Taxing Sugar and Sugary Products to Reduce Obesity: A CGE Assessment of Several Tax Policies *

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Abstract

Adopting an original approach with the use of a Computable General Equilibrium trade model, we propose a new assessment of several tax policies on sugar and sugary products to fight obesity. We emphasize our study on the effects of these taxes on production and trade. We compare an homogeneous tax on the final consumption of products with high sugar content against a tax on sugar as an intermediate consumption, associated or not with a complementary specific tax on final consumptions of sugar. The most efficient tax scheme appears to be the specific tax on sugar as an intermediate consumption in the production of food products, complemented by a tax of the same amount on final consumptions of sugar. A tax on the final consumption of sugar rich products leads to a reduction of the sugar intake through a decrease of the quantities of sugar rich products consumed, whereas a tax on sugar as an intermediate consumption mostly reduce the sugar content of food products. Such tax schemes would be in most cases detrimental to the agricultural and food processing sectors of most countries. These negative impacts can be reinforced when the taxes are implemented collectively around the World, highlighting some possible competitive effects.

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1 Introduction

Obesity and diet-related chronic diseases have become a major concern in many countries around the World. According to the World Health Organization (WHO), most of the world's population live in countries where overweight and obesity kills more people than underweight.The increasing consumption of sugar and sweeteners has been identified as one of the main cause of this epidemic. Therefore, WHO strongly recommends reducing the intake of free sugars to less than 10% of total energy intake and even suggests a further reduction below 5% of total energy intake (WHO, 2015). In order to reach those objective, taxation of sugar and sugar rich products is suggested and has already been applied in a number of states (Mexico, Finland, France, Hungary...). Numerous studies in the economic and medical literature have evaluated the effects of such kinds of taxes on demand and health as well as their regressivity. However, the estimated efficiency and the possible outcomes of such kinds of taxes vary greatly from one study to another.

We can identify multiple causes for this heterogeneity of results. Firstly, we observe a high heterogeneity across studies in the chosen demand elasticities and in particular own-price elasticities for sweet and sugary demand. Those elasticities are key elements in any assessment of a sugar tax as they enable to calibrate in which extent the demand for a product will react to change in prices or in consumer incomes (Zhen et al., 2014). If many early studies on taxes of sweet and sugary products were based mainly on the effect of own-price elasticity (Dharmasena et al., 2011), a growing literature also tries to include substitution effects across and within sectors. Indeed, even when consumers respond positively to a tax by reducing their consumption of the taxed products, they can possibly switch to some other non-taxed products that will reduce or even cancel the positive health effects of the tax (Haines, 1999; Zhen et al., 2014; Finkelstein et al., 2010; Fletcher et al., 2010; Smed et al., 2007; Adam and Smed, 2012). However, some studies also found a relatively small extent of this effect (Dharmasena et al., 2011; Finkelstein et al., 2013; Zhen et al., 2011). Another possibility of substitution that can reduce the effect of a tax is within-sector substitution. In particular, in response to a price increase, the households can reduce the quality of the products they consume rather than the quantity (McKelvey, 2011) and so the efficiency of the tax will be lowered (Silva et al., 2013). Miao et al. (2011) also emphasize the importance of within-group substitution towards lighter products when a nutrient tax is applied. They demonstrate that omitting this within-group substitution as most studies do undermines greatly the health benefits of such a tax.

Numerous tax designs have been studied in the literature that differ mostly by the range of products to which they apply. A tax on sugar-sweetened beverages has been much studied (Gustavsen, 2005; Finkelstein et al., 2010; Lin et al., 2010, 2011; Adam and Smed, 2012; Finkelstein et al., 2013; Silva et al., 2013; Powell, 2014) as these products have been identified as one of the major contributor to obesity (Smith, 2010). However, because of various substitution patterns, most studies that have tested different schemes agree that taxes that target a broader range of products such as nutrient taxes are much more efficient than the ones taxing only certain categories of products (Smed et al., 2007; Finkelstein et al., 2010; Harding and Lovenheim, 2014; Adam and Smed, 2012). Miao et al. (2012) also evaluate the effects of taxing caloric sweeteners as inputs in comparison of taxing final products rich in sweeteners. They find that the tax on inputs is the most efficient as it enables to reduce both the final consumption of sugar rich products as well as reducing the quantities of sugar and corn sweeteners used in their composition. Bonnet and Réquillart (2011) also finds similar results with an excise tax based on sugar content of soft drinks.

Most studies on sugar taxes ignore firm strategic pricing and assume that any tax implemented is fully shifted to the consumer (Bonnet and Réquillart, 2011; Okrent and Alston, 2012; Dharmasena et al., 2011; Allais et al., 2010; Zhen et al., 2014). Nonetheless, Cawley and Frisvold (2017) finds that only 43% of a tax on sugar-sweetened beverages in Berkeley, California is passed on to the consumers. Bonnet and Réquillart (2011) evaluate different tax schemes while further specifying the supply side and find that ignoring strategic pricing can lead to misestimate the impact of taxation by 15% to 40%. Dharmasena et al. (2011) even find that the consideration of the supply side is more important than the one of substitution effects and that strategic pricing can severely affect the benefits of a tax. A few other studies gives further specifications of the sugar and sugary products supply and in particular the substitution in inputs between cane-sugar and High-Fructose Corn Syrup (HFCS) as do Hailu et al. (2013); Miao et al. (2012); Okrent and Alston (2012). However, the outcomes of such taxes on the productive sectors and on trade have never been analyzed.

In order to give supplementary insights in the search for the optimal policy to tackle obesity, we propose a new assessment of several tax policy options on sugar and sugary products. We focus on the effects on production and trade by taking an original approach with the use of a global Computable General Equilibrium (CGE) trade model. Using detailed trade data, we modified the MIRAGRODEP CGE trade model to differentiate the sectors containing sugars into high and low sugar content sub-sectors. This modification enables us to better account for substitution between similar products with different sugar contents. We developed a national index of global sugar intake in order to follow the direct and indirect consumption of sugar. We compare different sugar tax schemes by computing the tax levels that will enable to reach a 5% of reduction of this sugar index. We compare an homogeneous tax on final consumption of products with high sugar contents against a tax on sugar as an intermediate consumption, associated or not to a complementary specific tax on final consumptions of sugar .

For most countries, the most efficient tax scheme appears to be a specific tax on intermediate consumptions of sugar, complemented by a tax of the same amount on final consumptions of sugar. In most cases, a sole tax on sugar as an intermediate consumption in the production of food products would be less efficient and an homogenous specific tax on sugar rich products would be even worse. Such taxes could raise some substantial governmental incomes in some countries. We notice that a tax on the final consumption of sugar rich products leads to a reduction of the sugar intake through a decrease of the quantities of sugar rich products consumed, whereas a tax on sugar as an intermediate consumption mostly reduce the sugar content of food products. Such tax systems would be in most cases detrimental to the agricultural sector and food processing sector.

The following Section 2 presents the MIRAGRODEP model, the modifications that were applied to it for this study and the data used. Section 3 presents a few takeaways from the model's Social Accounting Matrix on the production, trade and consumption of sugar. We then presents the scenarios tested in Section 4. We analyse the results in Section 5 and conclude in Section 6.

2 The MIRAGRODEP model and the modifications applied

2.1 General features of the MIRAGRODEP model and data

We assess the effects of the different tax policies on production and trade in this paper by using the global CGE trade model MIRAGRODEP (Laborde et al., 2013). This model is a multi-regional and multisectoral dynamically recursive model in which the regional and sectoral aggregation can be adapted to each application. It has already been used in a number of studies focused on trade and agricultural issues (Laborde and Martin, 2018; Bouët et al., 2018; Bouët and Laborde, 2018). The social accounting matrix and the trade data in MIRAGRODEP are based on GTAP 9.1 (Aguiar et al., 2016). The GTAP 9.1 database is a fully documented global database that contains complete bilateral trade, transport, and protection data in 140 regions for all 57 GTAP commodities for 2011. The production follows in each country a nested structure in which the total output is a Leontieff aggregation of value added and intermediate inputs, themselves being a Constant Elasticity of Substitution (CES) composite of different aggregates of respectively inputs and factors. Domestic absorption of each commodity is the sum of consumer demand, demand from public administrations, demand for intermediate consumptions and demand for investment purposes. The demand from households is originally characterized by a LES-CES (Linear Expenditure System - Constant Elasticity of Substitution) specification. Government spending on each commodity are fixed shares of total public expenditures and the demands for investments and for intermediate consumptions are characterized by a CES function. A system of nested CES functions is used to reflect preferences among domestic varieties and the ones imported from different other countries following the Armington assumption.

2.2 Subdivision of food sectors into high- and low-sugar content sub-sectors

The MIRAGRODEP model distinguishes multiple sectors, each of them producing one single commodity or product. The sets of sectors and commodities are referred indifferently by using the indices $tcom$ or $trad\_comm$. The sectoral disaggregation of the MIRAGRODEP model used in this study distinguished 33 sectors. The disaggregation is available in Appendix A.

In order to better account for product substitution in the sweet and sugary products sectors, we modify the original model by subdividing some sectors into one high and one low-sugar content sub-sectors. We index all the subsectors indifferently by the indices i or j. We use the indices *hq* (or *hqual*) and *lq* (or *lqual*) to refer respectively to high and low-sugar subsectors. The high and low-sugar subsectors of a product or differentiated using respectively the suffixes h and l (e.g. $ofdh$ and $ofdl$ for the high and low sugar products in the sector ofd, other foods products). The subsectors disaggregation is presented in Appendix A.

This subsectoral disaggregation based on sugar content requires a full split of these sector in the Social Accounting Matrix. The methodology used is fully described in Appendix B. We use trade data from the UN COMTRADE database detailed at the HS6 level to compute shares of high- and low-sugar content products in the original sectors of the MIRAGRODEP model. A calibration model is then used to redistribute intermediate consumptions in the newly created sub-sectors.

The structure of the model remains similar to the original MIRAGRODEP model in the most part and is simply extended over the sub-sectors set *i*, rather than the sectors set *tcom*. Production in each sub-sector is independent from the one in its complementary subsector and follows the same nested structure as in the original model. The total demand in each sub-sector follows independently the same Armington structure as the sectors in the original model. The government demand and the demands for intermediate consumptions and investments are the same as in the original model, directly extended over all the sub-sectors. Only the demand from households is modified, as described in the next sub-section 2.3.

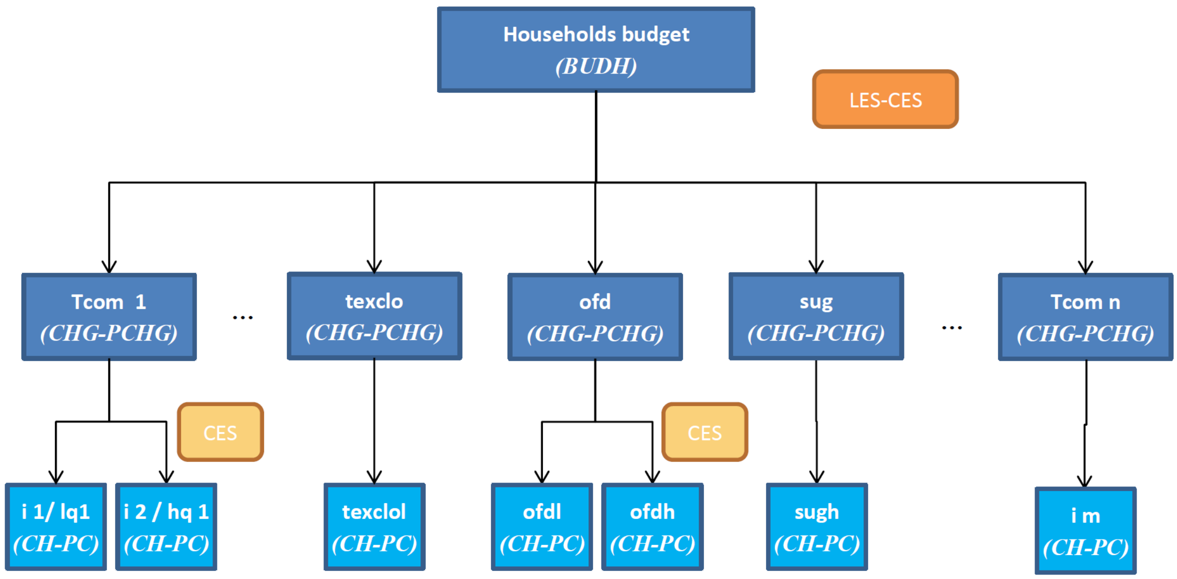
2.3 Modification of the households demand system

We enable the representation of different substitution patterns between high and low-sugar content varieties of a same product by adding another tier to the private demand system. The top tier-remains identical to the original model with a LES-CES specification over the different sectors *tcom*. However, the demand for each sector are now CES aggregates of the demands for their corresponding sub-sectors. This enables to specify an independent elasticity of substitution between the low and high sugar variety of each product. As some sectors are non differentiated because they are purely low-sugar (for example non-food sectors) or high-sugar (e.g. the sugar sector), the demand for their sector will be identical to the demand for their corresponding sub-sector.

The private demand system is calibrated in each country with a calibration model that determines the LES-CES parameters. This model enable to find the parameters to match the initial sectoral demands (over the *tcom* sets) and sectoral own-price elasticities data from USDA () while minimizing the weighted sum of squared differences between the sectoral income elasticities in the model and in USDA data ().

On the second tier for differentiated sectors, the CES share parameters are computed using the initial sub-sectoral demands. We choose an elasticity of substitution between high and low-sugar sub-sectors of 0.9 for every sectors except *bevtob* (beverages and tobacco) for which it is fixed to 1.96 (Miao et al., 2011, following).

Figure 1: Modified private demand system



2.4 Creation of overall sugar intake index

In order to analyse the effects of each policy scenario on the total sugar intake in each country each year, we create an indicator that account for the direct final consumptions of sugar but also for the consumption of sugar, incorporated in other agrofood products [1]. This indicator $ConsoSugT(s,t,sim)$ of the total private consumption of free sugar in region s, for the year t under the scenario sim is build in the following way:

$$\begin{aligned} ConsoSugT(s,t,sim) = CH('sugh',s,t,sim) + \sum_{r,j \in agrofood/\{'sugh'\}} IC('sugh',j,r,t,sim) \\ \times \frac{TRADE(j,r,s,t,sim)}{Y(j,r,t,sim)} \times \frac{CH(j,s,t,sim}{DEMTOT(j,s,t,sim)} \end{aligned} \quad (1)$$

With:

- $CH('sugh',s,t,sim)$: The final consumption of sugar in region s at time t under scenario sim,

[1] The MIRAGRODEP product codes classified as agrofood are: rice, cereals, v_f, osd, ocr, cattle, onr, fish, meat, vol, sug, ofd, dairy, otherani, bevtob, c_b.

- $IC('sugh', j, r, t, sim)$: The sugar use as an intermediate consumption in the production of the product j in region r,
- $\frac{TRADE(j,r,s,t,sim)}{Y(j,r,t,sim)}$: The proportion of the production of j in region r exported to s
- $\frac{CH(j,s,t,sim}{DEMTOT(j,s,t,sim)}$: The proportion of the total demand for the product j in region s consumed by households.

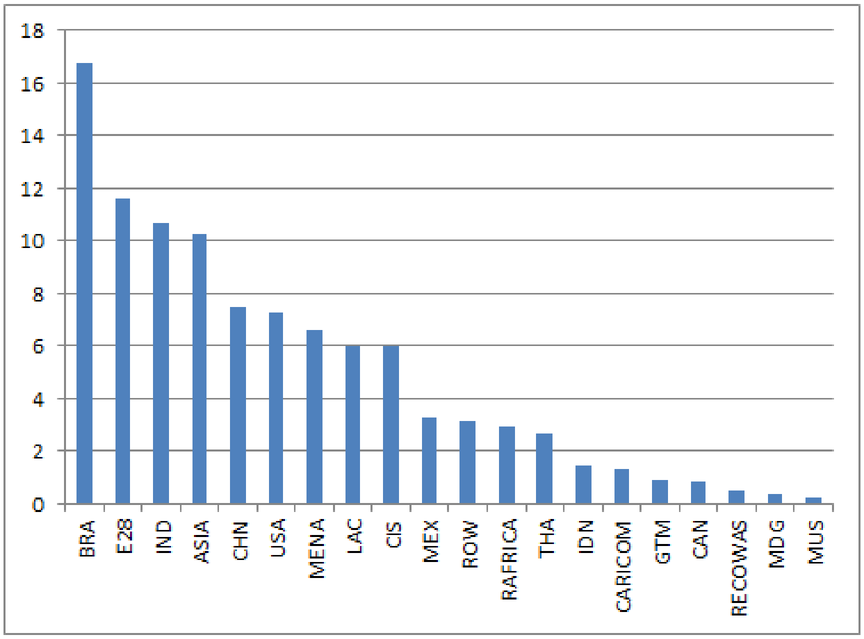
This indicator therefore accounts for the sugar consumed by the households, directly or as content of other food and beverage products. We omit however the sugar that could have been incorporated further up in the food value chain in the production of other intermediate inputs of the final products.

3 Takeaways from the model Social Accounting Matrix on the production, consumption and trade of sugar and sugary products

We compute some preliminary indicators using the Social Accounting Matrix of the model for the base year 2018. These indicators enabled us to pick the targeted countries in which we implement the tax scenarios, because of their importance in the World sugar and sweet product production and trade, or the importance of sugar and sweet product in their economy.

We notice on Figure 2 that Brazil, the European Union and India are the 3 top sugar producers in the World, accounting together for about 40% of the World production. We can see on Figure 3 that the production of sugar, sugar beet and sugar cane, and sweet products account for more than 3% of the Gross Domestic Product (GDP) in Madagascar, Guatemala and Mauritius. Figure 4 shows that Brazil, Thailand and India are the 3 top net exporter of sugar whereas Indonesia, China and the United States are among the biggest importer. On Figure 5, we notice that the European Union, China and the United States are the largest producers of sweet products with about 60% of the World production. We can see on Figure 6, that Thailand, Mexico and Brazil are among the largest exporters of sugar rich products, whereas the United States is among the largest importers. On Figure 7, we notice that sugar and sugar rich products account for more than 1.5% of the total national imports in Madagascar, Guatemala, Canada, Mauritius and the European Union. Finally, Figure 8 displays for every region of the model, the sugar content in the most sweetened products. We see that sugar can account for a large share of the value of sugar rich beverages with 20% and more in Brazil, India and Thailand. The share of sugar in products value also exceed 10% for other sugar rich food and sugar rich dairy products in Madagascar.

Figure 2: Sugar production per region for the base year (2018, % from World production)



4 Sugar tax schemes and implementation scenarios

We propose to test three schemes of sugar and sugary product taxation to reduce obesity:

The first taxation scheme corresponds to the implementation of an homogenous specific tax on the final consumption of all agrofood products with high sugar contents ($hq(agrofood)$). This scheme is denoted *CC*. The tax is of an amount *TaxLevCC* per unit of product.

The second taxation scheme corresponds to the implementation of a homogenous specific tax on the intermediate consumption of sugar in all agrofood products, except sugar itself. This scheme is denoted *IC*. The tax is of an amount *TaxLevIC* per unit of sugar incorporated in the production.

The third and final taxation scheme is similar to the *IC* scheme but includes a complementary tax on the direct final consumption of sugar, of the same level *TaxLevIC*. It enables to avoid the

Figure 3: Share of sugar, Sugar cane and sugar beet, and sugar rich product in the GDP at the base year (2018, %)

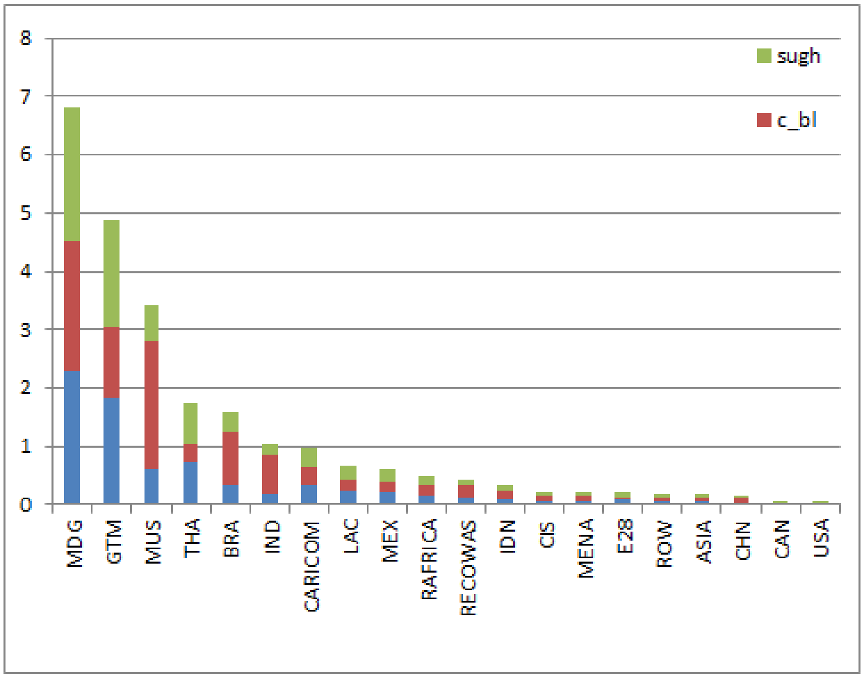


Figure 4: Sugar net trade per region at the base year (2018, net exports in % of World total exports)

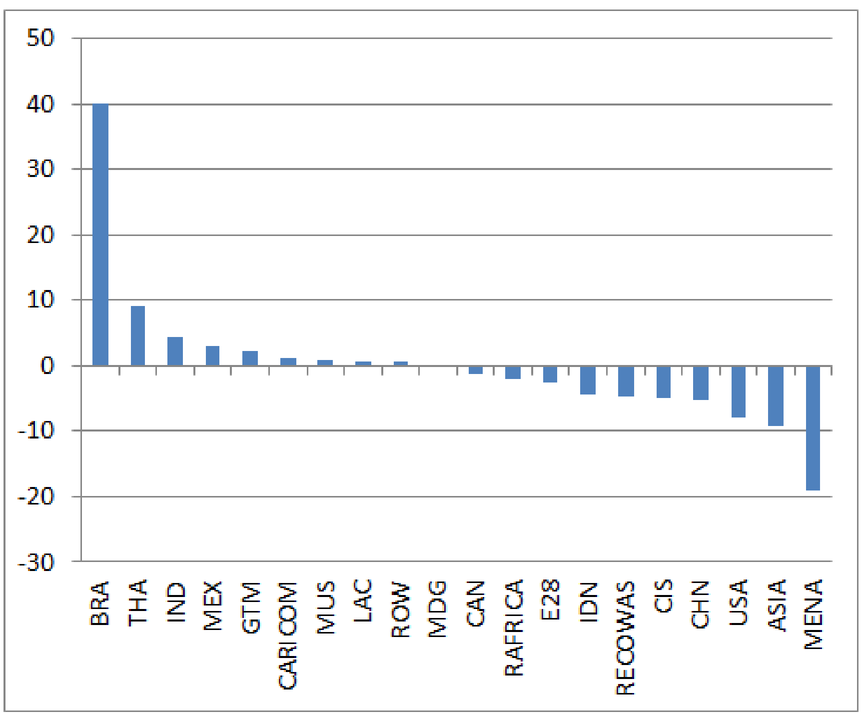
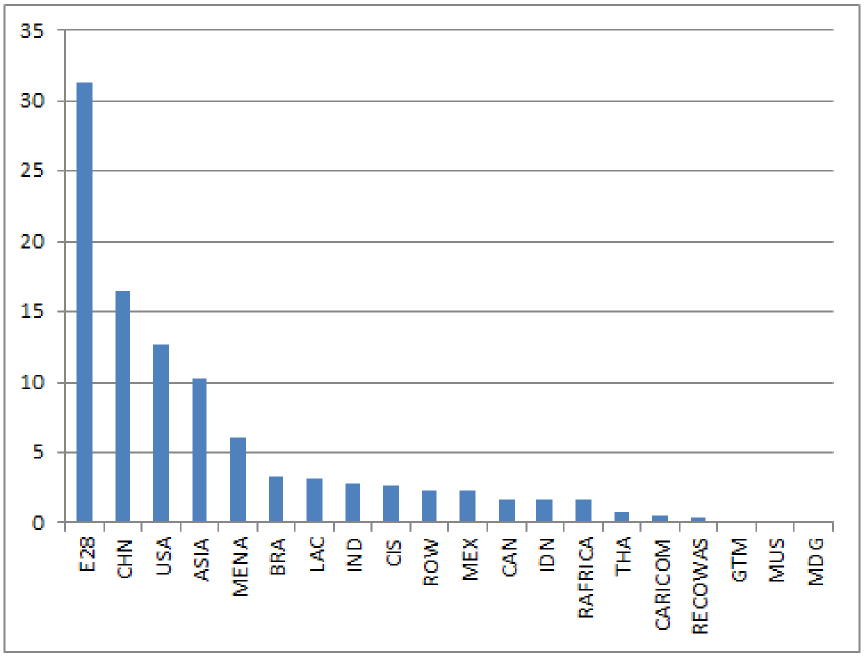


Figure 5: Sugar rich product production per region for the base year (2018, % from World production)



fact that sugar itself is not taxed when it is directly consumed under the *IC* scheme. This scheme is denoted *ICsug*.

For all taxation scheme *CC*, *IC*, or *ICsug*, the profit of the new tax is fully redistributed through a direct flat transfer to the households.

In every scenarios, respectively one of the tax scheme *CC*, *IC*, or *ICsug* is implemented in a set of target countries *rsim*. The model is solved each year *t* between 2019 and 2023 in order to find the respective tax levels $TaxLevCC(rsim,t)$ or $TaxLevIC(rsim,t)$ that will enable to reach a 5% reduction of the total sugar intake $ConsoSugT(s,t,sim)$ in every target country, every year.

For every tax scheme, we run 13 scenarios. In the first scenario, the tax scheme is set-up simultaneously in all the regions of the model, i.e. all over the World. This scenario is quite unlikely but it allows us to uncover the possible cooperative or competitive consequences that could arise if a number of countries implement such taxes. We then run 12 other scenarios by tax scheme where the tax is set-up individually in one of the following countries or region: Brazil, Canada, China, European Union, Guatemala, India, Indonesia, Madagascar, Mauritius, Mexico, Thailand, United States. These countries have been selected because of the importance of sugar

Figure 6: Sugar rich product net trade per region at the base year (2018, net exports in % of World total exports)

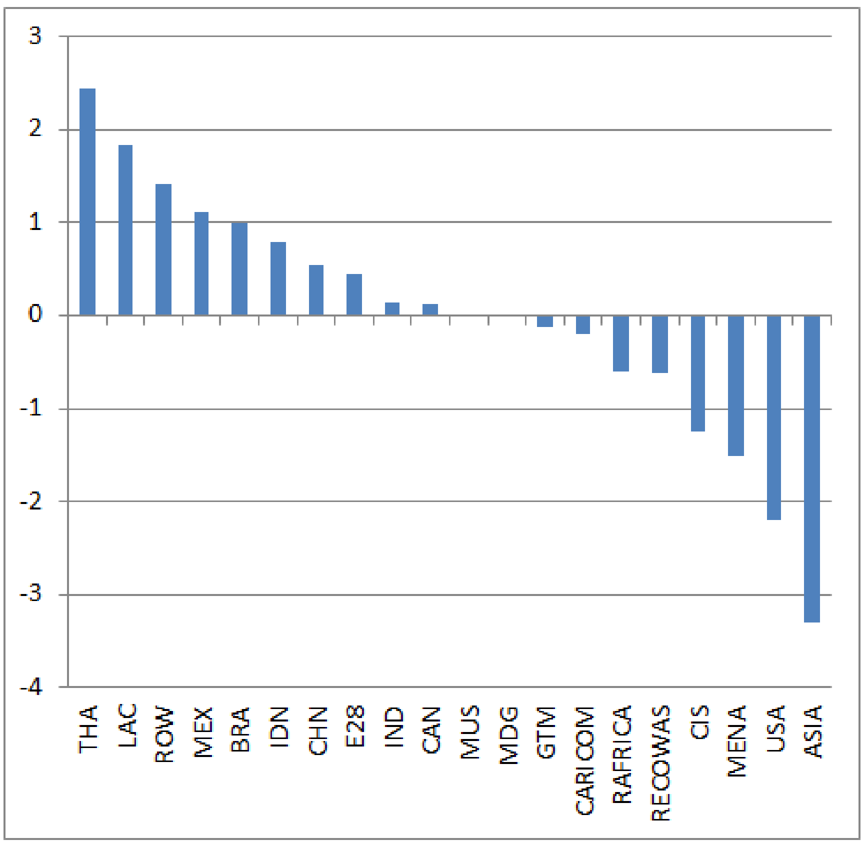


Figure 7: Share of sugar and sugar rich product in the national imports at the base year (2018, %)

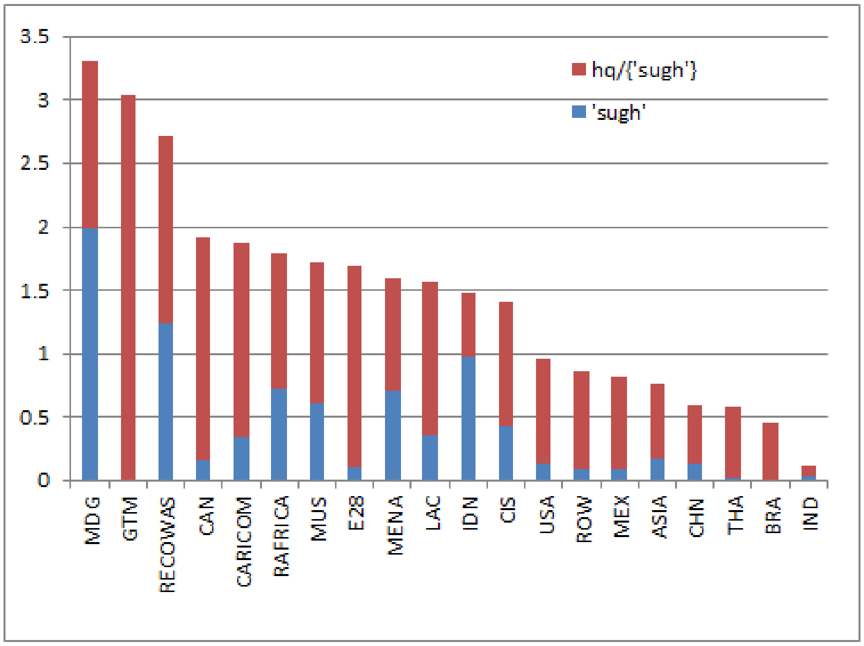
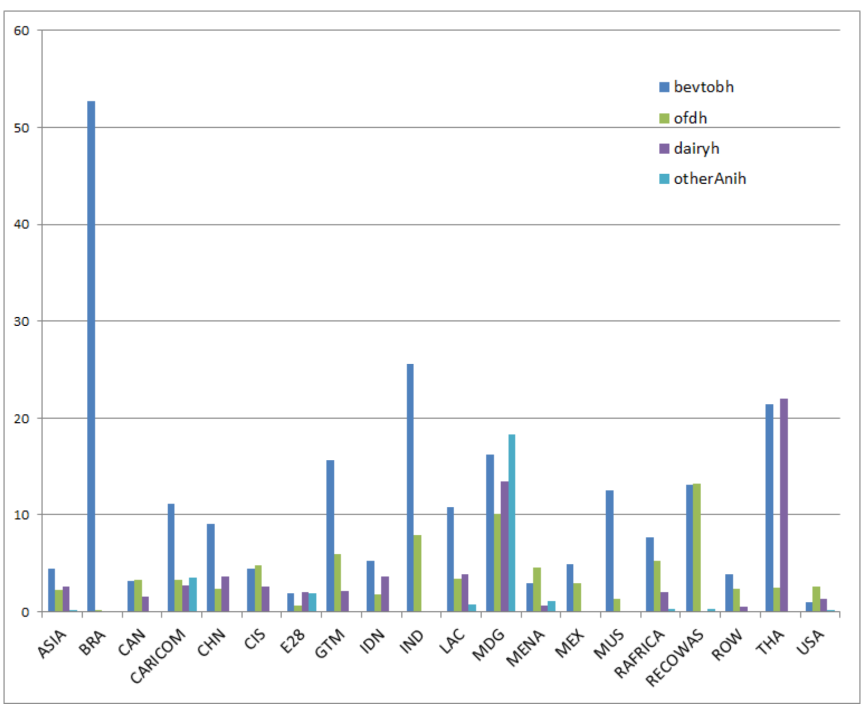


Figure 8: Sugar content at the production (Share of the sugar intermediate consumptions in the value of the product, %)



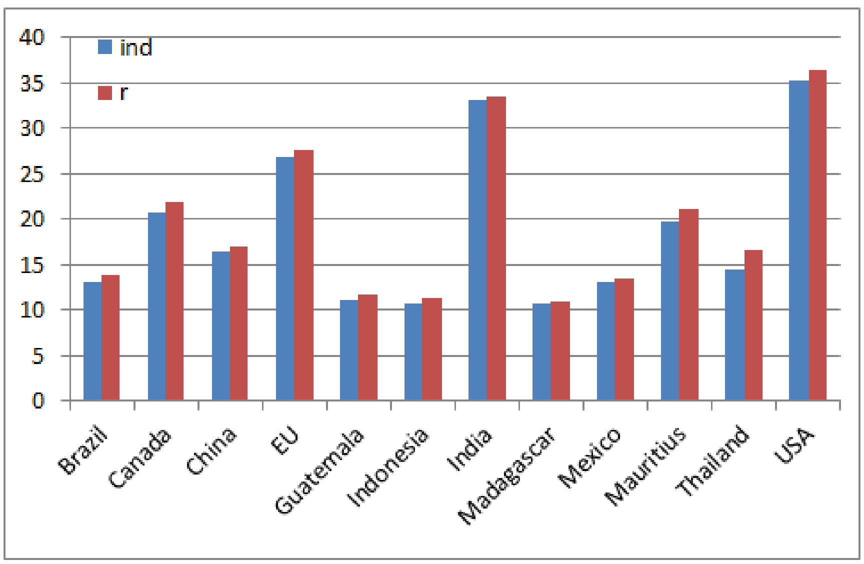
and sweet product in their economy, or their importance in global sugar trade and production .

5 Results

5.1 Efficiency of the tax systems

We see on Figure 9 that the ad-valorem level of the CC tax required to achieve a 5% in sugar intake is relatively homogenous across countries, from around 10% Indonesia to around 35% in the United States. We notice little difference between the tax levels when the tax is set-up independently in each country or simultaneously all around the World.

Figure 9: Ad-valorem level of the CC tax (%, average 2019-2023)



The tax levels are much more spread out when looking at the IC tax on Figure 10, with ad-valorem tax levels around 8% in China up to more than 250% in Mauritius. The tax levels are again quite similar when the tax is set up independently or simultaneously.

The tax levels with ICsug tax on Figure 11 are much more homogenous, between 8% in Canada and 23% in China. They are overall fairly reduced proportionally to the tax levels with the CC scheme.

We notice on Figure 12, that all the tax scenarios have a negative outcome on the utility of the

Figure 10: Ad-valorem level of the IC tax (%, average 2019-2023)

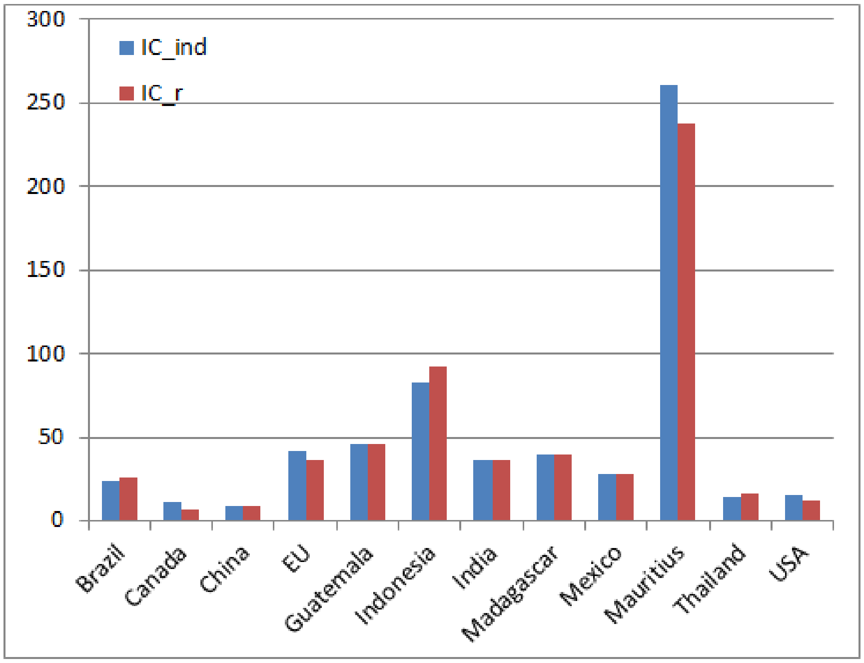
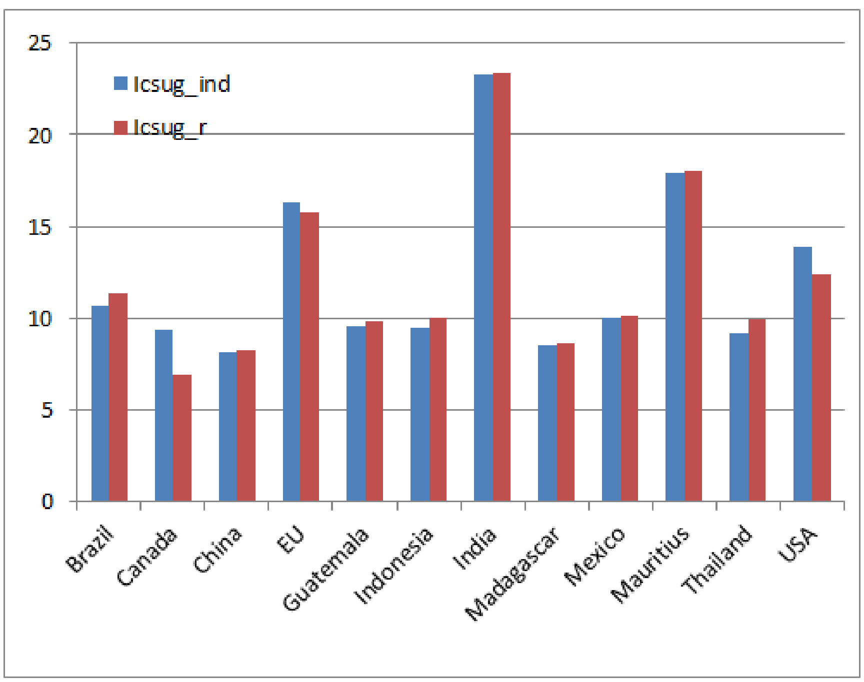


Figure 11: Ad-valorem level of the ICsug tax (%, average 2019-2023)



targeted countries. The CC scheme is especially damaging in Canada, China, European-Union, Mexico and the United States in comparison to the other schemes. In the other countries, the difference in the reduction of utility is more similar across the proposed tax schemes. We notice that the CC scheme is the most damaging in Guatemala and Mauritius when set-up collectively, and in every case in Madagascar. The ICsug scheme is the least damaging in every country at the exception of China and India, where it ranks behind the IC scheme.

We should however acknowledge that the utility function used in this model is uniquely based on the quantities of every product consumed. It does not account for the perception of the possible changes in product sweetness when the sugar content are modified. It also doesn't account for the possible health improvement outcomes brought by the reduction of the sugar intake.

Figure 12: Average evolution of the utility in comparison to the reference (%, average 2019-2023)

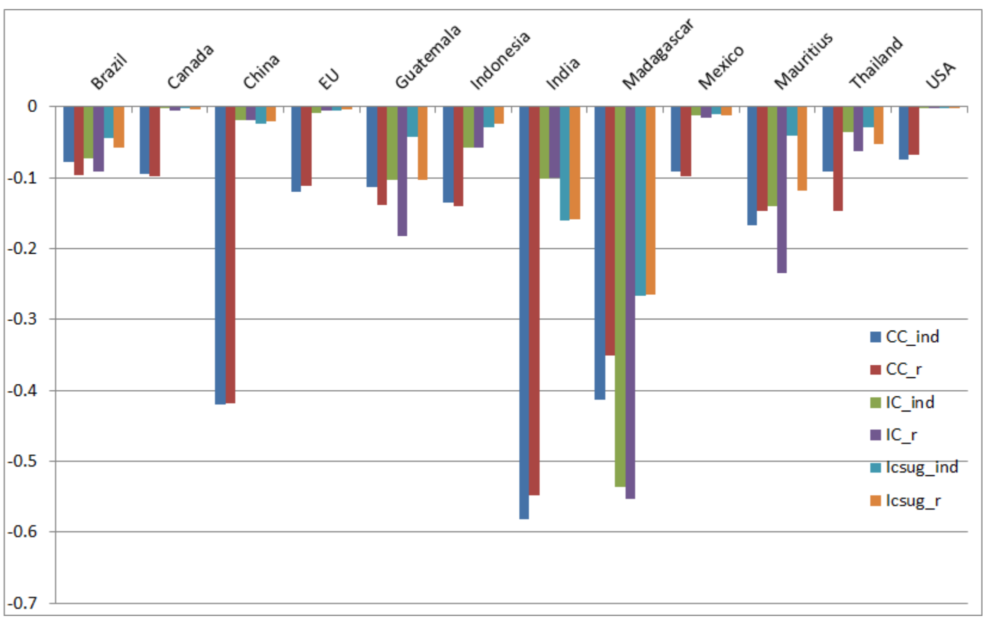
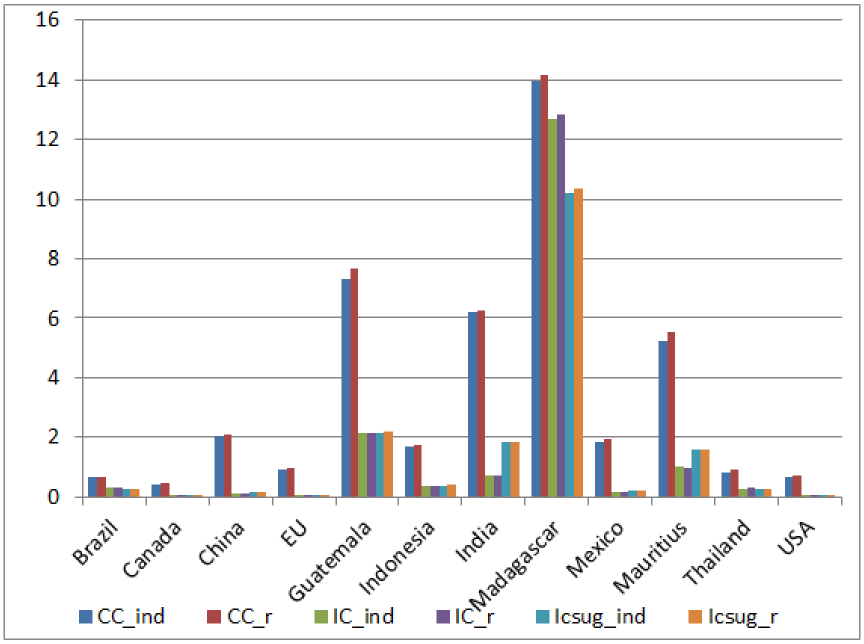


Figure 13 presents the incomes brought by the different tax schemes to the Government of the countries targeted. If for most scenarios, the incomes don't exceed 1% of the Government budget, they can be substantial for some of the tax schemes in some countries and go as high as more than 5% of the budget in Guatemala, India, Mauritius and up to 14% in Madagascar. In every scenario, the CC scheme brings the most incomes to the governments.

Figure 13: Average share of the tax in the Government incomes (%, average 2019-2023)



5.2 Reduction in the consumption versus reduction of the sugar content

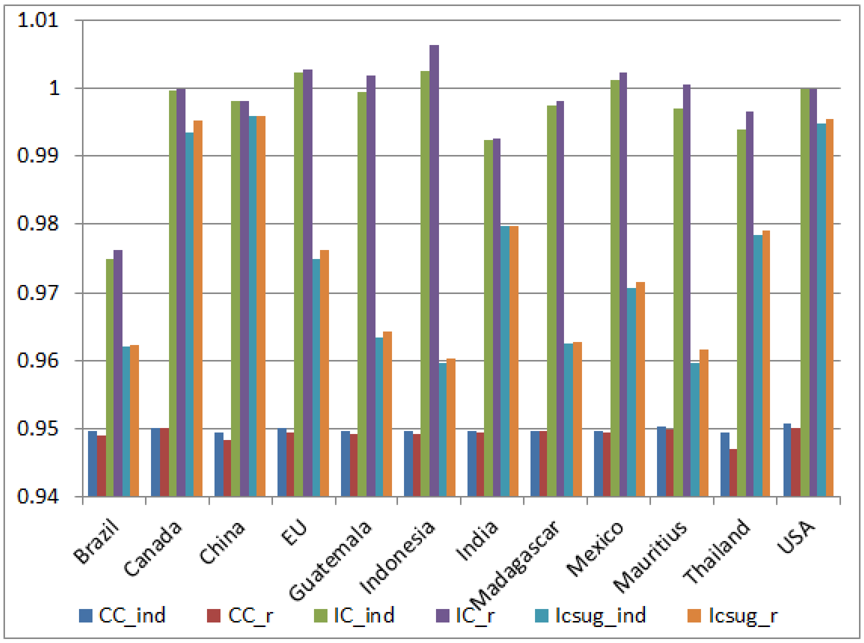
In order to disentangle the chanel of the reduction of sugar intake $ConsoSugT(s,t,sim)$ between a reduction in the quantity of sugary products consumed and a reduction in the sugar content of the products, we develop two joint indices.

The first one $ConsIndex(s,t)$ compute the relative evolution of the sugar intake in the simulated scenarios compared to the reference, if the sugar content of every product had remained similar to the reference scenario. It allows to uncover the part of the reduction of sugar intake due to a reduction of the quantities $CH(i,s,t,sim)$ of sugary products consumed by the households . We have:

$$ConsIndex(s,) = \frac{CH('sugh',s,t,'sim') + \sum_{r,j \in agrofood/\{'sugh'\}} IC('sugh',j,r,t,'ref') \times \frac{TRADE(j,r,s,t,'ref')}{Y(j,r,t,'ref')} \times \frac{CH(j,s,t,'sim')}{DEMTOT(j,s,t,'ref')}}{CH('sugh',s,t,'ref') + \sum_{r,j \in agrofood/\{'sugh'\}} IC('sugh',j,r,t,'ref') \times \frac{TRADE(j,r,s,t,'ref')}{Y(j,r,t,'ref')} \times \frac{CH(j,s,t,'ref'}{DEMTOT(j,s,t,'ref')}} \quad (2)$$

The results for every scenarios are presented on Figure 14. We can notice that for the CC schemes, the reduction of the sugar intake is for every country, mostly driven by a reduction in the quantities consumed of sweet products. Under the IC schemes, we observe little reduction of the quantities of sweet product consumed and even in some cases we can observe an increase, such as in the European Union, in Guatemala, Indonesia or Mexico. The results for the ICsug schemes are in every cases intermediate between the CC and the IC schemes.

Figure 14: Average ConsIndex (%, average 2019-2023)

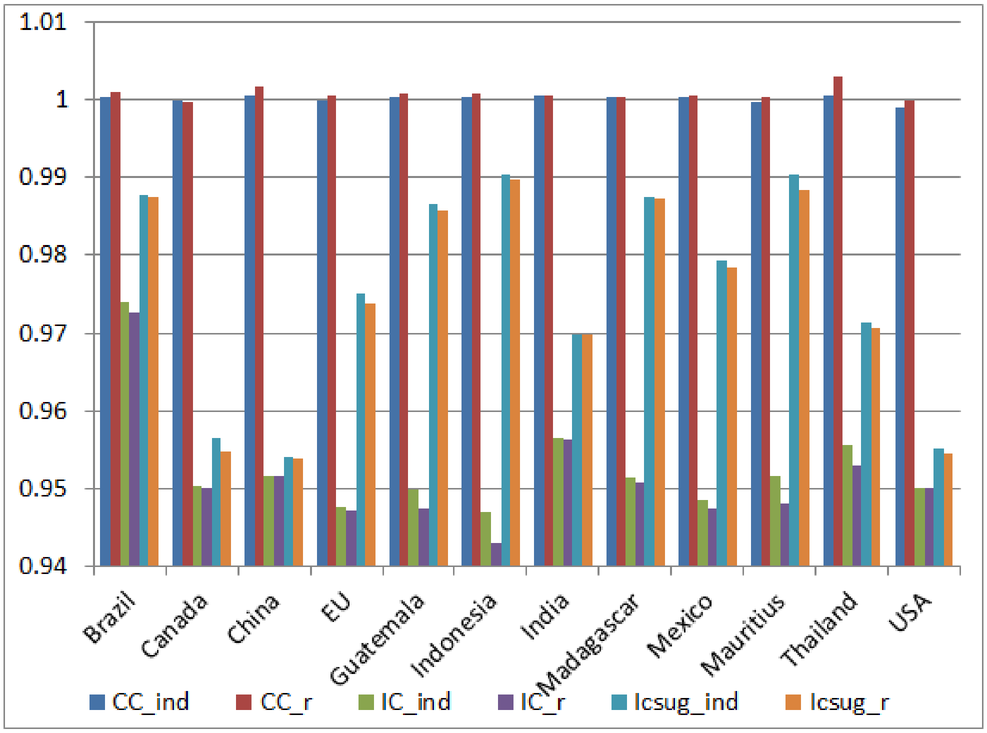


The second index $ContentIndex(s,t)$ compute the relative evolution of the sugar intake in the simulated scenarios compared to the reference, if the quantities of every agrifood product consumed by the households $CH(i,s,t,sim)$ had remained similar to the reference scenario. It allows to uncover the part of the reduction of sugar intake due to a reduction of the sugar content of the agrofood products. We have:

$$ContentIndex(s,) = \frac{CH('sugh',s,t,'ref') + \sum_{r,j \in agrofood/\{'sugh'\}} IC('sugh',j,r,t,'sim') \times \frac{TRADE(j,r,s,t,'sim')}{Y(j,r,t,'sim')} \times \frac{CH(j,s,t,'ref')}{DEMTOT(j,s,t,'sim')}}{CH('sugh',s,t,'ref') + \sum_{r,j \in agrofood/\{'sugh'\}} IC('sugh',j,r,t,'ref') \times \frac{TRADE(j,r,s,t,'ref')}{Y(j,r,t,'ref')} \times \frac{CH(j,s,t,'ref'}{DEMTOT(j,s,t,'ref')}} \quad (3)$$

We notice on Figure 15 that under the IC scheme, the reduction of the sugar intake is mostly driven by a reduction of the sugar content of the products. On the contrary, under the CC scheme, the sugar content are mostly unchanged or we can even observe some slight increases such as in China or Thailand. Again, the results in the evolution of the sugar contents are intermediate in the ICsug scheme between the ones of the CC and IC schemes.

Figure 15: Average ContentIndex (%, average 2019-2023)



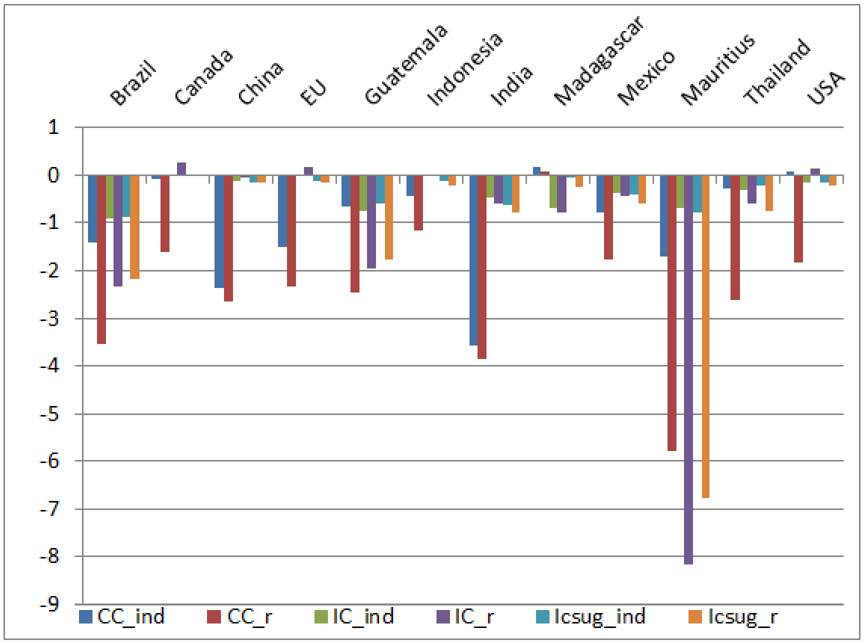
5.3 Consequences on the agricultural and food processing sectors

We notice on Figure 16 that most tax scenarios are detrimental to the production of Value Added in agricultural sectors, with few exceptions in Canada, the European-Union, Madagascar and the United States. Some countries' agriculture such as India, Brazil or Mauritius can loose more than 3% of their agricultural Value Added.

The collective implementation of the CC scheme appears to be always more detrimental to agriculture than the individual implementation, highlighting some possible competitive effects in the set up of the tax. With the IC schemes, the results are contrasted. Some countries loose way more when the tax is set up everywhere such as Brazil, Guatemala or Mauritius, whereas some others even become winners such as Canada, the European Union or the United States. The ICsug schemes provides on its side intermediate results.

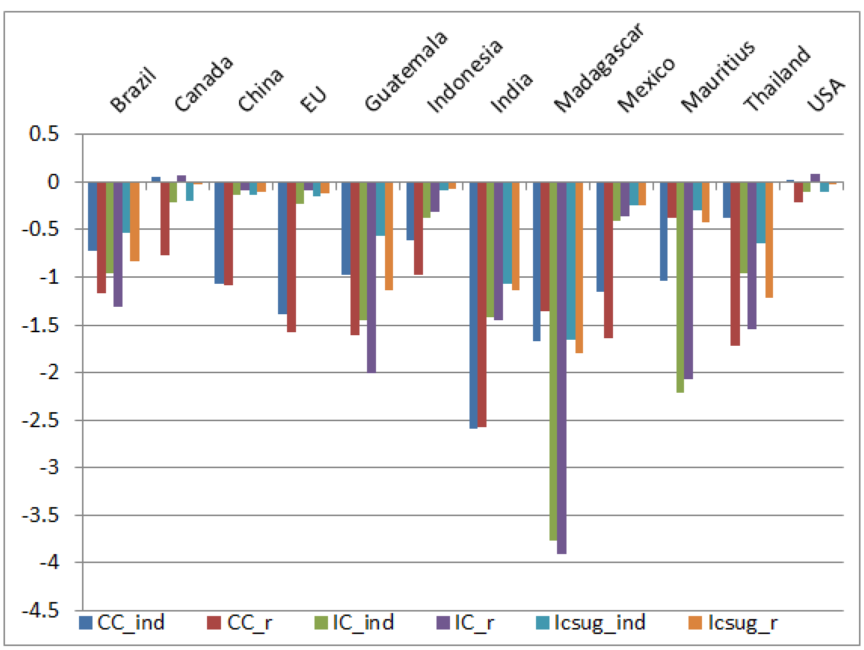
Food processing sectors also appear to be loosers in most scenarios, with few exceptions in Canada and the United States. The difference across tax schemes are more reduced than for the agricultural sectors. Most countries see their Value Added from food processing decreasing of around 1% under most tax schemes and Mauritius food processing sector loose more than 3.5%

Figure 16: Evolution of the agricultural value added in comparison to the reference (%, average 2019-2023)



under the IC scheme.

Figure 17: Evolution of the value added in the food processing sectors in comparison to the reference (%, average 2019-2023)



6 Conclusion

The use of a Computable General Equilibrium model enabled us to uncover the consequences on production and trade of several tax schemes targeted to reduce sugar intake and fight obesity.

For most countries, the most efficient tax scheme to achieve a 5% reduction of the total sugar intake would be a specific tax on sugar as an intermediate consumption in the production of food products, complemented by a tax of the same amount on final consumptions of sugar, with an ad-valorem level of about 10%. In most cases, a sole tax on sugar as an intermediate consumption in the production of food products would be less efficient and an homogenous specific tax on sugar rich products would be even worse. Such taxes could raise some substantial governmental incomes as high as more than 5% of the total governmental incomes.

We noticed that if a tax on the final consumption of sugar rich products will lead to a reduction of the sugar intake by a decrease of the quantities of sugar rich products consumed; a tax on sugar as an intermediate consumption in other food product can lead to a similar reduction of the sugar intake mostly by reducing the sugar content of food products.

Finally, such tax systems would be in most cases detrimental to the agricultural sector and food processing sector, leading to decreases of the sectoral Value Added of a few percents in some cases for a reduction of 5% of the total sugar intake. These negative impacts can be reinforced when these taxes are implemented collectively around the World.

All the tax schemes tested appear to have a negative effect on the utility of the agents. However, we do not account for the possible health benefits of the sugar intake reduction on the productivity and the well-being of the agents. The specification of utility used also do not account for the role of sugar content in the taste of the products. Therefore, we can imagine that the reduction of sugar content generated by tax on sugar as intermediate consumption could have further damage on utility.

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Appendices

A Sectoral and regional disaggregation of the MIRAGRODEP model

B Repartition of the initial data between the high and low sugar sub-sectors

B.1 Extracting high-sugar products proportion from HS6 trade data

In order to differentiate the sectors between high and low sugar sub-sectors, we need to redistribute the GTAP initial data for demand, production and trade over the new sub-sectoral set i. For this purpose, we use detailed trade data from UN comtrade database defined at the HS6 classification level. This level of detail enables us to classify each line of the HS6 classification in the high-sugar or low-sugar category depending on their name or on some nutritional contents from other sources, including the USDA National Nutrient Database. The list of HS6 categories classified as high-sugar is available in Tables 3 and 4.

We can then compute sectoral proportions of high-sugar products on each trade link ($PropHS(tcom,r,s)$) by summing the trade flux from the HS6 to the GTAP level depending on their high or low sugar classification:

$$PropHS(tcom,r,s) = \frac{\sum_{hs6\in(tcom\ and\ hq)} TradeHS6(hs6,r,s)}{\sum_{hs6\in tcom} TradeHS6(hs6,r,s)} \tag{4}$$

Assuming that the sectoral proportion of high-sugar products is the same in production as in exports, we compute the proportion of high sugar products in the production following:

$$PropProd(tcom,r) = \frac{\sum_{s}\left(\sum_{hs6\in(tcom\ and\ hq)} TradeHS6(hs6,r,s)\right)}{\sum_{s}\left(\sum_{hs6\in tcom} TradeHS6(hs6,r,s)\right)} \tag{5}$$

Table 1: Sectoral disaggregation used of the MIRAGRODEP model

Sector	Code	Subsectors
Rice	rice	ricel
Cereals	cereals	cerealsl
Vegetables. fruit. nuts	v_f	v_fl
Oil seeds	osd	osdl
Sugar cane. sugar beet	C_b	C_bl
Plant-based fibers and crops nec	ocr	ocrl
Cattle.sheep.goats.horses and raw milk	cattle	cattlel
Other animal products	otherAni	otherAnil and otheranih
Forestry and minerals nec	onr	onrl
Fishing	fish	fishl
Coal, Oil, gas and Petroleum Coal products	ffl	ffll
Meat products	meat	meatl
Vegetable oils and fats	vol	voll
Dairy products	dairy	dairyl and dairyh
Sugar	sug	sugh
Food products nec	ofd	ofdl and ofdh
Beverages and tobacco products	bevtob	bevtobl and bevtobh
Textiles and Clothing	texclo	texclol
Wood and Paper products. publishing	woodpap	woodpapl
Chemical.rubber.plastic prods	crp	crpl
Mineral products nec	mat	matl
Metals	metals	metalsl
Motor vehicles and parts	mvh	mvhl
Capital goods	cgd	cgdl
Electronic equipment	ele	elel
Manufactures nec	omf	omfl
Utilities	utilities	utilitiesl
Construction	cns	cnsl
Trade	trade	tradel
Transport	trans	transl
Private sector services	privser	privserl
Recreation and other services	ros	rosl
PubAdmin/Defence/Health/Educat	pubserv	pubservl
Dwellings	otherserv	otherservl

Table 2: Regional disaggregation of the MIRAGRODEP model

Region	Code
Brazil	BRA
Canada	CAN
China	CHN
European Union	E28
Guatemala	GTM
India	IND
Indonesia	IDN
Madagascar	MDG
Mauritius	MUS
Mexico	MEX
Thailand	THA
United States	USA
Caribbean Community	CARICOM
Commonwealth of Independent States	CIS
Middle East and North Africa	MENA
Rest of Africa	RAFRICA
Rest of Asia	ASIA
Rest of ECOWAS	RECOWAS
Rest of Latin America and Carribean	LAC
Rest of the World	ROW

Table 3: HS6 categories classified as high-sugar content

GTAP	HS6	Label
mil	40299	MILK AND CREAM CONCENTRATED AND SWEETEN
oap	40900	NATURAL HONEY
ofd	81210	CHERRIES PROVISIONALLY PRESERVED BUT U
ofd	81220	STRAWBERRIES PROVISIONALLY PRESERVED B
ofd	81290	FRUIT AND NUTS PROVISIONALLY PRESERVED
ofd	81400	PEEL OF CITRUS FRUIT OR MELONS INCL. WA
c_b	121291	SUGAR BEET FRESH OR DRIED WHETHER OR N
c_b	121292	SUGAR CANE FRESH OR DRIED WHETHER OR N
sgr	170111	RAW CANE SUGAR EXCL. ADDED FLAVOURING O
sgr	170112	RAW BEET SUGAR EXCL. ADDED FLAVOURING O
sgr	170191	REFINED CANE OR BEET SUGAR CONTAINING A
sgr	170199	CANE OR BEET SUGAR AND CHEMICALLY PURE S
mil	170211	LACTOSE IN SOLID FORM AND LACTOSE SYRUP
mil	170219	LACTOSE IN SOLID FORM AND LACTOSE SYRUP
sgr	170220	MAPLE SUGAR IN SOLID FORM AND MAPLE SY
ofd	170230	GLUCOSE IN SOLID FORM AND GLUCOSE SYRUP
ofd	170240	GLUCOSE IN SOLID FORM AND GLUCOSE SYRUP
ofd	170250	CHEMICALLY PURE FRUCTOSE IN SOLID FORM
ofd	170260	FRUCTOSE IN SOLID FORM AND FRUCTOSE SYRU
ofd	170290	SUGARS IN SOLID FORM INCL. ARTIFICIAL
sgr	170310	CANE MOLASSES RESULTING FROM THE EXTRACT
sgr	170390	BEET MOLASSES RESULTING FROM THE EXTRACT
ofd	170410	CHEWING GUM WHETHER OR NOT SUGAR COATED
ofd	170490	SUGAR CONFECTIONERY NOT CONTAINING COCOA
ofd	180610	COCOA POWDER SWEETENED
ofd	180620	CHOCOLATE AND othr FOOD PREPARATIONS CO
ofd	180631	CHOCOLATE AND othr PREPARATIONS CONTAIN
ofd	180632	CHOCOLATE AND othr PREPARATIONS CONTAIN
ofd	180690	CHOCOLATE AND othr PREPARATIONS CONTAIN
ofd	190110	PREPARATIONS FOR INFANT USE RETAIL SALE

Table 4: HS6 categories classified as high-sugar content (continued)

GTAP	**HS6**	**Label**
ofd	190120	MIXES AND DOUGHS OF FLOUR MEAL STARCH
ofd	190190	PREPARATIONS OF FLOUR MEAL STARCH OR M
ofd	190410	PREPARED FOODS OBTAINED BY SWELLING OR R
ofd	190520	GINGERBREAD AND THE LIKE WHETHER OR NOT
ofd	190530	SWEET BISCUITS WAFFLES AND WAFERS WHET
ofd	190590	BREAD PASTRY CAKES BISCUITS AND othr
ofd	200600	FRUIT NUTS FRUIT PEEL AND othr PARTS
ofd	200710	HOMOGENIZED PREPARATIONS OF JAMS JELLIE
ofd	200791	CITRUS FRUIT JAMS JELLIES MARMALADES
ofd	200799	JAMS JELLIES MARMALADES PUREES OR PAS
ofd	200820	PINEAPPLES PREPARED OR PRESERVED WHETH
ofd	200830	CITRUS FRUIT PREPARED OR PRESERVED WHE
ofd	200840	PEARS PREPARED OR PRESERVED WHETHER OR
ofd	200850	APRICOTS PREPARED OR PRESERVED WHETHER
ofd	200860	CHERRIES PREPARED OR PRESERVED WHETHER
ofd	200870	PEACHES PREPARED OR PRESERVED WHETHER
ofd	200880	STRAWBERRIES PREPARED OR PRESERVED WHE
ofd	200891	PALM HEARTS PREPARED OR PRESERVED WHET
ofd	200911	FROZEN ORANGE JUICE WHETHER OR NOT CONT
ofd	200919	ORANGE JUICE WHETHER OR NOT CONTAINING
ofd	200920	GRAPEFRUIT JUICE WHETHER OR NOT CONTAIN
ofd	200930	JUICE OF CITRUS FRUIT WHETHER OR NOT CO
ofd	200940	PINEAPPLE JUICE WHETHER OR NOT CONTAINI
ofd	200950	TOMATO JUICE WHETHER OR NOT CONTAINING
ofd	200960	GRAPE JUICE INCL. GRAPE MUST WHETHER O
ofd	200970	APPLE JUICE WHETHER OR NOT CONTAINING A
ofd	200980	JUICE OF FRUIT OR VEGETABLES WHETHER OR
ofd	200990	MIXTURES OF FRUIT JUICES INCL. GRAPE MU
ofd	210112	PREPARATIONS WITH A BASIS OF EXTRACTS E
ofd	210120	EXTRACTS ESSENCES AND CONCENTRATES OF T
ofd	210320	TOMATO KETCHUP AND othr TOMATO SAUCES
ofd	210390	PREPARATIONS FOR SAUCES AND PREPARED SAU
mil	210500	ICE CREAM AND othr EDIBLE ICE WHETHER
ofd	210690	FOOD PREPARATIONS N.E.S.
b_t	220210	WATERS INCL. MINERAL AND AERATED WITH
b_t	220290	NON ALCOHOLIC BEVERAGES EXCL. WATER FR
crp	294000	SUGARS CHEMICALLY PURE EXCL. SUCROSE

B.2 Using high-sugar products proportion to redistribute initial data into new sub-sectors

Using the high-sugar proportions computed in sub-section B.1, we can redistribute the initial data defined on the sectoral $tcom$ set to their new indexes defined at the sub-sectoral i level. For trade and production data, we can apply directly the corresponding proportions $PropHS(tcom,r,s)$ and $PropProd(tcom,r)$ computed in B.1. The input/output matrix for intermediate consumptions needs some further work to account for the various proportions of high and low sugar inputs in the production of high and low-sugar outputs. We use another calibration model described in the next sub-section B.3 to compute input shares $PropIC\_dom(r,i,j)$ and $PropIC\_imp(r,i,j)$ (respectively for domestic and imported inputs) in the production of each variety at the sub-sectoral level. Finally, we compute proportion of high sugar products in the demand for domestic and imported products that we apply to the corresponding initial data. We assume that the households and the governments demand the same proportion of high-sugar products. We get the sectoral proportions of high-sugar products in the demand for domestic and imported products by computing the proportions of high-sugar products remaining available after intermediate consumptions demands (respectively $ICdom(i,r)$ and $ICimp(i,r)$):

$$PropDemD(r,tcom) = \frac{\sum_{hq \in tcom} (Production(hq,r) - Exports(hq,r) - ICdom(hq,r))}{\sum_{i \in tcom} (Production(i,r) - Exports(i,r) - ICdom(i,r))} \quad (6)$$

$$PropDemI(r,tcom) = \frac{\sum_{hq \in tcom} (Imports(hq,r) - ICimp(hq,r))}{\sum_{i \in tcom} (Imports(i,r) - ICimp(i,r))} \quad (7)$$

The next table present the initial data and the proportions that are applied to redistribute them to the sub-sectoral level:

Original data	Description	Proportion applied
$CMFRV(tcom,r,s)$	Protection MFA export subsidy equivalent	$PropHS(tcom,r,s)$
$CVIWS(tcom,s,r)$	Bilateral imports at world price	
$CVIMS(tcom,s,r)$	Bilateral imports at market price	
$CVXMD(tcom,r,s)$	Bilateral exports at world price	
$CVXWD(tcom,r,s)$	Bilateral exports at market price	
$CVFM(f,pcom,r)$	Endowments Firms Purchases at Market Prices	$PropProd(pcom,r)$
$CFBEP(f,pcom,r)$	Factor-based subsidies	
$CFTRV(f,pcom,r)$	Factor employment tax revenue	
$COSEP(tcom,r)$	Ordinary output subsidies	
$CVDFA(tcom,pcom,r)$	Firms domestic purchases at agent prices	$PropIC\_dom(r,i,pqual)$
$CVDFM(tcom,pcom,r)$	Firms domestic purchases at agent prices	
$CVIFA(tcom,pcom,r)$	Firms imported purchases at agent prices	$PropIC\_imp(r,i,pqual)$
$CVIFM(tcom,pcom,r)$	Firms imported purchases at agent prices	
$CVDGA(tcom,r)$	Government domestic purchases at agents prices	$PropDemD(r,tcom)$
$CVDGM(tcom,r)$	Government domestic purchases at market prices	
$CVDPA(tcom,r)$	Households domestic purchases at agents prices	
$CVDPM(tcom,r)$	Households domestic purchases at market prices	
$CVIGA(tcom,r)$	Government imported purchases at agents prices	$PropDemI(r,tcom)$
$CVIGM(tcom,r)$	Government imported purchases at market prices	
$CVIPA(tcom,r)$	Households imported purchases at agents prices	
$CVIPM(tcom,r)$	Households imported purchases at market prices	

B.3 The specific case of intermediate consumption: use of a calibration model

The splitting of initial intermediate consumptions data into the new high and low sugar sub-sectors requires some further rules as the splitting is made both on the products used as inputs, as well as on the products that are made using these intermediate consumptions, as shown on Figure 18. It must also account for the differences in sugar concentrations between the high and low-sugar varieties of a product. We use a calibration model to compute inputs redistribution shares ($PropIC\_dom(r,i,j)$ and $PropIC\_imp(r,i,j)$) that will enable this splitting while imposing a number of given constraints.

Figure 18: Illustrative example of the redistribution of the input/output matrix for the production in the "other food" (ofd) sector

Intermediate consumptions before differentiation

	sug	v_f	dairy
ofd	IC(sug,ofd)	IC(v_f,ofd)	IC(dairy,ofd)

PropIC_dom(r,i,pqual)
PropIC_imp (r,i,pqual)

Intermediate consumptions after differentiation

	sugh	v_fl	dairyl	dairyh
ofdl	IC(sugh,ofdl)	IC(v_fl,ofdl)	IC(dairyl,ofdl)	IC(dairyh,ofdl)
ofdh	IC(sugh,ofdh)	IC(v_fl,ofdh)	IC(dairyl,ofdh)	IC(dairyh,ofdh)

As a prerequisite, we compute first the proportions of high sugar products in the production available domestically ($PropDom(r, pcom)$) and in the imports($PropImp(r, pcom)$):

$$PropDom(r,tcom) = \frac{\sum_{hq \in tcom} (Production(hq,r) - Exports(hq,r))}{\sum_{i \in tcom} (Production(i,r) - Exports(i,r))} \tag{8}$$

$$PropImp(r,tcom) = \frac{\sum_{hq \in tcom} (Imports(hq,r))}{\sum_{i \in tcom} (Imports(i,r))} \tag{9}$$

The different constraints that we impose throughout the calibration model are:

1. The proportions of high-sugar inputs in the production of a global sector (high and low-sugar products) are equals to the proportion of high-sugar products available domestically and from imports ($PropDom(r, pcom)$ and $PropImp(r, pcom)$):

$$\begin{cases} \frac{CVDF(ipth,optl)+CVDF(ipth,opth)}{CVDF(ipth,optl)+CVDF(ipth,opth)+CVDF(iptl,optl)+CVDF(iptl,opth)} = PropDom(r,ipt) \\ \frac{CVIF(ipth,optl)+CVIF(ipth,opth)}{CVIF(ipth,optl)+CVIF(ipth,opth)+CVIF(iptl,optl)+CVIF(iptl,opth)} = PropImp(r,ipt) \end{cases}$$
$$\Leftrightarrow \begin{cases} PropIC\_dom(r,ipth,optl) + PropIC\_dom(r,ipth,opth) = PropDom(r,ipt) \\ PropIC\_imp(r,ipth,optl) + PropIC\_imp(r,ipth,opth) = PropImp(r,ipt) \end{cases} \tag{10}$$

2. For differentiated outputs:

   (a) The ratio between the quantities of high-sugar inputs and their low-sugar counterpart in the production of a high sugar product must be higher of a fixed factor *SugProp* than in its low sugar counterpart.

$$\frac{IC(ipth,opth)}{IC(iptl,opth)} = SugProp \times \frac{IC(ipth,optl)}{IC(iptl,optl)}$$
$$\Leftrightarrow \begin{cases} \frac{PropIC\_dom(r,ipth,opth)}{PropIC\_dom(r,iptl,opth)} = SugProp \times \frac{PropIC\_dom(r,ipth,optl)}{PropIC\_dom(r,iptl,optl)} \\ \frac{PropIC\_imp(r,ipth,opth)}{PropIC\_imp(r,iptl,opth)} = SugProp \times \frac{PropIC\_imp(r,ipth,optl)}{PropIC\_imp(r,iptl,optl)} \end{cases} \tag{11}$$

(b) The sugar concentration of a high sugar product must be higher of a fixed factor *SugProp* than in its low sugar counterpart.

$$\frac{IC(sugh,opth)}{Production(opth)} = SugProp \times \frac{IC(sugh,optl)}{Production(optl)}$$
$$\Leftrightarrow \begin{cases} \frac{PropIC\_dom(r,sugh,opth)}{PropProd(r,opt)} = SugProp \times \frac{PropIC\_dom(r,sugh,optl)}{(1-PropProd(r,opt))} \\ \frac{PropIC\_imp(r,sugh,opth)}{PropProd(r,opt)} = SugProp \times \frac{PropIC\_imp(r,sugh,optl)}{(1-PropProd(r,opt))} \end{cases} \tag{12}$$

(c) For low-sugar non-differentiated inputs, the input concentration must me the same in the output of both sub-sectors.

$$\frac{IC(iptl,opth)}{Production(opth)} = \frac{IC(iptl,optl)}{Production(optl)}$$
$$\Leftrightarrow \begin{cases} \frac{PropIC\_dom(r,iptl,opth)}{PropProd(r,opt)} = \frac{PropIC\_dom(r,iptl,optl)}{(1-PropProd(r,opt))} \\ \frac{PropIC\_imp(r,iptl,opth)}{PropProd(r,opth)} = \frac{PropIC\_imp(r,iptl,opt)}{(1-PropProd(r,opt))} \end{cases} \tag{13}$$