Annex 1: Data Sources and Methodology

We developed a full-fledged global CGE model, which has comprehensive details on tobacco and tobacco product sectors. This is based on the Global Trade Analysis Program-Environment (GTAP-E) model and data base, further augmented using country-specific data on tobacco crop and tobacco products, from various national and international data sources. Particular sources include FAO for production and prices of tobacco crop, UN commodity statistics as well as National Accounts Statistics (of Tanzania) for production of tobacco products, World Development Indicators dataset for macro-economic aspects of Tanzania. Employment effects are then captured based on the production function in the model.

The calculations to translate a 30% reduction in consumption to the shock to the CGE model are the following:

Tobacco Consumption = Prevalence * Population * Per-capita Tobacco Consumption

When we linearize the equation above, the right hand side gets translated into the sum of percentage changes in prevalence, population and per-capita tobacco consumption.

1. ΔTobacco Consumption = ΔPrevalence + ΔPopulation + ΔPer-capita Tobacco Consumption

Per-capita tobacco consumption (in percent changes, named ConsPC) is derived from a simple demand equation with income (ELASTY) and price elasticities (ELASTP), depending on consumption prices (PricesCons), as follows:

2. ΔConsPC = ELASTY * (Δincome – Δpopulation) – ELASTP * ΔPricesCons

Result of 2 is substituted in equations one to obtain a 17.6%change in tobacco consumption. Change in populations is the estimated population growth set by the Tanzanian government.

The GTAP 9 Data Base includes data on aggregated sectors such as crops and beverages/tobacco products. We added detailed data on tobacco and tobacco products for our analysis. In this context, the latest available Social Accounting Matrix (SAM) for Tanzania for the year 2009 was used. This has been documented in detail by Pradesha and Diao (2009) and contains both tobacco and tobacco products sectors. We employed the SAM shares of these sectors within GTAP, using the SplitCom tool (Horridge, 2008), to separate raw tobacco from the GTAP sector 'other crops' and tobacco products from the GTAP sector 'beverages and tobacco products'.

However, the SAM is from 2009 and the GTAP Data Base from 2011, so we use the World Development Indicators dataset to update the macro-economic aspects of GTAP Data base, so that all sectors are scaled up accordingly using a comprehensive tool named GTAPAdjust (Horridge, 2010).

We also used FAO statistics for raw tobacco and Tanzania's national account for data on tobacco products to augment the sector level information. Our final reference year for the augmented GTAP data base is 2015.

Annex 2: Description of the GTAP Modelling Framework

A CGE model can also capture the potential substitution of tobacco by other crops in the case of former's decline. We model tobacco control policy in terms of reduction in *production and trade* of this sector. Changes in all variables in this section are measured as a percentage.

In the GTAP model, the production function has different levels of nesting; at the top level, there is no substitution between the total primary factors and the total intermediate inputs, implying a Leontief function and Constant Returns to Scale (CRS). In other words, if output has to increase by x% in a sector, the total of all primary factors and intermediate inputs would also have to increase by x%. There is, however, a substitution between labor, capital, land and natural resources, which are all primary factors. Therefore, the multiplier in the model depends on the extent to which output changes in different sectors as well as the extent to which labor and other primary factors substitute each other. This multiplier is not a single number and would depend on the simulations that are conducted, since it is a combination of changes in different variables and the fixed elasticity parameters.

The model developed in this paper is an extension of the standard GTAP model (Hertel, 1997). We define the sets SECT of sectors (indexed by *k*) and REG of regions (indexed by *r* in most cases and if the region is the source of exports/imports but by *s* if the region is destination of exports/imports). We turn now to a discussion of key components of the GTAP model.

a. International Trade

The change in imports of each region from each of the others is determined by three factors: (i) substitution among different sources, based on the differential between import prices from specific sources and the sum of import-augmented technical change and aggregate import prices $pimk_{k,s}$, multiplied by the elasticity of substitution of imports between the sources $\sigma_{M,k}$, using the Armington +elasticity for the sector as in the GTAP Data Base, (ii) import-augmenting technical change, $amsk_{k,r,s}$, that lowers the effective price of a good in the destination market, and (iii) the import penetration as captured by the change in composite imports of subsector commodity *k*, $qimk_{k,s}$. Note that the substitution effect for a particular flow *(k,r,s)* increases in divergence of import tariff for good *k* from regions *r* to *s*, from the weighted-average tariff of *s*. Since a higher weight means

lower divergence, this effect decreases in import-shares of region *r* in the total imports by region *s* of the good *k*.

For all sectors k in SECT, regions r and s in REG:

$$qxsk_{k,r,s} = -amsk_{k,r,s} + qimk_{k,s} - \sigma_{M,k} * [pmsk_{k,r,s} - amsk_{k,r,s} - pimk_{k,s}] \quad \ldots\ldots\ldots\ldots (1)$$

Global transport margins are treated in the same manner as in the standard GTAP model, with the quantity of international trade, transport and insurance services required being a fixed proportion of the volume of goods shipped. Technical change in this sector is represented with the variable $atmfsdk_{k,r,s}$ and is obtained by adding up the changes at different levels, which are directly translated from the aggregate changes in the corresponding variables. Trade and transport services are provided at a common price, *pt*, which represents a Cobb-Douglas aggregation of trade and transport services exports from all regions in the model. Deducting the rate of technical progress from this price change gives the percentage change in the commodity and route-specific transport margin, $ptransk_{k,r,s}$. The price linkages in the model also include export taxes, $txsk_{k,r,s}$, export *fob* prices $pfobk_{k,r,s}$, and import *cif* prices $pcifk_{k,r,s}$. Changes in import tariff and export taxes are the policy variables here.

b. Domestic Consumption

There are three broad categories of consumption of products and services manufactured in a country: private households, government and firms. In addition, each of these categories of agents also consume imports that are aggregated across exporters, based on the descriptions in section a, above. For private households, GTAP assumes a Constant Difference Elasticity (CDE) functional form, which is flexible enough to handle Linearized Expenditure Systems (LES) and Constant Elasticity of Substitution (CES) as special cases. For government to consume different products and for firms to consume different intermediate inputs, the CES functional form is used. There is also a nested CES function between domestic and imported products for each of these agents.

c. Domestic Production

Production functions in GTAP involves 3 levels of nests: (1) There is a Leontief function on the topmost part of production system, wherein intermediate inputs are a composite single input and primary factors as another composite single input are complements. (2) Within the intermediate inputs, there is a CES function. (3) Within the primary factor inputs, there is a CES function. With the exception of land and natural resources, which can move only within agricultural and extraction

sectors respectively. Other factors are mobile across sectors. GTAP-E model, which focuses on energy and environmental aspects, modifies the system above to introduce substitution between energy sectors and capital input, while further introducing substitution (CES) between different types of energy sources to capture channels of emissions reduction.

d. Links between Production, Consumption and International Trade:

The sub-modules explained above are linked with each other. The percentage change in sector-level domestic consumption, $qdmk_{k,s}$, with a corresponding price change $pmk_{k,s}$, substitutes for imported subsector goods, $qimk_{k,s}$, with a corresponding price change $pimk_{k,s}$. The CES elasticity between these two variables is $\sigma_{D,k}$, and this substitution takes place based on their respective price differentials from the sector-level domestic prices $pdk_{k,s}$, as illustrated by equations (2) and (3):

For all *k* in *SECT* and *s in* REG:

$$qimk(k,s) = qdk(k,s) - \sigma_D(k) * [pimk(k,s) - pdk(k,s)] \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$qdmk(k,s) = qdk(k,s) - \sigma_D(k) * [pmk(k,s) - pdk(k,s)] \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Domestic market and import price changes are aggregated to domestic price changes by weighting according to their respective shares. $VDK_{k,r}$ is the total value of domestic consumption of goods corresponding to the sub-sector k in the region r, $VDMK_{k,r}$ is the value of domestic consumption of goods produced by the domestic sector k in the region r and $VIMK_{k,s}$ is the value of imports of goods produced by the sub-sector k to the region s.

For all *k* in *SECT* and *s in* REG:

$$pdk_{k,s} = \alpha D_{k,s} * pmk_{k,s} + \alpha M_{k,s} * pimk_{k,s} \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

where: $\alpha D_{k,s} = VDMK_{k,s} / VDK_{k,s}$ *and* $\alpha M_{k,s} = VIMK_{k,s} / VDK_{k,s}$

Finally, the total changes in supply and demand are equalized to ensure equilibrium, by equating the percentage change in total output $qok_{k,r}$ with the share-weighted sum of exports and domestic consumption for all sectors k in SECT and regions r in REG. When the slack variable $tradslackk_{k,r}$ is exogenized, this equilibrium condition determines the change in market prices, $pmk_{k,r}$ (output, $qok_{k,r}$) is determined by Equation (5).

For all *k* in *SECT* and *r in* REG:

$$qok_{k,r} = \beta D_{k,r} * qdmk_{k,r} + \Sigma_s \beta M_{k,r,s} * qxsk_{k,r,s} + tradslackk_{k,r} \quad \ldots\ldots\ldots\ldots\ldots\ldots (5)$$