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Jörgen Levin and Yeasmin Sayeed
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Örebro University School of Business
701 82 Örebro
SWEDEN

# Welfare impact of broadening VAT by exempting local food markets: The case of Bangladesh

**Jörgen Levin and Yeasmin Sayeed**

Örebro University School of Business

Abstract

The spread of value-added tax (VAT) in developing countries has been dramatic since the beginning of 1990's. Adopted by more than 130 countries, including many of the poorest, VAT has been, and remains, the key of tax reform in many developing countries. While adopting VAT, there are arguments for and against uniform general VAT system. A uniform and general VAT on all commodities is considered to be efficient and less distortionary. On the other hand, from the distributional perspective many goods especially food is exempted from VAT as low income households spend a high share of income on food. The contribution of this study is to analyze the income distribution and welfare impact of VAT reform when the food sectors are divided into local markets and supermarkets. A Computable General Equilibrium (CGE) model is used to evaluate the consequences of VAT reforms for Bangladesh. Our simulation results show that, a VAT reform that exempts the agriculture sector and local market food commodities provides the best welfare and distributional impact.

**Keywords:** VAT, VAT reform, incidence analysis, equity and welfare, CGE, Bangladesh.

**JEL Classification:** H21, H22, H23, I31

## 1. Introduction

The spread of value-added tax (VAT) in developing countries has been dramatic since the beginning of 1990's.[1] Adopted by more than 130 countries, including many of the poorest, VAT has been, and remains, the key of tax reform in many developing countries. VAT is a modern tax technology with good performance characteristics, and it is generally believed that a broad based VAT tax, with certain exemptions, is the preferred source of indirect tax revenue. The VAT is considered as an efficient way of raising public funds (Boeters et al., 2006, Keen & Lockwood, 2010). VAT eliminates the cascading[2] effects of taxes on intermediate inputs and helps economic agents to make investment decision independent of tax policies (Ebrill et al 2001; Go et al 2005). However, imperfections in the refund system, and/or excessive statutory exemptions, may have meant that the VAT has in practice functioned largely as a tax on exports and intermediate production, and so tended to reduce exports and national output (Keen, 2008). When informal traders do not remit VAT on their sales, but are subjected to VAT, without benefit of any refund, on both their imports and their purchases from VAT-compliant firms, then the VAT functions as an input tax.

The proportion of VATs that were introduced with a single rate has increased markedly over time (Keen, 2013). This goes against the general advice to use exemptions schemes to avoid adverse distributional outcomes. With regard to VAT exempting commodities with proportionate high spending by the poor is believed to reduce the incidence of taxation. However, exemptions imply foregone revenue that could have been used to target poorer households on the expenditure side. For example, in Mexico the implicit subsidy, relative to income, is greatest for the lowest income deciles, but the share of the total VAT revenue foregone by zero rating is large: for each $100 foregone by zero-rating, less than $5 benefits the poorest 10 percent of the population; and more than $20 benefits the top 10 percent (Keen, 2013).

A broad-based VAT (elimination of zero-rated VAT on food for example) could lead to higher revenue and hence increased public spending. Even if public spending is poorly targeted to

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[1] For a comprehensive review of VAT, see Le (2003). See also Keen and Lookwood (2010) on various issues related to VAT.

[2] Cascading is levying of tax in items that have already been taxed.

the poor it still could be a better strategy to support the poor rather than differentiated VAT rates (Keen, 2013). However, the outcome is a complex web of various factors which calls for country-specific analysis on incidence of taxation and the benefits of public spending.

The impact of broadening the VAT would also depend on how prices change across different segments of the market. Broadening of VAT will change prices among registered (VAT) operators, like supermarkets, and not smaller operators. For example, in Kenya the lowest income quintile buys 60% of their maize consumption from smaller shops/kiosks while the richest quintile purchases the same share from large supermarkets (Kirimi et al., 2012). A likely impact of VAT broadening would be that richer households are affected relatively more than the poorer households, assuming that prices do not adjust in the non-VAT registered firms.

Bangladesh adopted VAT in 1991 as one of the key reforms in its tax modernization program. Introducing VAT had a positive impact on the revenue but merely compensating the loss of revenue from trade taxes. The tax-GDP ratio for Bangladesh has been around 10 percent in recent years, which is low compared to other low-income countries. The excessive use of tax holidays, basic design flaws in the tax laws and weak tax administration are the main reasons behind this low tax intake (IMF 2008). Indeed, if Bangladesh were as efficient as the average Low Income Country (LIC), that would imply an additional VAT revenue in the order of 2.9 and 1.7 per cent of GDP (IMF, 2011). That would be achieved without changing the standard rate, but by combining base-broadening and improving compliance. However, concerns have been raised on the distributional effects of base-broadening.

In this paper, we analyze the welfare and distributional aspects of reforming the existing VAT system in Bangladesh. Does a uniform VAT system hurt poorer household groups in the Bangladesh society? Or VAT with exemptions is preferable? One of the contributions of this paper is that we divide the food sectors into local and super markets with the assumption that low income households purchase products mostly from local market. Moreover, we apply a CGE model where tax rates are specified not only on the commodity purchased but also on different purchasers, meaning that the purchaser's price of the same commodity differs between actors. Therefore, it is possible to model the impact from the VAT payment with rebates on intermediate inputs.

The outline of the paper is as follows: Chapter two reviews some of the literature on VAT with a focus on incidence and exemption schemes. Chapter three describes methodology and data used in the paper. Chapter four summarizes the results. Chapter five discusses the results. Chapter six concludes.

## 2. Literature review

In order to improve efficiency and to raise additional revenue governments are often advised to broaden the base of the VAT. The consequence of such reform on income distribution is an important concern (Ahmad & Ludlow, 1989). VAT base broadening is usually thought to be regressive as high income households spend a smaller fraction of their income on newly taxed products than low income households (Piggott & Whalley, 2001). Because of equity consideration, many countries are reluctant to broaden VAT.

There are few studies that looked specifically at whether the exemption scheme has been targeted to the poor. Munoz and Cho (2003) found in the case of Ethiopia that most of the VAT exempted goods and services are disproportionately consumed by the non-poor. Alderman and del Ninno (1999) studying South Africa observe that while some exemptions were good instruments for achieving equity or nutritional objectives, others were less effective. Jenkins et al. (2006) analysed progressivity of VAT in the Dominican Republic and found that the VAT structure was progressive. Even when broadening the VAT, with a few remaining exemptions, it remained progressive.

Other studies have looked at exemption schemes in a broader context such as evaluating the impact of moving from a sales tax system to non-uniform VAT based system. It is usually found that it does not necessarily worsen the welfare of the poor, since most goods consumed of the poor are zero-rated (Chen, Matovu & Reinikka, 2001). For example, Haughton et al (2006) argue that the shift from a complex turnover tax to a VAT in Vietnam had a small impact, possibly progressive. Part of the reason is that home consumption which is untaxed represents almost 40 percent of total spending for the low-income households.

Although the scanty empirical evidence is mixed VATs with a single rate have increased significantly over time (Keen, 2013). Broadening VAT or equivalent, moving towards a uniform system, has become the norm. Why has this changed? It might be based on the belief that any

effects on the poor are likely to be small, since the poor in practice pay few taxes directly. It also commonly believed that public social expenditures provide a better means to target the poor rather than redistribution by the tax system (Harberger 2003, Bird et al 2008). Another explanation of neglecting the incidence of exemption schemes would be that it is more important to look at the incidence of the tax system as a whole; ultimately, the overall effectiveness of fiscal policy will be judged by its net impact (Devarajan & Hossain, 1998). Looking at tax incidence at in a piecemeal fashion is likely to lead to inaccurate conclusions about the impact of the tax system on distribution of income (Martinez-Vazquez, 2007).

However, evaluating the fiscal system as a whole, considering both the revenue and expenditure side, is quite complex. In this paper we focus on the taxation side and VAT. There is a trade-off between exemptions and amount of revenue collected, more exemptions imply less revenue and hence less expenditures that can be used to target poor households. How to balance the trade-off between exemptions and expenditure-targeting depends on the government's capacity to design well-targeted programmes. If its capacity is weak a call for higher level of exemptions seems plausible. Even looking at the impact of a piecemeal reform, such as VAT broadening, can give us some insights on how to compensate potential losers from such a reform.

Two previous studies have analyzed on VAT reform and VAT incidence for Bangladesh. Mujeri & Khandaker (1998) analyzed the potential revenue and incidence implications of tariff liberalization. They combined the tariff reduction along with adjustment of VAT rate to maintain revenue neutrality in a general equilibrium context. A recent study on incidence analysis of VAT was done by Faridy & Sarker (2011). By applying the Suits index and the Kakwani index they revealed that VAT in Bangladesh is regressive. Hossain (1994) studied distributional implications of different Value Added Tax (VAT) schemes in Bangladesh. The policy implication of Hossain's partial analysis was that selective VAT with some exemptions coupled with some additional excises (revenue neutral) was preferable to the uniform proportional VAT from the perspective of distributional concern.

## 3. Methodology and data

### 3.1 Methodology

The Computable General Equilibrium (CGE) models are straightforward instruments to assess the quantitative impact and relative efficiency of alternative tax instruments (Radulescu & Stimmelmayr, 2010). They can include a large number of economic variables to assess the overall effect of VAT reform. A CGE model integrates consumer and producer behavior and also the interaction between other economic agents and therefore incorporates the direct and indirect effects on the distribution of income and consumer welfare. A change in tax rates has two effects: an income effect (household get poorer and richer because prices are changing) and a substitution effect (relative prices will change). Widening the VAT net or rerating the VAT would mainly affect the budget constraints of the households. As capital and land are sectorally fixed in the short run, output would change due to change in labor use as factor price changes. Changes in factor returns and sectoral absorption would lead to variation in household income. Due to changes in relative income and prices the real consumption would change as well. New market clearing prices and quantities consistent with the optimizing behavior of the consumer and producers will arise, which might modify the sectoral structure of the economy. With the help of CGE modeling, we can capture the direct and indirect effect of changes in VAT on distributional and welfare aspects. There are many welfare indicators. We are using equivalent variation (EV) since it is the standard approach used in many tax analysis studies

We apply a CGE model developed by Bohlin (2010). The model is an extension of the IFPRI[3] standard static CGE model. The indirect taxes are implemented as value added and unit taxes on the purchase of commodities. The tax rates are specified not only on the commodity purchased but are also allowed to differ between agents (here activities and households). In terms of modeling VAT payments with rebates on intermediate inputs our approach is similar to Go et al. (2005) for South Africa. In their approach VAT rebates is based on total intermediate input used in different activities. Then the rebate is subtracted from a price that includes VAT. Alternatively, in the Bohlin (2010) model VAT is calculated from a price that does not include VAT multiplied with 1 plus the VAT tax rate. Being a consumption tax, the ultimate burden of

[3] International Food Policy Research Institute

VAT is transferred to the consumers. The Bohlin (2010) model is developed and calibrated so that if any commodity is charged the VAT then it is the consumer who pays the tax. As a result, the model imposes the zero tax paid on intermediate use by activities that are included in the VAT since they get rebate. Since the tax rate is zero there is no need to model rebate separately. On the other hand, if there are some commodities which are not under the VAT, i.e., consumers do not pay VAT. But if the producer pays VAT on their intermediate purchase, they do not get rebate and the tax rate is the same as for the households.

The general features of the model are in line with a standard (IFPRI) neoclassical model. In each sector, output is produced by using intermediate inputs, four types of labor (illiterate, semiskilled, skilled and highly skilled based on their educational background), two types of capital (physical and livestock) and three types of land (marginal, small scale and large scale). Production technology is represented by a nested tree structure[4]. A Leontief specification at the top combines value added and intermediate inputs. The value added is modeled by a nested Constant Elasticity of Substitution (CES) function between four types of labor, three types of land and two factors capital.[5] The aggregated intermediate input demands are modeled as Leontief functions.

The commodities in the domestic market are assumed to be imperfect substitutes i.e., CES between domestically produced and imported following the Armington specification. Domestic producers either sell their commodities in the domestic market or exports according to Constant Elasticity of Transformation (CET). The household consumption is maximized according to the Linear Expenditure System (LES) following the Stone-Geary utility function. This is in line with the standard tradition used in many CGE models. For model calibration with the LES demand function, parameter values for Frisch and expenditure elasticities are required[6].

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4 A nested structure of production technology is sketched in figure B.1

5 The elasticity value between CES aggregated capital and labor is assumed to be 0.8 by following Fontana (2004) who used these values for Bangladesh. The elasticity values for both the CES and CET are also borrowed from Fontana (2004) where agricultural commodities are assumed to have elasticity of substitution of 2, the manufacturing commodities have 1.5 and the services have 0.8 respectively.

6 By following Arndt et al (2002), the Frisch parameter value was chosen to be -1.6 for the urban non-poor households and -4 for rest of the households. Household's expenditure elasticity was assumed to be one for all the commodities.

We choose the consumer price index (CPI) as the numéraire. A flexible exchange rate clears the current account of the rest of the world. We have investment driven saving, where savings rates of domestic institutions are scaled to generate enough savings to finance exogenous investment quantities. We assume that capital is fully employed and sector specific. In the labor market closure, low skilled workers are assumed to be unemployed and mobile between the sectors. The unemployment is also modeled for semi-skilled workers but activity specific. The high skilled workers are assumed to be fully employed but activity specific.

### 3.2 Data

A Social Accounting Matrix (SAM) developed by Dorosh and Thurlow (2008) for Bangladesh is used as the core database for the CGE model calibration. The original Bangladesh SAM 2005 had 60 production sectors and here we have aggregated the SAM into 30 production sectors.[7] Households are divided into seven socioeconomic groups based on location and land endowment (rural) and skills (urban). In the rural areas agricultural households are grouped as landless farmer engaged in agricultural production), marginal farmers (farm households with less than half an acre of cultivated land), small scale farmers (households with between 0.5 and 2.5 acres of cultivated land), and large farmers (households with more than 2.5 acres of cultivated land).

[7] How the sectoral classification was done in SAM2005 is outlined in the appendix A1. For reporting purposes we have further aggregated the activities into seven sectors.

Table 1 Population and per capita income across household groups

| Household groups | Population share (%) | Food (% of spending) | Income share (%) | Per capita income (Bangladesh Taka) | Per capita income (US$) | VAT payment (% of income) |
|---|---|---|---|---|---|---|
| Rural areas | | | | | | |
| marginal farmer | 20.3 | 38.7 | 9.2 | 11932.1 | 186.4 | 1.9 |
| landless | 15.2 | 43.4 | 10.1 | 17676.6 | 276.2 | 2.0 |
| small farmer | 28.7 | 32.9 | 26.1 | 24007.6 | 375.1 | 1.8 |
| large farmer | 8.2 | 23.5 | 17.0 | 54952.6 | 858.6 | 1.6 |
| Urban areas | | | | | | |
| low-skilled | 19.3 | 41.5 | 14.4 | 19795.8 | 309.3 | 2.0 |
| semi-skilled | 5.7 | 39.7 | 12.0 | 55764.0 | 871.3 | 1.6 |
| high-skilled | 2.7 | 17.3 | 11.1 | 110767.6 | 1730.7 | 1.3 |

Source: Own calculation based on the information given in SAM 2005 for Bangladesh.[8]

The non-agricultural households are grouped as low skilled, semi-skilled and high skilled households. Table 1 gives an overview of the income shares and per capita income for each household group. The marginal farmers have lowest per capita income of US$186.4. They comprise the 20.3 percent of the population with 9.2 percent of income share. There is a significant difference in average incomes across the household groups. For example, average income in the urban high-skilled group is almost ten times higher compared to the marginal farmer.

In the original SAM taxes are collected on three accounts, i.e. direct tax, import tax and sales tax. The import tax is comprised of VAT, tariff, and customs duty at import level. The sales tax account combines VAT and excise tax at domestic level (Dorosh & Thurlow, 2008). In a first step we split the import tax and sales tax accounts into import tariff, a VAT account and an excise tax account across commodities and households. In a second step, we calculate the de facto VAT on certain commodity paid by different activities and consumers across non-exempted sectors[9]. Further adjustment in terms of total value for VAT both at import and domestic level, tariff and excise/supplementary duty was done by following Begum (2007). Table A2 shows the calculated effective VATs rate paid by households for different commodities. It is calculated by dividing total amount of VAT paid for each commodity by total amount of consumption expenditure

[8] The per capita income in US$ (2005) based on the exchange rate of 1 US$= 64 Bangladesh Taka.

[9] We assume that all households pay the same VAT rate on commodities subject to VAT.

excluding VAT for that commodity. The effective VAT rates are different from the official 15 percent as many of the goods and services are low rated and truncated. Moreover, the table reveals the prevailing VAT avoidance in the economy. For electricity it is higher than the official VAT rate because electricity is among one of those service sectors where 60 percent of the total VAT paid on input is credited (Rahman, 2010). It might be that the burden is transferred to the final consumer.

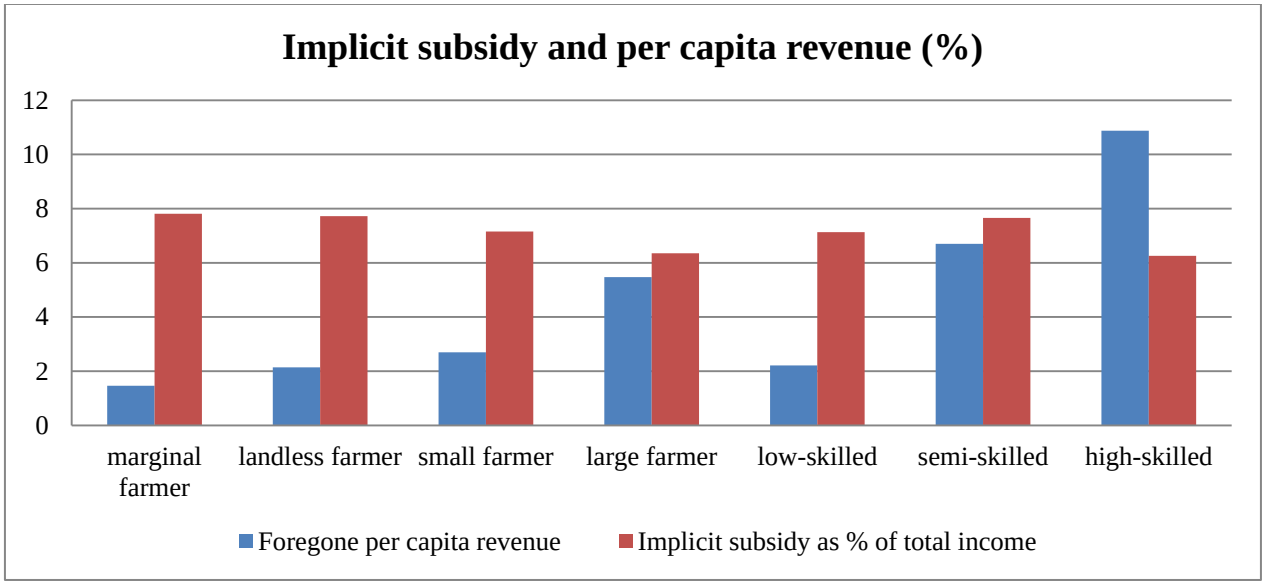
VAT in Bangladesh is of the consumption type (*ad valorem* basis) and is based on the destination principle (Mujeri & Khandaker, 1998). VAT is applied on domestic and imported goods[10] but exempted for basic food and agricultural products, animal products, poultry sector, agriculture inputs, cloths made of cotton and synthetics, malaria, TB/ cancer preventive medicine, homoeopathic medicine, family planning items, books and periodicals, etc. Services exempted from VAT include fundamental services for livelihood, social welfare services, services relating to culture, services relating to money and finance, transport services, personal services and other services than the above (Alam & Alam, 2008). All VAT paid on intermediate inputs and capital machinery is creditable against the VAT payable on the sale of domestic output. Exported goods are zero-rated, i.e. no VAT is charged on export sales, and VAT on all inputs used in the production of export goods is rebated. Even though the agricultural sectors are exempted from VAT, the Bangladesh Social Accounting Matrix (SAM) 2005 reveals that producers in the agricultural sector do not get rebate when they pay VAT on the purchase of their intermediate inputs. This is the outcome of a differentiated VAT system where the input VAT 'sticks' and the VAT acquires elements of a tax on production rather than consumption.

As mentioned earlier, the prevailing VAT system in Bangladesh is characterized of exemptions, reductions and zero-rating. Generally, these exemptions and reductions are made as an equity concern. As low income group normally has high expenditure share for food, hence, food is usually exempted from VAT. The implicit subsidy as forgone revenue from the VAT exemptions can be calculated as the amount of money each household does not need to pay in VAT due to the exemptions. We estimate the implicit subsidy based on information in the

[10] 15 percent VAT is applicable for all business and industrial units with annual turnover TK. 2 million and above.

SAM2005 and Rahman (2010) and Khan (2005) which provides detailed information on sectors exempted from VAT and information on which sectors that pay excise duties.

Figure 1: Calculated forgone per capita revenue and implicit subsidy for different households due to exemptions




Source: Own calculations based on SAM 2005

The implicit subsidy (from exemption of agriculture and food items), relative to income (figure 1), is greater for the low-income groups (around 8%) compared to the high-income groups (6%). As Keen (2013) emphasized, the high income group spends more on food in absolute term, therefore, the most of the forgone revenue by low rating or exempting commodities accrues to the high income group. In Figure 1 the absolute VAT-revenue foregone from these exemptions is large: on a per-capita (in US$) basis the subsidy is ten times greater for the high income group compared to the low income group.

From Table 1 it is seen that the low income households, to a large degree, spend a higher share of income on food. Moreover, based on our calculations (last column in Table 1) we see that low income households pay a high share of their income as VAT compared to the high income household groups. Also, all the households pay a high amount of income as VAT in the base case for the processed/ imported food products compared to other commodities. On the other hand, the share of consumption expenditure for these food products is not high. These food products are edible oil, processed sugar, other processed food and tobacco and beverages (see table A3).

The intuition would then be that VAT base broadening of including food in the VAT chain would adversely affect the low income households. Therefore, from the equity perspective we might want to exclude the food items from VAT. But such an exclusion would on the other hand, create cascading effects in the economy, mainly because producer of the exempted commodities do not get rebate on their input use (Keen, 2013). This exemption would also provide an implicit subsidy to the high income group. One way to avoid the problem of implicit subsidy to the high income group is to only exclude food items sold in the local markets from VAT and impose VAT on supermarkets food sectors. In reality, the poor households might not get hurt that much from an increase in the VAT rate on food if they buy their food on an informal or local market with a larger share of tax avoidance.

As the Bangladesh economy to a large extent is comprised of informal sectors, we will in this study assume that low income households mostly buy products from local market that might not be covered by the VAT net. The threshold for VAT obligation is a yearly turnover TK. 2 million and above. To capture that effect in the model we extend the SAM2005 by splitting the food sectors i.e., agricultural food, manufactured rice, edible oil, sugar and processed food and tobacco and beverages (see table A1 for detail information) into the local markets and supermarkets segments. We assume that low income households such as marginal farmers, small farmers, landless and low skilled buy food from the local market and high income households such as large farmers, semi-skilled and high skilled buy from supermarkets. The division into local markets and supermarkets was done based on the household's consumption expenditure share. That is, based on the consumption expenditure share of the low income and high income group the original food sectors were divided into local markets and supermarkets food sectors.

## 4. Simulation and Results

Is a uniform and general VAT on all commodities or VAT with exemptions preferable from the distributional perspective? To analyze the distributional and welfare aspects of the VAT reform we experiment with the four different simulations described in Table 2. All the scenarios are revenue neutral, which requires different VAT rates for different scenarios (see table A4).

The simulation results are evaluated according to equivalent variation (EV)[11] as one of the welfare indicators and are compared with Base.

**Table 2: Description of the simulation scenarios**

| Name | Description |
|---|---|
| **Base** | Business as usual scenario |
| **VAT1** | Broadening VAT base by including all the goods and services |
| **VAT2** | Broadening VAT base by exempting agricultural and food sectors |
| **VAT3** | Broadening VAT base by zero rating agricultural and food sectors |
| **VAT4** | Broadening VAT base by exempting agricultural and local market food sectors |

Base is a business as usual scenario that shows how much of VAT are paid by different actors in the economy, according to the base dataset Bangladesh SAM 2005. The simulation results are compared with this pre reform VAT base scenario, which is the initial equilibrium prevailing in the base year. A general and uniform VAT system equals a uniform consumer tax on all goods and services. It is less distortionary and might reduce administrative cost. In the VAT1 scenario, we eliminate the current exemptions on any goods and services and broaden the base by including all the commodities in VAT net. A 3.5 percent uniform VAT on all goods and services is sufficient to make a revenue neutral reform. When VAT base is broadened and imposed on all the goods and services (VAT1), we see (Table 3) that low income households pay more of their income share as VAT than the high income households.

[11] EV is evaluated as the income change at base year prices that would yield the same level of utility after simulation. The EV asks the question "How much money is a particular change equivalent to?" That is, EV is one of the welfare indicators by analyzing how the consumer's purchasing power is affected due to changes in income and prices. An increase in the EV would indicate an overall improvement in welfare.

**Table 3: Percentage share of income paid as VAT and Equivalent Variation (EV) for different simulations**

| | marginal farmers | landless farmers | small farmers | large farmers | low-skilled | semi-skilled | high-skilled | |
|---|---|---|---|---|---|---|---|---|
| | | | | VAT/Income (%) | | | | |
| Base | 1.9 | 2.0 | 1.8 | 1.6 | 2.0 | 1.6 | 1.3 | |
| VAT1 | 3.0 | 3.0 | 2.8 | 2.4 | 2.9 | 2.7 | 2.3 | |
| VAT2 | 1.9 | 1.7 | 2.0 | 2.0 | 1.6 | 1.7 | 2.1 | |
| VAT3 | 2.8 | 2.5 | 2.8 | 2.8 | 2.3 | 2.4 | 3.0 | |
| VAT4 | 1.7 | 1.5 | 1.7 | 2.7 | 1.4 | 3.1 | 2.5 | |
| | | | | Equivalent Variation as consumption expenditure (%) | | | | Total |
| VAT1 | 0.1 | 0.1 | 0.2 | 0.3 | 0.3 | 0.0 | -0.1 | 0.2 |
| VAT2 | 0.1 | 0.1 | 0.1 | 0.0 | 0.3 | 0.1 | -0.6 | 0.0 |
| VAT3 | 0.1 | 0.2 | 0.0 | -0.3 | 0.5 | 0.1 | -1.3 | 0.0 |
| VAT4 | 0.4 | 0.4 | 0.4 | -0.3 | 0.6 | -0.6 | -0.7 | 0.1 |

Source: Simulation results based on the model calibration

From the uniform and general VAT1 scenario, we see that welfare of the semi-skilled households remain unchanged and high-skilled households get worse off (Table 3). Welfare of all the households in the rural area improves but less distributional. This result is bit different from Hossain (1994) where the high income groups gained when the earlier excise taxes, import duties and sales taxes were replaced by uniform proportional VAT. In our base scenario, VAT was imposed at a non-uniform rate with many exemptions and reductions. Therefore, when a uniform VAT rate of 3.5 percent is imposed on all the goods and services, prices for goods which were earlier exempted, zero-rated or low rated would increase and which was VAT rated more than 3.5 percent would decrease (see Table A5). Hence, the overall change in the real income might be positive or negative. This explains partly, why the welfare of the high income households, especially for the high skilled, deteriorates. A major share of consumption expenditure for the high skilled group includes trade, hotel and financial services (broadly defined under other services). These services were mostly exempted from VAT in the pre-reform scenario.

For the equity concern, food is generally exempted from the VAT as it is assumed that members of the low income group spend more of their income on food than those in the high income group (Go et al, 2005, Keen, 2013). As it is seen in Table A3 for the case of Bangladesh, lower income groups spend a pretty big amount of income share on food. And also due to administrative difficulty, agriculture is exempted from VAT in the base scenario. Therefore, in the VAT2 simulation we exempt agriculture and all the food commodities from VAT. Consumers

pay zero VAT on agricultural products and on rice, pulses, other cereals, other oil, vegetables, spices, fruits, vegetables, fishes, sugar, beverages and tobacco and other food products. A uniform VAT rate of 4.7 percent is required to impose on all other goods and services both at domestic and import level to maintain the revenue neutrality. Here, we see that marginal farmer pay a little more percentage of their income as VAT compared to the land less households.

Welfare of the low income households in the rural area does not improve if we compare VAT2 with the scenario VAT1. And among the urban households only the welfare of the semi-skilled group improves. Even though the agricultural and food items are exempted, welfare of the households in the rural area is not improving significantly as they still purchase non-food commodities. On the other hand, even if the agricultural and food commodities are exempted now, there is some cascading effect as the producer of those commodities do not get rebate on their input purchased for production (Keen, 2013).

One way to remove this cascading effect is by zero rating the commodities. In scenario VAT3 food and agricultural products are zero rated. The difference between scenario VAT3 and the base scenario is that in the base food and agricultural products are exempted from VAT, and inputs used for the production of these commodities do not get rebate. In scenario VAT3 when food and agricultural commodities are zero rated, the final consumers do not pay any VAT on those commodities. On the other hand, the producer of those commodities get rebate. Since the producers get rebate, a revenue neutral reform would lead to a VAT rate of 6.8 percent. Still this is very low compared to the current official 15 percent rate. Welfare of the large farmers in the rural area and of the high skilled group in the urban area deteriorates. The equivalent consumption expenditure is more distributional.

Exemptions would provide implicit subsidies (as discussed in section 3.2) because they would transfer funds to the high income households. However, from the administrative point of view, VAT exemption is preferable to zero rating. Hence, we experiment further by running a scenario (VAT4) where agriculture and the local market food sectors are exempted from the VAT. We assume that the low-income households are more likely to buy from local markets with de facto zero-VAT and impose a VAT rate of 4.1 percent on rest of the goods and services in the economy including the supermarkets food sectors. The high-income households pay more of their income as VAT compared to the low-income households (as it was opposite for the base

scenario, see Table 3). For low income households EV is higher in VAT4 than in VAT1 since they do not pay VAT on food, compared to base and VAT2 and VAT3, EV improves from lower tax rate on other commodities.

## 5. Discussion

From the above three simulation scenarios we see that broadening of the VAT would have different impact on different household's welfare. Some groups get better off and some get worse off. A uniform and general VAT is more efficient and less administrative costly. It should also remove the cascading effect. The concern is more on implementation issues for any informal economy. For the equity concern, we study the scenario VAT2 by exempting the agricultural and food items from VAT. The overall welfare impact is not better than the scenario VAT1. Moreover, exemptions create cascading effect in the economy. Therefore, in the scenario VAT3 we have zero rated the food and agricultural commodities. The welfare equivalent to percentage change in household's consumption expenditure is preferable from a distributional perspective. A similar type of experiment was conducted by Hossain (1994) where a uniform VAT rate was imposed with zero rating on food items and also imposing additional excise duties on certain commodities. His analysis (by using Household's Income and Consumption Expenditure data) resulted into less regressive compared to a revenue neutral uniform and general VAT. However, Hossain (1994) also found that the low-income group loses and the high-income group gains, although the magnitudes were less compared to the uniform and general VAT reform.

From the distributional perspective and to avoid the implicit subsidy to the high-income groups the scenario VAT4 is conducted. Measured by the equivalent variation in terms of consumption expenditure (Table 3), the low-income groups both at rural and urban are even better off. But the large farmers, semi-skilled and high-skilled groups get worse off. This implies that the richer households purchase their food at the supermarkets and also spend a bigger share of their income on other commodities than food.

Among the four scenarios, welfare of the low-income households improves more and of the high-income households deteriorates more for the scenario VAT4. That is from the equity and distributional view point; a reform based on a uniform and general VAT with exemptions on agriculture and local market food sectors might be preferable.

Furthermore, we conducted sensitivity analysis by changing the expenditure elasticity values only for the food commodities. Values for Frisch parameter and expenditure elasticities for rest of the commodities remain same. We chose high and low elasticity values by following Ahmed and Shams (1993). They estimated the demand elasticities of Almost Ideal Demand System (AIDS) models for the rural households in Bangladesh. Their estimated parameter values for most of the food commodities vary between 0.5 to 1.5 except for meat and eggs. The demand elasticity was estimated to be 2.47 implying meat and eggs are luxury goods for the rural households. From the sensitivity analysis, we see that (table A7) all conclusions drawn in the paper would be the same with higher or lower elasticities.

## 6. Conclusions

The spread of value-added tax (VAT) in developing countries has been dramatic over the decade of 1990s. Adopted by more than 130 countries, including many of the poorest, VAT has been, and remains, the key of tax reform in many developing countries. While adopting VAT, there are arguments for and against uniform general VAT system. A uniform and general VAT on all commodities is considered to be efficient and less distortionary. On the other hand, from the distributional perspective many goods especially food are exempted from VAT net as low income people spend a high share of income on food. This paper analyzes income distribution and welfare impact of VAT reform for Bangladesh with taking the special consideration into local and super market food sectors.

Being a developing country with low tax-GDP ratio, reforming the existing tax structure is essential for Bangladesh. The challenge is how to redesign the VAT system without deteriorating the income distribution. We applied the CGE model by Bohlin (2010) to analyze effects from VAT reforms where all the simulations were made to keep the revenue unchanged.

Comparing the equivalent variations we see that a uniform and general VAT on all the goods and services is welfare improving. However, it is more about an implementation issue. For a low income country with a large informal sector, VAT avoidance is existent. For the equity concern food and agricultural commodities are exempted from VAT in Bangladesh. Moreover, there is a threshold for VAT compliance. Therefore, VAT broadening by exempting the

agriculture and local market food sector is justified in the presence of an informal economy with tax avoidance. The imposed VAT rate is much lower than the present official VAT rate.

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Appendix

**Table A1: Description of how the activities/commodities were aggregated**

| Original activities | Aggregated Activities |
|---|---|
| Rice Aus (local) | Agricultural Goods |
| Rice Aus (hyv) | |
| Rice Aman (local & trans) | |
| Rice Aman (hyv & hybrid) | |
| Rice Boro (local) | |
| Rice Boro (hyv & hybrid) | |
| Jute | |
| Other cash crops | |
| Livestock | |
| Poultry | |
| Sugarcane | |
| Wheat | |
| Other cereals | Agricultural Food |
| Pulses | |
| Rapeseed | |
| Other oil crops | |
| Spices | |
| Potatoes | |
| Vegetables | |
| Fruits | |
| Shrimp farming | |
| Other fishing | |
| Forestry | Nature |
| Mining & quarrying | |
| Rice milling (Aus) | Manufactured rice |
| Rice milling (Aman) | |
| Rice milling (Boro) | |
| Other cereal milling | |
| Edible oils | Edible oils |
| Sugar processing | Sugar and Other food |
| Other food processing | |

| Original Activities | Aggregated Activities |
|---|---|
| Beverages and tobacco | Beverages and tobacco |
| Leather & footwear | Leather & footwear |
| Jute textiles | Textile |
| Yarn | |
| Mill cloth | |
| Other cloth | |
| Ready-made garments | Ready-made garments |
| Knitwear | Other textile |
| Other textiles | |
| Wood & paper | Wood & paper |
| Chemicals | Chemicals |
| Fertilizers | Fertilizers |
| Petroleum products | Petroleum products |
| Non-metallic minerals | Non-metallic minerals |
| Metals products | Metals products |
| Machinery | Machinery |
| Other manufacturing | Other manufacturing |
| Construction | Construction |
| Natural gas | EGW |
| Electricity | |
| Water | |
| Retail & wholesale trade | Trade |
| Hotels & catering | Hotel |
| Transport | Transport |
| Communications | Communications |
| Business & real estate | Business & real estate |
| Financial services | Financial services |
| Community & social services | Community & social services |
| Public administration | Public administration |
| Education | Health and education |
| Health and social works | |

**Table A2: Average effective VAT rate for different Commodities paid by the households**

| Commodities | VAT rate | Commodities | VAT rate |
|---|---|---|---|
| Aus rice | | Leather & footwear | 0.13 |
| Aman rice | | Jute textiles | |
| Boro rice | | Yarn | |
| Wheat | | Mill cloth | 0.14 |
| Other cereals | | Other cloth | 0.00 |
| Jute | | Ready made garments | 0.02 |
| Sugarcane | | Knitwear | 0.12 |
| Other cash crops | | Other textiles | 0.12 |
| Pulses | | Wood & paper | 0.02 |
| Rapeseed | | Chemicals | 0.15 |
| Other oil crops | | Fertilizers | |
| Spices | | Petroleum products | 0.14 |
| Potatoes | | Non-metallic minerals | 0.01 |
| Vegetables | | Metals products | 0.15 |
| Fruits | | Machinery | |
| Livestock | | Other manufacturing | 0.07 |
| Poultry | | Construction | |
| Shrimp farming | | Natural gas | |
| Other fishing | | Electricity | 0.18 |
| Forestry | | Water | 0.09 |
| Mining & quarrying | | Retail & wholesale trade | |
| Rice milling (Aus) | | Hotels & catering | 0.04 |
| Rice milling (Aman) | 0.01 | Transport | 0.00 |
| Rice milling (Boro) | | Communications | 0.14 |
| Other cereal milling | 0.02 | Business & real estate | |
| Edible oils | 0.12 | Financial services | |
| Sugar processing | 0.12 | Community & social services | |
| Other food processing | 0.05 | Public administration | |
| Beverages and tobacco | 0.15 | Education | 0.01 |
| | | Health and social works | |

Source: Own calculation based on the Bangladesh SAM 2005.

**Table A3: Household's consumption expenditure share of income (%) for different commodities**

| | agriculture | food | prcssd/imp Food | textile | other manu | Services* | Transport | Other service |
|---|---|---|---|---|---|---|---|---|
| **marginal farmer** | 4.9 | 31.0 | 7.6 | 4.7 | 5.2 | 4.6 | 4.9 | 22.6 |
| **landless farmer** | 6.7 | 35.7 | 7.7 | 5.1 | 5.4 | 6.0 | 4.0 | 16.6 |
| **small farmer** | 4.5 | 25.7 | 7.1 | 4.5 | 6.5 | 5.5 | 4.5 | 21.2 |
| **large farmer** | 3.3 | 17.9 | 5.7 | 4.0 | 5.7 | 5.7 | 3.9 | 23.2 |
| **low-skilled** | 5.8 | 34.0 | 7.5 | 4.4 | 4.8 | 4.3 | 4.1 | 16.8 |
| **semi-skilled** | 3.5 | 33.5 | 6.2 | 3.8 | 4.6 | 5.2 | 4.5 | 17.9 |
| **high-skilled** | 2.1 | 12.5 | 4.8 | 3.8 | 3.4 | 4.6 | 4.6 | 29.3 |

Source: Own calculation based on the Bangladesh SAM 2005. */gas, electricity, water, health and education sectors are named as services.

**Table A4: Percentage of Tax-GDP ratio and different VAT rates as a result of the different simulations**

| | BASE | VAT1 (3.5) | VAT2 (4.7) | VAT3 (6.8) | VAT4 (4.1) |
|---|---|---|---|---|---|
| **Direct tax** | **3.3** | **3.3** | **3.3** | **3.3** | **3.3** |
| -Income tax | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| -Factor Tax | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 |
| **Indirect tax** | **6.7** | **6.7** | **6.6** | **6.6** | **6.6** |
| -VAT | 2.8 | 2.7 | 2.7 | 2.7 | 2.7 |
| Excise tax | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 |
| Import tax/customs duties | 2.7 | 2.8 | 2.8 | 2.8 | 2.8 |
| **Total Tax revenue** | **10.0** | **10.0** | **10.0** | **10.0** | **10.0** |

**Table A5: Percentage change in prices for households and producers for different simulations**

| | VAT1 | | VAT2 | | VAT3 | | | VAT4 | |
|---|---|---|---|---|---|---|---|---|---|
| Commodities | HH | Prod | HH | Prod | HH | Prod | Commodities | HH | Prod |
| Agri. Goods | 2.7 | -0.8 | 1.1 | 1.1 | 0.0 | 0.0 | Agri. Goods Loc | 0.8 | 0.8 |
| Agri. food | 2.2 | -1.2 | 0.9 | 0.9 | 0.0 | 0.0 | Agri. Goods Sup | 0.7 | 0.7 |
| Natural good | 2.9 | -0.6 | 1.6 | 1.6 | -0.2 | -0.2 | Agri. food Loc | 1.1 | 1.1 |
| Rice manuf | 1.8 | -1.2 | 0.8 | 1.2 | -0.5 | -0.1 | Agri. food Sup | 2.4 | 2.4 |
| Edible oil | -9.5 | 0.3 | -11.1 | 2.0 | -12.1 | 0.9 | natural good | 1.4 | 1.4 |
| Sugar & other food | -4.7 | 0.1 | -6.0 | 2.3 | -7.4 | 0.7 | Rice manu Loc | 1.2 | -0.2 |
| Beverage & Tobacco | -8.2 | 7.5 | -9.6 | 10.7 | -10.3 | 9.3 | Rice manu Sup | 2.4 | 1.6 |
| Leather | -9.1 | 0.8 | -7.2 | 6.5 | -6.3 | 0.7 | Edible oil Loc | 1.6 | -11.5 |
| Textile | -13.2 | -2.2 | -11.2 | 3.5 | -10.2 | -1.9 | Edible oil Sup | -8.1 | -8.1 |
| RMG | 0.6 | -1.0 | 1.9 | 3.8 | 3.2 | -1.6 | Sugar & other food Loc | 2.1 | -7.4 |
| Other textile | -9.4 | -0.4 | -7.2 | 5.7 | -6.2 | -0.1 | Sugar & other food Sup | -2.6 | -4.8 |
| Wood process | -0.5 | -3.9 | 1.5 | 1.5 | 2.7 | -3.8 | Beverage & Tobacco Loc | 9.7 | 9.7 |
| Chemicals | -12.9 | -15.9 | -10.8 | -10.8 | -9.9 | -15.7 | Beverage & Tobacco Sup | -6.9 | 13.4 |
| Fertilizer | 1.0 | -2.4 | 3.4 | 3.4 | 4.5 | -2.1 | Leather | -7.9 | 5.8 |
| Petrolium | -23.8 | -26.4 | -21.8 | -21.8 | -21.1 | -26.1 | Textile | -10.9 | 2.7 |
| Nonmetal | 2.2 | 0.2 | 3.9 | 5.5 | 5.1 | -0.1 | RMG | 1.4 | 3.3 |
| Metal | -13.4 | -16.3 | -11.5 | -11.5 | -10.5 | -16.2 | Other textile | -8.0 | 4.8 |
| Machinaries | 2.9 | -0.6 | 5.5 | 5.5 | 6.6 | -0.2 | Wood process | 0.8 | 0.8 |
| Othe manu | -3.3 | -6.6 | -1.6 | -1.6 | -0.3 | -6.7 | Chemicals | -11.5 | -11.5 |
| Construction | 1.4 | -2.0 | 3.1 | 3.1 | 4.6 | -2.1 | Fertilizer | 2.6 | 2.6 |
| EGW | -1.9 | -5.6 | -0.1 | -0.4 | 0.0 | -6.8 | Petrolium | -22.5 | -22.5 |
| Trade | 3.2 | -0.3 | 4.5 | 4.5 | 6.3 | -0.5 | Nonmetal | 3.3 | 3.3 |
| Hotel | -0.8 | -0.5 | 1.6 | 5.5 | 2.7 | -0.2 | Metal | -12.2 | -12.2 |
| Transport | 3.1 | -0.4 | 4.5 | 4.5 | 6.2 | -0.6 | Machinaries | 4.6 | 4.6 |
| Communications | -6.8 | 2.4 | -5.9 | 7.0 | -4.8 | 1.3 | Othe manu | -2.2 | -2.2 |
| Business & Real Est | 1.8 | -1.6 | 2.1 | 2.1 | 2.7 | -3.8 | Construction | 2.5 | 2.5 |
| Financial serv | 3.0 | -0.5 | 5.3 | 5.3 | 6.3 | -0.4 | EGW | 1.2 | -3.5 |
| Community & social servc | 2.4 | -1.1 | 3.4 | 3.4 | 4.9 | -1.7 | Trade | 3.9 | 3.9 |
| Public adm | 1.9 | -1.6 | 3.3 | 3.3 | 5.0 | -1.7 | Hotel | 0.8 | 4.6 |
| Health & Edu | 2.0 | -1.3 | 2.3 | 2.5 | 2.9 | -3.5 | Transport | 3.9 | 3.9 |
| | | | | | | | Communications | -6.4 | 6.5 |
| | | | | | | | Business & Real Est | 2.0 | 2.0 |
| | | | | | | | Financial serv | 4.5 | 4.5 |
| | | | | | | | Community & social servc | 2.9 | 2.9 |
| | | | | | | | Public adm | 2.7 | 2.7 |
| | | | | | | | Health & Edu | 1.9 | 2.4 |

**Table A6: Household's percentage share of income paid as VAT for different commodities by different simulations**

| | Agric | food | procss/imp Food | textile | other manu | servcs | Trnsprt | Other serv | Total Share |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Base | | | | |
| marginal farmer | | 0.08 | 0.88 | 0.22 | 0.53 | 0.05 | 0.00 | 0.15 | 1.91 |
| landless farmer | | 0.10 | 0.92 | 0.25 | 0.53 | 0.04 | 0.00 | 0.16 | 2.01 |
| small farmer | | 0.07 | 0.78 | 0.22 | 0.54 | 0.06 | 0.00 | 0.17 | 1.84 |
| large farmer | | 0.04 | 0.59 | 0.21 | 0.53 | 0.06 | 0.00 | 0.15 | 1.59 |
| low-skilled | | 0.09 | 0.93 | 0.19 | 0.51 | 0.04 | 0.00 | 0.21 | 1.97 |
| semi-skilled | | 0.05 | 0.70 | 0.18 | 0.42 | 0.08 | 0.00 | 0.20 | 1.63 |
| high-skilled | | 0.03 | 0.48 | 0.18 | 0.39 | 0.08 | 0.00 | 0.17 | 1.32 |
| | | | | | VAT1 | | | | |
| marginal farmer | 0.17 | 1.07 | 0.28 | 0.16 | 0.18 | 0.16 | 0.17 | 0.78 | 2.97 |
| landless farmer | 0.23 | 1.23 | 0.28 | 0.18 | 0.19 | 0.21 | 0.14 | 0.58 | 3.03 |
| small farmer | 0.15 | 0.89 | 0.26 | 0.16 | 0.23 | 0.19 | 0.16 | 0.74 | 2.76 |
| large farmer | 0.11 | 0.62 | 0.20 | 0.14 | 0.20 | 0.20 | 0.13 | 0.81 | 2.40 |
| low-skilled | 0.20 | 1.17 | 0.27 | 0.15 | 0.17 | 0.15 | 0.14 | 0.59 | 2.85 |
| semi-skilled | 0.12 | 1.14 | 0.23 | 0.13 | 0.16 | 0.18 | 0.15 | 0.62 | 2.75 |
| high-skilled | 0.07 | 0.43 | 0.34 | 0.13 | 0.12 | 0.16 | 0.16 | 1.01 | 2.26 |
| | | | | | VAT2 | | | | |
| marginal farmer | | | | 0.22 | 0.17 | 0.21 | 0.23 | 0.59 | 1.95 |
| landless farmer | | | | 0.24 | 0.17 | 0.28 | 0.19 | 1.75 | 1.73 |
| small farmer | | | | 0.21 | 0.18 | 0.25 | 0.21 | 0.63 | 1.96 |
| large farmer | | | | 0.19 | 0.17 | 0.26 | 0.18 | 0.84 | 1.97 |
| low-skilled | | | | 0.20 | 0.16 | 0.20 | 0.19 | 1.33 | 1.61 |
| semi-skilled | | | | 0.18 | 0.16 | 0.24 | 0.20 | 0.85 | 1.67 |
| high-skilled | | | | 0.18 | 0.14 | 0.21 | 0.21 | 1.08 | 2.11 |
| | | | | | VAT3 | | | | |
| marginal farmer | | | | 0.31 | 0.35 | 0.31 | 0.32 | 0.91 | 2.79 |
| landless farmer | | | | 0.34 | 0.37 | 0.39 | 0.27 | 0.89 | 2.48 |
| small farmer | | | | 0.30 | 0.43 | 0.36 | 0.30 | 0.96 | 2.81 |
| large farmer | | | | 0.27 | 0.37 | 0.37 | 0.26 | 0.86 | 2.81 |
| low-skilled | | | | 0.29 | 0.33 | 0.29 | 0.28 | 0.94 | 2.31 |
| semi-skilled | | | | 0.25 | 0.31 | 0.34 | 0.29 | 0.90 | 2.38 |
| high-skilled | | | | 0.26 | 0.23 | 0.30 | 0.30 | 1.17 | 3.01 |
| | | | | | VAT4 | | | | |
| marginal farmer | | | | 0.19 | 0.15 | 0.19 | 0.20 | 0.92 | 1.71 |
| landless farmer | | | | 0.21 | 0.15 | 0.24 | 0.16 | 0.68 | 1.52 |
| small farmer | | | | 0.18 | 0.16 | 0.22 | 0.18 | 0.86 | 1.72 |
| large farmer | | 0.72 | 0.24 | 0.16 | 0.14 | 0.23 | 0.16 | 0.94 | 2.67 |
| low-skilled | | | | 0.18 | 0.14 | 0.18 | 0.17 | 0.69 | 1.41 |
| semi-skilled | | 1.33 | 0.27 | 0.15 | 0.14 | 0.21 | 0.18 | 0.72 | 3.06 |
| high-skilled | | 0.50 | 0.20 | 0.16 | 0.12 | 0.19 | 0.18 | 1.18 | 2.54 |

Source: Own calculation based on the Bangladesh SAM 2005. */gas, electricity, water, health and education sectors

**Table A7: Sensitivity Analysis (Equivalent Variation for three different elasticity values)**

| **Elasticities** | **0.5** | | | | **1** | | | | **1.5** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | VAT1 | VAT2 | VAT3 | VAT4 | VAT1 | VAT2 | VAT3 | VAT4 | VAT1 | VAT2 | VAT3 | VAT4 |
| Marg farmer | 0.1 | 0.0 | 0.1 | 0.4 | 0.1 | 0.1 | 0.1 | 0.4 | 0.1 | 0.1 | 0.1 | 0.4 |
| Landless far | 0.1 | 0.1 | 0.2 | 0.4 | 0.1 | 0.1 | 0.2 | 0.4 | 0.2 | 0.2 | 0.3 | 0.5 |
| Small farmer | 0.2 | 0.0 | -0.1 | 0.4 | 0.2 | 0.1 | 0.0 | 0.4 | 0.2 | 0.1 | 0.0 | 0.4 |
| Large farmer | 0.3 | 0.0 | -0.3 | -0.4 | 0.3 | 0.0 | -0.3 | -0.3 | 0.3 | 0.0 | -0.3 | -0.3 |
| Low-skilled | 0.2 | 0.3 | 0.4 | 0.6 | 0.3 | 0.3 | 0.5 | 0.6 | 0.3 | 0.3 | 0.5 | 0.6 |
| Semi-skilled | 0.0 | 0.0 | 0.1 | -0.7 | 0.0 | 0.1 | 0.1 | -0.6 | 0.1 | 0.1 | 0.1 | -0.5 |
| High-skilled | -0.1 | -0.6 | -1.3 | -0.8 | -0.1 | -0.6 | -1.3 | -0.7 | 0.0 | -0.6 | -1.3 | -0.7 |
| Total | 0.1 | 0.0 | -0.1 | 0.1 | 0.2 | 0.0 | 0.0 | 0.1 | 0.2 | 0.1 | 0.0 | 0.1 |

Appendix B

**A complete mathematical formulation of the model**

A.1 SETS

Sets defining different kinds of accounts in the SAM

| | |
|---|---|
| AC | global set for model accounts - aggregated microsam accounts |
| ACNT(AC) | all elements in AC except TOTAL |
| A(PNI) | activities |
| C(AC) | commodities |
| F(AC) | factors |
| FCAP(F) | capital |
| FLAB(F) | labour |
| FLAND(F) | natural capital |
| H(INSD) | households |
| INS(P) | institutions |
| INSD(PNI) | domestic institutions |
| INSNG(INS) | non-government institutions |
| P(AC) | all purchasers |
| PNE(PNI) | all purchasers except exports and investments |
| PNI(P) | all purchasers except investments |

Sets used to define the nest structures

| | |
|---|---|
| CGH | set to define commodity groups in household consumption |

Sets used to define different kinds of commodities

| | |
|---|---|
| CD(C) | commodities with domestic sales of output |
| CDN(C) | commodities without domestic sales of output |
| CE(C) | exported commodities |
| CEN(C) | non-export commodities |

| | |
|---|---|
| CGOV(C) | commodities consumed by government |
| CLEO(C) | commodities with Leontief technology |
| CM(C) | imported commodities |
| CMN(C) | non-imported commodities |
| CSUBI(C) | commodities with ces technology in production |
| CTR(C) | commodities used for trade margins |
| CX(C) | commodities with output |

## A.2 VARIABLES

Variables where the first letter is P are prices, Q quantities and Y income.

| | |
|---|---|
| CPI | consumer price index (based on purchaser prices) |
| DMPC | change in marginal propensity to consume for selected inst |
| DTINS | change in domestic institution tax share |
| EG | total current government expenditure |
| $EH_h$ | household consumption expenditure in household *h* |
| EXR | exchange rate |
| FSAV | The financial account in domestic currency, note that positive investments abroad are equal to negative financial account. If the variable FSAV is positive, foreigners invest more in the domestic country than domestic citizens invests abroad. |
| $FTM_{c,pni}$ | fix part of trade margins on commodity *c* purchased of *pni* |
| $FTMINV_{c,a}$ | fix part of trade margins on investments in *c* in activity *a* |

| | |
|---|---|
| GADJ | government demand scaling factor |
| GOVSHR | govt consumption share of absorption |
| $GRPROF_{a,fcap}$ | gross return from capital *fcap* in activity *a* |
| GSAV | government savings |
| $IADJ_{a,fcap}$ | investment scaling factor in activity a for capital *fcap* |
| IADJM | general investment scaling factor |
| INVSHR | investment share of absorption |
| $MPC_{insd}$ | marginal propensity to consume for dom non-gov institution *insd* |
| MPCADJ | savings rate scaling factor |
| $PA_a$ | output price of activity *a* |
| $PCAP_a$ | price of aggregate capital in activity *a* |
| $PCGA_{a,cga}$ | price of intermediate aggregate *cga* in activity *a* |
| $PCGH_{h,cgh}$ | price of aggregated commodity *cgh* in household *h* |
| $PDS_c$ | supply price for com'y *c* produced & sold domestically |
| $PE_c$ | price of exports of commodity *c* in national currency |
| $PI_{a,fcap}$ | price per unit of investments of *fcap* in activity *a* |
| $PLAB_a$ | price of labour aggregate in activity *a* |
| $PLEO_a$ | price of aggregate Leontief intermediates in activity *a* |
| $PM_c$ | price of imports of commodity *c* in national currency |
| $PQ_c$ | price of composite good *c* (basic price i.e. without taxes and trade margins) |

| | |
|---|---|
| $PSC_a$ | price of production less Leontief inputs in activity *a* |
| $PWE_c$ | world price of exports of commodity *c* in foreign currency |
| $PWM_c$ | world price of imports of commodity *c* in foreign currency |
| $PX_c$ | average output price of commodity *c* |
| $QA_a$ | level of domestic activity in activity *a* |
| $QAGGINV_{a,fcap}$ | quantity of aggregate investments *fcap* in activity *a* |
| $QCAP_a$ | quantity of capital aggregate in activity *a* |
| $QCGA_{a,cga}$ | quantity of aggregated commodity *cga* in activity *a* |
| $QCGH_{h,cgh}$ | quantity of aggregated commodity *cgh* in household *h* |
| $QD_c$ | quantity of domestic sales of commodity *c* |
| $QE_c$ | quantity of exports of commodity *c* |
| $QF_{f,a}$ | quantity demanded of factor *f* from activity *a* |
| $QFS_f$ | quantity of factor supply of factor *f* |
| $QG_c$ | quantity of government consumption of commodity *c* |
| $QH_{h,c,cgh}$ | quantity consumed of com *c* by household *h* in group *cgh* |
| $QINT_{c,a}$ | quantity of intermediate use of commodity *c* in activity *a* |
| $QINTA_{csubi,a,cga}$ | quantity of intermediate use of *csubi* in activity *a* in commodity group *cga* |
| $QINV_{c,a,fcap}$ | quantity of investment demand for commodity *c* in activity *a* to be used in formation of capital |

| | |
|---|---|
| | good *fcap* |
| $QLAB_a$ | quantity of labour aggregate in activity *a* |
| $QLEO_a$ | quantity of aggregate Leontief intermediate inputs in activity *a* |
| $QM_c$ | quantity of imports of commodity *c* |
| $QQ_c$ | quantity of composite goods supply of commodity *c* |
| $QSC_a$ | quantity of production less Leontief inputs in activity *a* |
| $QT_c$ | quantity of trade and transport demand for commodity *c* |
| $QX_c$ | quantity of aggregate marketed output of commodity *c* |
| TABS | total absorption |
| TFIN | rate of direct tax on financial return |
| TFINADJ | scaling factor for tax on returns from financial assets |
| $TFLAB_{flab}$ | rate of direct tax on labour (soc sec and income tax) |
| $TINS_{insd}$ | rate of direct tax on domestic institutions *insd* |
| TINSADJ | direct tax scaling factor |
| TLABADJ | labour tax scaling factor |
| $TM_{c,pni}$ | trade margins on commodity *c* when purchased by *pni* (always domestic currency, even for exports) |
| $TMI_{c,a}$ | trade margins on commodity *c* when purchased by activity *a* for investments |
| WALRAS | savings-investment imbalance (should be zero) |
| | Walras squared |

WALRASSQR

| | |
|---|---|
| $WEALTH_h$ | the wealth of household *h* |
| $WF_f$ | economy-wide wage (rent) for factor *f* |
| $WFDIST_{f,a}$ | factor wage distortion variable for factor *f* in activity *a* |
| $YFIN_a$ | total financial income of domestic financial asset *a* |
| $YFLAB_{flab}$ | total labour income from domestic and foreign activities |
| YG | government income |
| $YH_h$ | household income in household $_h$ |
| $YIFIN_{insd}$ | financial income of institution $_{insd}$ |

A.3 PARAMETERS

Parameters other than tax rates

| | |
|---|---|
| $\alpha_a^{cap}$ | shift parameter for CES production function capital in activity *a* |
| $\alpha_a^{cga}$ | shift parameter for ces production function cga in activity *a* |
| $\alpha_h^{cgh}$ | shift parameter in nested ces utility function for household *h* |
| $\alpha_a^{lab}$ | shift parameter for CES production function labour in activity *a* |
| $\alpha_c^{q}$ | shift parameter for Armington function for commodity *c* |
| $\alpha_a^{sc}$ | shift parameter for CES prod. function qsc nest in activity *a* |
| $\alpha_a^{sub}$ | shift parameter for CES prod. function sub nest in activity *a* |
| $\alpha_a^{subi}$ | shift parameter for CES production function subi in activity *a* |
| $\alpha_c^{t}$ | shift parameter for CET function for commodity *c* |
| $\beta_{cgh,h}$ | marg. share of hhd cons on com. group *cga* for household *h* |
| $cint_h$ | the marginal increase in consumption from an increase in wealth in household *h* |
| $cwts_{c,h}$ | consumer price index weights for commodity *c* in household *h* |

$\delta_c^{arm}$ share parameter for CET function for commodity *c*

$\delta_{fcap,a}^{cap}$ share parameter for CES activity production function capital for capital good *fcap* in activity *a*

$\delta_c^{cet}$ share parameter for Armington function for commodity *c*

$\delta_{csubi,a,cga}^{cga}$ share parameter for ces activity production function cga for commodity *csubi* in commodity group *cga* in activity *a*

$\delta_{h,c,cgh}^{cgh}$ share parameter in nested ces utility for commodity *c* in commodity group *cgh* in household *h*

$\delta_{flab,a}^{lab}$ share parameter for CES activity production function labour for labour category *flab* in activity *a*

$\delta_c^q$ share parameter for import demand equation for commodity *c*

$\delta_a^{sc}$ share parameter for CES production function qsc nest in activity *a*

$\delta_c^t$ share parameter for export supply equation for commodity *c*

*factinret* return on foreign assets

*FAP* foreign asset position this year

*finin* financial income from abroad in foreign currency

$finout_a$ share of foreign income in total financial income from activity *a*

*FLP* foreign liabilities this year

*FNAP* foreign net asset position this year

$ftmq_{c,pni}$ fix part of trade margins in quantities on commodity *c*

$ftmqinv_{c,a}$ fix part of trade margins in quantities on investments of commodity *c* in activity *a*

$\gamma_{cgh,h}$ subsist. consumption of commodity group *cgh* for household *h*

$ica_{c,a}$ Leontief intermediate input *c* per unit of aggregate Leontief intermediate in activity *a*

$inta_a$ aggregate Leontief intermediate input share in activity *a*

$isc_a$ aggregate substitutable intermediate input share in activity *a*

$iwts_{c,a,fcap}$ quantity commodity *c* in one unit of investment in capital good *fcap* in activity *a*

$labin_{flab}$ income from abroad of labour category *flab* in foreign currency

| | |
|---|---|
| $labout_{flab}$ | share of foreign income of labour category *flab* in total income of labour category *flab* from domestic activities |
| $mpc01_{insd}$ | 0-1 parameter for potential flexing of savings rates |
| $mpcbar_{insd}$ | marg. prop. to consume for dom non-gov inst *insd* (exog part) |
| $\overline{qg}_c$ | exogenous (unscaled) government demand for commodity *c* |
| $\overline{qinv}_{c,a,fcap}$ | Investment demand in base year for commodity *c* in the formation of capital good *fcap* in activity *a* |
| $qdst_c$ | inventory investment in commodity *c* |
| $qpermit_a$ | domestic supply of $CO_2$ permits to activity *a* |
| *return* | required rate of return on investments |
| $\rho_c^{arm}$ | Armington function exponent for commodity *c* |
| $\rho_a^{cap}$ | CES production function exponent capital in activity *a* |
| $\rho_c^{cet}$ | CET function exponent for commodity *c* |
| $\rho_a^{cga}$ | CES production function exponent cga in activity *a* |
| $\rho_{h,cgh}^{cgh}$ | CES expenditure system exponent for commodity group *cgh* in household *h* |
| $\rho_a^{lab}$ | CES production function exponent labour in activity *a* |
| $\rho_c^{q}$ | Import demand function exponent for commodity *c* |
| $\rho_a^{sc}$ | CES production function exponent qsc nest in activity *a* |
| $\rho_a^{sub}$ | CES production function exponent qsub nest in activity *a* |
| $\rho_a^{subi}$ | CES production function exponent subst. intermediates in activity *a* |
| $\rho_c^{t}$ | Export demand function exponent for commodity *c* |
| $shifl_{insd,flab}$ | share of dom. institution i in income of labour *flab* |
| $shifin_{insd,a}$ | share of dom. institution i in income from the capital return of activity *a* |
| $shifinin_{insd}$ | share of dom. institution i in financial income from abroad |
| $shtr_c$ | share of commodity *c* in transactions |
| $supernum_h$ | LES supernumerary income |
| $\theta_{a,c}$ | yield of commodity *c* per unit of activity *a* |
| $tins01_{insd}$ | 0-1 parameter for potential flexing of dir tax rates |

$trnsfr_{p,p}$ transfers from purchaser *p* to purchaser *p* (All transfers from rest of the world are in foreign currency; all transfers to rest of he world are in domestic currency)

$trq_{c,pni}$ quantity of trade margins when commodity *c* is purchased by purchaser *pni*

$trqi_{c,a}$ quantity of trade margins in investments when commodity *c* is invested in activity *a*

Tax rates

$ta_a$ rate of tax on producer gross output value in activity *a*

$te_c$ rate of tax on exports of commodity *c*

$tflbar_{flab}$ rate of direct tax on labour category *flab* in base (soc sec tax)

*tfinbar* rate of direct tax on financial return in base

$tinsbar_{insd}$ rate of direct tax on dom inst *insd* in base

$tar_c$ rate of import tariff on commodity *c*

$tq_{c,pni}$ unit tax on commodity *c* when purchased by purchaser *pni*

$tqi_{c,a}$ unit tax on commodity *c* when used as investment in activity *a*

$tv_{c,pni}$ value tax on commodity *c* when purchased by purchaser *pni*

$tvi_{c,a}$ value tax on commodity *c* when used as investment in activity *a*

## A.4 EQUATIONS

Price Block

The price block consists of two equations that determine import and export prices in domestic currency, one equation that defines CPI and several equations that ensure that price multiplied by quantity of an aggregate is equal to prices multiplied by quantities of its components.

### Import price

$$PM_C = pwm_C \cdot (1 + tar_C) \cdot EXR \qquad c \in CM$$

The price in domestic currency for an imported good is equal to the world market price of that good, multiplied with 1 plus the ad valorem import tariff and the exchange rate defined as domestic currency over foreign currency.

**Export price**

$$PE_c = pwe_c \cdot (1 - te_c) \cdot EXR - TM_{c,'row'} \qquad c \in CE$$

The price in domestic currency for an exported good is equal to the world market price of that good, multiplied with 1 minus the ad valorem export tax and the exchange rate defined as domestic currency over foreign currency.

**Absorption**

$$PQ_c \cdot QQ_c = PDS_c \cdot QD_C + PM_c \cdot QM_c \qquad c \in CD$$

The money paid for domestic absorption is equal to the domestic price multiplied with total quantity but must also be equal to the money paid for imports plus the money paid for goods that are produced and sold domestically.

**Value of domestic production**

$$PX_c \cdot QX_c = PDS_c \cdot QD_C + PE_c \cdot QE_c \qquad c \in CX$$

Total sales of domestic firms are equal to their sales in the domestic market plus their sales in the international market.

**Activity price from demand side**

$$PA_a = \sum_{c \in C} PX_c \cdot \theta_{a,c} \qquad a \in A$$

The price of total output in an activity is equal to the sum of the price of each produced commodity times the output share of that commodity in one unit of production.

**Input price of aggregate Leontief intermediates**

$$PLEO_a = \sum_{cleo \in C} \left( \left( PQ_{cleo} + tq_{cleo,a} + TM_{cleo,a} \right) \cdot \left( 1 + tv_{cleo,a} \right) \right) \cdot ica(cleo, a) \qquad a \in A$$

The price of the aggregate of those intermediate goods that are used in fixed proportion to output is equal to the sum of the share of that commodity in one unit of output times the basic price of each commodity together with taxes and trade margins.

**Activity price from supply side**

$$\begin{aligned} &PA_a \cdot (1 - ta_a) \cdot QA_a + Qpermit_a \cdot PPERMIT \cdot EXR \\ &= PSC_a \cdot QSC_a + PLEO_a \cdot QLEO_a + \sum_{c \in C} FTM_{c,a} \cdot (1 + tv_{c,a}) \end{aligned} \qquad a \in A$$

Total income in an activity is equal to the price of its output times the quantity of output less activity taxes plus received emission permits and it is also equal to the total cost in the activity. Total cost is equal to fix trade margins and the cost of the two main aggregates in the production function.

**Price of substitutable costs plus operating surplus**

$$PSC_a \cdot QSC_a = PCAP_a \cdot QCAP_a + PSUB_a \cdot QSUB_a \qquad a \in A$$

**Price of substitutable costs less Capital**

$$PSUB_a \cdot QSUB_a = PLAB_a \cdot QLAB_a + PSUBI_a \cdot QSUBI_a \qquad a \in A$$

The sum of labour cost and cost for substitutable intermediates.

**Consumer price Index**

$$CPI = \sum_{c \in C} \sum_{h \in H} (1 + tv_{c,h}) \cdot \left( PQ_c + tq_{c,h} + TM_{c,h} \right) \cdot cwts_{c,h}$$

**Cost of emission permits per unit of fossil fuel used**

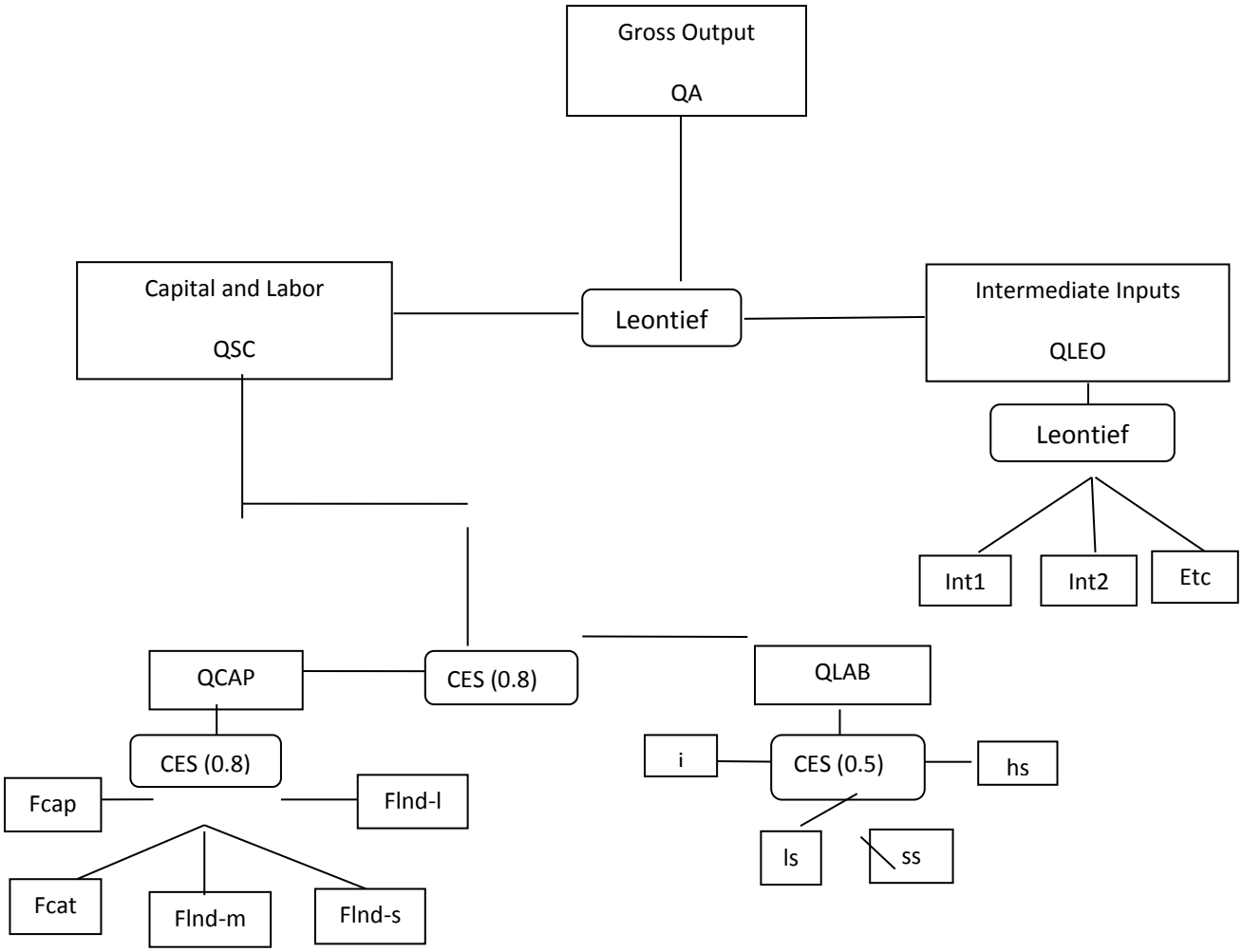
$$PT_{fossilperm,aets} = carbshare_{fossilperm} \cdot PPERMIT \cdot EXR \qquad \begin{matrix} a \in AETS \\ c \in FOSSILPERM \end{matrix}$$

**Production Block**

The nest structure of the production function is shown in Figure 3.1. At top nest the substitutable inputs, QSC, are aggregated together with the intermediate goods that are used in fixed proportion to output, QLEO. QCAP is aggregated from the different kinds of capital goods. There are two sets of capital goods, FCAP and FCAT for real capital and FLAND are for natural capital. QLAB is aggregated from the different categories of labour, FLAB.

At the top of the nest there is Leontief technology and the rest of the nest is CES. The elasticity of substitution has to be symmetric i.e. the same between every pair of CGA, as well as between every pair of commodities included in the same CGA group. In the same way the elasticity of substitution has to be the same between every two kinds of capital or labour.

**Figure B.1 Nest structure of production functions**




Total output in an activity may consist of more than one kind of commodity; the parameter defines the share of a specific commodity in total output of an activity. The same commodity may be produced in different industries and the make matrix equation aggregates the total output of a commodity from the output in specific industries. For simplicity, the production function is divided into several equations aggregating together the different aggregates. The production block consists of these equations and their first order conditions together with the make matrix equation.

**Demand for aggregate Leontief intermediates**

$$QLEO_a = inta_a \cdot QA_a \qquad a \in A$$

The total quantity of intermediate inputs that are used in fixed proportions to output is always equal to that fixed proportion.

**Demand for substitutable intermediates plus the capital stock**

$$QSC_a = isc_a \cdot QA_a \qquad a \in A$$

The quantity of all inputs with substitution possibilities has to be a constant share of output since they cannot be substitutes for anything else.

**QSC part of production function**

$$QSC_a = \alpha_a^{sc} \cdot \left( \delta_a^{sc} \cdot QCAP_a^{-\rho_a^{sc}} + \left(1 - \delta_a^{sc}\right) \cdot QSUB_a^{-\rho_a^{sc}} \right)^{\frac{-1}{\rho_a^{sc}}} \qquad a \in A$$

The quantity of total substitutable inputs is a CES function of capital and other substitutable inputs.

**QSUB part of production function** $a \in A$

$$QSUB_a = \alpha_a^{sub} \cdot \left( \delta_a^{sub} \cdot QLAB_a^{-\rho_a^{sub}} + \left(1 - \delta_a^{sub}\right) \cdot QSUBI_a^{-\rho_a^{sub}} \right)^{\frac{-1}{\rho_a^{sub}}}$$

**QSUB part of production function for activities not using substitutable intermediates**

$$QSUB_a = QLAB_a \qquad a \in A$$

The quantity of substitutable inputs other than capital is a CES function of total labour and total substitutable intermediate inputs if substitutable intermediate inputs are used in the activity. For other activities it is simply equal to aggregated labour.

**Aggregation of different capital good**

$a \in A$

$$QCAP_a = \alpha_a^{cap} \cdot \left( \sum_{fcap \in FCAP} \delta_{fcap,a}^{cap} \cdot QF_{fcap,a}^{-\rho_a^{cap}} + \sum_{fcap \in FCAP} \delta_{land,a}^{land} \cdot QF_{fland,a}^{-\rho_a^{cap}} \right)^{\frac{-1}{\rho_a^{cap}}}$$

The total quantity of capital is equal to a CES function of all different capital goods.

**Aggregation of different groups of intermediate goods**

$$QSUBI_a = \alpha_a^{subi} \left( \sum_{cga \in CGA} \delta_{a,cga}^{subi} \cdot QCGA_{a,cga}^{-\rho_a^{subi}} \right)^{\frac{-1}{\rho_a^{subi}}} \qquad a \in A$$

The total quantity of substitutable intermediate goods is a CES function of the different commodity groups defined by the user.

**Aggregation of different labour categories**

$$QLAB_a = \alpha_a^{lab} \left( \sum_{flab \in FLAB} \delta_{flab,a}^{lab} \cdot QF_{flab,a}^{-\rho_a^{slab}} \right)^{\frac{-1}{\rho_a^{lab}}} \quad a \in A$$

The total quantity of labour is a CES function of the different labour categories defined by the user.

**Aggregation of different substitutable intermediates**

$$a \in A$$
$$cga \in CGA$$

$$QCGA_{a,cga} = \alpha_a^{cga} \left( \sum_{csubi \in CSUBI} \delta_{csubi,a,cga}^{cga} \cdot QINTA_{csubi,a,cga}^{-\rho_{a,cga}^{cga}} \right)^{\frac{-1}{\rho_{a,cga}^{cga}}}$$

The total quantity in each commodity group is a CES function of the specific substitutable intermediate goods.

**First order condition QSC part of PF**

$$\frac{QCAP_a}{QSUB_a} = \left( \frac{\grave{}PSUB_a}{PCAP_a} \cdot \frac{\delta_a^{sc}}{1-\delta_a^{sc}} \right)^{\frac{1}{1+\rho_a^{sc}}} \qquad a \in A$$

**First order condition QSUB part of PF**

$$\frac{QLAB_a}{QSUBI_a} = \left( \frac{\grave{}PSUBI_a}{PLAB_a} \cdot \frac{\delta_a^{sub}}{1-\delta_a^{sub}} \right)^{\frac{1}{1+\rho_a^{sub}}} \qquad a \in A$$

**First order condition capital**

$$a \in A$$
$$f \in CAP$$

$$WF_{fcap} \cdot \overline{WFDIST}_{fcap,a} = PCAP_a \cdot QCAP_a \cdot$$
$$\left( \sum_{fcap' \in FCAP'} \delta_{cap',a}^{cap} \cdot QF_{cap',a}{}^{-\rho_a^{cap}} + \sum_{fland' \in FLAND'} \delta_{fland',a}^{land} \cdot QF_{fland',a}{}^{-\rho_a^{cap}} \right)^{-1} \cdot \delta_{fcap,a}^{cap} \cdot QF_{fcap,a}{}^{-\rho_a^{cap}-1}$$

This is the demand equation for a specific capital good

**First order condition land**

$$a \in A$$
$$f \in FLAND$$

$$WF_{fland} \cdot \overline{WFDIST}_{fland,a} = PCAP_a \cdot QCAP_a \cdot$$
$$\left( \sum_{fcap' \in FCAP'} \delta_{cap',a}^{cap} \cdot QF_{cap',a}{}^{-\rho_a^{cap}} + \sum_{fland' \in FLAND'} \delta_{fland',a}^{land} \cdot QF_{fland',a}{}^{-\rho_a^{cap}} \right)^{-1} \cdot \delta_{fland,a}^{land} \cdot QF_{fland,a}{}^{-\rho_a^{cap}-1}$$

This is the demand equation for a specific natural capital

**First order condition labour**

$$a \in A$$
$$f \in FLAB$$

$$WF_{flab} \cdot \overline{WFDIST}_{flab,a} =$$

$$PLAB_a \cdot QLAB_a \cdot \left( \sum_{flab' \in FLAB'} \delta^{lab}_{flab',a} \cdot QF_{flab',a}{}^{-\rho^{lab}_a} \right)^{-1} \delta^{lab}_{flab,a} \cdot QF_{flab,a}{}^{-\rho^{lab}_a - 1}$$

This is the demand equation for a specific category of labour

**First order condition intermediate aggregates**

$$a \in A$$
$$f \in FLAB$$

$$PCGA_a = PSUBI_a \cdot QSUBI_a \cdot$$
$$\left( \sum_{cga' \in CGA'} \delta^{subi}_{a,cga'} \cdot QCGA_{a,cga'}{}^{-\rho^{subi}_a} \right)^{-1} \delta^{subi}_{a,cga} \cdot QCGA_{a,cga}{}^{-\rho^{subi}_a - 1}$$

**First order condition substitutable intermediates**

$$a \in A$$
$$c \in CSUBI$$
$$cga \in CGA$$

$$\left(1 + tv_{csubi,a}\right)\left(PQ_{csubi} + tq_{csubi,a} + TM_{csubi,a}\right) = PCGA_{a,cga} \cdot QCGA_{a,cga} \cdot$$
$$\left( \sum_{csubi' \in CSUBI'} \delta^{cga}_{csubi',a,cga} \cdot QINTA_{csubi',a,cga}{}^{-\rho^{cga}_a} \right)^{-1} \delta^{cga}_{csubi,a,cga} \cdot QINTA_{csubi,a,cga}{}^{-\rho^{cga}_a - 1}$$

This is the demand equation for a specific substitutable intermediate good. For every commodity group this equation would only be defined for the commodities in that group.

**Demand for substitutable intermediate goods**

$$QINT_{csubi,a} = \sum_{cga \in CGA} QINTA_{csubi,a,cga} \qquad \begin{array}{l} a \in A \\ c \in CSUBI \end{array}$$

In practise this is not a sum since for every commodity QINTA is only defined for one CGA. This equation is needed only because we need the variable to be defined with and without the cga index.

**Disaggregated demand for Leontief intermediates**

$$QINT_{cleo,a} = ica_{cleo,a} \cdot QLEO_a \qquad \begin{array}{l} a \in A \\ c \in CLEO \end{array}$$

This is the demand equation for a specific Leontief intermediate good The parameter ica defines the share of every specific commodity in one unit of aggregate Leontief intermediates.

**Aggregation of output from different industries (the make matrix)**

$$QX_c = \sum_{a \in A} \theta_{a,c} \cdot QA_a \qquad c \in C$$

Total output of a specific commodity is the sum of the produced quantity of that commodity in all activities. The model assumes no substitution between outputs i.e., secondary products must be produced in specific proportions to the main product. If this assumption is regarded unrealistic the user may prefer to redistribute secondary products using BWSEC.GMS

**Investment block**

Demand for commodities for investment purposes is determined in the investment block. Moreover gross return and unit price of investments are calculated.

**Gross return to a specific real capital**

$$GRPROF_{a,\,fcap} = WF_{fcap} \cdot \overline{WFDIST}_{\,fcap,a} \cdot QF_{fcap,a} \quad a \in A$$

This equation calculates gross return of a specific capital good in a specific activity.

**Gross return to a specific natural capital**

$$GRRENT_{a,\,fland} = WF_{fland} \cdot \overline{WFDIST}_{\,fland,a} \cdot QF_{fland,a} \qquad a \in A$$

This equation calculates gross return of a specific capital good in a specific activity.

**Investment demand**

$$QINV_{c,a,\,fcap} = IADJM \cdot IADJ_{a,\,fcap} \cdot \overline{qinv}_{c,a,\,fcap} \quad \begin{matrix} a \in A \\ c \in C \\ fcap \in FCAP \end{matrix}$$

In simulations with variable investments IADJM adjusts so that investments equal saving. In simulations with fixed investments IADJM is fixed and investment is the same as in the base scenario.

**Unit price of aggregate investment**

$$PI_{a,\,fcap} = \sum_{c \in C} \left(1 + tvi_{c,a}\right)\left(PQ_c + tqi_{c,a} + TMI_{c,a}\right) \cdot iwts_{c,a,\,fcap} \quad \begin{matrix} a \in A \\ fcap \in FCAP \end{matrix}$$

The price of a real capital good is equal to the sum of the prices of the goods it is made of times the share of these goods in one unit of the capital good.

**Aggregate investment demand**

$$QAGGINV_{a,\,fcap} = \sum_{c \in C} \frac{(1+tvi_{c,a})(PQ_c + tqi_{c,a} + TMI_{c,a}) \cdot QINV_{c,a,\,fcap}}{PI_{a,\,fcap}} \qquad \begin{array}{l} a \in A \\ fcap \in FCAP \end{array}$$

The quantity of investment is equal to the money spent on investments divided by the price per unit of that capital good.

**Trade block**

The trade block consists of the Armington and CET functions and their first order conditions.

**CET function**

$$QX_c = \alpha_c^t \cdot \left(\delta_c^{cet} \cdot QE_c^{\rho_c^{cet}} + (1-\delta_c^{cet}) \cdot QD_c^{\rho_c^{cet}}\right)^{\frac{1}{\rho_c^{cet}}} \qquad c \in (CE \cap CD)$$

The CET equation addresses the allocation of marketed domestic output to two alternative markets, the domestic market and exports. It reflects the assumption of imperfect transformability between the two destinations.

**Export - domestic supply ratio**

$$\frac{QE_c}{QD_c} = \left(\frac{PE_c}{PDS_c} \cdot \frac{1-\delta_c^t}{\delta_c^t}\right)^{\frac{1}{1+\rho_c^t}} \qquad c \in (CE \cap CD)$$

Producers are assumed to allocate their selling efforts between the domestic and foreign market according to the relative prices on the different markets. Note that this is not the f.o.c of the CET equation if $\rho_c^t \neq \rho_c^{cet}$ giving a possibility of relaxing the assumption of optimal behaviour in international trade.

**Output Transformation for domestically sold outputs without exports and for exports without domestic sales**

$$QX_C = QD_C + QE_C \qquad c \in (CD \cap CEN) \cup (CE \cap CDN)$$

**Armington equation**

$$QQ_c = \alpha_c^q \cdot \left(\delta_c^{arm} \cdot QM_c^{-\rho_c^{arm}} + (1-\delta_c^{arm}) \cdot QD_c^{-\rho_c^{arm}}\right)^{-\frac{1}{\rho_c^{arm}}} \qquad c \in (CM \cap CD)$$

The Armington equation assumes imperfect substitutability between domestic production and imports.

**Import - domestic supply ratio**

$$\frac{QM_c}{QD_c} = \left(\frac{PDS_c}{PM_c} \cdot \frac{\delta_c^q}{1-\delta_c^q}\right)^{\frac{1}{1+\rho_c^q}} \qquad c \in (CM \cap CD)$$

The choice between domestic production and imports will depend on their relative price. Note that this is not the f.o.c of the Armington equation if $\rho_c^q \neq \rho_c^{arm}$ giving a possibility of relaxing the assumption of optimal behaviour in international trade.

**Armington equation for non-imported outputs and non-produced imports**

$$QQ_C = QD_C + QM_C \qquad c \in (CD \cap CMN) \cup (CM \cap CDN)$$

Trade Margins Block

The trade margins block determines the cost of retail trade services and allocates the payment for them to the market of retail trade services.

**Demand for trade margins (retail service)**

$$c \in CTR$$

$$QT_{ctr} = shtr_{ctr} \cdot \left( \begin{array}{l} \sum_{a \in A} \sum_{c \in C} trq_{c,a} \cdot QINT_{c,a} + \sum_{h \in H} \sum_{c \in C} trq_{c,h} \cdot \sum_{cgh \in CGH} QH_{h,c,cgh} \\ + \sum_{a \in A} \sum_{c \in C} trqi_{c,a} \cdot \sum_{fcap \in FCAP} QINV_{c,a,fcap} + \sum_{c \in C} trq_{c,gov} \cdot QG_c \\ + \sum_{c \in C} trq_{c,row} \cdot QE_c + \sum_{pni \in PNI} \sum_{c \in C} ftmq_{c,pni} + \sum_{a \in AI} \sum_{c \in C} ftmqinv_{c,a} \end{array} \right)$$

The sum of all trade margins for all purchasers and commodities defines total demand for retail services.

**Determination of trade margins**

$$TM_{c,pni} = \sum_{ctr \in CTR} trq_{c,pni} \cdot shtr_{ctr} \cdot PQ_{ctr} \qquad \begin{array}{l} c \in C \\ pni \in PNI \end{array}$$

**Determination of trade margins on investments**

$$TMI_{c,a} = \sum_{ctr \in CTR} trqi_{c,a} \cdot shtr_{ctr} \cdot PQ_{ctr} \qquad \begin{array}{l} c \in C \\ a \in A \end{array}$$

The size of the trade margin will depend on the amount of retail service that is required, when this actor purchases this commodity, and the unit price of retail services.

**Fix trade margins**

$$FTM_{c,pni} = \sum_{ctr \in CTR} ftmq_{c,pni} \cdot shtr_{ctr} \cdot PQ_{ctr} \qquad \begin{array}{l} c \in C \\ pni \in PNI \end{array}$$

**Fix TM on investments**

$$FTMINV_{c,a} = \sum_{ctr \in CTR} ftmqinv_{c,a} \cdot shtr_{ctr} \cdot PQ_{ctr} \qquad \begin{array}{l} c \in C \\ a \in A \end{array}$$

Fix trade margins are independent of the quantity purchased, and are used to get a more realistic price of a marginal unit of the good.

Institution block

The institution block determines the income and expenditure of households and government.

**Labour income**

$$YFLAB_{flab} = \sum_{a \in A} WF_{flab} \cdot WFDIST_{flab,a} \cdot QF_{flab,a} + labin_{flab} \qquad flab \in FLAB$$

Total labour income is equal to the wage rate times the amount of labour in each activity plus labour income from abroad.

**Income of financial assets**

$$YFIN_a = \sum_{fcap=FCAP} GRPROF_{a,fcap} + \sum_{fland=FLAND} GRRENT_{a,fland} \qquad fin \in FIN$$

Income of the shares in an activity is equal to the operating surplus, which will be equal to the return to real capital and the value of emission permits allocated to this activity. All profits are assumed to be paid out to the households.

**Institutional labour income**

$$flab \in FLAB$$
$$i \in INSD$$
$$YIFL_{i,flab} = shifl_{i,flab} \cdot \left(1 - tflab_{flab}\right) \cdot \left( YFLAB_{flab} - labout_{flab} \cdot \sum_{a \in A} WF_{flab} \cdot wfdist_{flab,a} \cdot QF_{flab,a} \right)$$

Labour income to a specific institution (most often household) is equal to this institution's share of labour income less labour taxes and labour income to other countries.

**Institutional financial income**

$$i \in INSD$$
$$YIFIN_i = \sum_{a \in A} \left[ shifin_{i,a} \cdot \left(1 - tfin\right) \cdot \left(1 - finout_a\right) \cdot YFIN_a \right] + shifinin_i \cdot \left(1 - tfin\right) \cdot finin \cdot EXR$$

Financial income of a specific institution is equal to this institution's share of the return from domestic financial assets less capital taxes and financial income to other countries, plus this institution's share of the return from foreign assets less taxes.

**Income of domestic households** $h \in H$

$$YH_h = \sum_{flab \in FLAB} YIFL_{h,flab} + YIFIN_h + trnsfr_{h,gov} \cdot CPI + trnsfr_{h,row}$$

Total income of a domestic household is equal to the sum of labour income, financial income, transfers from the government and transfers from the rest of the world.

**Wealth of the household** $h \in H$

$$WEALTH_h = shifinin_h \cdot FAP + \sum_{a \in A} shifin_{h,a} \cdot (1 - finout_a) \cdot \left( \sum_{fcap \in FCAP} \frac{GRPROF_{a,fcap}}{deprate_{a,fcap} + RETURN} + \sum_{fland \in FLAND} \frac{GRRENT_{a,fland}}{RETURN} \right)$$

Total wealth of a household is equal to the value of its share of domestic financial assets plus the value of its share of foreign assets.

**Household consumption expenditure** $h \in H$

$$EH_h = MPC_h \cdot \left( (1 - TINS_h) \cdot YH_h - trnsfr_{row',h} \right) + cint_h \cdot WEALTH_h$$

Total consumption in a household is equal to MPC times its income less taxes and transfers to other countries plus an intercept that is dependent on the wealth of the household.

Total consumption is allocated to the different commodity groups, CGH, by a linear expenditure system. The household has a fixed quantity of each CGH determined from $\gamma_{cgh,h}$, the subsidiary or habit consumption. The money left is spent on the different commodity groups according to fix budget shares determined from $\beta_{cgh,h}$. Within each CGH the consumption is allocated to the specific commodities from a CES utility function.

**The EH Les equations** $h \in H$, $cgh \in CGH$

$$QCGH_{h,cgh} \cdot PCGH_{h,cgh} = PCGH_{h,cgh} \cdot \gamma_{cgh,h} + \beta_{cgh,h} \cdot \left( EH_h - \sum_{c' \in C'} FTM_{c',h} (1 + tv_{c',h}) - \sum_{cgh' \in CGH'} PCGH_{h,cgh'} \cdot \gamma_{cgh',h} \right)$$

This is the LES equation defining fixed shares of spending of the different commodity groups for that part of household expenditure that is not used up for subsidiary consumption.

**Household's commodity demand**

$h \in H$
$cgh \in CGH$
$c \in C$

$$\left(1+tv_{c,h}\right)\left(PQ_c + tq_{c,h} + TM_{c,h}\right) = QCGH_{h,cgh} \cdot PCGH_{h,cgh}$$
$$\cdot \left( \sum_{c' \in C'} \delta_{h,c',cgh}^{cgh} \cdot QH_{h,c',cgh}^{-\rho_{h,cgh}^{cgh}} \right)^{-1} \cdot \sum_{c \in C} \delta_{h,c,cgh}^{cgh} \cdot QH_{h,c,cgh}^{-\rho_{h,cgh}^{cgh}-1}$$

The first order condition of the CES equation determines the demand for a specific commodity.

**Government consumption demand**

$$QG_c = GADJ \cdot qbarg_c \qquad c \in CGOV$$

GADJ is a fixed adjustment factor for the size of government consumption. It becomes flexible in static simulations when siclos 4 or 5 is used, where it is instead government consumption as a share of domestic absorption that is constant.

**Government revenue**

$$YG = \sum_{h \in H} TINS_h \cdot YH_h + tfin \cdot \left( \sum_{a \in A} \left(1 - finout_a\right) \cdot YFIN + finin \cdot EXR \right)$$
$$+ \sum_{flab \in FLAB} tflab_{flab} \cdot \left( YFLAB_{flab} - labout_{flab} \cdot \sum_{a \in A} WF_{flab} \cdot WFDIST_{flab,a} \cdot QF_{flab,a} \right)$$
$$+ \sum_{c \in CM} tar_c \cdot pwm_c \cdot QM_c \cdot EXR + \sum_{c \in CE} te_c \cdot pwe_c \cdot QE_c \cdot EXR$$
$$+ \sum_{flab \in FLAB} YIFL_{gov,flab} + YIFIN_{gov} + trnsfr_{gov,row}$$
$$+ \sum_{a \in A} \sum_{c \in C} \left[ tq_{c,a} \cdot QINT_{c,a} + tv_{c,a} \cdot \left(PQ_c + tq_{c,a} + TM_{c,a}\right) \cdot QINT_{c,a} \right]$$
$$+ \sum_{a \in A} ta_a \cdot PA_a \cdot QA_a + \sum_{h \in H} \sum_{c \in C} \sum_{cgh \in CGH} \left[ tq_{c,h} \cdot QH_{h,c,cgh} + tv_{c,h} \cdot \left(PQ_c + tq_{c,h} + TM_{c,h}\right) \cdot QH_{h,c,cgh} \right]$$
$$+ \sum_{a \in A} \sum_{c \in C} \left[ tqi_{c,a} \cdot \sum_{fcap \in FCAP} QINV_{c,a,fcap} + tvi_{c,a} \cdot \left(PQ_c + tqi_{c,a} + TMI_{c,a}\right) \cdot \sum_{fcap \in FCAP} QINV_{c,a,fcap} \right]$$
$$+ \sum_{c \in C} \left[ tq_{c,gov} \cdot QG_c + tv_{c,gov} \cdot \left(PQ_c + tq_{c,gov} + TM_{c,gov}\right) \cdot QG_c \right]$$
$$+ \sum_{pni \in PNI} \sum_{c \in C} \left( tv_{c,pni} FTM_{c,pni} \right) + \sum_{a \in A} \sum_{c \in C} \left( tvi_{c,a} FTMINV_{c,a} \right)$$

Government revenue is the sum of all kinds of taxes plus factor income and transfers from abroad.

**Government expenditure**

$$EG = \sum_{c=C} \left(PQ_c + tq_{c,gov} \cdot TM_{c,gov}\right) \cdot \left(1 + tv_{c,gov}\right) \cdot QG_c$$
$$+ \sum_{h=H} trnsfr_{h,gov} \cdot \overline{CPI} + trnsfr_{row,gov} + \sum_{c=C} FTM_{c,gov} \cdot \left(1 + tv_{c,gov}\right)$$

Government expenditure is equal to government consumption plus transfers to households and transfers to other countries.

System constraints block

The system constraints block consists of the market equilibrium conditions, balance of payments, and the savings investments balance.

**Factor market**

$$\sum_{a \in A} QF_{f,a} = QFS_f \qquad f \in F$$

Total factor supply is equal to factor supply in all activities.

**Market for retail trade services**

$$c \in CTR \qquad QQ_{ctr} = \sum_{a \in A} QINT_{ctr,a} + \sum_{h \in H} \sum_{cgh \in CGH} QH_{h,ctr,cgh} + QG_{ctr}$$
$$+ \sum_{a \in A} \sum_{fcap \in FCAP} QINV_{ctr,a,fcap} + qdst_{ctr} + QT_{ctr}$$

**Commodity market for commodities other than retail services**

$$c \in CNTR$$

$$QQ_c = \sum_{a \in A} QINT_{c,a} + \sum_{h \in H} \sum_{cgh \in CGH} QH_{h,c,cgh} + QG_c + \sum_{a \in A} \sum_{fcap \in FCAP} QINV_{c,a,fcap} + qdst_c$$

Supply equals demand in all commodity markets. There are two different market equilibrium equations for commodity markets since QT is only defined for retail services.

**Balance of payments**

$$\sum_{c \in C} pwm_c \cdot QM_c \cdot EXR + \sum_{flab \in FLAB} labout_{flab} \cdot \sum_{a \in A} WF_{flab} \cdot WDIST_{flab,a} \cdot QF_{flab,a}$$
$$+ \sum_{a \in A} finout_a \cdot YFIN_a + \sum_{i \in I} trnsfr_{row,i} + NETPERMIT$$
$$= \sum_{c \in C} pwe_c \cdot QE_c \cdot EXR + \sum_{flab \in FLAB} labin_{flab} + finin \cdot EXR + \sum_{i \in I} trnsfr_{i,row} + FSAV$$

If we have a surplus in the current account, it has to be equal to foreign saving (financial account). Note that factor payments to rest of the world are dependent on domestic wage levels and profit rates.

**Government balance**

$$YG = EG + GSAV$$

Government saving is equal to income less expenditure.

**Direct institutional tax rates**

$$h \in H$$

$$TINS_h = tinsbar_h \cdot (1 + TINSADJ \cdot tins01_h) + DTINS \cdot tins01_h$$

The direct income tax can be adjusted in specific closures. In govclos 2 DTINS is adjusted while in govclos 3 TINSADJ is adjusted.

**Labour tax rates**

$$TFLAB_{flab} = tflbar_{flab} \cdot (1 + TLABADJ) \qquad f \in FLAB$$

In govclos 4 the labour tax rate is adjusted through the adjustment factor TLABADJ for the government saving to remain constant.

**Capital tax rates**

$$TFIN = tfinbar \cdot (1 + TFINADJ)$$

In govclos 5 the capital tax rate is adjusted through the adjustment factor TFINADJ for the government saving to remain constant.

**Saving investment balance**

$$\sum_{h \in H} \left[ (1 - MPC_h) \cdot ((1 - TINS_h) \cdot YH_h - trnsfr_{row',h}) - cint_h \cdot WEALTH_h \right]$$
$$+GSAV + FSAV =$$
$$\sum_{c \in C} \sum_{a \in A} (PQ_c + tqi_{c,a} + TMI_{c,a}) \cdot (1 + tvi_{c,a}) \cdot \sum_{fcap \in FCAP} QINV_{c,afcap}$$
$$+ \sum_{c \in C} PQ_c \cdot qdst_c + \sum_{a \in A} \sum_{c \in C} \left[ (1 + tvi_{c,a}) \cdot FTMINV_{c,a} \right] + walras$$

Total saving is always equal to total investments if the Walras law holds. If it does not hold the variable Walras will not be equal to zero and an error message will be received.

**Closure block**

The closure block includes the equations needed to implement the different macro closures.

**Household's marginal propensity to consume**

$$h \in H$$

$$MPC_h = mpcbar_h \cdot \left(1 + MPCADJ \cdot mpc01_h\right) + DMPC \cdot mpc01_h$$

In specific closures the marginal propensity to consume is adjusted.

**Total absorption**

$$TABS = \sum_{h \in H} \sum_{c \in C} \left(1 + tv_{c,h}\right) \cdot \left(PQ_c + tq_{c,h} + TM_{c,h}\right) \cdot \sum_{cgh \in CGH} QH_{h,c,cgh}$$
$$+ \sum_{c \in C} \left(1 + tv_{c,gov}\right) \cdot \left(PQ_c + tq_{c,gov} + TM_{c,gov}\right) \cdot QG_c$$
$$+ \sum_{c \in C} \sum_{a \in A} \sum_{fcap \in FCAP} \left(1 + tvi_{c,a}\right) \cdot \left(PQ_c + tqi_{c,a} + TMI_{c,ga}\right) \cdot QINV_{c,a,fcap} + \sum_{c \in C} PQ_c \cdot qdst_c$$

**Ratio of investments to absorption**

$$INVSHR \cdot TABS = \sum_{c \in C} \sum_{a \in A} \sum_{fcap \in FCAP} \left(1 + tvi_{c,a}\right) \cdot \left(PQ_c + tqi_{c,a} + TMI_{c,a}\right) \cdot QINV_{c,a,fcap}$$
$$+ \sum_{c \in C} \sum_{a \in A} FTMINV_{c,a} \cdot \left(1 + tvi_{c,a}\right) + \sum_{c \in C} PQ_c \cdot qdst_c$$

**Ratio of government consumption to absorption**

$$GOVSHR \cdot TABS = \sum_{c \in C} \left(PQ_c + tq_{c,gov} + TM_{c,gov}\right) \cdot \left(1 + tv_{c,gov}\right) \cdot QG_c + \sum_{c \in C} \left(1 + tv_{c,gov}\right) \cdot FTM_{c,gov}$$

The last three equations are needed in closures where investments and government consumption are not fixed in quantities but as shares of domestic absorption.