantations and a high input system only. A mixed scenario will also be presented.

As both, outgrower and large-scale plantations apply different methods of field management and input systems, their economic viability varies. The tendencies are that large-scale plantations are less profitable than the outgrower system. In particular the economic viability of monocultures is questioned in several studies, claiming that fencing is the only profitable strategy to cultivate Jatropha. (Wahl 2009; GTZ 2009) It is because of these diverse approaches, which differ strongly in their use of land and labor as well as intermediate inputs, that the macro-economic impacts of an increased Jatropha cultivation and biodiesel production may be manifold, depending on the applied set up. For this reason and in order to differentiate between several approaches, this study investigates four scenarios. Two are based on a smallholder setting applying a low and an intermediate input system. A third scenario investigates the effects of large-scale plantations. While these three scenarios apply a policy induced 20% blending target, the fourth scenario is based on the planned capacity for growing Jatropha of companies currently investing in Tanzania, thereby creating a scenario in which different methods of field management and input systems are combined. The purpose of each scenario is to construct a vector of technical coefficients which is to be included into the technical coefficients matrix of the initial Input-Output table (see section 2.2). This vector is composed of the production cost for oil seeds and their processing to SVO and biodiesel.

4.2.1. Low and intermediate input system in a small-holder setting

In the smallholder setting outgrower cultivate Jatropha on family owned farms and deliver their harvested oil seeds to contracting companies. These undertake the production of SVO and biodiesel. This decentralized production offers an additional source of income to the rural population and is therefore regarded as a way to alleviate poverty in the poorest areas in Sub-Saharan Africa. In addition, woody by-products of Jatropha plants pose an alternative to fuel wood, which is labor intensive in its collection and adds to the deforestation in Tanzania. According to the Ministry of Energy and Minerals (2003), 90% of Tanzania's primary energy use is met by biomass-based fuel, by charcoal and firewood. Commercial energy sources account for approximately 8% only. Therefore the Ministry aims at reaching rural households in particular to reverse deforestation by promoting alternative energy sources for cooking and lightening. Jatropha wood by-products could be such an alternative option.

Data for the cost of seed production (see table 4.2) is taken from van Eijck (2010). The low versus intermediate input system vary in terms of crop management. In the intermediate input system are fertilizer and pesticides applied. In addition, trees are regularly pruned and weeding is carried out more often. Naturally this leads to higher labor costs. Wages are assumed to be 1.9 USD regardless of the input system. In both scenarios labor is treated as being paid, although it would be more realistic to acknowledge that unpaid family labor plays an important role in the smallholder setting. Nevertheless this is necessary in order to obtain consistent results, as the initial Input-Output table for Tanzania accounts for this kind of labor by constructing a separate row and column for a so-called 'Subsistence Factor', which comprise labor too. In addition, this approach is more precise, as it takes opportunity costs for labor into account. This is important for modeling a demand shock on the labor market and the consequent response in wages.
Yields in both scenarios are rather conservative. Unsurprisingly, the yield in the intermediate input system is higher.

According to table 4.2 total costs for each hectare planted with Jatropha trees add up to roughly 87 USD per year in the low input scenario and 184 USD in the intermediate input system scenario. The individual cost figures have been calculated under the assumption of annual harvests from year four to year 40 after establishment. Land clearing has not been taken into account.

Interestingly, van Eijck et.al. (2010) finds that the Net Present Value in the low input system is higher than in the intermediate input system. This provokes the conclusion that it is not profitable to increase inputs for the cultivation of Jatropha. In addition, profitability is strongly sensitive to wages, as expenses for labor constitute up to 68-72% of total production costs.

Table 4.2: Cost data for the Low and Intermediate Input System

	Low input system	**Intermediate input system**
Yield in kg ha^{-1} $year^{-1}$	977.725	1745.65
Labor input in days ha^{-1} $year^{-1}$	31.175	68.425
Costs for Seed production in USD ha^{-1} $year^{-1}$:		
Field preparation (hoes and matches)	0.250	0.250
Planting material (seeds)	0.004	0.004
Tools for pruning (matches)	0	3.333
Tools for weed control	0.600	0.600
Fertilizer	0	11.000
Pesticides	0	6.050
Packaging material	7.333	13.092
Land cost /rent	20.000	20.000
Labor cost	59.233	130.008
Total costs	**87.419**	**184.337**
Costs for biodiesel production in USD l^{-1}:		
SVO	0.358	0.422
Transport	0.013	0.013

Crushing charge	0.120	0.120
Energy	0.014	0.014
Methanol/catalyst	0.073	0.073
Management/maintanance	0.003	0.003
Capital cost	0.044	0.044
Total cost	**0.625**	**0.690**
Land necessary for E20 in ha:	**384,595**	**215,409**

In order to produce one liter of SVO approximately 4kg of Jatropha oil seeds are needed. Operating costs for processing oil seeds to bio-diesel are taken from a cost analysis of biodiesel production from Jatropha in Tanzania by Mulugetta (2009)[15]. Capital costs were deduced from a break-down of methanol ex-distillery prices in Thailand by Nguyen (2008). Total costs for one liter of biodiesel turn out to be 62.5 USD cents in the low input system and 69 USD cents in the intermediate input system, which is roughly equivalent to the average diesel price in Tanzania between 2006 and 2008 net of taxes with 68USD cents per liter of fossil diesel.

According to FAO statistics the total area of uncultivated usable land in Tanzania adds up to 1,393,949 hectare. This is a multiple of land, which would be additionally needed in both scenarios for a blending target of 20%.

Table 4.3: Vector of technical coefficients in the Low and Intermediate Input System

	Low input system	**Intermediate input system**
Farming	0	0.037
Cash-crops	0	0
Manufacturing 1	0.165	0.170
Manufacturing 2	0	0
Services	0.021	0.019
Petro	0.022	0.020
Jatropha	0.192	0.174
Labor	0.393	0.436
Agricultural capital	0.006	0.014
Non-agricultural capital	0.070	0.064
Land	0.131	0.066

Finally, the price split up in table 4.2 is used to determine a vector of technical coefficients for both scenarios. This is done by adding the share of each cost factor to a sector, which corresponds to the respective cost factor. Expenses for transportation for instance are added to the services sector, while

[15] Costs for Management/maintanance and Methanol/catalyst were calculated using a mark-up relative to the price of Jatropha oil.

Manufacturing 1 contains chemical fertilizers. The technical coefficients as given in table 4.3 naturally add up to 1 and are the final figures which are to be included into the technical coefficients matrix.

4.2.2. Large-scale plantations in monoculture

This scenario features companies that cultivate and harvest Jatropha on own large-scale plantations applying intensive crop-management techniques and hired labor only.

The perception of these enterprises amongst Tanzania's population is very critical and sustainability issues are complex. Particularly the rural population fears negative social and environmental impacts. The latter concerns are being supported by the WWF (2009). Attention is especially led to irrigation systems of large plantations, which could negatively impact local water resources and thus threaten one of the most essential livelihoods of nearby residents. Furthermore, the conservation of biodiversity is a sensitive matter. The WWF claims that there is an urgent need for thorough biodiversity studies on all sites before the establishment of large-scale Jatropha cultivations. With respect to social impacts of large-scale plantations, the GTZ (2005) draws a rather positive picture. Especially employment effects are expected to be key benefits. However, as large-scale plantations have a lower labor input relative to their yield in comparison to smallholder schemes, expectations should not be too high. Nevertheless, regional development primarily with respect to the establishment of infrastructure in remote areas will surely be a positive influence. In sum, large-scale plantations raise manifold negative expectations especially with respect to environmental matters. However there certainly are some positive side effects to be expected which benefit the rural development and infrastructure.

Data concerning the cost of seed production in table 4.4 was taken from a study on Jatropha plantations in Kenya by the GTZ (2009)[16]. All figures refer to monocultures with an average plot size of less than one hectare. Unfortunately, there is no systematical compilation of data from large-scale Jatropha plantations which could compete with the profundity of the formerly mentioned study. Since yields cannot possibly be anticipated with any degree of accuracy, they were assumed to be 4000 kg $ha^{-1}year^{-1}$and thus significantly higher than in the smallholder settings. Nevertheless, they range at the lower end of reported yields for Jatropha plantations of 2t ha-1 to 9.9 t ha-1 in Wahl (2009). Principally, the higher the yields the lower are production costs of SVO and thus the smaller is the share of costs associated with seed production relative to processing costs in the final vector of technical coefficients.

Table 4.4: Cost data for Large-Scale Plantations

	Large-scale plantations
Yield in kg ha^{-1} $year^{-1}$	4000

Table 4.5: Vector of technical coefficients in the Large Scale Plantations Scenario

	Large scale plantations
Farming	0.052
Cash-crops	0
Manufacturing 1	0.254
Manufacturing 2	0
Services	0.018
Petro	0.019

[16] The following exchange rate was applied: 1USD = 83.5769 KSH (31.03.2

Costs for Seed production in USD ha^{-1} $year^{-1}$:	
Land preparation/planting equipment	0.591
Seeds	0.558
Weeding/pruning equipment	1.663
Manure	37.730
Pest/disease control	110.948
Harvesting equipment	2.144
Seed processing/storage	158.823
Labor	117.561
Land	20
Total costs	**450.019**
Costs for biodiesel production in USD l^{-1}:	
SVO	0.450
Transport	0.013
Crushing charge	0.120
Energy	0.014
Methanol/catalyst	0.073
Management/maintanance	0.003
Capital cost	0.051
Total cost	**0.724**
Land necessary for E20 in ha:	**94,007**

Total costs for each hectare planted with Jatropha trees add up to roughly 450 USD per year. These high production costs are largely offset by a high yield. Nevertheless costs for SVO in this scenario are higher than in the smallholder setting and thus confirm claims of lower profitability of intensive crop-management systems. Data on operating costs and capital costs of processing plants was derived in the same way as for the previous two scenarios. Total cost for one liter of biodiesel finally sums up to 72.4 USD cents and is thus only marginally higher than in the intermediate input system. Total land use on the contrary is roughly halved.

The resulting vector of technical coefficients in table 4.5 naturally proves that an intensive input system, such as applied on large-scale plantations, demands significantly less land and labor as in the smallholder setting. Intermediate inputs from Manufacturing 1on the contrary, which comprise goods such as fertilizers and equipment, are applied more intensively.

4.2.3. Planned capacity at present

This scenario is to assess the impacts of biodiesel production capacities as aimed for at present by companies currently investing in Tanzania (see table 4.6). One major player in the cultivation of Jatropha is 'Diligent Tanzania ltd' which follows an outgrower scheme and aims for 200,000ha of

Jatropha cultivation by 2016 (van Eijck 2009). Bioshape is another major player planning around 400 plantations of 200ha each in monoculture and on own lands according to the company's web pages. However, there are no precise time frames publicly known yet. In sum total planned capacity for biodiesel production exceeds the 20% blending target for fossil diesel. In this scenario one third of total consumption of fossil diesel could be substituted by local biodiesel production. While in the first three scenarios total consumption of petroleum products was substituted up to 12.42% by biodiesel (see section 3.1.), an additional 8.82% are now added to final demand and could potentially be exported, in this way improving Tanzania's trade balance.

Table 4.6: Companies active in the cultivation of Jatropha in Tanzania in 2010

	Low input system	**Intermediate input system**	**Large-scale plantations**
Land by company	Prokon Renewable Energy ltd (13,600 ha) Diligent Tanzania ltd (200,000 ha)		Sun Biofuels (8,000 ha) Bioshape (80,000 ha)
Management system	Smallholder/ Outgrower		Plantations, Monoculture
Land in ha	106,800	106,800	88,000
Biodiesel production in l year $^{-1}$	26,105,258	46,608,855	88,000,000

Table 4.7: Vector of technical coefficients in the planned capacity at present scenario

	Planned capacity at present
Farming	0.040
Cash-crops	0
Manufac 1	0.217
Manufac 2	0
Services	0.019
Petro	0.020
Jatropha	0.297
Labor	0.277
Agricultural capital	0.008
Non-agricultural capital	0.069
Land	0.054

The technical coefficients vector (see table 4.7) in this scenario is composed of prices applying to several field management methods and input systems. It is based on the pricing structures of the latter three scenarios, with each price factor being weighted by the biodiesel production capacity of the respective input system (see table 4.6). Naturally, the technical coefficients for this scenario lie within the range of the previous three scenarios.

5. Macro-economic impacts assuming Leontief production functions

This section is to discuss the macro-economic impacts of a significant Jatropha cultivation and biodiesel production in Tanzania assuming that Leontief production functions are the basis of each sector in the Input-Output table. Thus this section goes no further than common Input-Output analysis. A theoretical approach towards the introduction of a new industry to the economy was discussed in sub-sections 2.1. and 2.2. The technical coefficients vectors for each scenario, which are to be included into the initial matrix of technical coefficients in order to derive a new equilibrated total output and associated input quantities, were taken from the Scenario sub-sections 4.2 to 4.4. As there are four different scenarios to be assessed, the initial Input-Output table presented in sub-section 3.1 will lead to four newly balanced tables, one for each scenario. In order to summarize and present a structured overview on all results obtained, it seems best to focus on three indicators instead of presenting all tables in full length. These indicators are total output or total employment of primary inputs, imports and GDP.

The absolute change in total output for a certain good or commodity is the difference between the respective row sums of all industries in the initial Input-Output table and the new table comprising the additional industry. Thus it is given by the difference between Y_i and Y_i' from table 2.1 and 2.3. The reader should keep in mind, that total output also includes imports from other countries and is thus no indicator for GDP. Similarly, the change in primary inputs is the difference between V and V' in table 2.1 and 2.3. Results in absolute and relative terms for the change in total output of each industry and total employment of primary inputs are given for all four scenarios in table 5.1.

Table 5.1: Change in total output assuming Leontief production functions

	Smallholder *Low input system*		**Smallholder** *Intermediate input system*		**Large-Scale Plantations** *High input system*		**Planned capacity at present** *Mixed input system*	
	Absolute*	**Relative**	**Absolute***	**Relative**	**Absolute***	**Relative**	**Absolute***	**Relative**
Farming	0.034	0.001%	1.734	0.045%	3.344	0.086%	3.484	0.090%
Cash-crops	-0.277	-0.039%	-0.276	-0.039%	-0.265	-0.038%	-0.260	-0.037%
Manufacturing 1	7.279	0.442%	7.333	0.445%	15.997	0.971%	18.598	1.129%

Manufacturing 2	0.036	0.001%	0.047	0.002%	0.138	0.005%	0.176	0.007%
Services	1.722	0.022%	1.653	0.022%	3.189	0.042%	4.261	0.056%
Petro	-35.070	-12.125%	-35.180	-12.164%	-34.864	-12.054%	-34.393	-11.891%
Jatropha	44.464	-	43.493	-	58.502	-	78.693	-
Labor	17.382	0.549%	19.601	0.619%	11.487	0.363%	23.809	0.752%
Agricultural capital	0.206	0.017%	1.031	0.086%	1.226	0.103%	1.559	0.131%
Non-agricultural Capital	3.377	0.125%	3.009	0.111%	5.953	0.220%	7.877	0.291%
Land	5.804	1.135%	3.073	0.601%	1.989	0.389%	4.621	0.903%
Sum	44.958	0.185%	45.517	0.187%	66.696	0.274%	108.424	0.445%

* Absolute change in billion TZS

Overall, the production in all industries except for ‘Cash-crops’ and ‘Petro’ increases. This is, because petrol products, which are being substituted to a certain extent, where mainly imported. The production of biodiesel on the contrary, takes place in Tanzania. Consequently, not only does the Jatropha sector grow, but also do all other sectors, which deliver intermediate inputs to the production of biodiesel. The ‘Cash-crops’ sector turns out to have a marginally smaller output, because its intermediate deliveries to the ‘Petro’ sector decreased while it is not at all employed in the production of biodiesel. Naturally, total output of petroleum products strongly decreases, as it is substituted by biodiesel. In general, the production of those input industries and primary inputs, which are more intensively employed in the production of biodiesel, will increase most. Throughout all scenarios this is foremost ‘Labor’ and ‘Land’ for the cultivation of Jatropha and ‘Manufacturing 1’ for processing the seeds to biodiesel. Within the ‘Large scale scenario’ and the ‘Planned capacity scenario’ land and labor are less intensively used, while employment of ‘Agricultural – ‘ and ‘Non-agricultural capital’ is higher. This is due to the management system in both scenarios, which is more or less based on large plantations and the application of heavy machinery thereby calling for less labor input and leading to higher yields per hectare.

The change in ‘Labor’ basically describes the increase of the total wage sum in Tanzania. All entries are measured in monetary values. This indicator is of particular interest, as it reflects possible developments on the labor market and an increase in total employment in Tanzania. Unsurprisingly, positive employment effects in the ‘Large scale scenario’ are smaller than in the smallholder scenario, since the former applies a more capital-intensive production, while the latter is rather labor intensive. Labor input intensity in the ‘Planned capacity scenario’ is somewhere between the other three scenarios. However, since the production volume in the latter scenario is increased from 12.42% of former total petrol products consumption to 21.24%, it is this scenario which leads to the highest increase in the wage sum and thus to the largest employment effects.

The change in imports to each sector associated with the introduction of a new industry is determined by the differences in m_j and m_j' in table 2.1 and 2.3. Total change in imports is given by the difference in the row sums *M* and *M'*. The results in table 5.2 are summarized for each sector separately. Basically, all figures resemble the variation of total output in the previous table 5.1. This is because of the constant input shares, which are the basis of Leontief production functions. Thus, as total output increases, imports increase proportionally. For this reason imports generally grow in all sectors except for the 'Cash-crops' and the 'Petro' sector, with the latter declining strongly as was to be expected. In total the decrease in 'Petro' imports outweighs all other increasing imports, such that, as expected, the trade balance is overall positively affected by the substitution of imported diesel by domestically produced biodiesel.

Unsurprisingly, total imports decrease less in the 'Large scale scenario' and the 'Planned capacity scenario'. This is mainly because both scenarios induce higher inputs from the 'Manufacturing 1' sector as a substitute for primary inputs. This sector however imports around 54% of its total output while primary inputs on the contrary are being delivered from inside the country.

Table 5.2: Change in imports assuming Leontief production functions

	Smallholder *Low input system*		**Smallholder** *Intermediate input system*		**Large-Scale Plantations** *High input systems*		**Planned capacity at present** *Mixed input system*	
	Absolute*	**Relative**	**Absolute***	**Relative**	**Absolute***	**Relative**	**Absolute***	**Relative**
Farming	0.001	0.001%	0.031	0.045%	0.059	0.086%	0.062	0.090%
Cash-crops	-0.020	-0.039%	-0.020	-0.039%	-0.019	-0.038%	-0.019	-0.037%
Manufacturing 1	3.920	0.442%	3.949	0.445%	8.614	0.971%	10.014	1.129%
Manufacturing 2	0.004	0.001%	0.005	0.002%	0.014	0.005%	0.017	0.007%
Services	0.114	0.022%	0.109	0.022%	0.211	0.042%	0.282	0.056%
Petro	-29.319	-12.125%	-29.411	-12.164%	-29.147	-12.054%	-28.753	-11.891%
Sum	-25.301	-1.259%	-25.337	-1.261%	-20.268	-1.009%	-18.396	-0.916%

* Absolute change in billion TZS

Unsurprisingly, total imports decrease less in the 'Large scale scenario' and the 'Planned capacity scenario'. This is mainly because both scenarios induce higher inputs from the 'Manufacturing 1' sector as a substitute for primary inputs. This sector however imports around 54% of its total output while primary inputs on the contrary are being delivered from inside the country.

Table 5.3: Change in total value added / GDP assuming Leontief production functions

	Smallholder *Low input system*		**Smallholder** *Intermediate input system*		**Large-Scale Plantations** *High input system*		**Planned capacity at present** *Mixed input system*	
	Absolute	**Relative**	**Absolute**	**Relative**	**Absolute**	**Relative**	**Absolute**	**Relative**
Farming	0.029	0.001%	1.498	0.045%	2.888	0.086%	3.009	0.090%
Cash-crops	-0.184	-0.039%	-0.183	-0.039%	-0.175	-0.038%	-0.172	-0.037%
Manufacturing 1	1.903	0.442%	1.917	0.445%	4.183	0.971%	4.863	1.129%
Manufacturing 2	0.013	0.001%	0.017	0.002%	0.051	0.005%	0.065	0.007%
Services	0.690	0.022%	0.662	0.022%	1.277	0.042%	1.706	0.056%
Petro	-4.073	-12.125%	-4.086	-12.164%	-4.049	-12.054%	-3.994	-11.891%
Jatropha	26.660	-	25.250	-	15.832	-	32.048	-
Sum	25.039	0.302%	25.075	0.302%	20.006	0.241%	37.523	0.453%

* Absolute change in billion TZS

The change in total value added and GDP is equivalent to the sum of all changes in primary inputs. In table 2.1 and 2.3 this is the difference between the sum of all v_j and the sum of all v_j'. The total change is given by the difference between V and V'. The contribution to GDP is summarized for each sector separately in table 5.3. Again all entries resemble the results of the previous two tables. Since the 'Petro' sector shrinks, its added value is negative. However this is outweighed by the strong rise in the additional value added brought about in the Jatropha sector. In addition, not only the latter sector adds to GDP, but also all other sectors, which deliver intermediate inputs to the production of biodiesel. Interestingly, while both smallholder scenarios add approximately the same to total GDP in table 5.3, the contribution of the 'Large scale scenario' is significantly less. The reasons are similar to the previous argumentation: as this scenario substitutes large amounts of labor by capital and inputs from 'Manufacturing 1', it employs less primary inputs and thus it contributes less to the rise in GDP. Not surprisingly, the 'Planned capacity scenario' adds most to GDP. This is, because its' production volume is by far the largest out of all scenarios.

In sum, the directions in which all macro-economic indicators change turn out to be as expected. GDP and total Wage sum are generally positively affected, while Imports decrease. Consequently, from a macro-economic point of view the production of bio-diesel from Jatropha in Tanzania is to be associated with beneficiary developments. Their magnitude however is rather small, corresponding to the intensity of the modeled shock. Especially when keeping in mind that the outcomes under Leontief production functions are an upper bound with respect to total output and thus tend to overestimate the actual results (see sub-section 1.3). In addition, all changes are pure shifts in the level of the respective macroeconomic indicator and cannot be understood as growth rates.

In a case study for Argentina by Wicke et. al. (2009) the increased production of bio-energy introduced to an Input-Output model based on Leontief production functions leads to a soaring GDP (4%), employment (6%) and imports (10%)[17]. As expected, the macro-economic impacts in the Argentinean case turn out to be positive, similarly to this study. Imports in Wicke et. al. increase because there is no substitution of imported fossil fuels assumed which could outweigh additional imports of intermediate inputs. The stronger increase in all three indicators stems from a much larger production capacity in the bio-energy sector. While in Wicke et. al. 10% of all Argentinean lands are employed, the smallholder scenario in this study for instance uses only 0.38 Mha. In comparison, 10% of Tanzania's area is equivalent to 9.4 Mha and thus much larger than the area assumed to be planted in this study. Section 7 will come back to these results with a replication of the Argentinean study for the case of Tanzania and a discussion on the plausibility of such large shocks.

Overall, the results obtained in this section assist in evaluating different frameworks for the production of bio-diesel. As it turns out the Smallholder setting increases GDP and total wage sum to a larger extend than large-scale plantations. In addition, imports decrease stronger in the former setting.

6. Macro-economic impacts assuming Cobb Douglas production functions

Throughout the analysis in this section the traditional Leontief production functions with their fixed technical coefficients were replaced by the more flexible Cobb-Douglas production functions that were estimated above in sub-section 3.2. As Cobb-Douglas allows for substitution between inputs where Leontief does not, the main question to be answered in this section is, how the final equilibrium in the Input-Output table is affected by the use of Cobb-Douglas production functions and how results differ from the Leontief case. To assess this question, the focus in all four scenarios will be on the three indicators GDP, Wagesum and Imports again.

[17] These results are based on direct effects within the bio-energy sector only. When taking indirect and induced effects into account all three indicators increase even more (GDP 18%, employment 26%, imports 20%). Induced effects are brought about by the extra household income spend on domestic goods and services.

The final tables from section 5, based on the Leontief assumptions, are used as a starting point. They resemble newly equilibrated Input-Output tables in response to the introduction of a new industry. The consequent increase of total output in table 5.1 results into a demand shock for additional production in all sectors. According to the supply-side elasticities as determined in sub-section 3.3 increasing demand for intermediate inputs in turn translates into rising prices. These price variations induce industries to substitute those intermediate and primary inputs, which have become relatively more expensive. This mechanism is guided by the respective Cobb-Douglas production functions and did not materialize under Leontief production functions, where input shares stay constant. As discussed in the theory section in 2.3, the substitution itself affects the total output of each industry again, which in turn will lead to a price variation and another round of input structure adjustments in each industry. In order to model the resulting Input-Output table, these steps are repeated successively, until the whole system is in equilibrium.

The results will depend on the magnitude of all supply-side elasticities. For land, labor and capital, however, these cannot be determined numerically from the Input-Output table alone. For this reason results are generated in form of a sensitivity analysis and presented graphically below. In the following sub-sections the three macroeconomic indicators, GDP, Imports and Wage sum are discussed separately. To keep the analysis tractable, results are presented individually for each indicator in figures 6.1 to 6.2. All figures show a graph for each of the four scenarios in which the equilibrium change in the indicator is shown in function of the supply elasticity of labor, capital and land respectively. A fourth line shows how the indicators would change, if all four variable elasticities are simultaneously varied over the relevant domain. For comparison, the benchmark value of the indicators that was presented above and would be associated with Leontief production functions is marked by a horizontal line. To gain a better overview, all ranges of resulting macroeconomic indicators are summarized in table 6.4 in a concluding section.

In general the market response under Cobb-Douglas production functions is such that those sectors which formerly (under Leontief production functions) had a strongly increasing total output are now the sectors which decrease their total output again. Similarly, those primary inputs which were formerly employed much more intensively now tend to be substituted by other inputs. The market response reduces the absolute size of effects and smoothes out the results under Leontief production functions, which is in correspondence to the literature (see sub-section 1.3). These mechanisms become clearer when looking at each macroeconomic indicator individually below.

6.1. GDP

Generally, the GDP increases further under Cobb-Douglas production functions, if primary inputs are more intensively employed in comparison to the Leontief case. This is the case if prices for primary inputs rise less than prices for intermediate inputs, which is determined by two variables: the strength of the demand shock and the magnitude of supply side elasticities for primary inputs relative to intermediate inputs. Since both affect input prices to a certain extent industries are induced to substitute.

Firstly, the strength of the demand shock for intermediate and primary inputs of each sector determines how prices will increase. If total demand rises strongly, prices are inclined to go up too and thus sectors are induced to substitute for other inputs. In figure 6.1 this is clearly visible for labor. Since labor is intensively used for the production of biodiesel, it becomes relatively more expensive and thus is substituted by other inputs to such an extent that GDP might turn out to be even lower than in the Leontief case, if the elasticity for labor is small. In other words: the stronger the demand shock for a certain primary input is, the larger is the sensitivity of GDP to this input.

Second, under Cobb-Douglas production functions industries tend to employ primary inputs more intensively, if the former elasticities are higher than those of intermediate inputs. Consequently a rise in demand leads to a lower increase in prices for primary inputs relative to intermediate inputs. These will then be substituted for the former, because industries are induced to decrease their total production cost by substituting relatively more expensive intermediate inputs by relatively less expensive primary inputs. This mechanism is clearly visible in figure 6.1. Here the GDP reaches its optimum with maximum elasticities for primary inputs and thus when these are available at constant prices. Elasticities for intermediate inputs are lower and presented in sub-section 3.3. One could argue that intermediate inputs call for primary inputs themselves; however, this is only partially the case as all industries import a non-negligible share of their total output.

In both smallholder scenarios in particular, land and labor are relatively freely available. Only the supply of capital might be more inelastic. However, according to figure 6.1 the elasticity of capital has no large impact on GDP, since its initial demand shock is weaker. Consequently, the GDP is certain to be larger under Cobb-Douglas production functions than under Leontief production functions in the smallholder scenarios.

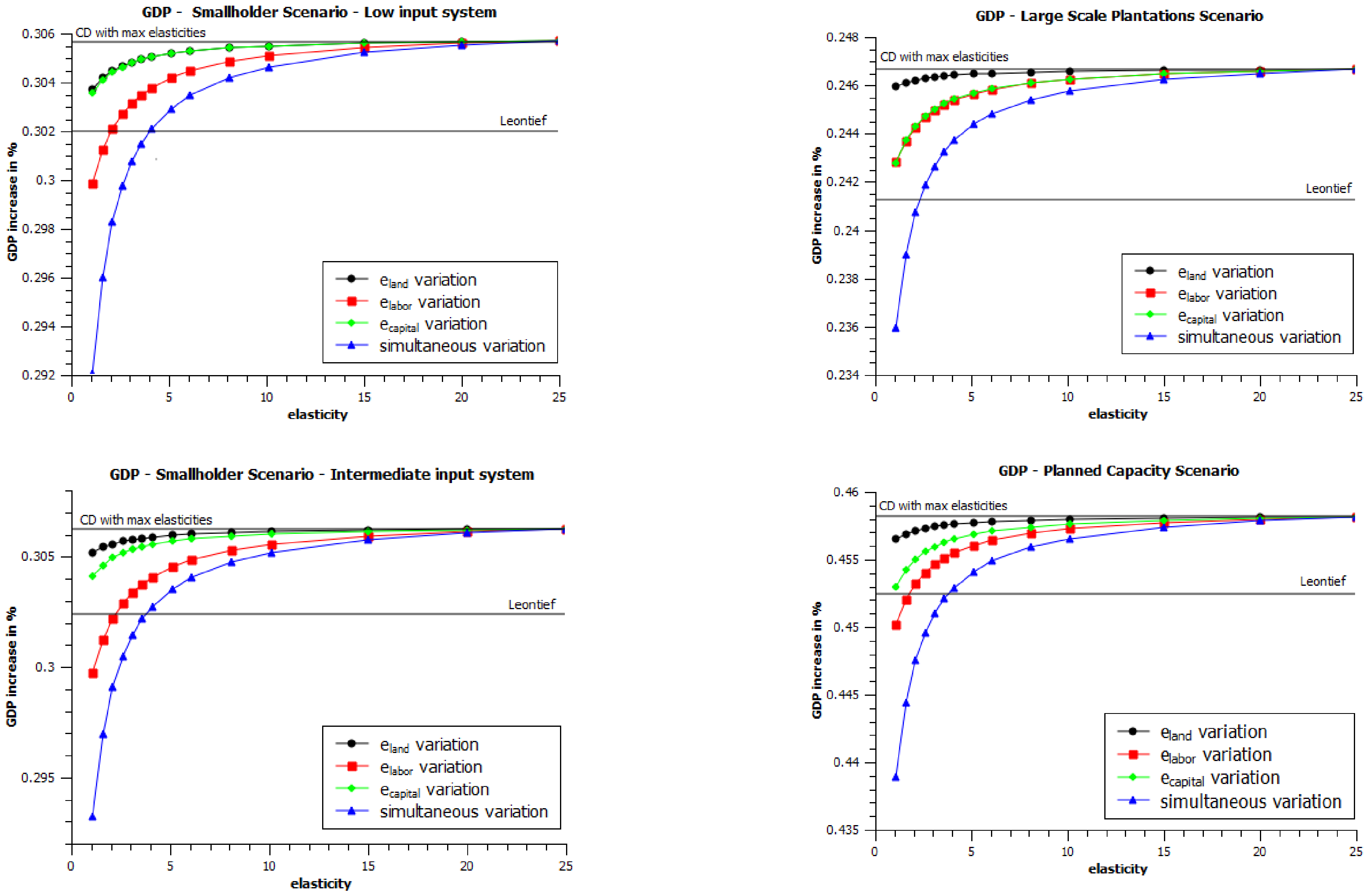
In the 'Large scale scenario' and 'Planned capacity scenario' the availability of land might be a little more restrictive, while labor and capital are unlikely to limit the production. The elasticity of the latter, however, implies the lowest impacts on total GDP. Therefore, in these scenarios again the Leontief production function underestimates the increase in GDP after the introduction of a biodiesel industry to Tanzania's economy.

The comparison of these outcomes to the results based on the Upper Bound 80% confidence interval supply-side elasticities (see Appendix C figure C1) confirms the above discussed intuition on the magnitude of elasticities. Here the elasticity of intermediate inputs is higher and thus the need for substituting them is smaller as their prices rise to a lesser extent in response to demand shocks. Thus total input of primary factors is smaller and therefore the resulting range of GDP is also lower than in the previous case where intermediate input elasticities were smaller.

Despite these findings, one may argue that both production functions lead to very similar results in the scenario setup of this analysis. Therefore the question arises whether the additional efforts are worth their results. In this case they might not be, but at the same time they give proof, that larger shocks immediately turn into stronger deviations in GDP. While in the first three scenarios final demand is not increased at all but only imports are substituted by domestic production which resembles 0.163% in total output, in the 'Planned capacity scenario' biodiesel is eventually exported thereby increasing final demand and total output by 0.2787%. This rather small differentiation between magnitudes of demand shocks does already lead to an about 50% larger range for GDP in the 'Planned capacity scenario' than in the other three scenarios. In larger shocks final results literally become more sensitive to the elasticities of primary inputs. Thus it seems justified to claim that for larger shocks the possibility of substituting inputs does matter and should be considered.

In conclusion, in the case of a large-scale introduction of bio-diesel production from Jartopha in Tanzania the analysis assuming Leontief production functions is bound to underestimate the real increase in total GDP when elasticities for all primary inputs are sufficiently large.

Figure 6.1: GDP variation in all four scenarios



6.2. Imports

Generally, total imports decrease as the elasticities for primary inputs increase. This goes hand in hand with the previous line of argument explaining an increase in value added. The substitution of intermediate inputs by primary inputs decreases imports at the same time as it increases GDP. Basically, this is because a fair share of intermediate inputs is imported to the country, which is substituted for by primary inputs delivered from the domestic market.[18]

The ranks in the strength of impacts by all primary inputs are the same as previously for GDP. Again the availability of labor has the largest impact on decreasing imports. The more prices for labor rise in response to the domestic production of biodiesel, the more it will be substituted by intermediate inputs which in their production call for a non-negligible share of imports.

In the smallholder scenarios with the only restraining factor being capital, which again has little impact on total imports, imports are likely to be close to the ones under Leontief production functions. Similarly, in the 'Large scale scenario' and the 'Planned capacity scenario' where land is the only restraining primary input, imports are very close to the results under Leontief production functions.

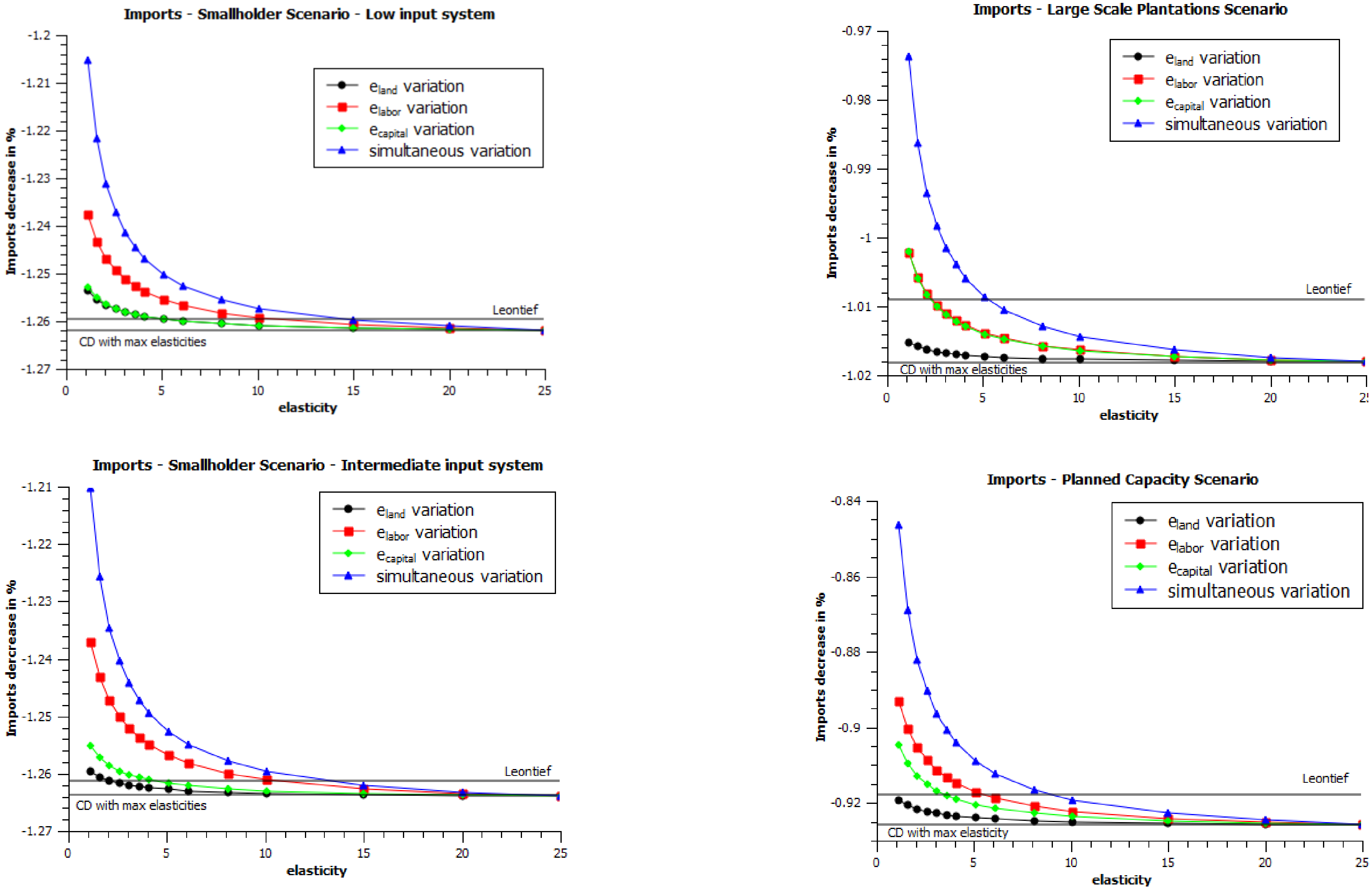
The results associated with elasticities based on the upper bound 80% confidence interval (see Appendix C figure C2) show, that imports generally decrease less if the elasticities for intermediate inputs are higher. Again the reasons are similar to the ones for a smaller increase in GDP: intermediate inputs will be used more since their prices do not increase as strongly as with lower elasticities and since they have their fair share in imports, these are bound to decrease to a lesser extent.

Again one could ask, whether these insights were worth the additional effort. In this case the range of imports endogenous to the elasticities of intermediate inputs is larger than for GDP, nevertheless in total it is still fairly small. However, the 'Planned capacity scenario' again proves that a larger shock immediately turns into stronger deviations, making the additional assessment with Cobb-Douglas production functions necessary.

The resulting effects on the trade balance are of additional interest. In Tanzania imports still outweigh exports by far. While in the first three scenarios a reduction in imports is what affects the trade balance in total, in the 'Planned capacity scenario' there is also a rise in exports to be taken into account. The total extension of exports in this scenario amounts to 1.63%. In absolute terms the maximum increase in net exports is given by 40 bln TZS from -703 bln TZS to -663 bln TZS.

[18] One could ask why there is a range of elasticities for which GDP and imports rise. This is because in some instances the demand for labor is so strong such that it is being substituted by a mix of other primary inputs and intermediate inputs. Thus the total use of intermediate inputs rises which increases imports, while at the same time total employment of primary inputs and thus GDP rises since labor is being substituted by even more primary inputs.

Figure 6.2: Imports variation in all four scenarios



6.3. Wagesum

It turns out that the Wagesum is far more sensitive to changes in the elasticities of primary inputs than the other macroeconomic indicators. In general, low elasticities for labor have very strong negative impacts on the Wagesum. This is intuitively clear, as a low elasticity goes hand in hand with strongly increasing prices and thus labor is being substituted for by other inputs as demand for it is increasing. Capital and land on the contrary have positive effects on the Wagesum if their elasticities are low, as they are rather being substituted for by labor in the face of increasing prices for capital and land.

Overall, if elasticities for all primary inputs are high, the equilibrium Wagesum converges to a level, which is slightly lower than in the Leontief case. The reason is that bio-energy production from Jatropha is labor intensive and therefore its price increases more relative to all other inputs. In the market response to the introduction of a new industry labor is consequently being substituted by other inputs. The substituting input is foremost capital and thus in sum total value added rises even tough labor inputs decrease.

In the Smallholder scenario, where capital is the only primary input which is not fully elastic, the total Wagesum consequently turns out to be in the upper part of its range. The same holds for the 'Large scale scenario' and the 'Planned capacity scenario', where land is the only inelastic resource. Again the change in total Wagesum will manifest itself somewhere in the upper part of its range. Nevertheless, results are very similar to the Leontief outcomes. This is, however, mainly due to the fact that labor is supplied almost perfectly elastic in Tanzania, while capital and land are a little scarcer. Otherwise the total Wagesum would turn out to be significantly below the outcome based on Leontief production functions.

The range of results based on the upper bound 80% confidence interval is somewhat higher (see Appendix C figure C3). This is opposed to what one would expect, since higher elasticities for intermediate inputs would lead to less substitution of the former by primary inputs and thus to a lower Wagesum. However, while this effect is surely in place, it is offset by another one. The sum of all total outputs increases when assuming Cobb-Douglas production functions in comparison to Leontief production functions and, if the elasticities for intermediate inputs are higher, the sum of all total outputs increases to a larger extent. Thus, overall more labor is needed to fulfill higher production volumes.

Figure 6.3: Wagesum variation in all four scenarios

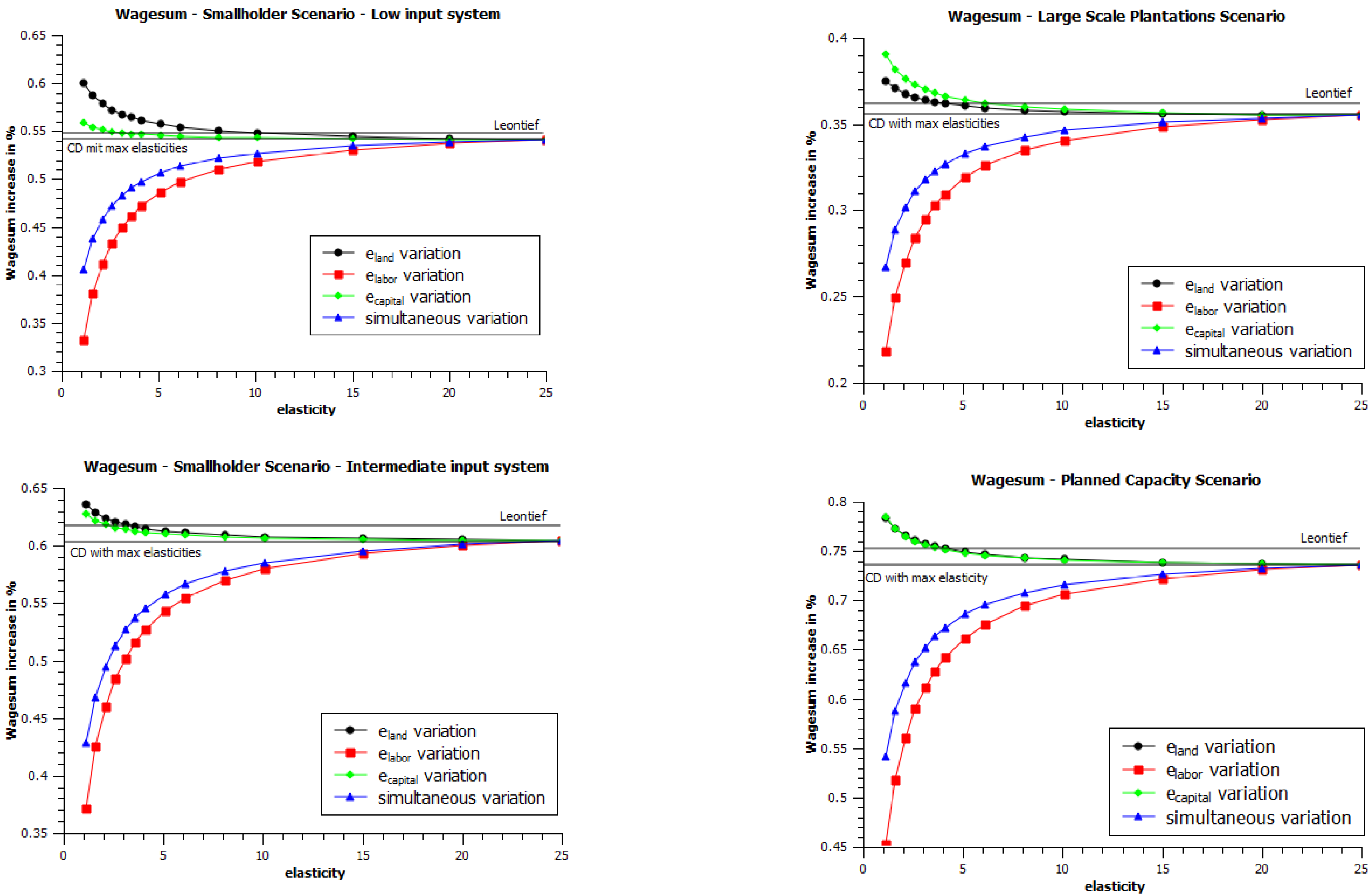


Table 6.4: Range of the change in macroeconomic indicators in % with varying elasticities

	[min; max]	Smallholder *Low input system*	Smallholder *Intermediate input system*	Large-Scale Plantations *High input system*	Planned capacity at present *Mixed inp. sys.*
GDP	[min. simult. var.; CD with max. elasticity]	[0.292; 0.3057]	[0.2932; 0.3062]	[0.2359; 0.2467]	[0.4389; 0.4581]
Imports	[min. simult. var.; CD with max. elasticity]	[-1.2053; -1.2618]	[-1.2102; -1.264]	[-0.9738; -1.018]	[-0.8464; -0.9257]
Wagesum	[min ε_{labor} var.; min ε_{land} var./min $\varepsilon_{capital}$ var.]	[0.3326; 0.6002]	[0.3715; 0.6356]	[0.2181; 0.3908]	[0.4526; 0.784]

Table 6.4 summarizes the results discussed above with respect to all three indicators. When comparing all four scenarios, again, it becomes evident that GDP and Wagesum tend to increase and imports tend to decrease stronger in the smallholder scenarios than in the 'Large-scale' scenario. As expected the 'Planned capacity at present' scenario has the largest positive macroeconomic effects because its production volume is bigger. In addition, the range of resulting indicators in this scenario turns out to be larger. Thus, overall the effects still seem to be rather small, but it becomes clear that as production volumes of bio-fuels rise, the differentiation between Cobb-Douglas and Leontief production functions becomes more important. To further investigate this issue, section 7 will continue with the analysis of a larger shock.

7. Modeling a larger shock

Changes of all macro-economic indicators following the introduction of a bio-diesel industry to Tanzania's economy in the scenario set up of section 5 are little. Nevertheless, this was to be expected in accordance to the assumed shock, which was rather small in its magnitude. In addition, section 6 reveals that the difference between Leontief and Cobb-Douglas production functions is only marginal. Mostly this is because in the case of Tanzania there is hardly any scarcity of those primary production factors at hand, which are intensively used for the cultivation of Jatropha. But even if there were constraints on the availability of primary inputs, the maximal range of the resulting macro-economic indicators is probably limited. As was argued above, however, such differences start to kick in when larger shocks and longer time horizons are considered.

Therefore the question remains, how the economy reacts to a shock such as has been modeled in Wicke et. al. (2009), where the implementation of a large bio-ethanol industry based on eucalyptus trees in Argentina is assessed. The fundamental assumption herein is that through an agricultural intensification about 10% of the total Argentinean area can be freed and directed to the production of this bio-fuel. Unsurprisingly, this results in a tremendous shock with a strongly increasing GDP, employment and imports. Throughout the remaining part of this section the 'Wicke et. al. setup' shall be applied to the case of a large-scale bio-diesel production from Jatropha in Tanzania. This thought experiment could eventually reveal the importance of a flexible production function in Input-Output tables.

In order to do so it seems best to extend the 'Planned capacity at present' scenario in terms of production volume. Since this scenario comprises a mix of management systems according to the actual planned capacities of companies in Tanzania, this certainly is the most realistic approach. A cultivation of Jatropha plants on an area corresponding to 10% of Tanzania's size results into the usage of 9.4 Mha. This stands in sharp contrast to the area needed initially in the 'Planned capacity at present' scenario of 0.301 Mha and compares to the area planted with eucalyptus in Wicke et. al. of 28 Mha. The total production volume in this extended scenario amounts to 5.04 bln liter and in value 1610 bln TZS. The mix of management systems for the production of Jatropha seeds in this scenario is an extrapolation of the 'Planned capacity at present' scenario. Smallholder under a low input system contribute 16% to total production, smallholder under an intermediate input system 29% and large-scale plantations 55%. The 20% blend of all fossil diesel products in Tanzania remains in this scenario. A non-negligible share of the total production volume itself is employed to accommodate the increasing size of the Jatropha sector.[19] The remaining larger share is added to the final demand column in form of exports in the initial Input-Output table. The capacity of this sector thus builds up to almost halve the size of the farming sector in Tanzania.

Table 7.1: Leontief and Cobb-Douglas results in an extended 'Planned capacity at present' scenario

	Leontief	**Cobb-Douglas**	
		boundaries	***range***
GDP	10.48%	[min. simult. var.; CD with max. elasticity]	[10.11%; 10.54%]
Imports	11.3%	[CD with max. elasticity; min. simult. var.]	[11.05%; 12.82%]
Wagesum	15.85%	[min ε_{labor} var.; min $\varepsilon_{capital}$ var.]	[9.7%; 16.64%]

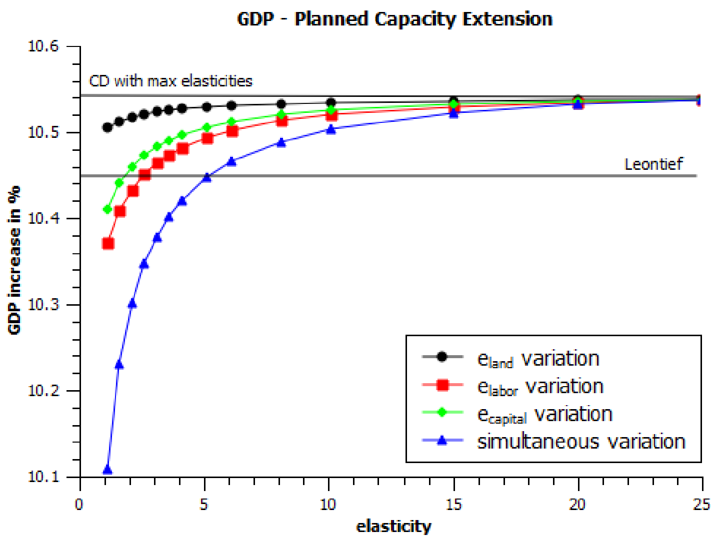
[19] The reason is that all sectors which deliver intermediate inputs to the Jatropha and bio-diesel industry use a 20% blend for all their diesel inputs. Thus an increasing domestic production of bio-diesel does also lead to a higher domestic need of bio-diesel. In short, the Input-Output table turns into a mixed endogenous-exogenous model.

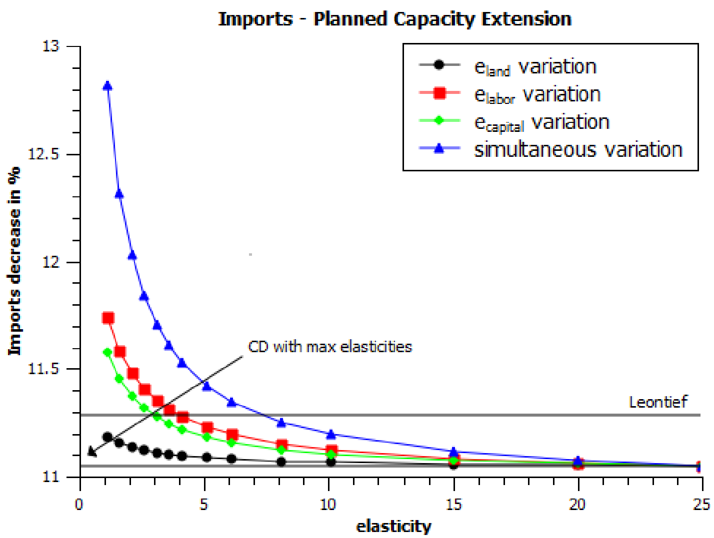
Unsurprisingly, the resulting increase in GDP, Wagesum and Imports is large (see table 7.1). The reduction in petroleum imports is outweighed by the additional imports needed to satisfy the production of bio-diesel. In total, the trade balance is positively affected, however, since most of the bio-diesel production is intended to be exported. In absolute terms net-exports soar from -703bln TZS to 174bln TZS. Total exports increase by roughly 84%.

Again the results based on Leontief production functions tend to be similar to those generated with Cobb-Douglas production functions under high elasticities for all primary inputs. Their ranges are given in table 7.1 and visualized in figure 7.2. The sensitivity of Imports and in particular of the Wagesum towards the elasticities of primary inputs under Cobb-Douglas production functions however becomes much stronger. This means that as long as all primary inputs are elastically supplied, it might not matter which production functions were assumed in the first place. But as soon as some primary inputs become scarce and relative prices start responding, results are bound to differ. With respect to GDP variations remain limited. This is mainly because those primary inputs which have low elasticities are to a large degree substituted by other primary inputs and only to a limited extent by intermediate inputs.

In sum, the one conclusion that can confidently be ventured from this analysis is that if intermediate and primary inputs are supplied elastically at constant prices such that prices hardly change in response to a demand shock, then both production functions will lead to similar results. However, even in the case for Tanzania, where primary inputs are relatively freely available and elasticities are thus assumed to be high, an increase in employment of about 9.7-16.64% is almost certain to drive up wages.

Overall, the extension of the 'Planned capacity at present' scenario provides proof that some macro-economic indicators respond strongly to a large shock based on bio-diesel production and that under these circumstances the application of a more flexible production function allowing for substitution does matter. Nevertheless, the extension in this section is rather theoretical in its nature. Firstly, to assume that 10% of Tanzanian's terrain could be planted with Jatropha in addition to the already existing fields is hardly realistic. Also because FAOSTAT estimates that only 1.4 Mha land in Tanzania is uncultivated and usable. Second, in Input-Output analysis one generally assumes that while manipulating some sectors all other factors within the economy will stay constant. However, while this approximates small shocks in the short run with a good degree of accuracy, larger shocks over longer horizons are bound to influence the whole economy in a way that a model needs to be fully dynamic in order to accommodate all changes. For these reasons the pure merit of the extended scenario in this section is to demonstrate how the assumption of a certain production function matters. It should not be understood as an attempt at a realistic set up for implementing a bio-diesel industry into Tanzania's economy.





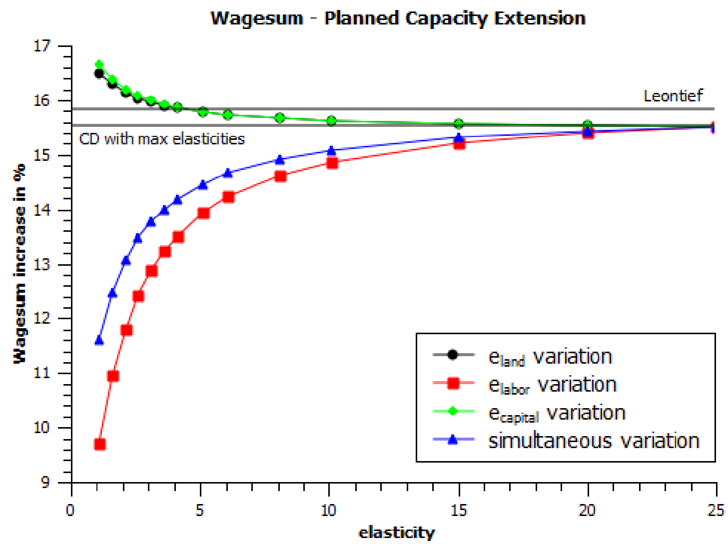


Figure 7.2: GDP, Imports and Wagesum variation in an extended ‘Planned capacity at present’ scenario

8. Conclusions and Discussion

With respect to the first research question, which inquires into the response of several macro-economic indicators to the introduction of a large-scale bio-diesel industry in Tanzania, all models predict mostly positive effects. In all scenarios GDP, Wagesum and net-exports rise. The magnitude of their response naturally depends strongly on the assumed scale of bio-diesel production (see table 8.1) and thus the extent of the simulated demand shock. In the first three scenarios, where total-biodiesel production is equivalent to a 20% blend of former fossil diesel imports, all macro-economic indicators change only marginally. Even if production is extended like in the 'Planned capacity at present' scenario where redundant production is assumed to be exported, macro-economic effects are hardly observable. Only in the extended version of the 'Planned capacity at present' scenario, where the total production volume is increased much more, the resulting effects are clearly stronger. However the question remains whether this scenario, where 10% of all Tanzanian lands are planted with Jatropha, is realistic.

Table 8.1: Production volume and Exports in all scenarios in monetary values:

	Smallholder Scenario		**Large-Scale Plantations**	**Planned Capacity at present**	
	Low input system	*Intermediate input system*		*Initial*	*Extended*
Production volume (in bln TZS)	44.46	43.49	58.50	78.69	1610.32
Production volume (in mio USD[20])	46.80	45.78	61.57	82.82	1694.82
Exports of bio-diesel (in mio USD)	-	-	-	22.44	1099.16

At present it seems that at best the initial 'Planned capacity at present' scenario could be realized in Tanzania in the nearer future. This setup comprises of approximately 300,000ha land of which more than half has not yet been cleared and cultivated. In this case GDP and Wagesum will increase only slightly.

When considering that Jathopha is not the only energy crop planted in Tanzania, the extended scenario could be taken as an indication for how soaring production volumes of energy crops in general will boost benefits. Therefore, further investigations into the macro-economic advantages of an increased production of energy crops would reveal more insights and distinguish between different energy plants.

Interestingly, the analysis has also shown that smallholder systems in comparison to large-scale plantations yield a higher increase in GDP, net-exports and Wagesum. This is mostly the case, because an outgrower system is more labor intensive and relies to a lesser extent on intermediate inputs such as

[20] Exchange rate for December 2001: 1USD = 950.14TZS
(see: http://www.oanda.com/lang/de/currency/historical-rates)

machinery, which is often imported into Tanzania. This result is in correspondence to observations in the seminal literature on the micro-level, where the tendencies are that the profitability of outgrower systems is higher than that of large-scale plantations. These results show that Jatproha implementation schemes and bio-diesel policies should pay specific attention to management systems and support smallholder farmers more than large-scale investments. This line of argument is particularly supported by Channing et.al. (2009), who claim that policies should not be intended to "…displace smallholders on the highest quality land, employ highly capital intensive technologies, and repatriate profits to foreign investors and / or accrue profits to elite Mozambicans." Since this would certainly not support poverty reduction and income growth.

The second research question was meant to assess whether the application of more flexible Cobb-Douglas production functions in Input-Output analysis leads to different results than in the common analysis based on Leontief production functions. Again a differentiation between scenarios seems appropriate. In all four scenarios where total production volume does not exceed 85 million USD, the deviation in GDP, Wagesum and Imports between both production functions is marginal. However, as production volumes are assumed to soar up to 1694 million USD, differences become clearly visible and can hardly be neglected. Interestingly, in all cases, under Cobb-Douglas production functions macro-economic indicators reveal similar sensitivities towards price variations. Their respective range of different outcomes is simply smaller if the Leontief result itself is smaller. Thus, as long as small shocks are modeled, common Input-Output analysis is fairly accurate. If shocks become larger, differences gain in importance. However, it is hardly possible to tell in advance whether a certain modeled shock is large enough to matter. Therefore, more flexible models should generally be preferred over static ones. This is especially the case if some input factors are scarcely available and thus industries are induced to widely substitute these in the face of rising prices.

Overall, the aim of this study was to assess the macro-economic impacts associated with an extended bio-energy production from Jatropha in Tanzania, when applying Input-Output analysis in a more flexible form by taking substitution between input factors into account. Throughout all intermediate steps the analysis strives to achieve optimal results under a relatively constrained availability of data. Therefore, some compromises had to be made, which could have been avoided if further data was available. In particular this relates to the high level of aggregation in the Input-Output table, which prevents an in-depth analysis of structural changes and the estimation of Cobb-Douglas coefficients in a small cross-section data set rather than from extended time series. Due to these limitations, estimated coefficients and their respective elasticities often lack economic background. Some industries were estimated to produce under increasing returns to scale and some industries were theoretically operating under negative supply-side elasticities. In these cases corrections had to be made such that their influences on the final results are minimal.

Naturally, there are also many possibilities to improve the model itself. Firstly, final demand is kept constant throughout the modeling procedure and does not respond to price variations as it would in CGE models. However, these would necessitate data and assumptions about consumer behavior and utility functions and it is unclear if such investments would pay in terms of additional insights, as consumer behavior in developing countries is relatively stable and simple. This implies that the present model and its results are completely demand driven. It leads to the rather artificial implication that Jatropha plantations in general do not substitute food production, which is assigned for final demand as might be the case in more dynamic modeling. By assumption, Jatropha is planted on additional lands. As a result the competitiveness of Jatropha with other crops from a farmers or investors perspective is totally left aside. Secondly, this framework neglects the possibility that there might be more profitable uses for Jatropha seeds than for the production of bio-diesel. Openshaw (2000) for instance sees more potential in medical uses and cosmetics. In addition, byproducts can be exploited as wood fuel or fertilizer. Thirdly, the danger persists that the modeler makes seemingly harmless but questionable assumptions, which end up driving the results. (Wing 2007)

In general, while the previous criticisms can be neglected in small shocks since they hardly bias results at all, larger shocks require more dynamic modeling because they override not only input structures, but also provoke substitution and demand responses. The model developed in this analysis is meant to be a good compromise between both, since it is more flexible than common Input-Output analysis while requiring far less data and behavioral specifications than the CGE model.

Appendix:

Appendix A:

<u>The derivation of optimal input quantities employing Lagrangian multipliers (see sub-section 2.3):</u>

(A 2.1) Production function: $Y = A * \prod_{k=1}^{K} X_k^{\alpha_k}$

(A 2.2) Cost function: $C = \sum_{k=1}^{K} c_k X_k$

with c_k being the price of input k and C total production cost

(A 2.3) Lagrangian: $£ = \sum_{k=1}^{K} c_k X_k - \lambda\left(A * \prod_{k=1}^{K} X_k^{\alpha_k} - Y\right)$

(A 2.4) $\frac{d£}{dX_1} = c_1 - \lambda\left(A * \alpha_1 X_1^{\alpha_1 - 1} * \prod_{k=2}^{K} X_k^{\alpha_k}\right) =^! 0$

(A 2.5) $\frac{d£}{dX_2} = c_2 - \lambda\left(A * \alpha_2 X_2^{\alpha_2 - 1} * \prod_{k=1, k\neq 2}^{K} X_k^{\alpha_k}\right) =^! 0$

.....

(A 2.6) $\frac{d£}{dX_K} = c_K - \lambda\left(A * \alpha_K X_K^{\alpha_K - 1} * \prod_{k=1, k\neq K}^{K} X_k^{\alpha_k}\right) =^! 0$

(A 2.7) $\frac{d£}{d\lambda} = A * \prod_{k=1}^{K} X_k^{\alpha_k} - Y =^! 0$

(A 2.8) Solve (A 2.7) for Y: $Y = A * \prod_{k=1}^{K} X_k^{\alpha_k}$

(A 2.9) Equate (A 2.4) and (A 2.5): $X_2 = \frac{c_1 \alpha_2 X_1}{c_2 \alpha_1}$

.....

(A 2.10) Equate (A 2.4) and (A 2.6): $X_i = \frac{c_1 \alpha_K X_1}{c_K \alpha_1}$

(A 2.11) Insert (A 2.9) and (A 2.10) into (A 2.8):

$$Y = A * X_1^{\alpha_1} * \left(\frac{c_1 \alpha_2 X_1}{c_2 \alpha_1}\right)^{\alpha_2} * \dots * \left(\frac{c_1 \alpha_K X_1}{c_K \alpha_1}\right)^{\alpha_K}$$

(A 2.12) Solve equation (A 2.11) for X_1 with $\pi = \sum_{k=1}^{K} \alpha_k$:

$$X_1 = Y^{\frac{1}{\pi}} * A^{\frac{-1}{\pi}} * \left(\frac{\alpha_1}{c_1}\right)^{\frac{\pi-\alpha_1}{\pi}} * \left(\frac{c_2}{\alpha_2}\right)^{\frac{\alpha_2}{\pi}} * \dots * \left(\frac{c_K}{\alpha_K}\right)^{\frac{\alpha_K}{\pi}}$$

(A 2.13) Continue simultaneously with all other inputs:

$$X_2 = Y^{\frac{1}{\pi}} * A^{\frac{-1}{\pi}} * \left(\frac{c_1}{\alpha_1}\right)^{\frac{\alpha_1}{\pi}} * \left(\frac{\alpha_2}{c_2}\right)^{\frac{\pi-\alpha_2}{\pi}} * \dots * \left(\frac{c_K}{\alpha_K}\right)^{\frac{\alpha_K}{\pi}}$$

.....

$$X_K = Y^{\frac{1}{\pi}} * A^{\frac{-1}{\pi}} * \left(\frac{c_1}{\alpha_1}\right)^{\frac{\alpha_1}{\pi}} * \left(\frac{c_2}{\alpha_2}\right)^{\frac{\alpha_2}{\pi}} * \dots * \left(\frac{\alpha_K}{c_K}\right)^{\frac{\pi-\alpha_K}{\pi}}$$

(2.14) Under constant returns to scale ($\sum_{k=1}^{K} \alpha_k = 1$) X_K can be simplified:

$$X_K = Y * A^{-1} * \left(\frac{c_1}{\alpha_1}\right)^{\alpha_1} * \left(\frac{c_2}{\alpha_2}\right)^{\alpha_2} * \dots * \left(\frac{\alpha_K}{c_K}\right)^{1-\alpha_K}$$

<u>Derivation of supply-side elasticities (see sub-section 2.3):</u>

Assuming that there is perfect competition in place along with zero profits for companies, the following relation holds:

(A 2.15) $$P * Y = \sum_{k=1}^{K} c_k K_k$$ with P being the market price for outputs

Inserting (A 2.12) and (A 2.13) into (A 2.15):

(A 2.16) $$P * Y = Y^{\frac{1}{\pi}} * A^{-\frac{1}{\pi}} * \sum_{k=1}^{K} \left(c_k * \left(\prod_{k=1, k \neq k}^{K} \frac{c_k}{\alpha_k}^{\frac{\alpha_k}{\pi}} \right) * \frac{\alpha_k}{c_k}^{\frac{\pi - \alpha_k}{\pi}} \right)$$

Solving for Y:

(A 2.17) $$Y = P^{-\frac{\pi}{\pi-1}} * A^{-\frac{1}{\pi-1}} * \gamma^{\frac{\pi}{\pi-1}} \quad with \quad \gamma = \sum_{k=1}^{K} \left(c_k * \left(\prod_{k=1, k \neq k}^{K} \frac{c_k}{\alpha_k}^{\frac{\alpha_k}{\pi}} \right) * \frac{\alpha_k}{c_k}^{\frac{\pi - \alpha_k}{\pi}} \right)$$

(A 2.18) $$\varepsilon_Y = \frac{dY}{dP} * \frac{P}{Y}$$

(A 2.19) $$\varepsilon_Y = \frac{\left(-\frac{\pi}{\pi-1}\right) * P^{-\frac{\pi}{\pi-1}} * A^{-\frac{1}{\pi-1}} * \gamma^{\frac{\pi}{\pi-1}}}{P^{-\frac{\pi}{\pi-1}} * A^{-\frac{1}{\pi-1}} * \gamma^{\frac{\pi}{\pi-1}}} = -\frac{\pi}{\pi - 1}$$

Appendix B:

(see sub-section 3.1)

Table B1: List of industries in the Farming, Cash-crops and Services sector

Sector	Farming	Cash-crops	Services
	maize	cotton	hotels and restaurants
	paddy	coffee	transport and communication
	sorghum or millets	tobacco	wholesale and retail trade
Industry	wheat	tea	real estate
	beans	cashew nuts	public administration, health
	cassava	sisal fiber	and education
	other cereals	sugar	business and other services
	oil seeds		utilities
	other rotts and tubes		construction
	fruit and vegtables		
	other crops		
	poultry and livestock		
	fish farms		
	hunting and forestry		

Total	14	7	8

Figure B2: List of industries in the Manufac 1 and Manufac 2 sector

Sector	**Manufac 1**	**Manufac 2**
Industry	mining and quarrying manufacture of basic and industrial chemicals manufacture of fertilizers and pesticides petroleum refineries rubber, plastic and other manufacturing glass and cement iron, steel and metal products manufacture all equipment	processing of meat dairy products grain milling processd food beverages and tobacco products textile and leather products wood paper printing
Total	8	6

(see sub-section 3.2)

An estimation in monetary values in comparison to an estimation in quantities does not affect the estimates for the Cobb-Douglas coefficients.

(B 3.1) The production function in values: $P * Y = A * (c_1 X_1)^{\alpha_1} * (c_2 X_2)^{\alpha_2}$

(B 3.2) In logarithms: $\ln(P * Y) = \ln A + \alpha_1 \ln(c_1 X_1) + \alpha_2 \ln(c_1 X_2)$

Equation (B 3.2) can be rewritten in an estimation of quantities, where the intercept is the only estimate which changes in comparison to an estimation in monetary values.

(B 3.3) $Y = B + \alpha_1 \ln X_1 + \alpha_2 \ln X_2$ $\qquad B = \ln A + \alpha_1 \ln c_1 + \alpha_2 \ln c_2 - \ln P$

Table B3: Regression results for Cobb-Douglas coefficients (OLS, weighted)

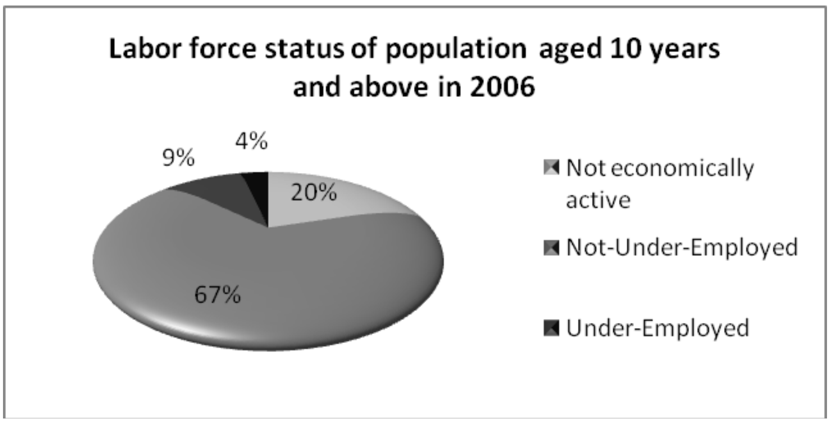
	Farming	Cash-crops	Manufac turing 1	Manufac turing 2	Services
Farming	**0.037***	0.016	-0.020	**0.072*****	**-0.022***
	(0.02)	(0.01)	(0.04)	(0.01)	(0.01)
Cash-crops	-	**0.036*****	-	**0.123*****	-
		(0.01)		(0.01)	
Manufacturing 1	**0.034****	**-0.061*****	**0.640*****	0.002	**0.078*****
	(0.02)	(0.01)	(0.09)	(0.01)	(0.03)
Manufacturing 2	**0.056*****	**-0.052*****	**0.111****	**-0.187*****	**0.071*****
	(0.02)	(0.01)	(0.05)	(0.02)	(0.01)
Services	**0.074*****	**0.283*****	-0.048	**0.621*****	**0.347*****
	(0.03)	(0.02)	(0.08)	(0.04)	(0.03)
Petro	**0.078*****	**0.072*****	**0.165*****	**0.318*****	0.005
	(0.02)	(0.02)	(0.04)	(0.03)	(0.01)
Labor	**0.301*****	-0.030	**-0.298****	-0.078	**0.106*****
	(0.06)	(0.07)	(0.13)	(0.06)	(0.03)
Agricultural capital	**0.272*****	**0.377*****	-	-	-
	(0.05)	(0.04)			

Non-agricultural capital	-	-	**0.314*** **	**0.178*** **	**0.111*** **
			(0.05)	(0.04)	(0.02)
Land	**0.131*** **	**0.433*** **	-	-	-
	(0.03)	(0.04)			
Constant	**2.329*** **	**2.028*** **	**2.495*** **	**3.090*** **	**3.401*** **
	(0.09)	(0.06)	(0.19)	(0.09)	(0.11)

(*** - significant at the 1% level; ** - significant at the 5% level; * - significant at the 10% level)

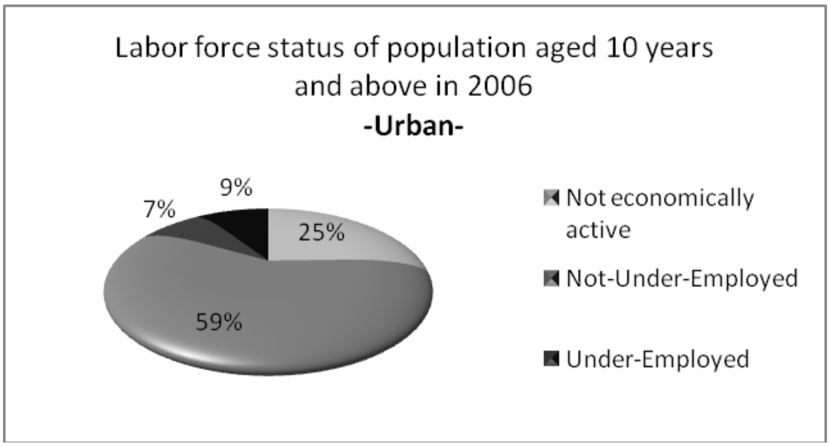
(see sub-section 3.3)

Figure B4:



Source: National Bureau of Statistics Tanzania: Statistical Abstract 2006

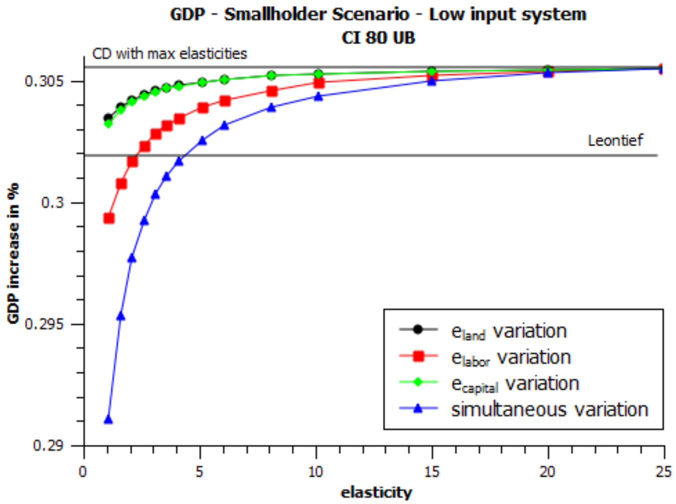
Figure B5:

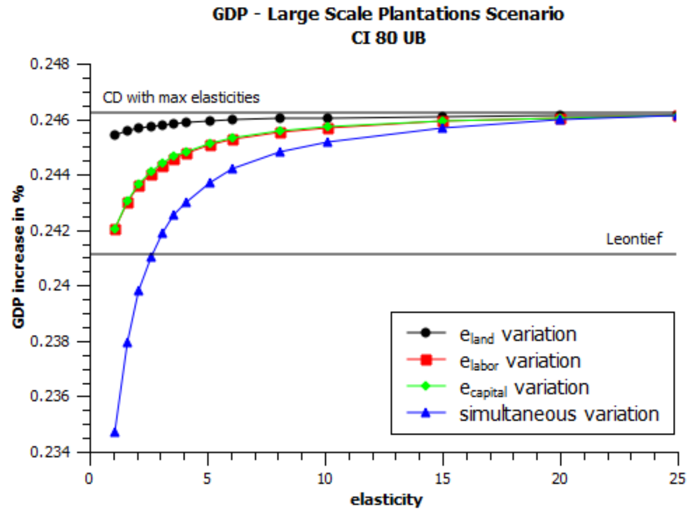


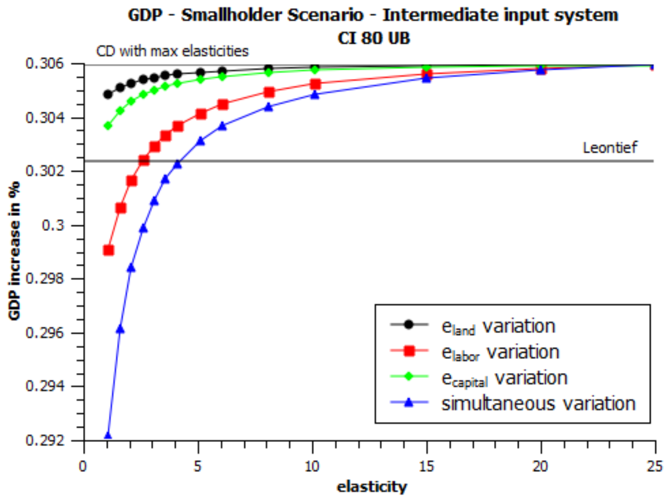
Source: National Bureau of Statistics Tanzania: Statistical Abstract 2006

Appendix C:

Figure C1: GDP variation in all four scenarios with elasticities at the upper bound of a 80% confidence interval







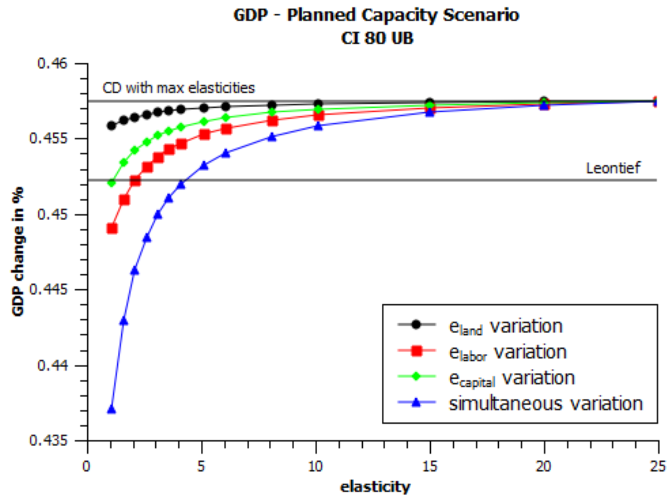


Figure C2: Imports variation in all four scenarios with elasticities at the upper bound of a 80% confidence interval

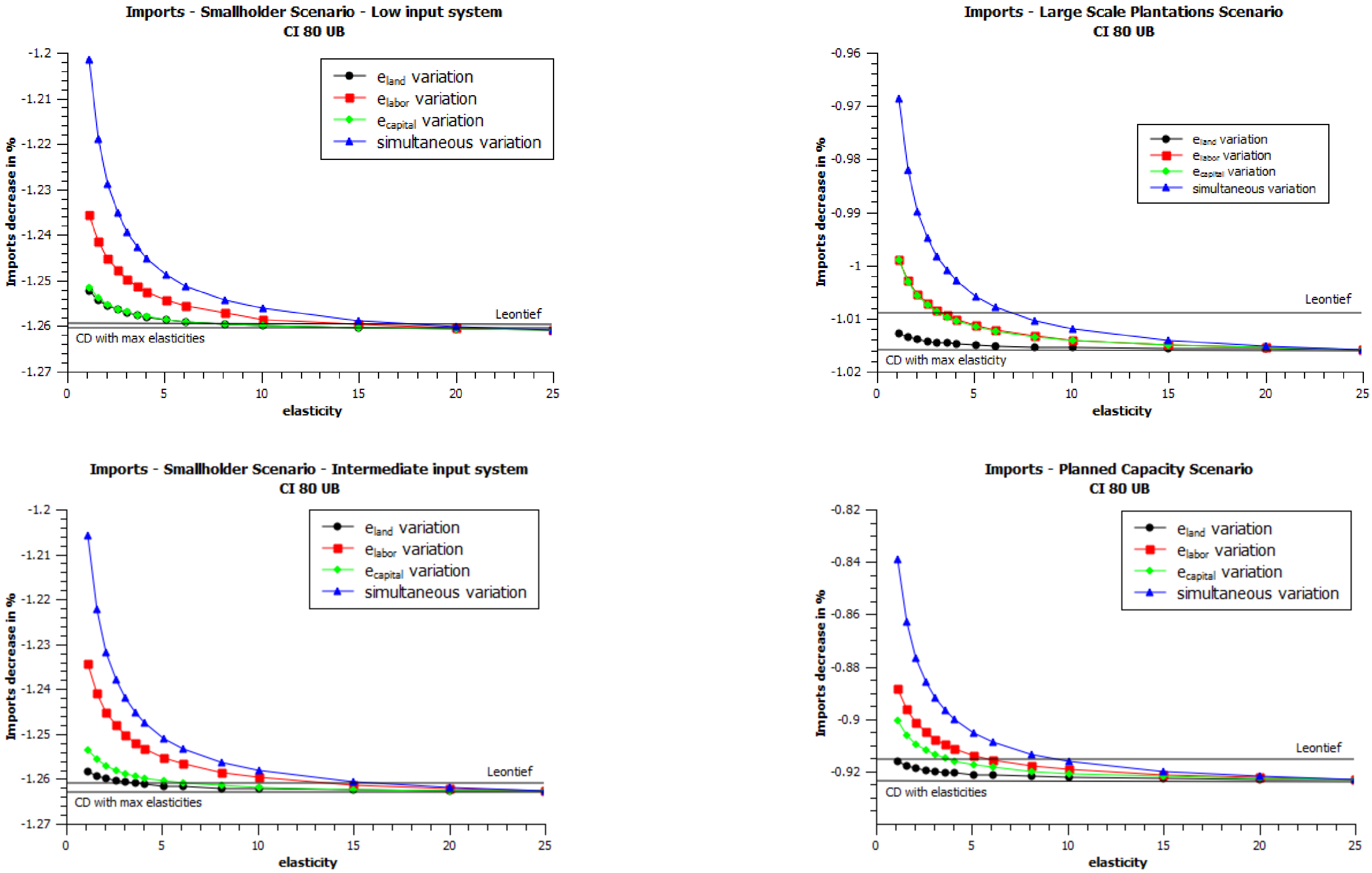


Figure C3: Wagesum variation in all four scenarios with elasticities at the upper bound of a 80% confidence interval

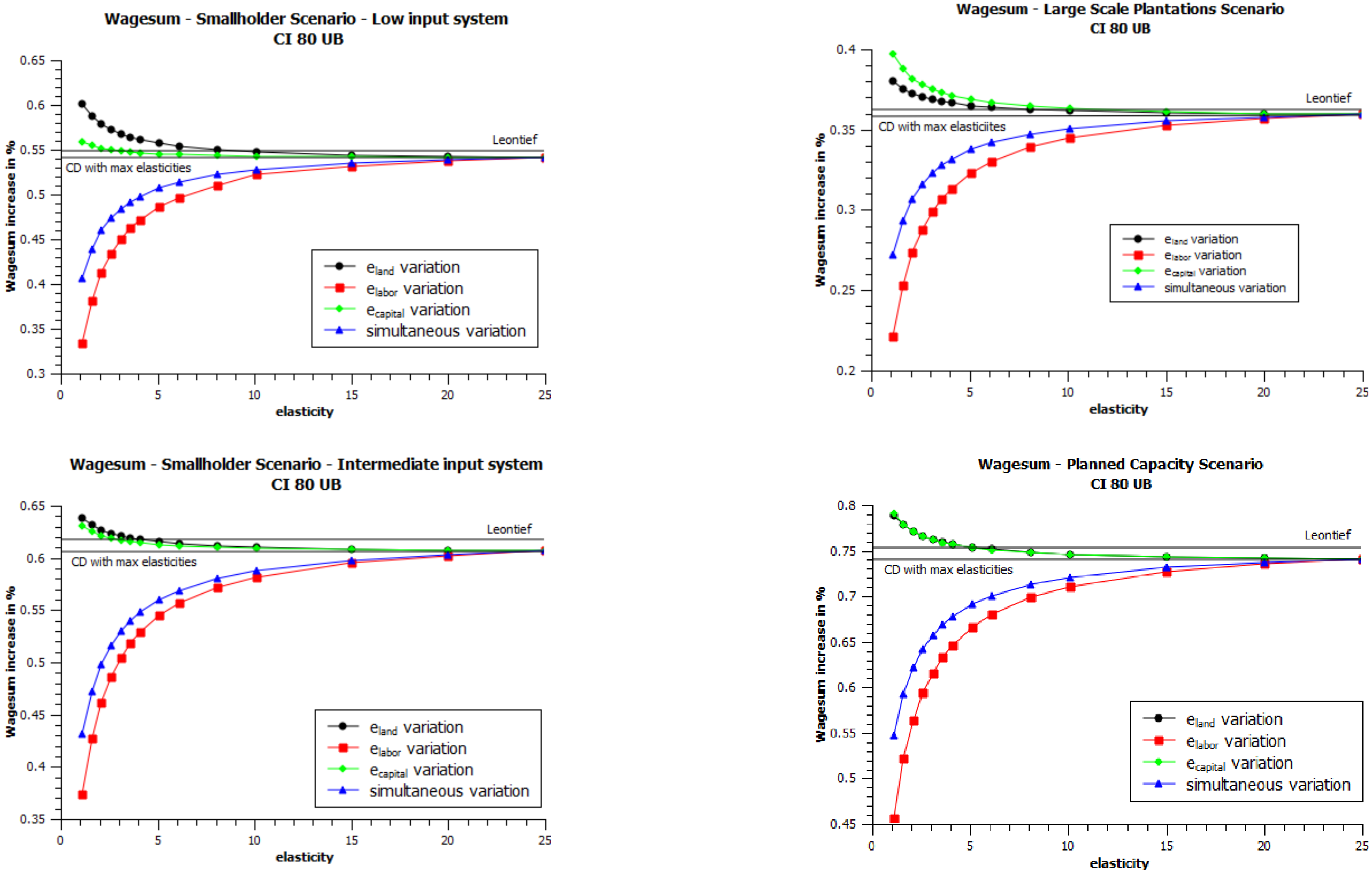


Table C4: Range of macroeconomic indicators with varying elasticities at the upper bound of a 80% Confidence Interval

	[min; max]	**Smallholder** *Low input system*	**Smallholder** *Intermediate input system*	**Large-Scale Plantations** *High input system*	**Planned capacity at present** *Mixed inp. sys.*
GDP	[min. simult. var.; CD with max. elasticity]	[0.2911; 0.3055]	[0.2922; 0.306]	[0.2347; 0.2461]	[0.4371; 0.4575]
Imports	[min. simult. Var.; CD with max. elasticity]	[-1.2015; -1.2609]	[-1.2059; -1.2628]	[-0.9688; -1.0158]	[-0.8389; -0.923]
Wagesum	[min ε_{labor} var.; min ε_{land} var./min $\varepsilon_{capital}$ var.]	[0.3332; 0.6007]	[0.3735; 0.6384]	[0.2212; 0.3969]	[0.4562; 0.7906]

Sources:

Berck, P; Hoffmann, S. (2002), *Assessing the Employment Impacts of Environmental and Natural Resource Policy,* Environmental and Resource Economics, Vol. 22, No. 1-2, pp. 133-156

Bioshape: http://bioshape.phpwebhosting.com/en/node/8

Brittaine, R; Lutaladio, N. (2010), *Jatropha: A Smallholder Bioenergy Crop – The Potential for Pro-Poor Development,* FAO, IFAD, Rome

Channing, A. et. al. (2009), *Biofuels, poverty, and growth: a computable general equilibrium analysis of Mozambique,* Environment and Development Economics, Vol. 15, No. 1, pp. 81-105, doi:10.1017/S1355770X09990027

Diligent Tanzania ltd: http://www.diligent.nl/links-en and http://www.diligent-tanzania.com/

EIA – U.S. Energy Information Administration: *Energy in Africa Chapter 4* http://www.eia.doe.gov/emeu/cabs/chapter4.html

Ezekiel, M. (1938), *The Cobweb Theorem*, The Quarterly Journal of Economics, Vol. 52, No. 2, pp. 255-280

FAOSTAT (2010), *CountrySTAT United Republic of Tanzania*, from http://www.countrystat.org/tza/en

GEXSI (2008), *Global Market Study on Jatropha,* Prepared for the World Wide Fund for Nature (http://www.jatropha-platform.org/documents/GEXSI_Global-Jatropha-Study_FULL-REPORT.pdf)

Goldberger, A.S. (1968), *The Interpretation and Estimation of Cobb-Douglas Functions*, Econometrica, Vol. 36, No. 3/4, pp. 464-472

Gordon-Maclean, A; Laizer, J; Harrison, P. and Shemdoe, R. (2009), *Biofuel Industry Study Tanzania: An Assessment of the Current Situation,* WWF

Griffiths, A; Wall, S. (2000), *Intermediate Microeconomics: theory and applications*, Pearson Education Limited, England

GTZ (2005), *Liquid Biofuels for Transportation in Tanzania: Potential and Implications for Sustainable Agriculture and Energy in the 21st Century*

GTZ (2009), *Jatropha Reality-Check: An independent field assessment of the agronomic and economic viability of Jatropha and other oilseed crops in Kenya*, Peer Review Draft

ILO (2010), *ILO LABORSTA*, from http://laborsta.ilo.org/STP/guest

IFPRI (2003), *Tanzania: Social Accounting Matrices (SAMs) 1998-2001,* from http://www.ifpri.org/dataset/tanzania

IFPRI (2005), *Uganda: Social Accounting Matrix 1999,* from http://www.ifpri.org/dataset/uganda-1

IFPRI (2005), *Kenya: Social Accounting Matrix 2001*, from http://www.ifpri.org/dataset/kenya-0

IFPRI (2006), *Kenya: Social Accounting Matrixs (SAM) 2003,* from http://www.ifpri.org/dataset/kenya-social-accounting-matrix-sam-2003

Liew, C. J. (2000), *The dynamic variable input-output model: An advancement from the Leontief dynamic input-output model,* The Annals of Regional Science, Vol. 34, No. 4, pp. 591 - 614

Loos, T.K. (2009), *Socio-economic Impact of a Jatropha-Project on Smallholder Farmers in Mpanda, Tanzania,* University of Hohenheim/ GTZ

Miller R.E, Blair P.D (2009), *Input-Output Analysis: Foundations and Extensions,* Cambridge University Press, New York

Ministry of Energy and Minerals (2003), *The National Energy policy,* from http://www.rea.go.tz/RESOURCES/VirtualLibrary/PublicLibrary/tabid/95/Default.aspx

Ministry of Energy and Minerals (2008), *Guidelines for sustainable development of liquid biofuels and co-generation in Tanzania*

Ministry of Energy and Minerals (2003), *The National Energy Policy*

Mulugetta, Y. (2009), *Evaluating the economics of biodiesel in Africa,* Renewable and Sustainable Energy Reviews, Vol. 13, No. 6-7, pp. 1592-1598

National Bureau of Statistics Tanzania (2010), *Statistical Abstract 2006,* from http://www.nbs.go.tz/index.php?option=com_content&view=article&id=91&Itemid=49

Nguyen, T.L.T; Gheewala, S.H; Bonnet,S. (2008), *Life cycle cost analysis of fuel ethanol produced from cassava in Thailand,* The International Journal of Life Cycle Assessment, Vol. 13, No. 7, pp. 564-573

Oanda (2010), *Historical exchange rates*, from http://www.oanda.com/lang/de/currency/historical-rates

Openshaw, K. (2000), *A review of Jatropha curcas: an oil plant of unfulfilled promise*, Biomass and Bioenergy, Vol. 19, No. 1, pp. 1-15

Ranis, G. (1997), *The Micro-Economics of "Surplus Labor"*, Economic Growth Center, Yale University, Discussion Paper No. 772

Reijnders L, Huijbregts M.A.J (2009), *Biofuels for Road Transport: A Seed to Wheel Perspective,* Springer-Verlag London, U.K.

REN21 (2009), *Renewables Global Status Report,* Renewable Energy Policy Network for the 21st Century

Reynolds, L.G. (1969), *Economic development with surplus labor: Some complications,* Oxford Economic Papers, Vol.21, No.1, pp.89-103

Sun Biofuels: http://www.sunbiofuels.com/index.html

Thurlow, J; Wobst, P. (2003), *Poverty-Focused Social Accounting Matrices for Tanzania,* IFPRI Discussion paper No. 112

Prokon Renewable Energy ltd: http://www.prokon-capital.de/prokon-jatropha-tansania.php and http://www.prokon-tanzania.com/index.html van Eijck, J.; Smeets, E.; Faaij, A. (2010), *The economic performance of different crop production systems for Jatropha, Cassava and Eucalyptus in an East African smallholder setting,* Copernicus Institute for Sustainable Development and Innovation, Utrecht, Working paper

van Eijck, J. (2009), *Case Study: The Smallholder Model of Biofuel Production in Tanzania*, Diligent Tanzania ltd

Wahl, N. et.al. (2009), *Economic viability of Jatropha curcas L. plantations in Northern Tanzania-Assessing farmers' prospects via cost-benefit analysis,* ICRAF Working Paper No. 97, Nairobi, World Agroforestry Centre

World Development Indicators - WDI (2009) provided by the World Bank Group

Wicke, B. et. al. (2009), *Macroeconomic impacts of bioenergy production on surplus agricultural land – A case study of Argentina,* Renewable and Sustainable Energy Reviews , Vol. 3, No. 9, pp. 2463-2473

Wing, I. S. (2007), *Computable General Equilibrium Models for the Analysis of Energy and Climate Policies,* Prepared for the International Handook of Energy Economics

Worldwatch Institute (2007), *Biofuels for transport: global potential and implications for sustainable energy and agriculture,* Earthscane London, U.K.