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Welfare Effects of Indirect Tax Policies in West Africa

Abstract

In West Africa, the Value Added Tax (VAT) policy consists of a uniform tax rate, but several items consumed by rich and poor households, are exempted. We provide an optimal tax framework to reflect on the welfare effects of such a tariff structure, in the context of current debates on domestic resource mobilisation in low-income countries (LICs). Our analysis includes the distinguishing feature that a significant part of the consumption goods in LICs stems from own production, and can therefore not be taxed. We also account for preference heterogeneity over market goods and auto-consumption. A preference consistent individual welfare measure that depends on both types of goods, is used. To determine optimal tax rates, individual welfare levels are aggregated by social welfare functions with different degrees of inequality aversion. We apply this framework to household data from Benin. The results support reforms for alternative VAT rate structures that improve welfare in the region. In comparison to the current VAT policy, our reforms yield higher average relative welfare gains for the lower deciles. Due to preferences heterogeneity, however, we find winners and losers in all welfare deciles. We develop a bootstrap procedure to construct confidence intervals on welfare indicators.

JEL-Codes: O550, O230, H210, H230, H750.

Keywords: Africa, Value Added Tax (VAT), optimal taxation, taste heterogeneity, domestic resource mobilisation, tax reform, welfare.

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1 Introduction

Developing countries face huge financing needs (*e.g.* for investment in infrastructure, education, and healthcare), but their tax revenue collection remains relatively low (*e.g.* Garcia-Escribano et al., 2019). In 2019, for instance, the average tax to GDP ratio of about 15%[1] in low income countries (LICs) is still below the United Nations (UN) minimal tax revenue threshold of 20% to achieve the Millennium Development Goals (UNDP, 2010). Whereas the 20% threshold has not yet been met, it is, however, important to notice that LICs have improved their tax collection over the last two decades, coming from an average of 12% in 2000. This progress was the result of various initiatives by governments in these countries and the international donor community. For instance, the Addis Tax Initiative (ATI) was established in 2015 in an agreement between 69 LICs and donors.[2] It has included a wide range of projects aiming "to promote fair and effective domestic revenue mobilisation (DRM), policy coherence and the social contract through partnerships and knowledge building."

We aim to understand the welfare effects of tax collection in WAEMU[3] (West African Economic and Monetary Union). In WAEMU the average tax to GDP ratio is about 16% in 2019. We focus on the value-added tax (VAT) which contributes about 44% to total tax revenue. VAT is harmonised among WEAMU members. The current VAT policy consists of fixing a unique rate (of 18% in all countries except Niger with 19%) but several goods and services are not subject to VAT.[4] For instance, several food products are exempted. While the list of exempted goods seems to be motivated by social objectives, a more thorough empirical analysis shows for some of them the budget share seems to increase with income. Little is known about the welfare implication of such a tax structure. In addition, WAEMU also adopted the UN goal to raise tax revenues to 20% of GDP. Increasing VAT revenue may require to raise the standard tax rate.[5] Doing so may, however, increase inequality.

This paper studies the welfare effects of alternative VAT rate structures in WAEMU. Thereto, we use an optimal indirect tax model with a fairly disaggregated commodity classification, designed to capture potential correlations between total expenditures and consumption of specific commodities. The optimal indirect tax model is of the Ramsey-type, assuming total expenditures to be exogenously given. It exhibits the following features. First, contrary to similar exercises in the literature that measure welfare of groups of individuals in terms of total expenditures or income (Ahmad and Stern, 1984, Decoster and Schokkaert, 1989), we use micro-data and a money metric utility measure of individual welfare (Creedy et al., 2020).

[1] Unless stated otherwise, data on tax revenue presented in this paper come from UNU-WIDER Government Revenue Dataset, 2022: `oi.org/10.35188/UNU-WIDER/GRD-2022`.

[2] The ATI was the third international financing for development conference. The two earlier international agreements were respectively held in Monterrey in 2002 (UN, 2002) and in Doha in 2008 (UN, 2008).

[3] WAEMU includes eight countries: Benin, Burkina Faso, Côte d'Ivoire, Guinée-Bissau, Mali, Niger, Senegal, and Togo.

[4] Guinée-Bissau introduced VAT only in 2023.

[5] The VAT revenue to GDP ratio can be decomposed into three main terms (Keen, 2013): the standard rate, the C-efficiency, and the consumption to GDP ratio. The C-efficiency, defined as actual VAT revenues over revenues if the standard rate would be applied to all consumption, can be further decomposed into the compliance gap (evasion from obliged VAT) and the policy gap (reductions on the standard rate). All these terms could be interrelated but this paper focuses on the tax rate structure and takes the other components as given.

Moreover, our model allows for individual preference heterogeneity (for example, Mirrlees, 1975, Mirrlees, 1976, Saez, 2002, Kaplow, 2006, Kaplow, 2008, Blomquist and Christiansen, 2008, Gauthier and Henriet, 2018, Spiritus, 2022). Second, our model accounts for the welfare effects of items that cannot be taxed. This is an important feature of LICs that is relevant for our analysis. Indeed, in such economies a non-negligible part of consumption stems from own produce (*e.g.* agricultural goods), and taxation of such non-traded commodities is impossible, or only at high administrative costs. The survey data we use for our empirical analysis, show that households in Benin spend on average 86.6% of their budget on market goods in 2015, and thus 13.4% is informal and auto-consumption. For food items the corresponding numbers are 82.1% and 17.9%. Third, we use individually specific nested Cobb-Douglas-CES type of preferences (which is a two-level nested CES, as introduced by Keller, 1976, with the upper level being of the Cobb-Douglas type) to capture substitution effects between market and auto-consumption varieties of commodities, in response to price and tax changes. Fourth, individual welfare levels are aggregated by Atkinson-Kolm-Sen type of social welfare functions. The equity-efficiency trade-off is covered by the inequality aversion parameter of that welfare function. At the lowest degree of inequality aversion, the objective is to maximise average (or total, in the present application, where the population size is kept fixed) welfare irrespective of its distribution among the population. At the other extreme, with maximal inequality aversion, only the welfare of the worst off is of importance.

In a Ramsey model, where total expenditures are exogenous, a uniform rate applied to all goods is equivalent to a lump sum tax, and so may be preferable in the absence of any inequality aversion of the social planner. We show such a uniform rate is nevertheless not optimal in that case. This feature follows from two specificities of our model. First, differences in households composition entail that redistributing money from one household to another may increase total welfare, as some households can increase the welfare of more members than others with the same amount of money. Second, as auto-consumption cannot be taxed, it might be more efficient to tax more heavily goods that are primarily bought on the market and less substitutable with auto-consumption varieties. It is known in the literature that limiting the number of goods that can be taxed, affects the optimal tax structure (Lerner, 1970, Munk, 1980, Munk, 1998, Munk, 2000, Munk, 2008), but this insight has not been much explored in empirical applications.

We apply our model to the case of Benin, using micro data from the Enquête Modulaire Intégrée sur les Conditions de Vie des Ménages (EMICoV) of 2015. In 2015 the tax collection in Benin amounted to 14.5% of GDP. The tax revenue to GDP ratio in Benin did not really increase recently. From 2016 to 2019 it evolved as follows: 12.5%, 13.2%, 14.0%, and 14.5%, respectively.[6] Our analysis focuses on the UN and WAEMU objective of 20% tax revenue to GDP ratio. As we will show, our framework is equally valid for an analysis of the tax structure without increasing the government budget (from 15.5 to 20%). We use the household data to calibrate the preference parameters. On that basis we estimate the VAT revenues stemming from the household sector to be equal to 3.5% of GDP, and they should be increased to 4.8% of GDP to reach the UN and WAEMU objective.[7] We estimate that the standard VAT rate should be increased from 18% to

[6] Data stem from the Direction Générale de l'Economie (DGE), but GDP data were re-scaled such that there was no rebasing (see the background Section 2.1 on GDP rebasing).

[7] Throughout, we did not include excises in our analysis. See the data Section 4.1 on this issue.

26.56% to reach that objective when the current tax policy structure is left unaltered (one standard rate and the current list of exempted goods remaining unaltered). This will serve as our baseline policy framework.

In the benchmark analysis we define 23 categories of goods for which we calculate optimal tax rates for six different values of the inequality aversion parameter (0; 0.5; 0.75; 1.25; 1.5; and 2). We compare the welfare obtained in the baseline policy (26.56% and untaxed goods) with welfare under optimal policies and provide a detailed distributional analysis of gains and losses. We furthermore study the political support for the optimal tax reforms by analysing whether a majority of individuals would gain compared to the baseline policy. We analyse also the welfare characteristics of winners and losers. Given that our results are based on data from a survey sample, we construct 95%-confidence intervals by means of a bootstrap procedure.

To make the exercise more policy relevant, we also introduce the following novelty. On the basis of the optimal tax rates for 23 different good categories, we calculate optimal taxes with a restricted degree of diversification (maximally 4 rates). It turns out that the restricted optima can approximate the welfare levels obtained by a much more diversified system (with 23 rates) very closely. In any case, the administrative feasibility of implementing a differentiated VAT policy in Benin has been facilitated nowadays, since the introduction in 2021 of a digitalised VAT system, allowing sellers to automatically apply the relevant VAT rates.

Five further main results stand out from the empirical analysis. First, we confirm that the presence of untaxable commodities and differences in household structure cause the optimal taxes not to be uniform. Second, our results clearly illustrate the equity-efficiency trade-off: in the absence of inequality aversion, government sets indirect taxes so that total (or average) welfare is maximised. As inequality aversion rises, commodities more intensely preferred by individuals living in households with higher equivalised incomes, tend to be taxed higher. The tax structure turns out to be more diversified. In return, gains for individuals belonging to households with lower equivalised incomes are more substantial, but overall welfare is lower than in the case of zero inequality aversion. A further analysis of the welfare effects by administrative departments illustrates that our results stand to reason: average welfare gain tends to be higher for poorer departments when inequality aversion increases. Third, we find that up to an inequality aversion level of 1.5, a statistically significant majority of the individuals would gain from switching to optimal taxes. On the contrary, optimal taxes for an inequality aversion level of 2 are rejected by a majority, though this result is not statistically significant at the 5% level. Fourth, we find winners and losers in all welfare deciles, due to preference heterogeneity within those deciles. Finally, our results turn out to be qualitatively unchanged when the government budget is set at the current level of 14.5% of GDP. The amount of winners and the average gain tend to increase slightly with the government budget. This means that when the government budget is raised, people tend to lose more under the existing policy of one standard rate and a fixed list of exempted goods, than under the application of optimal taxes. However, this result again hides a lot of heterogeneity.

Our paper is closely related to Bachas et al. (2021) who make a distinction between formal and informal markets. They assume that indirect taxation in developing countries is levied only in big shops and supermarkets, and not in small scale local shops, stalls, or in local markets, or on own production. As we do not have information on the place of transaction, we consider goods to be non-taxable only if they are not bought on the market (that is, received as gift or stemming from own production). In that sense we consider our figures for the share of nontaxable goods as a lower bound. Bachas et al. (2021) find that taxing formal consumption, including food, might be welfare improving in developing countries, as the share of expenditures on informal consumption declines with income. In our empirical analysis we give more details on the share of informal consumption and find that the declining pattern of the share of auto-consumption with income may depend on the type of good, even within the category of foods. Contrary to Bachas et al. (2021), we also give a structural specification of preferences that accounts for such a distinction between goods bought on the market and auto-consumed goods. Moreover, we allow for individual preference heterogeneity within and across welfare deciles. Doing so, implies that tax reforms might generate winners and losers in all welfare deciles, which we did indeed find in our application to Benin. de Quatrebarbes et al. (2016) provide a tax incidence analysis of VAT for Niger (one of the eight WAEMU countries) using a linkage between a Computable General Equilibrium model and a micro-simulation tool. This allows them to consider variable producer prices (incomplete pass-through of changes in the VAT-structure). However, such a modelling strategy only allows to capture the consequences of different arbitrarily predetermined tax scenario's. Our normative framework, on the contrary, allows us to provide principles of optimal tax design.

The remainder of the paper is structured as followed. Section 2 presents background on tax revenue and VAT policy in West Africa and Benin. Section 3 presents our framework for optimal indirect tax analysis and Section 4 presents the data used, the model calibration and the baseline policy. Section 5 discusses empirical results. The last section concludes.

2 Background

In this section we sketch the tax policy context to which our paper wants to contribute some insights from a welfare economic point of view. We start with background information on tax revenue and VAT policy in WAEMU (Section 2.1).[8] Subsequently, we provide specific information on tax revenues in Benin, the country to which we will apply our framework empirically (Section 2.2).

2.1 Tax policy and tax revenues in West Africa

In order to mobilise more means for the provision of public goods, the WAEMU aligned with the UN tax threshold and specified in 2015 a common objective for all WAEMU member countries to reach a tax revenue to GDP ratio of 20%.[9] In most of the WAEMU member states, VAT was only established in the nineties with the exception of three countries (Côte d'Ivoire introduced VAT already in 1960; Senegal in 1980, and Niger in 1986). After its introduction, VAT began to form a substantial part of total tax revenues in these countries (see Figure 2 below).

WAEMU is one of the economic areas in the world where fiscal coordination is the most advanced (Mansour and Rota-Graziosi, 2012). WEAMU's tax harmonisation includes both direct and indirect taxes, for the

[8] WAEMU includes eight countries: Benin, Burkina Faso, Côte d'Ivoire, Guinée-Bissau, Mali, Niger, Senegal, Togo.

[9] See the WEAMU directive Acte Additionnel N° 01/2015/CCEG/UEMOA. Prior to 2015, the WAEMU target for the tax revenue to GDP ratio was fixed in 2003 to be 17% in the directive Acte Additionnel N° 03/2003.

purposes of economic integration. The VAT coordination reform began in 1998 with a directive aiming to harmonise the VAT systems and tax policies in the area. According to the reform, each country must define a standard tax rate between 15% and 20%. All WAEMU countries adopted a standard rate of 18%, except for Niger where it is fixed at 19%, and Guinée-Bissau where VAT was only introduced in 2023, replacing a sales tax. The use of a single rate combined with a list of exempted goods is a common feature of indirect tax policies in developing countries in Africa and Latin-America.[10]

The WAEMU fiscal directives composed a list of goods that should be exempted from VAT for reasons of equity and poverty alleviation (Mansour and Rota-Graziosi, 2012). At the national level, other goods and services were added to this list. The list of exempted items defined by WEAMU and the national authorities has changed over time. The main purpose of the present paper is to show how this structure of a standard tariff and a list of exempted goods, can be improved upon from a welfare economic point of view. Our insights may contribute to the debate on a more equitable indirect tax structure, both given the current government budget, or in the light of a tax reform to come closer to the UN-WEAMU objective. We illustrate this with case of Benin.

Figure 1 displays tax revenue to GDP ratios across the WAEMU member states in 2015. The figure shows that the ratio of tax revenues to GDP differs widely across countries. With 15%, Senegal obtained the highest tax revenue to GDP ratio, while the lowest one is 11%, for Côte d'Ivoire. Figure 2 shows that VAT is a major source of tax revenue in the region, contributing between 23% (Côte d'Ivoire) to over 43% (Togo) of total tax revenue in 2015.

2.2 Tax revenue and VAT policy in Benin

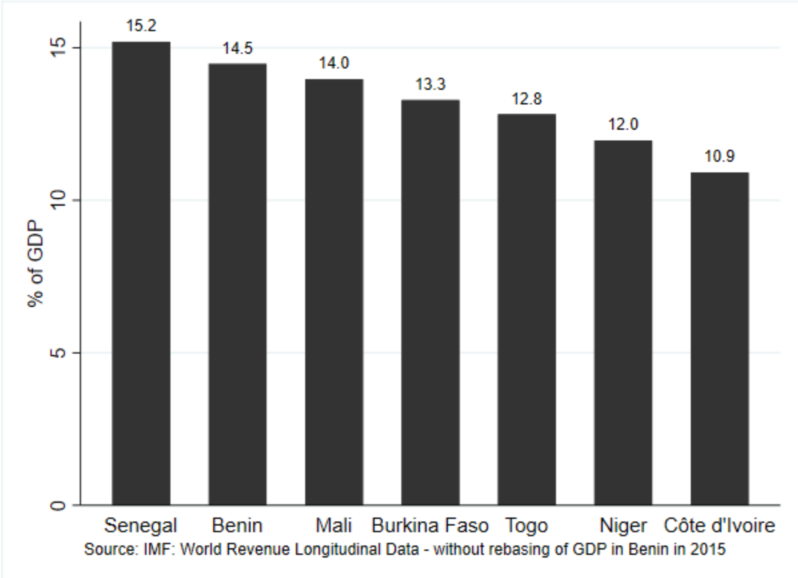
Figure 3 shows that tax revenue has increased in Benin between 1990 and 2015, from less than 10% to 14.5%. The improvement of tax collection in Benin coincided with the introduction of VAT in 1991. The introduction of VAT took place in the context of the structural adjustment program following financial and political crises that the country experienced in the late 1980s. Next to the international coordination of VAT policies, also the weak capacity of the tax administration motivated the choice for one standard rate, fixed at 18%. Its scope covers services such as telecommunication, large part of housing utilities and maintenance, housing furnishings and equipment, clothing and footwear, and a number of food items. The list of exempted goods in Benin includes: education and health services, domestic consumption of electricity and gas, books, mainly non-manufactured agricultural products, housing rents, and non-alcoholic beverages.[11] Several revisions of the list of exempted goods have been implemented over the years.

Like in other WAEMU countries, also in Benin VAT exemptions cause a gap between potential (the standard

[10] In response to energy and food price shocks that hit the region in 2006-2008, WAEMU introduced in 2009 a reform that allowed countries that wish to apply reduced rates between 5 and 10% on a restricted list of goods and services (Directive N° 02/2009/CM/UEMOA). Thus the following countries applied reduced rates: Burkina Faso (2020), Côte d'Ivoire (2021), Mali (2011), Niger (2018), and Senegal (2011) whereas Benin continues to apply a single rate (see Table A.1 of Appendix A). See Thorton's international Indirect Tax Guide:
https://www.grantthornton.global/en/insights/indirect-tax-guide/international-indirect-tax-guide/.

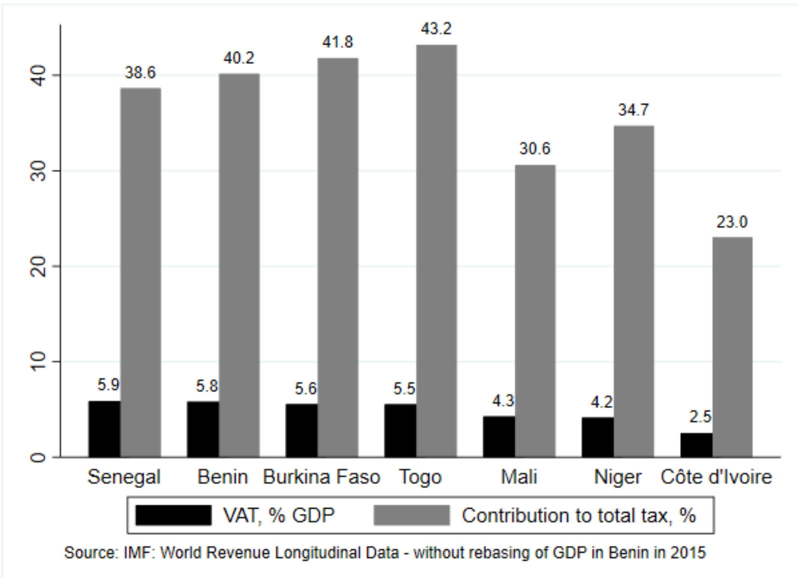
[11] In Section C.1 of Appendix C we provide a complete list of goods and services that are exempted in Benin in 2015.

Figure 1: Tax revenue to GDP ratio in WAEMU countries, 2015 (%)



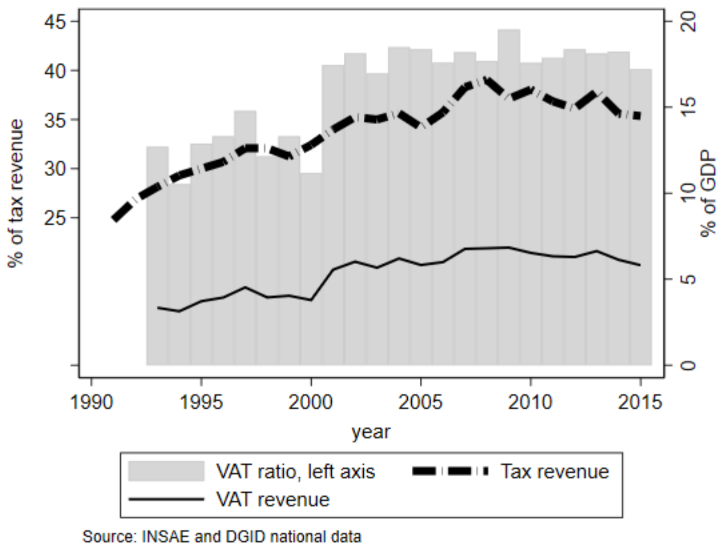
Note: Own calculations on the basis of https://data.imf.org.
In many African countries, historic GDP figures are retrospectively revised, attempting to include more items from mainly informal sectors, and coming this way closer to the standards of OECD countries. This revision is called GDP rebasing.

Figure 2: VAT revenue to GDP ratio in WAEMU countries, 2015 (%)



Note: Own calculations on the basis of https://data.imf.org.
In many African countries, historic GDP figures are retrospectively revised, attempting to include more items from mainly informal sectors, and coming this way closer to the standards of OECD countries. This revision is called GDP rebasing.

Figure 3: Tax and VAT revenues in Benin



Note: DGID stands for the Direction Générale des Impôts et des Domaines. The black dashed and full lines represent respectively the total tax revenues and VAT revenues to GDP ratio's, to be read off from the right vertical axis. The bars represent the VAT revenues to total tax revenues ratio (on the left vertical axis).

VAT rate times final consumption) and actual tax revenues, the so-called C-efficiency (Houssa et al., 2017, Banque Mondiale, 2018). Banque Mondiale (2018) argues that the erosion of VAT performance from 2014 onward in Benin (we provide some figures at the end of this section), results, among other things, from the increase in the number of exempted goods. Nevertheless, these exemptions serve at first glance social objectives. But actually, exempt items are consumed by both rich and poor households. Little quantitative analysis of the actual welfare implications of the exemption policy is available.

In 2017, the government adopted a Strategic Orientation Plan for Tax Administration[12] intended to modernise the tax administration and improve the mobilisation of internal resources. The most important reform in the field of VAT collection is the introduction of the standardised invoice since 2021, making use of electronic invoicing machines. The reform is part of a broader government reform agenda to digitise access to public services.

In practice, however, the government cannot tax goods purchased from the informal sector or those derived from own production. The calculations from the survey data reported in Table 1 that we use for our empirical analysis, show that households spend on average 86.6% of their budget on market goods in 2015, and thus 13.4% is auto-consumption. For food items, the corresponding numbers are 82.1% and 17.9%. On average, 57.5% of total expenditures on market goods is devoted to VAT liable commodities. Only 32% of expenditures on food bought on the market is liable to VAT.

In 2015, the tax administration reports that VAT revenues amounted to 286.4 billion CFA. That is 5.8% of GDP. VAT revenues accounted for 40% of the total tax revenues. According to our survey data , VAT

[12] The POSAF (Plan d'Orientation Stratégique de l'Administration Fiscale) covered the period 2017-2021. In 2022 the second POSAF plan was launched for the 2022-2026 period.

Table 1: Budget share in Benin (2015)

	% market in total	% taxed within market	% exempt
All	86.6	57.5	42.5
Food	38.9	31.9	68.1

Note: Own calculations from the Enquête Modulaire Intégrée sur les Conditions de Vie des Ménages (EMICoV) of 2015. More information on the data and definition of concepts is given in Section 4.1.

revenues collected from the domestic household sector equaled 172.6 billion CFA or 3.5% of GDP. The rest stems from taxation of imported goods that are re-exported to neighbouring countries. In order to augment the total tax revenue, which attained 14.5% in 2015 (Figure 1), to 20% of GDP, as recommended by the UN and WAEMU, by a proportional scaling-up of direct and indirect taxes, tax revenues should increase by 38%. VAT revenues collected from the domestic household sector thus need to rise from 3.5% to 4.8% of GDP or 237.7 billion CFA. According to the demand model we develop in Section 3.2, this could be reached by applying a standard VAT rate of 26.56% while keeping the list of exempted goods fixed. The next section presents a theoretical framework to assess such a reform, comparing the current VAT structure with optimal taxes. However, the tax revenue to GDP ratio in Benin did not really increase recently. From 2016 to 2019 it evolved as follows: 12.5%, 13.2%, 14.0%, and 14.5%, respectively. As we will show, our framework is equally valid for an analysis of the existing tax structure without increasing the budget.

3 An optimal indirect tax approach

In the present section we set out the model through which we will structure and analyse the data, and which we will use to get insights on optimal indirect tax policies from a welfare theoretical point of view. Thereto, we start from a classical many-person Ramsey model of optimal indirect taxation (Ramsey, 1927, Diamond, 1975, Chapter 3 of Salanié, 2011, and Lecture 12 of Atkinson and Stiglitz, 2015). In our implementation and elaboration of the model, we pay attention to two specific features which have hitherto been neglected in similar applied exercises. First, in agricultural household economies, a non-negligible part of consumption (13.6%) is auto-consumed, mainly (over 63%) food products. This implies that some commodities cannot or cannot easily be taxed. The introduction of this distinction between taxable and non-taxable goods has implications for the structure of optimal indirect taxation. This has been recognised in early theoretical contributions (Lerner, 1970, and Munk, 1980,1998). Recently, Bachas et al. (2021) integrated informality into their welfare analysis of indirect taxation. Second, we allow for preference heterogeneity. To that end, we use a specification of individual preferences such that observed consumption behaviour is completely explained by preference difference, and not by differences in income, as in Bachas et al. (2021). We use insights from the literature on the welfare analysis of tax reforms (Ahmad and Stern, 1984, Ray, 1999, Urzúa, 2005) to interpret the optimal tax rules. In order to make the exercise more policy relevant, we introduced restrictions on the number of tax rates. Belan and Gauthier (2006) and Belan et al. (2008) provide theoretical foundation for such a restricted optimal tax exercise.

After introducing some basic notation in Section 3.1. We next discuss our household demand model (Section 3.2). Section 3.3 contains the optimal tax model. It consists of a social welfare function, which is basically a weighted mean of individual welfare levels that can be derived from the demand model. This objective function is to be maximised subject to a government budget constraint. The instruments are the indirect tax rates. The model captures both, the effects on government revenue from changing tax rates and the change in individual welfare levels. In each of these, it is taken into account households will adapt their demand behaviour to changing tax rates.

3.1 Consumption, indirect taxes, and market model

A society is composed of H households. Households are indexed by $h = 1, 2, \ldots, H$. A household h consists of n_h members. So, there are $N \equiv \sum_{h=1}^{H} n_h$ individuals in society. Individuals are indexed by $i = 1, \ldots, N$. The vector of quantities of commodities consumed by a household h is denoted by $\mathbf{x}_h$. There are G commodity groups, indexed by g. For each commodity group g there is a variety which is available on the market, denoted by g, m, and a variety that is produced by the household, denoted by g, a; s will be an index running over a and m. Thus the consumption vector of household h can be decomposed as follows: $\mathbf{x}_h \equiv (\mathbf{x}_{m,h}, \mathbf{x}_{a,h})$ with $\mathbf{x}_{m,h} = (x_{1,m,h}, x_{2,m,h}, \ldots, x_{g,m,h}, \ldots, x_{G,m,h})$, being the vector of goods and services bought on the market, and $\mathbf{x}_{a,h} \equiv (x_{1,a,h}, x_{2a,h}, \ldots, x_{g,a,h}, \ldots, x_{G,a,h})$ the vector of auto-consumption.

Producer prices are fixed and normalised to one, so that producer prices are independent of taxes, and quantities $x_{g,s,h}$ are measured in monetary terms, at producer prices. The assumption of fixed producer prices can be rationalised by supposing all producers operate a constant returns to scale technology with only one non-produced production factor, labour time. The vector of *ad valorem* indirect tax rates is denoted by $\mathbf{t} = (t_1, t_2, \ldots, t_g, \ldots, t_G)$. Only commodities bought on the market can be taxed. Given the producer price normalisation, consumer market prices, denoted by $\mathbf{q}_m$, satisfy $\mathbf{q}_m \equiv (1 + \mathbf{t}) = (1 + t_1, 1 + t_2, \ldots, 1 + t_g, \ldots, 1 + t_G)$. Auto–consumption is not taxable, and therefore its consumer price is one: $\mathbf{q}_a = (\underbrace{1, \ldots, 1}_{G \text{ times}})$. The overall consumer price vector is denoted by $\mathbf{q} \equiv (\mathbf{q}_m, \mathbf{q}_a)$. Finally, $\mathbf{q}_g$ collects the market and auto–consumption variety consumer price of a commodity g: $\mathbf{q}_g = (q_{g,m}, q_{g,a}) = (1 + t_g, 1)$.

Expenditure on a good g, m equals $(1 + t_g)\, x_{g,m,h} = q_g x_{g,m,h}$, while for auto–consumption expenditure is valued at producer price and thus coincides with quantity. In general, expenditures by household h on a good g, s ($s = m, a$), denoted by $e_{g,s,h}$, thus equal $e_{g,s,h} = q_{g,s} x_{g,s,h}$. Total expenditures equal $\mathbf{q}'\mathbf{x}_h = \mathbf{q}'_m \mathbf{x}_{m,h} + \mathbf{q}'_a \mathbf{x}_{a,h} = \mathbf{q}'_m \mathbf{x}_{m,h} + \sum_g x_{g,a,h}$, and the (indirect) tax bill paid by a household equals $\sum_{g=1}^{G} t_g x_{g,m,h}$. Household h's budget is equal total expenditures. It is denoted by y_h and is assumed to be fixed. It will also be called disposable income in the sequel. It also includes the value of auto-consumed goods, as these goods stem from own production and thus generate revenue. Consequently, $y_h = \mathbf{q}'\mathbf{x}_h$. The budget share spent on good g is $\alpha_{g,h} = \frac{(1+t_g)x_{g,m,h} + x_{g,a,h}}{y_h}$.

3.2 Individual preferences

Differences across households in observed consumption commodities are assumed to be accredited to differences in preferences (shape of indifference curves) instead of being the consequence of attaining different indifference curves from a common underlying indifference map, due to income differences. In this way, we want to fully exploit the potential of indirect taxes to counteract inequities due to preference differences. Of course, in reality the famous distinction between necessities and luxuries may come on top of that. There is, however, a large literature, starting from the seminal contribution of Atkinson and Stiglitz (1976), which shows that, when allowing for an optimal direct tax instrument, indirect taxes should rather serve to relax the incentive constraints, in order to allow for a larger re-distributive role of income taxes. By taxing luxuries and/or complements to labour relatively less, more productive, richer, people find it more attractive to work more, despite relatively high income taxes for high earners. This literature assumes, however, that preferences are identical for all members in society. There is a growing body of insights that indirect taxes might continue to play a limited re-distributive role when preferences are heterogeneous, even under an optimal direct tax system (Cremer et al., 2001, Saez, 2002, Fleurbaey, 2006, Kaplow, 2008, Gauthier and Henriet, 2018, Spiritus, 2022). This depends upon the degree to which preference differences are correlated with incomes, or more exactly, welfare.

We thus opt for a class of homothetic preferences, and to keep efficiency considerations simple, no cross price effects between any pair of goods g and g' are allowed for. This implies that expenditure shares of commodities, previously defined as $\alpha_{g,h}$, are assumed to be fixed, but are allowed to be household specific. Within each commodity group g, the market and auto-consumption variety are assumed to be imperfectly substitutable. We impose this substitution elasticity between market and auto-consumption varieties to be common for all goods and households, and it is denoted by σ. Households may, however, exhibit a relatively more intense preference for the market or auto-consumption variety of a commodity g. This brings us to a nested preference structure where the upper layer captures the allocation of the global budget across commodities groups g. It is assumed to be of the Cobb-Douglas types, with household specific share parameters $\alpha_{g,h}$. Within each commodity group g, a Constant Elasticity of Substitution (CES) aggregator captures the household specific preference intensity over the market and auto-consumption variety of that good. As such, preferences can be represented by the following utility function:

$$u_h^{\mathrm{CCD}}(\mathbf{x}) = \prod_g \left(\sum_s \delta_{g,s,h}^{1-r} x_{g,s}^r \right)^{\frac{\alpha_{g,h}}{r}}, \tag{1}$$

where:

– the $\alpha_{g,h}$'s are the Cobb–Douglas share parameters, and equal household h's expenditure shares of the commodities g;

– the $\delta_{g,s,h}$'s are household and commodity specific distribution parameters indicating the relative intensity of preference for the s variety of good g. They are normalised such that $\sum_s \delta_{g,s,h} = 1$;

– $r = \frac{\sigma-1}{\sigma}$, with $\sigma \in [0, \infty)$ being the elasticity of substitution between market and auto–consumed varieties ($r < 1$). The elasticity of substitution is the percentage change of $x_{g,a}/x_{g,m}$ (along an indifference curve) in response to a percentage change in the marginal rate of substitution between a and m.

The resulting Marshallian demand functions equal:

$$d^{\text{CCD}}_{g,s,h}\left(\mathbf{q}_g; y\right) = \frac{\alpha_{g,h}\delta_{g,s,h}y}{\phi_{g,h}\left(\mathbf{q}_g\right)^{1-\sigma} q^{\sigma}_{g,s}}, \tag{2}$$

where $\phi_{g,h}\left(\mathbf{q}_g\right) = \left(\sum_s \delta_{g,s,h} q^{1-\sigma}_{g,s}\right)^{\frac{1}{1-\sigma}}$, is a CES price index.
The indirect utility function associated with the utility function (1) is equal to:

$$\begin{aligned} v^{\text{CCD}}_h\left(\mathbf{q}, y\right) &:= u^{\text{CCD}}_h\left(d^{\text{CCD}}_{g,s,h}\left(\mathbf{q}_g; y\right); s = a, m; g = 1, \ldots, G\right) \\ &= y \prod_g \left(\frac{\alpha_{g,h}}{\phi_{g,h}(\mathbf{q}_g)}\right)^{\alpha_{g,h}} \end{aligned} \tag{3}$$

3.3 Welfare analysis

In the present section we discuss the social objective and restrictions which should be taken into account when trying to maximise this social objective by means of choosing indirect tax rates. We assume the government has to raise a fixed budget $\bar{R}$. This budget is considered to be exogenously given. Alternatively, if the welfare generated by the public goods financed through that budget is additively separable in the social objective function, the determination of the size of the government can be treated separately from the problem of finding the optimal indirect tax rates. Indirect taxes are assumed to be linear: the tax bill is a proportion of the amount spent on a particular good g. Non-linear indirect taxes are not easily implementable, as the amount expended to different goods is not easily observed. Non-linear indirect taxes would easily lead to evasion by splitting or joining purchases.
Moreover, only goods transacted on the market can be taxed. Bachas et al. (2021) make the distinction between formal and informal markets. Remember that they claim that indirect taxation in developing countries is levied only in big shops and supermarkets, and not in small scale local shops, stalls, or in local markets. As we don't have information on the place of transaction, we consider goods to be nontaxable only if they are not bought on the market (that is, received as gift or stemming from own production). Similarly as in Bachas et al. (2021), we consider nontaxable and taxable commodities as different varieties of the same commodity. Contrary to Bachas et al. (2021), we give a structural specification of preferences that accounts for such a distinction between goods bought on the market and auto-consumed goods.
We start by defining the metric we will use to measure individual welfare. Then we discuss the social welfare function to be maximised under the government budget restriction to arrive at the optimal tax rules. We next give a detailed decomposition analysis of the social welfare weights embodied in social welfare function. We then show that the set of conditions under which uniform taxes are optimal is restrictive. To make the optimal tax rules more relevant from a policy perspective, we explain in the last paragraph how optimal taxation with a restricted number of possibly different tax rates, can be accomplished.

Individual welfare.

Following the renewed justification of money metric utilities (Fleurbaey, 2011, Fleurbaey and Blanchet, 2013), we use a member of this class of utility functions to measure individual welfare. A Money Metric Utility (MMU) is the amount of money a household would need when confronted with a set of reference prices, $\mathbf{q}_{\text{ref}}$, in order to be able to guarantee its members the same welfare as under the actual or counterfactual price regime $\mathbf{q}$ and given the actual or counterfactual income y. The minimal amount of income needed in order to be able to attain a welfare level U when prices equal $\mathbf{q}$, is known as the expenditure function and it is equal to the inverse of the indirect utility function. For the indirect utility function (3), this yields:

$$e_h^{\text{CCD}}(\mathbf{q};U) = U\prod_g\left(\frac{\phi_{g,h}(\mathbf{q}_g)}{\alpha_{g,h}}\right)^{\alpha_{g,h}}. \tag{4}$$

The welfare level U obtained when faced with a set of prices $\mathbf{q}$, and income level y is equal to $v_h^{\text{CCD}}(\mathbf{q},y)$. Choosing a set of reference prices $\mathbf{q}_{\text{ref}}$ to evaluate the expenditure function (4) at the welfare level $U = v_h^{\text{CCD}}(\mathbf{q},y)$, one obtains the following expression of the MMU:

$$MMU_h^{\text{CCD}}(\mathbf{q},y;\mathbf{q}_{\text{ref}}) \equiv e_h^{\text{CCD}}(\mathbf{q}_{\text{ref}};v_h^{\text{CCD}}(\mathbf{q},y)) = y\prod_g\left(\frac{\phi_g(\mathbf{q}_{\text{ref},g})}{\phi_g(\mathbf{q}_g)}\right)^{\alpha_g}. \tag{5}$$

Up to now we were somewhat loose about the distinction between households and their members. At the theoretical level, preferences and welfare are individual characteristics. In practice however people are making joint consumption decisions within small living units (households) and, even if they did not so, we do not actually observe individual consumption behaviour. We follow the by now classical approach in welfare analysis, to circumvent these problems by assuming that all household members have identical preferences and obtain the same welfare level, but that there are some economies of scale within the household to produce welfare for its members. This implies that to provide the members of a multi-person household h of size n_h, with the same welfare as a single, less than n_h times the income of that single is needed. The estimation of the extent of such economies of scale is the subject of the construction of an equivalence scale, which is a function that produces the amount θ_h by which household income y has to be divided such that a single with income y/θ_h can obtain the same welfare as the household members. This equivalence scale depends on the number of household members and possibly other characteristics, such as age, of the household members.[13] Consequently, an individual welfare measure can be obtained by dividing the MMU with the equivalence scale. In our parameterisation, this results in:

$$m_{i_h}^{\text{CCD}}(\mathbf{q},y;\mathbf{q}_{\text{ref}}) = \frac{MMU_h^{\text{CCD}}(\mathbf{q},y;\mathbf{q}_{\text{ref}})}{\theta_h} = \frac{y}{\theta_h}\frac{\Phi_h(\mathbf{q}_{\text{ref}})}{\Phi_h(\mathbf{q})}, \tag{6}$$

with $\Phi_h(\mathbf{q}) = \prod_g(\phi_{g,h}(\mathbf{q}_g))^{\alpha_{g,h}}$, a CES-CD-price index. Notice that $m_{i_h}^{\text{CCD}}(\mathbf{q},y;\mathbf{q}_{\text{ref}})$ is identical for all household members i_h, so that we will also write $m_h^{\text{CCD}}(\mathbf{q},y;\mathbf{q}_{\text{ref}})$ to denote the same function.

One can interpret this measure as real equivalised disposable income, because it is equivalised disposable income divided by a price index. It is the amount of money an individual i in household h, denoted by i_h,

[13] We do not integrate here the recent trend to model within household inequalities by means of a collective bargaining model (see part I of Browning et al., 2014 for a review of that literature, and Browning et al., 2013 for the implications with respect to the notion and use of equivalence scales). In this approach, usually only inequalities between partners in a couple are modelled, and children are considered to be public goods, not individual household members (Blundell et al., 2005, Cherchye et al., 2012). Dunbar et al. (2013) is a rare exception in that respect. Bargain and Donni (2014) provide an optimal indirect tax exercise within a collective household framework.

would need if he or she could buy consumption goods at reference prices, in order to be equally off as he or she is in the actual situation within the household h to which (s)he belongs. As such, it is a utility measure, that is, a numerical representation of preferences.

It is important to stress that the choice of reference prices in this measure does affect the ranking of individuals in terms of welfare. It does not affect however intra-personal comparisons. Certain interpersonal comparisons are also independent of the choice of reference prices. For example, suppose i_h is better off or equally well-off as $j_{h'}$ in situation A and $j_{h'}$ is not better off in situation B than in situation A, and i_h is at least as well-off in B than in A. In that case, the welfare difference between i_h and $j_{h'}$ is at least as large in B as in A, irrespective of the choice of reference prices. Moreover, this difference has become larger if at least one of the intra-personal comparisons between A and B in the premises, is strict. In order to neutralise somewhat the influence of reference prices, we will uniquely consider the case where all reference prices are equal to one (denoted by $\mathbf{q}_{\text{ref}} \equiv \mathbf{1}$). In this way $\Phi_h(\mathbf{q}_{\text{ref}}) = 1$ for all households, and no particular preference ordering is (dis)advantaged by the choice of the reference prices.

Equation (6) shows that individual welfare depends on (1) household disposable income, (2) the equivalence scale, and (3) a price index. Household disposable income affects individual welfare positively in a linear way. This is due to homotheticity of preferences (and the choice of a welfare measure expressed in monetary units). The equivalence scale affects individual welfare negatively. This stands to reason. The equivalence scale measures with how many *adult equivalent* persons an additional CFA franc of disposable income for the household, has to be shared. Finally, welfare is decreasing in the prices. The price index is household specific, as it depends on the preference parameters $\alpha_{g,h}$ and $\delta_{g,s,h}$. A combination of a tax lift on one good with a decrease on another –keeping government revenues constant– may be detrimental to someone relatively more intensely preferring the good on which the tax has been raised, but the opposite might hold for someone more intensely preferring the good on which the tax has been decreased. Intensity of preferences in this model depends on the relative height of $\alpha_{g,h}$ versus $\alpha_{g',h}$'s and of $\delta_{g,m,h}$ versus $\delta_{g,a,h}$.

Social welfare and optimal taxes.

Social welfare is a convex mean of the individual welfare measures. We use the Atkinson-Kolm-Sen aggregator (see e.g. Adler, 2019):

$$SWF = \sum_h n_h \frac{\left(m_h^{\text{CCD}}(\mathbf{q}, y_h; \mathbf{1})\right)^{1-e}}{1-e}, \tag{7}$$

with $e \geq 0$. The parameter e is known as inequality aversion parameter. When $e = 0$, we obtain the utilitarian case, that is a simple sum of individual utilities.[14] When $e \to \infty$, we obtain either the Rawlsian maximin case or its lexicographic extension (see Hammond, 1975).

Notice that social welfare is a function of the indirect tax rates and the distribution of total expenditures (or incomes), $\mathbf{y} := (y_1, y_2, \ldots, y_h, \ldots, y_H)$. The latter is exogenously given in this model. We will make this explicit by writing:

$$W(\mathbf{t}; \mathbf{y}) = \sum_h n_h \frac{\left(m_h^{\text{CCD}}((1+\mathbf{t}, \mathbf{q}_a), y_h; \mathbf{1})\right)^{1-e}}{1-e} = \sum_h \frac{n_h}{1-e} \left(\frac{y_h}{\theta_h \cdot \Phi_h(1+\mathbf{t}, \mathbf{q}_a)}\right)^{1-e}. \tag{8}$$

[14] When $e = 1$, the appropriate formula is: $SWF = \sum_h n_h \ln\left(m_h^{\text{CCD}}(\mathbf{q}, y_h; \mathbf{1})\right)$.

The government budget equation is equal to:

$$R(\mathbf{t};\mathbf{y}) = \sum_g t_g \sum_h d^{\text{CCD}}_{g,m,h}\left((1+t_g,1);y_h\right) = \sum_g t_g \sum_h \frac{\alpha_{g,h}\delta_{g,m,h}y_h}{\phi_{g,h}\left((1+t_g,1)\right)^{1-\sigma}(1+t_g)^{\sigma}}, \tag{9}$$

where it is taken into account that only market varieties can be taxed (the sum only runs over the m-varieties of each good).

Optimal indirect taxes are the solution to the following problem:

$$\max_{\mathbf{t}}\ W(\mathbf{t};\mathbf{y}) \qquad \text{s.t.} \quad R(\mathbf{t};\mathbf{y}) \geq \bar{R}. \tag{max}$$

In order to interpret the first order conditions of this maximisation problem, we introduce the concept of the marginal social welfare cost of raising an additional CFA franc by increasing the tax on commodity g, m.[15] Ahmad and Stern (1984) show that this cost is equal to:

$$MC_{g,m}(\mathbf{t};\mathbf{y}) = -\frac{\partial W/\partial t_g}{\partial R/\partial t_g} = \frac{\sum_h \beta_h(\mathbf{t})\, d^{\text{CCD}}_{g,m,h}\left((1+t_g,1),y_h\right)}{\sum_h \left(d^{\text{CCD}}_{g,m,h}\left((1+t_g,1),y_h\right) + t_g \partial d^{\text{CCD}}_{g,m,h}\left((1+t_g,1),y_h\right)/\partial q_{g,m}\right)}. \tag{10}$$

The numerator of this equation is the effect on social welfare of a marginal increase of the tax on commodity g, m. It is a weighted sum of individual consumption of commodity g, m. The weights $\beta_h(\mathbf{t})$ are known as marginal social welfare weights and denote the effect on social welfare of a marginal increase of household h's budget. We will discuss these weights more in detail in the next paragraph. The denominator of Equation (10) contains the effect on government revenues of such a marginal change in t_g. This denominator is lower, the higher own prices elasticities of demand are in absolute value. Indeed, the more an increase of the VAT tariff on a particular good reduces the demand for that good, the less revenues will increase, and thus the higher the social welfare cost will be.[16] Notice that a change in the tax rate t_g by $(\partial R/\partial t_g)^{-1}$, increases the government budget with one CFA franc. Consequently, the marginal social welfare cost $MC_{g,m}(\mathbf{t};\mathbf{y})$ is the effect on social welfare of a marginal increase of t_g multiplied by the increase in that tax rate needed to raise an additional CFA franc .

If the marginal social welfare costs of two goods are unequal, social welfare can be increased by decreasing the tax rate of the good g, m with higher $MC_{g,m}(\mathbf{t};\mathbf{y})$ with $(\partial R/\partial t_g)^{-1}$, and simultaneously increasing the tax rate on commodity g', m by $(\partial R/\partial t_{g'})^{-1}$. By construction, this leaves government revenues unchanged, while the social welfare loss increasing the latter tax rate $t_{g'}$, $MC_{g',m}(\mathbf{t};\mathbf{y})$, is less than the gain of decreasing the former rate t_g, with the initially higher social welfare cost $MC_{g,m}(\mathbf{t};\mathbf{y})$.

It follows that in an optimum, tax rates should be such that the marginal social welfare costs of all taxable goods are equal:

$$\lambda = MC_{g,m}(\mathbf{t}^*;\mathbf{y}), \quad \text{for all } g. \tag{11}$$

The value of the marginal social welfare costs in an optimum equals the Lagrange multiplier λ associated with government budget constraint in the maximisation problem (max). The interpretation of this multiplier is known to be the effect on social welfare of marginally decreasing the required government budget $\bar{R}$.

[15] The first order conditions are given in Equation A.10 of Appendix B.2.

[16] There are no cross price effects between market goods in the Marshallian demands of our individual behavioural model. If there were, gross substitutes of the considered commodity g, increase the denominator and thus reduce the marginal social welfare cost. The reverse holds for gross complements.

Social welfare weights.

From Equation (8), it can be derived that:

$$
\begin{aligned}
-\frac{\partial W}{\partial t_g} &= -\sum_h n_h \left(m_h^{\text{CCD}}\left(\left((1+\mathbf{t}),\mathbf{q}_a\right),y_h;\mathbf{1}\right)\right)^{-e}\frac{\partial m_h^{\text{CCD}}}{\partial t_g} \\
&= \frac{\partial W}{\partial y_h} d_{g,m,h}^{\text{CCD}}\left((1+t_g,1),y_h\right) \\
&= \sum_h n_h \left(m_h^{\text{CCD}}\left(\left((1+\mathbf{t}),\mathbf{q}_a\right),y_h;\mathbf{1}\right)\right)^{-e}\frac{\partial m_h^{\text{CCD}}}{\partial y_h} d_{g,m,h}^{\text{CCD}}\left((1+t_g,1),y_h\right),
\end{aligned}
\tag{12}
$$

where Roy's identity is used to obtain the second equality.

Comparing Equation (12) this with the numerator of Equation (10), one can see that the marginal social welfare weights are equal to:

$$
\begin{aligned}
\beta_h(\mathbf{t}) &= \frac{\partial W}{\partial y_h} \\
&= n_h \left(m_h^{\text{CCD}}\left(\left((1+\mathbf{t}),\mathbf{q}_a\right),y_h;\mathbf{1}\right)\right)^{-e}\frac{\partial m_h^{\text{CCD}}}{\partial y_h} \\
&= \frac{n_h}{\theta_h}\left(m_h^{\text{CCD}}\left(\left((1+\mathbf{t}),\mathbf{q}_a\right),y_h;\mathbf{1}\right)\right)^{-e}\frac{1}{\Phi_h\left(\left((1+\mathbf{t}),\mathbf{q}_a\right)\right)} \\
&= \frac{n_h}{\theta_h}\left(\frac{y_h/\theta_h}{\Phi_h\left(\left((1+\mathbf{t}),\mathbf{q}_a\right)\right)}\right)^{-e}\frac{1}{\Phi_h\left(\left((1+\mathbf{t}),\mathbf{q}_a\right)\right)}.
\end{aligned}
\tag{13}
$$

The marginal social welfare weight is the increase in social welfare induced by a marginal increase in the disposable income of household h.

In line with Ray (1999, 2018), and contrary to many exercises of this type, including Ahmad and Stern (1984) and Decoster and Schokkaert (1989), we will fully take into account that these marginal social welfare weights are not only a function of income y_h, but depend also on the tax rates (what is stressed in our notation by including the tax vector as an argument of the β's). Their values are therefore endogenous in the optimisation problem (max), and it also matters for marginal reform analysis (as in Ahmad and Stern, 1984, and Decoster and Schokkaert, 1989) if preferences are non-homothetic or if there are preference differences between individuals.

These marginal social welfare weights can be further decomposed into three components:

$$
\beta_h(\mathbf{t}) = \underbrace{\left(\frac{y_h/\theta_h}{\Phi_h(\mathbf{q})}\right)^{-e}}_{A}\underbrace{\frac{1}{\Phi_h(\mathbf{q})}}_{B}\underbrace{\frac{n_h}{\theta_h}}_{C}.
\tag{14}
$$

The first component (A) embodies the *equity* concerns built into the shape of the social welfare function and indicates the additional social welfare following a marginal increase in the individual welfare of a representative individual of household h. It depends on the degree of inequality aversion e. When $e > 0$ more weight is given to households whose members have a low level of individual welfare. In the utilitarian case ($e = 0$) this component vanishes: raising the welfare of any individual with one unit raises social welfare with one unit irrespective whether this individual has a high or low initial welfare level. One can then not increase welfare by redistributing welfare from individuals with relatively high individual welfare to individuals with lower welfare. When $e \to \infty$ only the welfare of the individual(s) with the lowest welfare counts in the social welfare function.[17] One cannot, however, transfer *welfare* from one individual to another. Only (monetary)

[17] Hammond (1975) argues that $e \to \infty$ can also result in the lexicographic extension of the maximin social welfare function: when the worst off in two welfare distributions have equal welfare, one looks at the second worst off. If they also have equal welfare, one moves to a comparison of the third worst off, and so on, until ties are broken. If not, the two distributions are considered to be equally good from a social welfare point of view.

resources can be redistributed. Parts B and C concern the *efficiency* with which a household h can transform an additional amount of money into individual welfare for its members. This depends on the tastes of the household members, captured by component B, and the degree to which the additional resources can simultaneously increase the individual welfare of several household members (component C). Component B will lower the welfare weight of households who's members more intensely prefer relatively more expensive goods. Again, mind that the degree to which a good is relatively more expensive than another, depends on the tax rate in our model, and is therefore endogenous.

Component C refers to the degree to which a household can serve a welfare improvement for relatively more individual members, with the same additional amount of money. There is some ambiguity as to whether the number of household members n_h should be considered as part of the marginal social welfare weights. One could also consider the effect of transferring an additional CFA to household h on the *individual* welfare of any of this household's members and the effect of that individual welfare change on social welfare. The household size, n_h, would then vanish from the definition of the marginal social welfare weight, and is to be considered as a weight, taking into account the number of (identical) individuals profiting from a transfer of one additional CFA to household h. As we are interested in the effect on social welfare of a change in an indirect tax rate t_g, and as this can be written as the weighted sum of households' demands for commodity g, where the weights are the β_h's as defined in Equation (14), we prefer to treat n_h as integral part of the welfare weights. Loosely speaking, we could interpret the term n_h/θ_h as a measure of relative advantage from economies of scale within the household.

The price index $\Phi(\mathbf{q})$ and the equivalence scale θ_h occur in both, the equity component (A) and the efficiency components (B and C) of the marginal social weights. Their impact has, however, an opposite sign in these components: a higher price index or equivalence scale increases the social weight through its equity component (as it reduces the welfare measure and people with lower welfare get higher weight in the welfare function) while it decreases the weights through the efficiency components (as a higher price index or equivalence scale decreases the effect on welfare of an additional CFA). The (positive) equity effect dominates the (negative) efficiency effect if $e > 1$.[18]

Optimal uniform indirect taxes.

Atkinson and Stiglitz (1976) initiated the debate on the conditions under which indirect taxes are uniform in the optimum. In our model, uniform optimal taxation of all goods (including auto-consumption varieties) amounts to a lump sum tax as total expenditure (disposable income) is exogenously given.[19] We will show however that a welfare function with zero inequality aversion ($e = 0$) and thus only exhibiting efficiency concerns, is not enough for uniform indirect taxation to be optimal in the present model.

When the β_h's are equal for all household members, the numerator of the marginal welfare costs to raise an additional CFA through increasing the tax on commodity g (Equation 10) equals the population's total demand for that good multiplied by this common social welfare weight β.

[18] For the equivalence scales, this ambivalence was already highlighted by Decoster (1988).

[19] In a model with a direct tax component and no other income than labour income, *uniform* indirect taxation is tantamount to saying that indirect taxation is redundant, as uniform indirect taxes are equivalent with a proportional tax on labour income.

So, let us concentrate on the denominator of Equation (10), supposing the β_h's are equal for all households h. The denominator contains the effect on government revenue of a marginal increase of the tax rate on commodity g. Now suppose that *all* goods can be taxed, market as well as auto-consumption varieties, and denote the tax rate on the s-variety of commodity g by $t_{g,s}$. Consumer prices are then equal to $q_{g,s} = 1 + t_{g,s}$, collected in the vector $\mathbf{q}$. In general, the government tax revenue equation then reads as:

$$R(\mathbf{q};\mathbf{y}) = \sum_h \sum_{g,s} t_{g,s} d_{g,s,h}(\mathbf{q}; y_h), \tag{15}$$

where $d_{g,s,h}$ denotes household h's Marshallian demand function for the s-variety of commodity g.
The effect on tax revenues of increasing the tax on variety s of commodity g, then equals:

$$\frac{\partial R(\mathbf{q};\mathbf{y})}{\partial t_{g,s}} = \sum_h d_{g,s,h}(\mathbf{q}; y_h) + \sum_h \sum_{g',s'} t_{g',s'} \frac{\partial d_{g',s',h}(\mathbf{q}; y_h)}{\partial t_{g,s}}. \tag{16}$$

When taxes are uniform, the uniform tax rate being denoted by t, this reduces to:

$$\begin{aligned} \frac{\partial R(\mathbf{q};\mathbf{y})}{\partial t_{g,s}} &= \sum_h d_{g,s,h}(\mathbf{q}; y_h) + t \sum_h \sum_{g',s'} \frac{\partial d_{g',s',h}(\mathbf{q};y_h)}{\partial t_{g,s}} \\ &= \frac{\sum_h d_{g,s,h}(\mathbf{q};y_h)}{1+t}, \end{aligned} \tag{17}$$

where the second equality is obtained by using the adding-up condition of demand (see Equation (A.1) in Appendix B.1).
Putting things together: when marginal social welfare weights are equal across households (denoted by β) and all goods can be taxed, the marginal social welfare costs under uniform taxation are equal to:[20]

$$MC_{g,s}(\mathbf{t};\mathbf{y}) = (1+t)\,\beta, \tag{18}$$

and so they are equal across goods and thus uniform taxation is optimal (see also Stern, 1987, p.85).
Under what conditions are the marginal social welfare weights equal for all households? From equation (14) one can see that it is not enough to put inequality aversion e equal to zero. Indeed, the B- and C-components remain household specific even when there is zero inequality aversion. Assume therefore that all households exhibit the same degree of economies of scale. This is for example the case when the household equivalence scale equals the household size n_h. Then we are left with the B-component, embodying the relative preference intensity for relatively cheaper or more extensive goods. Notice, however, that when all goods can be taxed, and there is a uniform tax rate t, the term $\Phi_h(\mathbf{q})$ is equal to $1+t$ for all households. It should however be stressed that the B-component is income independent only because of the assumption of homothetic preferences. Generically, this term equals $(\partial e_h(\mathbf{q}_{ref}; v_h(\mathbf{q}, y_h))/\partial U) \cdot (\partial v_h(\mathbf{q}, y_h)/\partial y)$, and it may well depend on household income y_h.
We can conclude that uniform taxation is optimal when the following set of (sufficient) conditions are jointly satisfied:

- absence of any inequality aversion ($e = 0$);
- homothetic preferences;

[20] By a slight abuse of notation the first argument of $MC_{g,s}$ is now a vector of length $G \times 2$ in stead of G; and all elements of $\mathbf{t}$ are equal to t here.

– absence of economies of scale ($n_h = \theta_h$);

– all goods can be taxed.

Relaxation of any of these four conditions can lead to non-uniform taxes in the optimum.
So, even in the absence of inequality aversion, non-uniform taxes can be optimal, if for example $n_h \neq \theta_h$ or when some goods cannot be taxed. When some goods cannot be taxed, not only the effect of marginal changes in indirect taxes on revenues matter but also the marginal social welfare weights become household specific. They are higher for households predominantly liking the (non taxable) auto-consumption variety of goods (in case there are no subsidised goods in the optimum). Bachas et al. (2021) stress the fact that these are especially the poorer households, but notice that this need not be the case, and if this is not the case, in the absence of inequality aversion, government's optimal policy might be advantageous for the richer households. When the government would become inequality averse, the distributive motive and the efficiency part of the welfare weights partially conflict with each other in such a case.

Restricting the number of tax rates.

Many results in optimal indirect taxation (among others, Ramsey, 1927, Corlett and Hague, 1953, Diamond and Mirrlees, 1971, Feldstein, 1972, Diamond, 1975, Atkinson and Stiglitz, 1976, Kaplow, 2010) depend on preference characteristics of commodities (for example, necessities versus luxuries, substitutability with leisure, and/or price elasticities). Goods exhibiting different price elasticities or different degree degrees of substitutability may therefore be taxed differently in the optimum and this requires a detailed level of commodity disaggregation. In theory this poses no problem as one could always disaggregate commodities at the finest level necessary from a theoretical point of view.
In practice, a classification of commodities into groups will always be necessary, and even a coarse approximation of theoretical prerequisites would lead to a number of goods (and potentially different tax rates) which is far beyond what is administratively manageable. Moreover, increasing the number of tax rates would open up the door for tax evasion opportunities and/or lobbying to obtain a favourable tax tariff. For example, in our application, we arrive at 23 commodity groups, while this is far beyond current tax diversification in countries with a well established tax administration, where the number of VAT rates rarely exceeds four.
There is, however, little theoretical guidance on how to optimally group commodities. Belan and Gauthier (2006) provide some theoretical results when only efficiency matters (in a Ramsey model with one representative agent). These results are extended to allow for distributional concerns by Belan et al. (2008), but their results crucially depend on the assumption of a continuum of goods, and therefore cannot easily be applied in practice. We therefore propose the following alternative. Once optimal taxes for our finer classification into 23 groups are derived for a specific simulation, we order these tax rates and break them up into four broader groups (low tax rate, middle low, middle high, and high).[21] Next we re-run our optimal taxation program imposing that commodities belonging to the same group in this broader classification should bear

[21] Admittedly, the determination of the breaks determining the division in four groups is somewhat arbitrarily, but where possible, we choose them such that there are clear jumps in the more granular optimal rates.

the same tax rate. If a policy maker would consider the highest tariffs resulting from such an exercise to be too high, in addition, an upper bound on taxes could be imposed in such an exercise (as well as a lower bound, if subsidies are considered to be too high).

4 Data, model calibration, and baseline policy

4.1 Data

We use the Benin Enquête Modulaire Intégrée sur les Conditions de Vie des Ménages (EMICoV) of 2015, collected by the Institut National de la Statistique et de l'Analyse Economique (INSAE). It is based on a representative sample covering households from the 77 administrative communes in Benin, including both rural and urban areas. The sample consists of 21409 households. It includes information on a wide range of household characteristics and on expenditures on goods and services. For some households we lack data on expenditures or household characteristics. After removing them from the data we end up with a sample of 19920 households. All results below are computed on the basis of this sub-sample.

Expenditure data are collected partly on a recall basis (with variable term, depending on the commodity), partly by letting a responsible in the household note down expenditures during a period of 15 days in a diary. These data were recorded at the lowest level of aggregation according to the COICOP classification.[22] As durable goods expenditures are too irregular to be captured accurately given the recall period of the survey, and because such goods yield services over a longer period than the one year period that forms the scope of our analysis, we only take into account expenditure on non-durable goods and services. At the most detail level of aggregation, 854 non-durable goods and services were distinguished.

For each record of expenditures, it is indicated in the data whether this commodity was bought on the market, obtained from productive activities within the household, received as a gift, or acquired with the purpose to make a gift to others. It is this information which served to distinguish between market varieties (bought for own consumption or with the purpose of making a gift) and auto-consumption varieties (stemming from own produce or received as a gift) of a given good.[23] So, we have in principle for each of the 854 commodities a market variety and an auto-consumption variety (see Section 3.2 for the distinction between market and auto-consumption varieties in our theoretical model).

Next, we coded for each of the 854 market varieties of the commodities whether they were liable to VAT at the moment of observation (recall that in 2015 there was only one VAT tariff of 18%). So the 854 commodities were subdivided into a class which is exempted, and a class which is taxed. Then, we aggregate goods within each of these two sets into broader categories. This was mainly done along the lines of the two-digit COICOP-classification (which distinguishes between 12 broad commodity groups). For example, *Transport* is such a broad commodity group. But within that broad category we distinguish goods that were liable

[22] COICOP (Classification of Individual Consumption according to Purpose) is an international standard for classifying consumption goods, maintained under the authority of the United Nations Statistics Division (UN, 2018).

[23] Bachas et al. (2021) use for Benin the same survey as we do. They make the split between informal and formal consumption on the basis of the type of store in which the good was bought, assuming that in small shops and on local markets, no VAT is charged. We do not dispose of this information on the location of purchase.

to VAT in 2015 and those that were exempt. Some of these aggregates, however, contained only taxed commodities (for example *Clothing and footwear*), or only exempted ones (*Health*).

For food commodities we constructed a non-conventional categorisation. On the basis of inspection of the pattern through the welfare distribution of budget shares and shares in total consumption of particular goods, we made a subdivision between 'poor' and 'rich' foods. The former ones are largely displaying a decreasing course of budget shares through the welfare distribution, the latter display an increasing one. In this way we want to exploit patterns of correlation between welfare levels and preferences (as far as they are reflected in budget shares), since such patterns are important for the redistributive potential of indirect taxation in the face of preference heterogeneity (see Section 3.3).

Table 2: Budget shares by goods category and by decile (%)

	Deciles				
Decile	**1**	**2**	**5**	**9**	**10**
All Market	73.4	75.5	83.9	86.8	91.3
All Auto	26.6	24.5	16.1	13.2	8.7
			Market		
Food rich taxed	3.6	4.0	5.8	8.1	10.3
Food rich exempt	9.4	10.6	16.3	18.0	18.8
Food poor taxed	8.8	6.8	5.5	4.2	3.3
Food poor exempt	10.8	12.6	11.6	8.0	7.7
			Auto		
Food rich taxed	0.9	0.7	0.7	1.1	0.7
Food rich exempt	3.1	3.6	3.8	4.3	2.7
Food poor taxed	0.3	0.4	0.4	0.1	0.1
Food poor exempt	12.9	12.5	5.3	3.1	1.6

Note: Deciles are constructed on the basis of the individual welfare measure (equivalised money metric utility, Equation 6) evaluated in the observed situation. Each decile contains 10% of the population of individuals (Section B.3). Average shares are calculated as mean household expenditures on a commodity g, s over mean total household expenditures on auto-consumption plus market goods (see Section B.3).

Given that for the purpose of model calibration (see Section 4.2) we can only group together commodities that face the same tax rate in the baseline policy of 2015, we thus arrive at four categories of food commodities labelled as follows: 'Food rich taxed', 'Food rich exempt', 'Food poor taxed', and 'Food poor exempt.' The 'rich' and 'poor' in these labels refer to the fact that the budget shares of the former tend to increase through the welfare distribution, and those of the latter tend to decrease. This is shown in the middle part of Table 2.[24]

[24] A full picture for all welfare deciles is given in Table C.2 of Appendix C.2.

We finally arrive at 23 market commodity aggregates.[25] For 21 of these, an auto-consumption variety exists. The following good categories are solely bought on the market: 'Education exempt' and 'Other services exempt.' The 'Food rich' category includes meat, fish, milk, cheese, eggs, etc., while 'Food poor' includes bread, cereals, oil, vegetables, sugar, etc. Full detail on the composition of all commodity categories can be found in Appendix C.1.

The top panel of Table 2 shows that there is a welfare gradient in the budget shares of auto- *versus* market varieties. A full picture for all welfare deciles is given in Tables C.2 and C.3 of Appendix C.2. The correlation between welfare and the share of goods bought on the market is the key observation in the analysis of Bachas et al. (2021), resulting in the key insight that it may be optimal to tax food expenditures on the formal market more heavily as these are predominantly commodities bought by richer groups in society, while poorer persons consume more auto-produced food. In the present paper, we provide more detail on this observation. Remark for example the welfare gradient is not so obvious for the auto-consumed 'Food rich' categories (bottom panel of Table 2 and corresponding information for all deciles in C.3 of Appendix C.2). Tables C.2 and C.3 of Appendix C contain also the budget share patterns across the welfare distribution for the other commodity categories we constructed. While it is true that in general the share of auto-consumed goods decreases as households are composed of individuals with higher welfare, the more detailed picture learns that this does not necessarily holds for all commodities and, as already indicated, this is so even if one solely concentrates on food products. This fact nuances somewhat the claims of Bachas et al. (2021) that taxing food commodities at lower rates or exempting them from taxation is regressive. Moreover, recall that even in the absence of distributive motives, it might be optimal to tax market commodities less intensely preferred by a large amount of people, irrespective of their welfare level. Finally, we add to the informality issue also the factor of possible preference heterogeneity within and across the welfare distribution in our analysis below.

In Table 3 we present the pattern of the share of auto-consumption across the twelve departments of the country. Compared to the overall share of expenditure on market goods in aggregate expenditures (86.6%), a relatively larger part of the budget is spent on these goods in Littoral (95.5%), Oueme (93.7%) and Mono (92.0%). In Atacora, Alibori, Borgou and Donga auto-consumption exceeds one fifth of total expenditures. These regions belong the north of Benin, where more poverty occurs and inequality is higher than in the rest of the country (INSAE, 2016). In that respect, Mono, the poorest of all departments, forms an exception, as auto-consumption is low there (8%).

4.2 Model calibration and baseline policy

Preference parameters were calibrated from the data as follows. First, the $\alpha_{g,h}$ were equated to the sum of observed expenditure on the market and auto-consumption varieties of a good divided by total expenditures. Calibration of the $\delta g, m, h$ is dependent on an assumption about the degree of substitutability between market

[25] We conjecture that at this level of aggregation, the fact that we did not cover excises, which are levied on a limited number of specific commodities within the categories of transport, non-alcoholic and alcoholic beverages, and other products with very small budget shares, will not seriously affect our results.

Table 3: Population shares (%), welfare rank, and auto-consumption shares (%) by region

Department	Population	Welfare rank	Auto-consumption
Alibori	9.3	3	24.4
Atacora	7.6	2	27.2
Atlantique	13.7	8	8.6
Borgou	13.4	5	23.8
Collines	7.6	10	15.3
Couffo	8.1	4	14.4
Donga	5.1	6	23.6
Littoral	6.6	12	4.5
Mono	5.2	1	8.0
Oueme	8.5	11	6.3
Plateau	5.6	9	13.0
Zou	9.4	7	13.7
All	100	–	13.4

Note: The first column shows the percentage of the population living in each department in 2015. The second column reports the welfare rank of each department, from poorest to richest, where the ranking is based on the average individual welfare (measured by the equivalised money metric utility, Equation 6) evaluated in the observed situation. Auto-consumption shares are calculated as mean household expenditures on auto-consumption over mean total household expenditures on auto-consumption plus market goods (see Section B.3).

and auto-consumption varieties of the same good (σ). We assume $\sigma = 0.5$ for all goods and households.[26] Given a value for σ, $\delta_{g,m,h}$ can be read off from the data as follows: $\delta_{g,m,h} = \left(1 + \frac{e_{g,a,h}}{e_{g,m,h}} \left(\frac{q_{g,m}}{q_{g,a}}\right)^{1-\sigma}\right)^{-1}$, where $q_{g,a} = 1$ and $q_{g,m} = 1 + t_g$, with $t_g = 0.18$ if the good is taxed, and $t_g = 0$ if it is exempted.

We use the demographic information from the survey to calculate household size and OECD equivalence scales. The latter are constructed as follows. The reference person in the household counts for one adult equivalent individual; each additional person in the household aged 14 and over counts for one half adult equivalent; and any additional other person aged less than 14 counts for 0.3 adult equivalent persons. The equivalence scale is the number of adult equivalents in the household.

We perform our optimal tax simulations using these calibrated parameters. Optimal taxes are calculated for different degrees of inequality aversion: $e = 0$, 0.25, 0.5, 0.75, 1.25, 1.5, and 2.[27] We compare the optimal tax simulations with a baseline policy that collects the same amount of revenues, but safeguards the existing tax structure with one standard rate and a fixed list of VAT exempted commodities. In this way our comparisons maintain the assumption of government budget neutrality and can be interpreted as assessments of the welfare implications of different indirect tax policies that all achieve the same government budget objective.

[26] We did a robustness check for $\sigma = 1.5$, but results were qualitatively comparable with the ones reported in the paper.

[27] According to Stern (1977) an inequality aversion $e = 2$ already comes close to the maximin case.

In our main analyses, we study the case where tax revenues are increased such that VAT revenues from the household sector meet the requirements implied by the WAEMU-UN objective to mobilise 20% of GDP. This amounts to VAT revenues from the household sector to attain 237.7 billion CFA or 4.8% of GDP, and can be obtained by a standard rate of 25.56% (see Section 2). This is our baseline policy. In Section 5.6 we investigate in how far our results are affected by this increase of the government budget. More specifically, we calculate also optimal taxes collecting the amount of VAT revenues from the household sector that we actually observed in the data (2015). This amounted to 172.6 billion CFA VAT revenues collected from the household sector, or 3.5% of GDP. The corresponding level of total tax revenue to GDP equals 14.5% in that case.

Notice that our individual demand model (see Section 3.2) implies that budget shares of some goods will (slightly) differ in each of the two scenarios. To illustrate this, Tables C.4 and C.5 of Appendix C report the estimated budget shares of different commodities for the case with the standard tariff increased to 25.56% (corresponding to reaching the WAEMU-UN objective) and can be compared with those in Tables C.2 and C.3, that apply the situation as observed in the data (standard rate 18%, and the same list of exempted goods). Budget shares on varieties who belong to the exempted categories are not changing. The differences across deciles for those goods are solely due to the fact that the deciles are differently composed in both cases. The budget shares of the market variety of the taxed good categories increase in the government budget, while those of the corresponding auto-consumption varieties decrease. The reverse holds for quantities consumed (decreases for the market variety of taxed commodities, and increases for the corresponding auto-consumption varieties).

5 Empirical results

In this section we present our main results. We start by analysing structure of optimal indirect tax rates we obtain for different degrees of inequality aversion (Section 5.1). Sections 5.2 and 5.3 consider the welfare effects of a switch from the baseline policy to optimal taxes. Section 5.2 treats the welfare gains and loss across the initial welfare distribution. Section 5.3 contains details about the number of winners and losers across deciles. In Section 5.4 we present the optimal tax results when the number of tax rates is restricted to 4. Section 5.5 inspects the regional impact of the optimal tax schemes. Finally, the role of the level of the government budget is studied in Section 5.6. More detailed results can be found in Appendix D.

5.1 Optimal tax structure

In Table 4 we investigate the relative contribution of, on the one hand, the fact that we can only tax market goods, and, on the other hand, the heterogeneity in the economies of scale as measured by the factor n_h/θ_h, in the deviation from uniform indirect taxation in the optimum. Recall from Section 3.3 that uniform indirect taxation is optimal when (i) inequality aversion is zero ($e = 0$); (ii) preferences are homothetic (which we assume throughout); (iii) there are no differences in economies of scale among the households ($n_h = \theta_h$), and (iv) all goods (including auto-consumption varieties) can be taxed. In the simulations of Table 4 we have therefore put inequality aversion equal to zero. In the first pair of columns we also eliminate the impact of differences in economics of scale across households ($n_h = \theta_h$ for all households h). In the first of both columns we also assume that all goods are taxable. In that case we saw that optimal taxes are uniform. The optimal rate is 11.7%. When only market goods are taxable, optimal taxes are overall higher than in the uniform case, which stands to reason as some goods cannot be taxed and the tax base is therefore smaller. Moreover, the optimal tax structure is not anymore uniform, and this is due to both, differences in own price elasticities among commodities, and intensity of preferences for particular market varieties. Taxes vary between 12.1% and 14.2%. Notice that 'food poor e', which recollects food commodities that are exempt from indirect taxes in the baseline policy and predominantly consumed by poorer households, are among the group with the highest tax rate in this case. Compare this with the last column where also only market goods can be taxed, but where we take into account the effect of differences in economics of scale ($n_h \neq \theta_h$). The tax rate on 'food poor e' is then only 11.8%, almost the same as under the uniform rate, and the seventh lowest tax rate out of 23. The third column also acknowledges differences in economies of scale, but assumes all goods can be taxed. Taxes are therefore lower than in the last column, but the optimal tax structure is very comparable (though not completely identical) to the one in the last columns.

Table 5 shows the impact of inequality aversion ($e = 0$, 0.25, 0.5, 0.75, 1.25, 1.5, and 2) on the optimal tax structure. Results are ranked from high to low taxes in the case of absence of inequality aversion ($e = 0$). Housing rent, currently not taxed, is the candidate for the highest VAT rate, irrespective of the degree of inequality aversion. This commodity refers to rents effectively paid for non owner-occupiers. About 11% of the population live in households that rent the house they live in.[28] These persons belong predominantly to the richest deciles according to the baseline situation; more than half belong to the top three deciles. This might explain why the tax rate is going up when inequality increases. Among renters the household budget share of rents among the poorer is relatively substantially higher though than among the richer ones. When all households are taken into account, the average budget share drops from 7.5% to 1.4%, and that share is almost monotonously increasing through the deciles.[29] Even for mild inequality aversion, some commodities should be subsidised in the optimum (*e.g.* 'food poor t' and 'other services t' in case $e = 0.5$). In case $e = 2$, the optimal tax rate of seven commodity categories is negative.

The evolution of the tax rates is not necessarily monotone in the degree of inequality aversion. For example the optimal tax on 'communication t' is increasing in inequality aversion up to a value $e = 1.25$, while afterwards it starts to decrease. On the contrary, the optimal tax on 'furnishings & equipment t' first decreases from 12.5% when $e = 0$ to 0.7% for $e = 1.25$, and start to increase again till 17.2% for $e = 2$.

Notice that a non-monotonous course of the optimal tax rate with inequality aversion does not imply that the change in ranking of the tax rates from low to high for each of the optimal tax rates is also non-monotonous.

[28] This and the following results on housing need to be treated with some care. Actually for 37% of our sample of households, we have no information on the house they live in. We have no value for rent neither one for imputed rent, in the data. Probably these are household that live in the house of relatives. If that is the right hypothesis, ideally we would like to have imputed rents also for the houses these households live in. Unfortunately the data do not contain such information. Also, the assumption that owner-occupiers cannot be taxed on the value of their house might be questionable.

[29] The budget shares per decile for the whole population are reported in Table C.4 of Appendix C. The conditional figures are not given in detail here but are available upon request.

Table 4: Optimal tax rates (%) – the role of nontaxable goods and n_h/θ_h

	Inequality aversion $e = 0$			
	Which goods are taxable?			
Commodity	All goods	Only market goods	All goods	Only market goods
	$n_h = \theta_h$		Actual values of n_h and θ_h	
Other services e	11.7	14.2	3.5	4.2
Other services t	11.7	12.1	5.4	6.0
Food poor t	11.7	12.9	8.5	9.0
Recreation, culture e	11.7	13.3	9.6	10.0
Recreation, culture t	11.7	13.4	10.3	10.6
Education e	11.7	13.6	11.1	11.5
Food poor e	11.7	14.2	11.6	11.8
Furnishings & equipm. t	11.7	12.8	11.9	12.5
Transport t	11.7	13.3	12.0	12.5
Health e	11.7	13.1	12.6	13.1
Food rich e	11.7	14.2	13.1	13.6
Clothing t	11.7	13.8	13.0	13.8
Others non serv. t	11.7	13.2	13.5	13.9
Alcoh. bev. & tob. e	11.7	12.8	12.9	14.0
Housing utilities e	11.7	13.3	14.1	14.4
Housing utilities t	11.7	13.5	14.4	14.8
Food rich t	11.7	14.0	14.4	14.9
Communication t	11.7	13.5	14.9	15.4
Alcoh. bev. & tob. t	11.7	13.3	14.7	15.9
Catering and accomm. t	11.7	13.7	15.4	16.0
Transport e	11.7	13.7	19.6	20.1
Non alcoh. bev.& tob. t	11.7	13.8	19.9	20.6
Housing rent e	11.7	14.6	25.2	26.2

Note: The numbers in the table represent the optimal tax rates for the corresponding commodities. Commodities are ranked from low to high tax rates according to the simulation in the last column (only market goods taxable and actual values for n_h and θ_h). Tax rates for auto-consumption varieties in cases where they are assumed to be taxable are not reported.

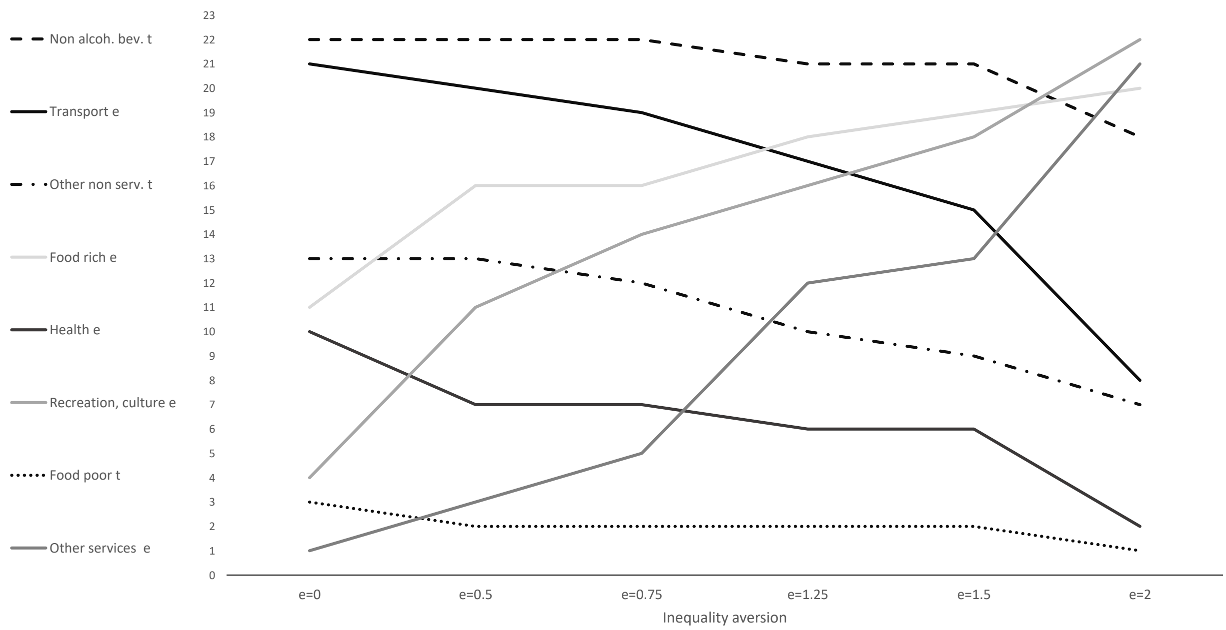
Table 5: Optimal indirect tax rates (%) – the role of inequality aversion

	Inequality aversion					
Commodity	$e = 0$	$e = 0.50$	$e = 0.75$	$e = 1.25$	$e = 1.50$	$e = 2.0$
Housing rent e	26.2	38.9	46.1	62.9	73.8	111.4
Non alcoh. bev. t	20.6	31.0	33.5	35.3	36.5	47.9
Transport e	20.1	23.2	24.2	22.2	16.7	-1.9
Catering and accomm. t	16.0	20.8	23.6	30.3	34.7	50.3
Alcoh. bev. & tob. t	15.9	10.0	5.4	-4.3	-7.7	-4.7
Communication t	15.4	21.3	24.4	28.7	28.3	21.0
Food rich t	14.9	26.9	32.8	43.0	46.3	46.9
Housing utilities t	14.8	8.8	7.1	6.7	9.1	27.7
Housing utilities e	14.4	13.5	13.2	14.1	16.1	30.0
Alcoh. bev. & tob. e	14.0	0.6	-5.5	-15.7	-18.9	-15.4
Others non serv. t	13.9	11.7	10.2	5.9	2.7	-4.7
Clothing t	13.8	11.6	9.5	4.5	2.3	3.5
Food rich e	13.6	17.2	19.8	27.4	33.2	51.2
Health e	13.1	7.2	4.5	-1.4	-6.7	-34.4
Transport t	12.5	15.2	16.4	18.5	20.2	31.4
Furnishings & equipm. t	12.5	6.7	4.0	0.7	1.5	17.2
Food poor e	11.8	1.2	-2.9	-8.9	-11.0	-14.8
Education e	11.5	19.1	21.1	19.4	16.1	11.9
Recreation, culture t	10.6	7.9	6.2	3.3	3.5	16.4
Recreation, culture e	10.0	11.4	13.4	21.7	30.1	71.2
Food poor t	9.0	-3.3	-8.6	-20.0	-27.1	-45.0
Other services t	6.0	-13.7	-20.8	-29.9	-31.4	-23.1
Other services e	4.2	0.2	1.1	8.3	16.1	55.3

Note: The numbers in the table represent the optimal tax rates for the corresponding commodities. Commodities are ranked from high to low tax rates according to the simulation in the first column ($e = 0$) which coincides with the simulation in the last column of Table 4.

For example, the tax rate on 'transport e' is increasing in inequality aversion until $e = 0.75$, (from 20.1% to 24.2%), and then decreases again to become even negative for $e = 2$, but the rank of the tax rates decreases monotonously with the degree of inequality aversion for that commodity: it bears the third highest tax rate when $e = 0$, while its rate is the eighth lowest one for $e = 2$. Since ranks and levels give independent information on the optimal tax structure, we report these ranks in Table D.1 of Appendix D. Also the evolution of these ranks with respect to inequality aversion is not necessarily monotonous. In Figure 4 we report the commodities for which these ranks evolve monotonously with inequality aversion. The black lines gives the evolution of the rank of the tax rate for commodities for which it is uniformly decreasing. The grey lines are for goods which become relatively more heavily taxed when inequality aversion increases. The selected commodities are ordered according the rank of their tax rate when
For example 'recreation, culture e', which is a commodity category that is not taxed in the baseline, is also relatively lowly taxed in the optimum when $e = 0$, the optimal rate being 10% in that case, the fourth lowest tax rate. On the other hand, with an optimal tax of 71% this commodity bears the second highest tax rate when $e = 2$. Notice that the current policy (exemption) is at odds with what would be advocated from a social welfare point of view with high concern inequality aversion (high taxation). This observation holds true for all the other goods for which the rank of the optimal tax is uniformly increasing in inequality aversion.

Figure 4: Optimal tax structure for selected goods: the impact of inequality aversion



Note: Each point on a line denotes the rank of the optimal tax rate of a given commodity for a given value of inequality aversion. Only commodities for which the rank is uniformly decreasing or increasing in inequality aversion are selected. Selected commodities are ordered according to the rank of their tax optimal tax rate for inequality aversion $e = 0$. Grey lines refer to the commodities for which the rank of the corresponding tax rate is increasing in inequality aversion; black lines are decreasing. Full lines refer to commodities that are exempt under the baseline situation and broken lines to those that are taxed in the baseline.

This is not necessarily true for the case where the rank of the optimal tax rate is decreasing in inequality aversion (black lines). Indeed, some of these goods, such as 'non-alcoholic beverages t' or 'food poor t' are taxed in the baseline simulation, while their rank is decreasing in inequality aversion. However, notice again that ranks of the tax rate are not always giving similar information as the levels of the optimal tax rate. The optimal tax on 'non-alcoholic beverages t' is 20,6% when $e = 0$, and it uniformly increases to almost 48% when $e = 2$, while its rank decreases from 22 when $e = 0$ to 18 when $e = 2$.

5.2 Average welfare gains and losses across the welfare distribution

We now turn to an analysis of the welfare effects of optimal indirect taxation. We compare for each individual of our sample the welfare obtained under the baseline policy (standard tariff of 25.56%, guaranteeing to reach the UN tax revenue objective of 20% of GDP, with goods exempted as in 2015), with the welfare level obtained when applying the optimal indirect taxes for different levels of inequality aversion. Individual welfare levels are calculated using the equivalised money metric utility defined in Equation (6). The difference will be expressed in levels (CFA) and relative to the baseline welfare (percentage).

Table 6 shows the overall average gains from switching from the baseline towards an optimal tax structure, for different values of inequality aversion. The confidence intervals are obtained from applying a bootstrap with 500 replications (see Section B.3). The table illustrates the well-known equity-efficiency trade-off. When inequality aversion is zero, government tries to maximise mean welfare, and the welfare gain in levels *vis-à-vis* the baseline is positive and maximal. Average welfare gain is decreasing when inequality aversion increases. The average gain is even negative when inequality aversion is higher or equal to 1.25. One wants to give up size of the pie in order to obtain a more equitable distribution. All differences are statistically significantly different from zero. It turns out that the same conclusions hold for the relative welfare changes.

Table 6: Inequality aversion and average welfare gain

	Average change in welfare					
	Levels (CFA)			Percentage		
Inequality aversion	LB 95% CI	Mean	UB 95% CI	LB 95% CI	Mean	UB 95% CI
e=0.00	2015	**2160**	2256	0.49	**0.53**	0.55
e=0.50	1273	**1426**	1559	0.31	**0.35**	0.38
e=0.75	355	**590**	770	0.08	**0.14**	0.19
e=1.25	-2422	*-1859*	-1445	-0.59	*-0.45*	-0.35
e=1.50	-4850	*-3671*	-2864	-1.19	*-0.89*	-0.71
e=2.00	-20030	*-12008*	-5560	-4.49	*-2.93*	-1.36

Note: Comparisons are with the individual welfare measure (equivalised money metric utility, Equation 6) evaluated in the baseline (standard tariff of 25.56%, guaranteeing to reach the UN tax revenue objective of 20% of GDP, with goods exempted as in 2015). Welfare levels are calculated using the equivalised money metric utility defined in Equation 6. Averages are calculated at the individual level. Percentage gains are calculated as average gain over average baseline welfare (see Section B.3).
Confidence intervals are calculated by means of 500 bootstrap replications of the estimates (see Section B.3). Bold face figures indicate significantly positive values at the 5% level, and italic numbers significantly negative ones.

Figures 5 and 6 show how these average gains are distributed across the baseline welfare distribution. For each decile of the baseline welfare distribution the average gain is calculated. The blue lines connect those averages. Each panel is for a different value of inequality aversion. Figure 5 shows the welfare gains in levels, while Figure 6 applies to the relative differences.[30] In absence of any inequality aversion ($e = 0$), the average gain in levels per decile is always significantly positive and it almost uniformly increases with deciles (the only exception being the small dip for decile 5). When inequality aversion is positive ($e > 0$), the average welfare gain across deciles has roughly an inverted U-shape. The top average gain is always obtained in the third decile, but the decreasing part is much steeper as inequality aversion increases. The decile at which the average gain becomes negative is decreasing in inequality aversion. For example, when $e = 0.5$ there is an average loss only for deciles 9 and 10 (and it is only statistically significant for the tenth decile). When $e = 2$, there is on average a loss from the fifth decile onwards, and it is statistically significant from the seventh decile onwards. Moreover, the redistribution is increasingly shifted towards the first decile: this is the only decile for which the average gain is increasing uniformly with inequality aversion. For the second decile, for example, the average gain is slightly lower when $e = 2$ compared to the case of $e = 1.5$, and this is even more explicitly so for the third and fourth decile. This confirms the equity efficiency trade-off we referred to earlier. When inequality aversion increases, one primarily wants to increase the welfare of persons belonging to the bottom deciles of the welfare distribution, at cost of larger losses for persons belonging to middle and higher deciles. Still, even for high inequality aversion, efficiency concerns remain important, reflected by the fact the average gain of the second and third decile is higher than that of the bottom decile.[31]

The picture is somewhat different when one looks at relative gains across deciles (Figure 6 and Table D.3), though the main qualitative conclusions on the equity-efficiency trade-off remain to hold. The most salient difference with the picture for welfare gains in levels is that the relative average welfare gain is not anymore inverted U-shaped, but uniformly decreasing across deciles when inequality aversion is positive. Moreover, the decline of the relative average gain across deciles becomes steeper when inequality aversion increases. In the absence of inequality aversion ($e = 0$), the negative slope only extends up to fifth decile after which the realtive average gain remains more or less constant. It remains to hold that only for $e = 0$ the relative average gain is (significantly) positive through all deciles.

We conclude that there is scope for redistributive policies through indirect taxes by a careful diversification of tax rates. However the effectiveness of such policies is very much dependent on the extent to which preference heterogeneity is correlated with welfare. For example, if a certain policy is hitting severely a person belonging to the top of the (initial) welfare distribution, and someone at the bottom has similar preferences at the bottom, she will be hot too.[32]

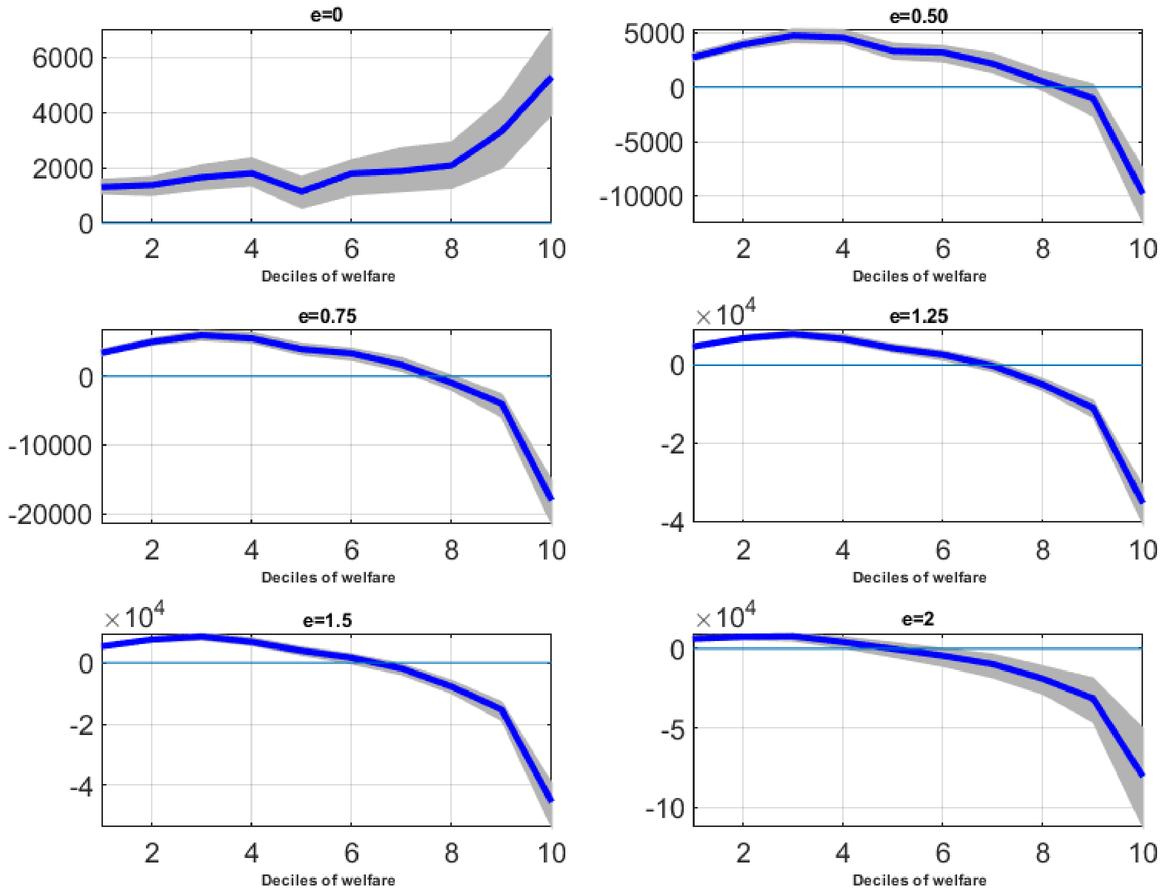
As a consequence of imperfect correlation between welfare level and preferences, any optimal policy will

[30] Tables D.2 and D.3 contain the numerical values of the point estimates.

[31] This prevalence of efficiency over equity of traditional social welfare functions was already noticed and analysed by Shorrocks (1983) and Bosmans (2007).

[32] This statement should be qualified when preference were non-homothetic, as it may then well be possible that indirect taxes have a different effect on welfare for two persons with the same preferences, but different (initial) welfare levels. Theoretically, it is the correlation with preferences and the welfare levels evaluated at the optimum that matter. As these welfare levels are partially dependent on the optimal taxes, the correlation between preferences and welfare partially depends on the optimal tax structure and is therefore endogenous. The extent to which the welfare distribution is affected by the optimal policy is discussed more in detail in Section 5.3.

Figure 5: Average welfare gain per decile from applying optimal taxes (levels, CFA)



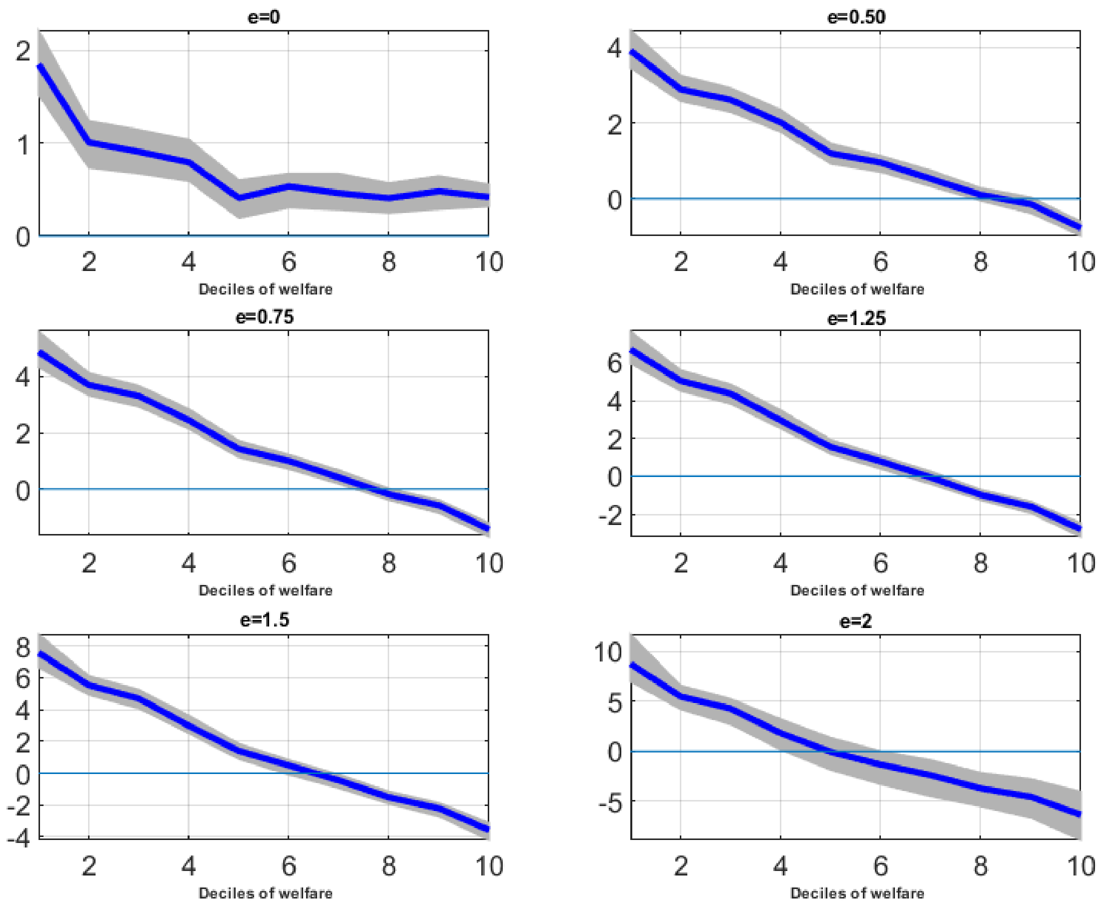
Note: The vertical axis reports average welfare differences in levels (CFA) between the application of the optimal tax and the baseline simulation (standard tariff of 25.56%, guaranteeing to reach the UN tax revenue objective of 20% of GDP, with goods exempted as in 2015). Each panel is for a different value of inequality aversion. The blue lines represent weighted averages within each decile. The grey areas represent the 95% confidence interval constructed from 500 bootstrap replications (see Section B.3). Averages and deciles are calculated for the population of individuals.

cause winners and losers all over the welfare distribution. Figure 7 illustrates the extent to which this is the case in our simulations. Within each decile of baseline welfare the first and ninth decile value, the first and third quartile, and the median of the relative gain in welfare for a switch from the baseline simulation to an optimal policy for a given value of inequality aversion.[33] The red lines in the figure connect the median values for each decile. If this median value is below zero, it means that more than half of the persons belonging to this decile are loosing from a switch of the baseline policy to the optimum. The dark gray areas in the figure are bounded by the first and third quartile value of the corresponding decile. If the lower boundary of that area is larger than zero for a given decile, less than a quarter of the population of that decile loses by the switch. On the contrary, when the upper boundary is below zero, less than a quarter of that same population gains. The light grey areas are bounded by the first and ninth decile value.

For the case of absence of inequality aversion, a majority of persons within each baseline welfare decile is

[33] The corresponding figure for levels of welfare gains, Figure D.1, is discussed in Appendix D.4.

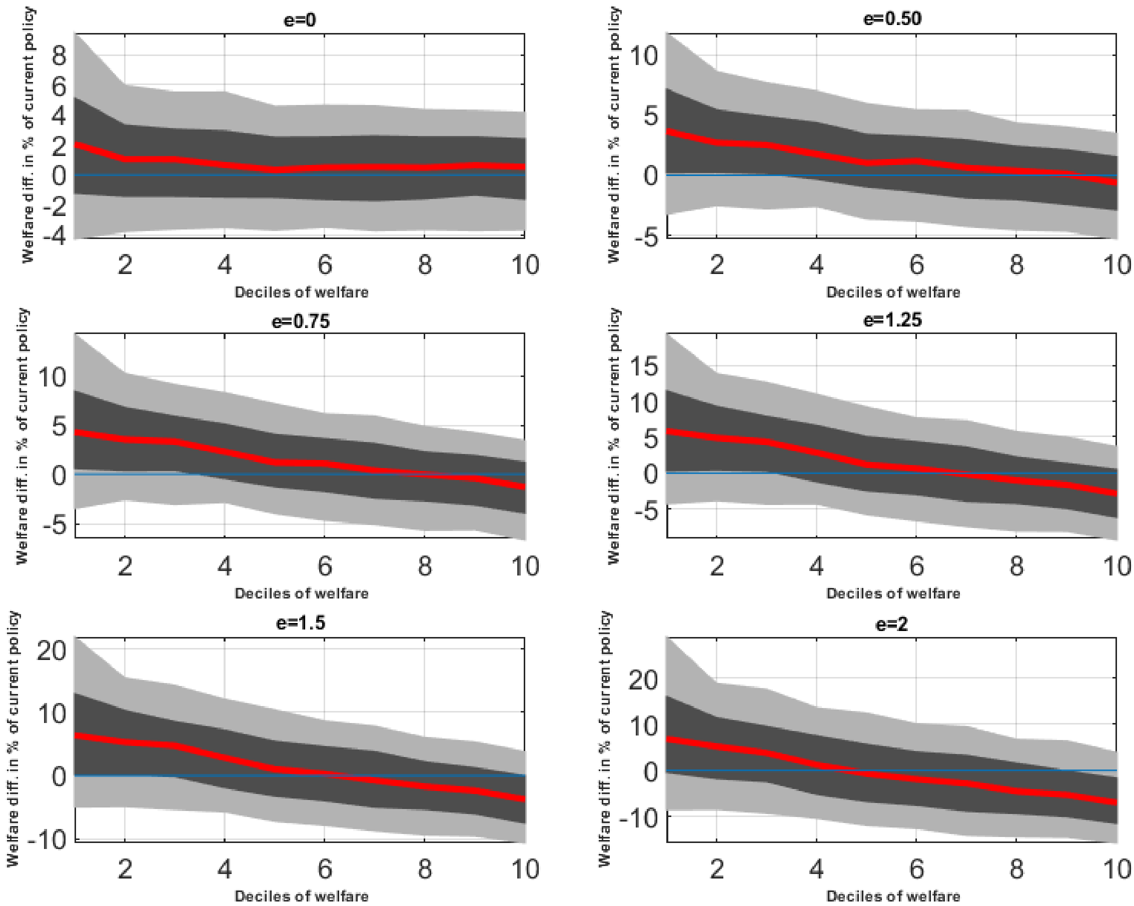
Figure 6: Average welfare gain per decile from applying optimal taxes (% of baseline welfare)



Note: The vertical axis reports relative welfare differences (in % of baseline welfare) between the application of the optimal tax and the baseline simulation (standard tariff of 25.56%, guaranteeing to reach the UN tax revenue objective of 20% of GDP, with goods exempted as in 2015). Each panel is for a different value of inequality aversion. The blue lines represent weighted averages within each decile. The grey areas represent the 95% confidence interval constructed from 500 bootstrap replications (see Section B.3). Averages and deciles are calculated for the population of individuals. The averages are calculated as the average gain of all individuals within a decile divided by the average welfare level of individuals within that decile (Section B.3).

gaining from a switch of the baseline to the optimal tax structure. At the same time, more than a quarter of the persons are losing from such a switch in all baseline deciles. When inequality aversion increases, the quantile values tend to have a decreasing and steeper course across deciles. In all cases with positive inequality aversion, a majority is gaining by the switch in the lower deciles, while a majority loses in the upper deciles. The switch from a majority of winners to a majority of losers occurs at lower deciles as inequality aversion increases. Surprisingly, for intermediate values of inequality aversion ($e = 0.5, 0.75$, or 1.25), less than a quarter among the population belonging to the lower deciles in the baseline, loses from the switch, while for a high value of inequality aversion more than a quarter loses in each decile, including the lowest decile. Moreover, the spread between the better off and worse off is increasing with inequality aversion. Nevertheless, the ninth to first decile ratio narrows down across deciles. This narrowing is limited to the first few deciles when there is no inequality aversion, and continues to hold throughout all deciles when

Figure 7: Heterogeneity of relative welfare gains within deciles



Note: The vertical axis reports the, within each baseline welfare decile, quantile values of relative welfare differences (in % of baseline welfare) between the application of the optimal tax and the baseline simulation (standard tariff of 25.56%, guaranteeing to reach the UN tax revenue objective of 20% of GDP, with goods exempted as in 2015). Each panel is for a different value of inequality aversion. The red lines connect the median value of the relative gain within each baseline decile. The dark grey areas are bounded by the first and third quartile value within each baseline decile. The light grey areas are bound by the first and ninth decile of the relative difference within each baseline.

inequality aversion is positive. For the higher values of inequality aversion ($e \geq 1.25$) the mean change is higher than the median for all baseline deciles, indicating that, within each decile, the distribution of welfare changes is skewed toward the upper half of the values. For lower values of inequality aversion the median is lower than the mean welfare for the lowest baseline deciles, while the reverse holds true for the highest baseline welfare deciles. Surprisingly, when there is no inequalty aversion the mean is lower than the median for both the lowest and highest baseline deciles. Only for the middle deciles the reverse holds true.

5.3 Winners and losers

Figure 7 already allowed to derive that there are winners and losers within *all* deciles, irrespective of the degree of inequality aversion. In Table 7 we show the estimated proportion of winners of a switch from the baseline to the optimal policy for different values of inequality aversion, across the whole population. For all except the highest value of inequality aversion we considered ($e = 2$), a statistically significant majority of the population would gain. When inequality aversion is high ($e = 2$), a slight majority would lose, although the result is not statistically significant. One can give a political economy interpretation to these results. If the whole population could chose between the baseline policy to reach the UN objective to attain a total tax revenue of 20% of GDP, and an optimal policy, and people would vote only on the base of the effects of such policies on their welfare, a majority is expected to vote for the optimal policy, except when the latter is designed by a policy objective embodying a considerable amount of inequality aversion, in which case we cannot make statistically significant conclusions.

Table 7: Inequality aversion and percentage of winners

Inequality aversion	Percentage of winners		
	LB 95% CI	Mean	UB 95% CI
e=0.00	57.8	**58.9**	59.7
e=0.50	62.3	**63.1**	63.9
e=0.75	60.5	**61.4**	62.2
e=1.25	55.4	**56.5**	57.7
e=1.50	52.2	**54.0**	55.5
e=2.00	40.2	46.4	52.5

Note: Comparisons are with the individual welfare measure (equivalised money metric utility, Equation 6) evaluated in the baseline (standard tariff of 25.56%, guaranteeing to reach the UN tax revenue objective of 20% of GDP, with goods exempted as in 2015). Cells show the percentage of winners when applying the optimal tax for a given value of inequality aversion (rows) compared to the baseline.
Confidence intervals are calculated by means of 500 bootstrap replications of the estimates. Bold face figures indicate significantly larger than 50% at the 5% significance level; italic numbers are significantly lower than 50%.

Figure 8 illustrates how the number of winners and losers are distributed across the deciles of baseline welfare.[34] Our first observation is that there a considerable number of losers across all deciles, irrespective of the degree of inequality aversion (at least one fifth of the persons within a decile lose).

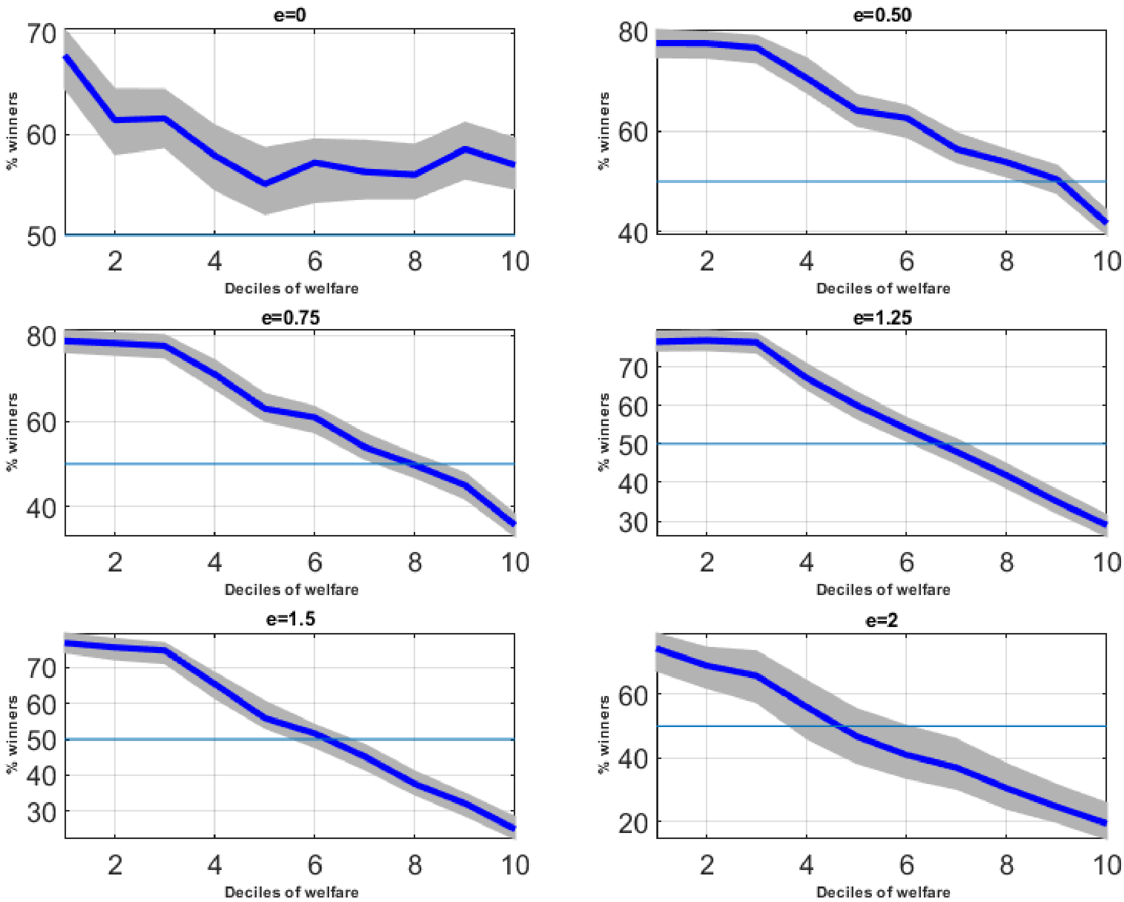
The patterns in Figure 8 closely resemble those of the average *relative* welfare gains across baseline deciles (Figure D.3). When there is no inequality aversion, the number of winners is decreasing almost uniformly until the middle, after which it wiggles around 55 to 57%. For each decile there is a statistically significant majority of winners. For intermediate values of inequality aversion, the number of winners is almost constant over the first three deciles and then decreases. For higher deciles a significant majority even loses. Wen $e = 2$, the percentage of winners is decreasing uniformly, and a majority loses from decile 5 on (though only statistically significant from decile 7 on). The deciles at which a significant majority becomes losers for $e = 1.5, 1.25, 0.75$, and 0.5, are respectively 7, 8, 9, and 10.

Surprisingly, from inequality aversion $e = 1.25$ on, the percentage of losers is increasing for all deciles, including the lower ones, to the corresponding results for inequality aversion. There are *e.g.* 26% losers in

[34] The values of the percentage of losers per decile are represented in Table D.4 of Appendix D.3.

the lowest decile when $e = 2$, while the corresponding figure for $e = 0.5$ is 23%. Apparently, when inequality aversion increases, it might become optimal to design policies such that a larger gain is obtained for a smaller number of poor persons, rather than distribute gains evenly across the poor. This stands to reason, as an extra gain for the poorer is worth more than the same gain for a rich person.

Figure 8: Percentage of winners by decile



Note: The vertical axis denotes the percentage of winners when switching from the baseline policy (standard tariff of 25.56%, guaranteeing to reach the UN tax revenue objective of 20% of GDP, with goods exempted as in 2015) to optimal taxation for different values of inequality aversion. The blue lines connect the point estimates for each decile. The grey areas represent 95% confidence intervals estimated from 500 bootstrap replications (see Section B.3).

As there are winners and losers in all deciles, the welfare ranking of individuals in the baseline might change under the optimal policies. Table 8 represents, for different values of inequality aversion, the percentage of persons who move to a different welfare decile under the optimal policy than they belong to under the baseline.[35] For example, one tenth of the population belongs to another welfare decile under the baseline simulation as compared to the decile they belong to under the optimal policy in absence of inequality aversion ($e = 0$). This percentage is gradually increasing with inequality aversion. When $e = 2$, almost three out of ten people move from decile. These figures illustrate that the welfare distribution under optimal policy is

[35] Tables D.5 and D.6 of Appendix D.5 give more detail on these figures. The main lesson is that there are more 'movers' in the middle of the distribution than at the extremes.

Table 8: Changes in welfare ranking across simulations

Percentage of movers from one decile to another					
Inequality aversion					
e=0	**e=0.5**	**e=0.75**	**e=1.25**	**e=1.5**	**e=2**
10	12	13	18	20	27

Note: The figures in the table indicate the percentage of individuals that belong to a different welfare decile in the baseline as compared to the decile they belong to under implementation of optimal taxes for different values of inequality aversion.

endogenous. Therefore, statistics on the correlation between preferences and welfare for a given, observed or simulated tax policy, can be misleading for drawing conclusions on the structure of optimal taxes in comparison with that observed or simulated policy.

5.4 Restricted optimal taxation

In the present section we turn to our results for the restricted optimal taxation exercises (see the last paragraph of Section 3.3). We perform a restricted optimal tax simulation for $e = 0$ and $e = 2$. Table D.7 of Appendix D.6 gives more information on the grouping of the commodities in the restricted taxation and the restricted optimal tax rates. Table 9 compares the average welfare gain and percentage of winners per decile with respect to the baseline policy, for both, the unrestricted and restricted optimal taxes. The first two columns show the results for the gain in levels (CFA franc).[36]

The figures for the gains and losses in levels from a switch from the baseline policy to the unrestricted versus restricted optimal policies are close to each other in case of absence of inequality aversion (see first two columns in the upper panel of Table 9). They never exceed 240 CFA franc per year. The same holds true for high inequality aversion $e = 2$, except for the first and last decile (see the first two columns of the lower panel of Table 9). But we saw that the gains and losses per decile under high inequality aversion are much larger too. Relative gains or losses are less than 0.1 percentage points for all cases, except for the first and last decile under high inequality aversion (third and fourth columns of Table 9). Even for the the first and tenth decile under high inequality aversion the difference is less than 1 percentage point. Qualitatively, the picture of losses and gains is the same for the unrestricted and restricted optimum, except for the fifth decile under high inequality aversion. The differences are, however, so close to zero in that last case, that this result will hardly be statistically relevant. Also the number of losers and winners are close to each other. We conclude that restricting the number of tax rates to a manageable number of at most four rates, can approximate the full optimum quite good. The most surprising result is perhaps that the number of winners under the restricted optimum is higher for the higher deciles than under the unrestricted optimum, even under high inequality aversion. We give somewhat more details comments on this observation in Appendix D.6.

[36] The figures the upper panel of Column 1 of Table 9 correspond to the first of Table D.2 in Appendix D.2; those of the lower panel of column 1 of Table 9 correspond to the last column of Table D.2 in Appendix D.2.

Table 9: Welfare gains and winners with respect to baseline: restricted vs. unrestricted optima

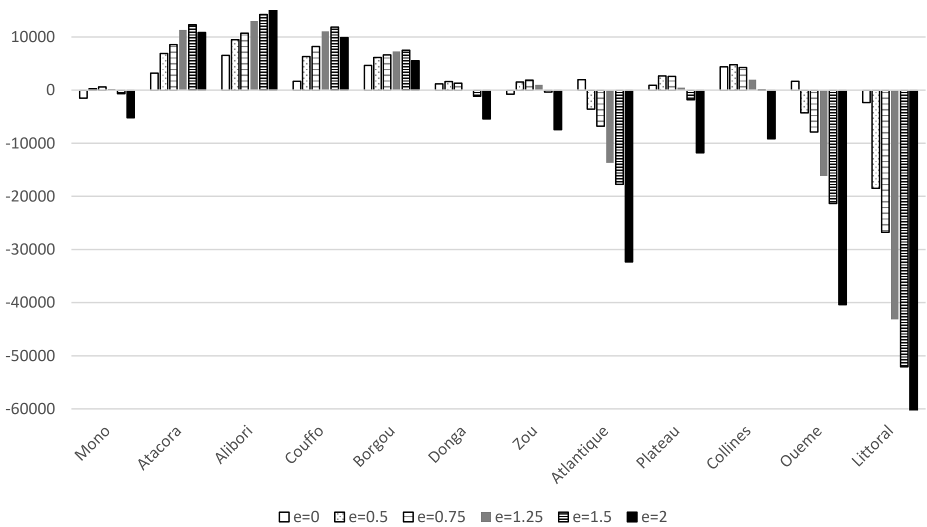
	Inequality aversion $e = 0$					
	Welfare change level (CFA)		Relative welfare change(%)		Winners (%)	
Decile	unrestricted	restricted	unrestricted	restricted	unrestricted	restricted
1	1297	1234	1.85	1.76	67.8	67.0
2	1369	1220	1.01	0.90	61.4	60.5
3	1648	1473	0.91	0.81	61.6	60.5
4	1799	1619	0.79	0.71	57.9	57.1
5	1132	1018	0.41	0.37	55.1	53.2
6	1790	1752	0.53	0.52	57.2	56.1
7	1878	1889	0.46	0.46	56.3	55.8
8	2083	2251	0.41	0.44	56.0	56.6
9	3316	3508	0.48	0.51	58.5	58.6
10	5289	5527	0.42	0.44	56.9	57.2
All	2160	2149	0.53	0.52	58.9	58.3
	Inequality aversion $e = 2$					
	Welfare change level (CFA)		Relative welfare change(%)		Winners (%)	
Decile	unrestricted	restricted	unrestricted	restricted	unrestricted	restricted
1	6144	5454	8.76	7.78	74.3	73.5
2	7468	7534	5.49	5.54	68.9	70.5
3	7787	7732	4.29	4.25	65.8	68.6
4	4123	4259	1.82	1.88	56.0	56.7
5	-159	59	-0.06	0.02	46.8	48.4
6	-4464	-4782	-1.33	-1.43	40.9	42.2
7	-9780	-9675	-2.40	-2.37	36.9	37.5
8	-19058	-18978	-3.72	-3.70	30.5	30.2
9	-31471	-31507	-4.57	-4.57	24.7	25.9
10	-80617	-70912	-6.37	-5.60	19.4	22.0
All	-12003	-11086	-2.93	-2.70	46.4	47.5

Note: The first two columns denote the average welfare gain (positive) or loss (negative) in CFA franc per *baseline* welfare decile (standard rate of 25.56%, thus guaranteeing to reach the UN tax revenue objective of 20% of GDP, with the list of exempted goods as in 2015) and overall, from a switch from the baseline policy to the optimal policy, with and without restriction. The next two columns show the relative welfare gain compared to the baseline (%) per *baseline* welfare decile and overall, in the unrestricted and restricted case. Average relative welfare gains are calculated as mean gain (per decile and overall) over mean baseline policy level of welfare (see Appendix B.3). The last two columns compare the percentage of winners from a switch from the baseline policy to the optimal policy under the unrestricted and restricted optimal taxes. The upper panel concerns the case of absence of inequality aversion ($e = 0$), the lower panel is for $e = 2$.

5.5 Welfare analysis by department

In the present section, we redo the analyses of Sections 5.2–5.3 but now from the point of view of regional inequalities rather than across the welfare distribution. Indeed, both consumption patterns (reflecting preferences) and availability of goods may differ across departments. This might result in differences in the redistributive patterns across regions (departments). We, however, do not investigate redistribution within departments, and/or its contribution to overall redistribution of optimal taxation, but simply study how welfare gains and winners and losers from the switch to optimal taxation are distributed across departments. In Figures 9 and 10, each group of six connected, differently patterned bars represents results of different levels of inequality for a given department. White bars refer to no inequality aversion, grey dotted ones to $e = 0.5$, grey striped to $e = .75$, full grey to $e = 1.25$, black striped to $e = 1.5$, and black ones to $e = 2$. Departments on the horizontal axes are ranked according to their average baseline welfare level (standard tariff of 25.56%, guaranteeing to reach the UN tax revenue objective of 20% of GDP, and list of exempted goods as in 2015), from lowest to highest. This ranking coincides well with welfare rankings of departments from other sources (e.g. INSAE, 2016).

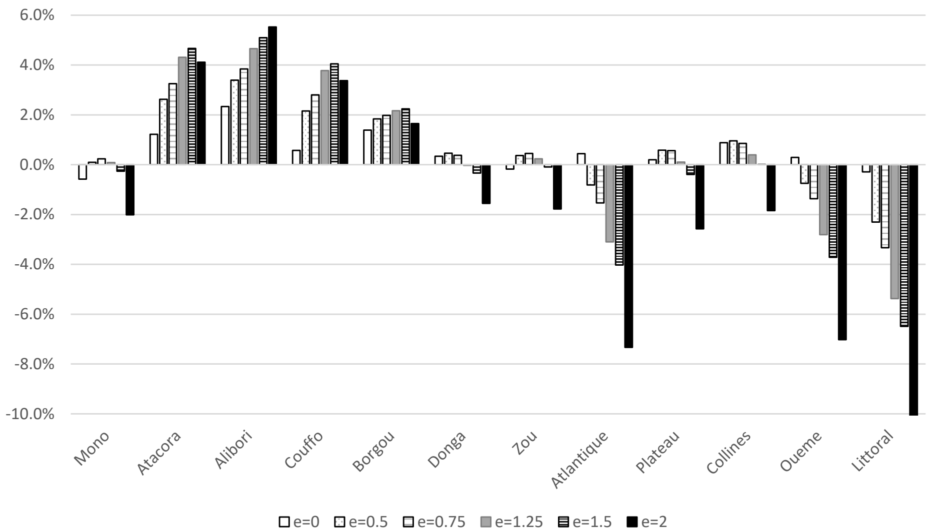
Figure 9: Average welfare gain by department – levels (CFA)



Note: The vertical axis reports average welfare differences in levels (CFA) between the application of the optimal tax and the baseline simulation (standard tariff of 25.56%, guaranteeing to reach the UN tax revenue objective of 20% of GDP, with goods exempted as in 2015). Each set of equally patterned bars is for a different level of inequality aversion. Each group of differently patterned bars is for a particular department. Departments are ranked from poorest to richest according to average baseline welfare level. The vertical axes is truncated below at -60 000 CFA. The underlying values of the figure can be found in Table D.9 of Apendix D.7.

Figure 9 reports average welfare gains per department in levels, and Figure 10 reports average welfare gains relative to baseline welfare. *Grosso modo* the figures reveal that poorer departments are gaining on average while richer ones are losing, the more so, when inequality aversion increases. The correlation is far from perfect though. And when inequality aversion becomes very high ($e = 2$), some poorer departments tend to gain less on average, both in levels and relatively speaking, than for a lower value of inequality aversion (Atacora and Couffo). There is one big exception though to this picture: the poorest department, Mono, loses on average both in the absence of inequality aversion and in presence of high inequality, and only gains modestly for intermediate values of inequality aversion. Recall that Mono is the department with the third lowest share of auto-consumption in total expenditures (see Table 3). As far as it is optimal to tax market substitutes for auto-consumption, as these are more preferred by persons with a lower welfare level, the poor in Mono might not benefit as such from such a policy.

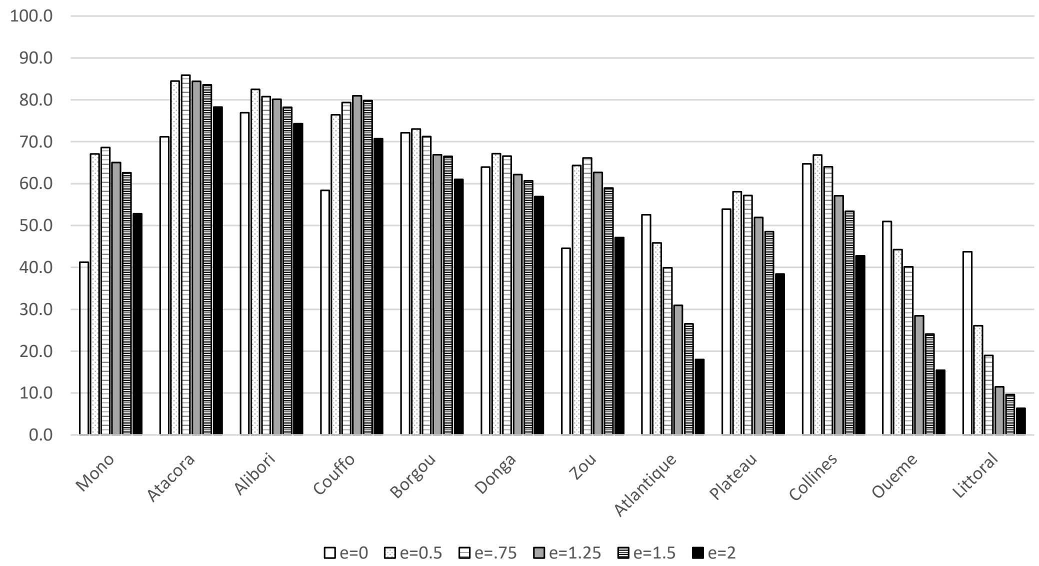
Figure 10: Average welfare gain by department – relative (%)



Note: The vertical axis reports relative average welfare differences between the application of the optimal tax and the baseline simulation (standard tariff of 25.56%, guaranteeing to reach the UN tax revenue objective of 20% of GDP, with goods exempted as in 2015). Averages are calculated as average welfare gain over overage baseline welfare level. Each set of equally patterned bars is for a different level of inequality aversion. Each group of differently patterned bars is for a particular department. Departments are ranked from poorest to richest according to average baseline welfare level. The vertical axes is truncated below at -10%. The underlying values of the figure can be found in Table D.10 of Apendix D.7.

Finally, Figure 11 represents the percentage of winners for each department and for different levels of inequality aversion. The number of winners is inversely U-shaped in inequality aversion for poorer departments, and uniformly decreasing for the richer departments. Even in the absence of inequality aversion a majority of residents in three departments (Mono, Zou, and Littoral) is losing. Interestingly, not always the same departments face a majority of losers for different values of inequality aversion. From a political economy perspective these observations are relevant, as it might reveal that representatives of different departments may favour different kind of optimal policies.

Figure 11: Percentage of winners by department



Note: The vertical axis the percentage of winners from a switch of the baseline simulation (standard tariff of 25.56%, guaranteeing to reach the UN tax revenue objective of 20% of GDP, with goods exempted as in 2015) to the optimal taxes. Each set of equally patterned bars is for a different level of inequality aversion. Each group of differently patterned bars is for a particular department. Departments are ranked from poorest to richest according to average baseline welfare level. The underlying values of the figure can be found in Table D.11 of Apendix D.7.

5.6 The role of the government budget level

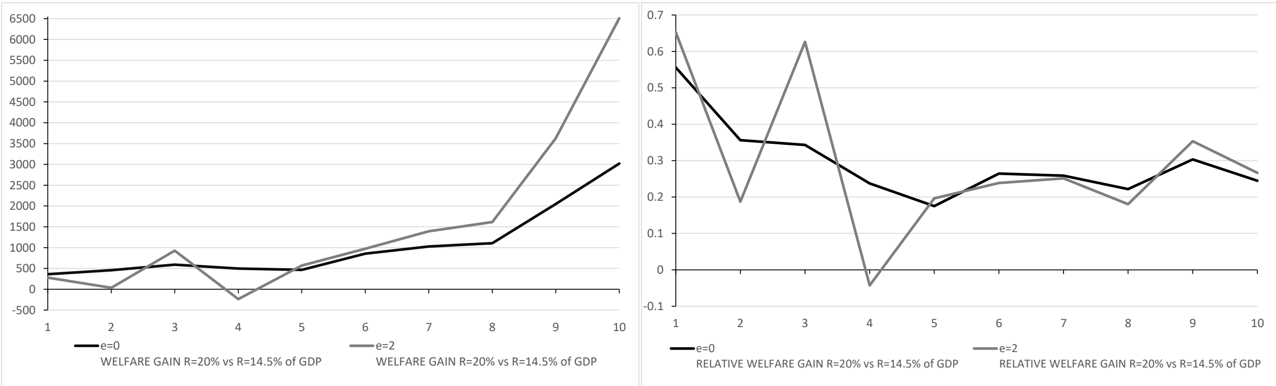
As was noted in Section 2.2, tax revenues in Benin were not on the rise the last few years. We therefore illustrate which insights our model provides on the tax structure and level of government revenues at the moment of the data collection.[37] We more in particular investigate which patterns may arise if we vary the government budget.[38] Given that we do not integrate the public goods financed through taxes in our analysis, it makes no sense to compare welfare levels obtained under different government budget constraints. Actually, all individuals lose, both in the baseline and in the optimum, when the government budget is increased. Alternatively, we compare gains and losses arising from a switch of the existing tax structure (one VAT tariff, 18% under the low budget, and 26.56% under the high one, and an unaltered list of exempted goods) to optimal taxes, under the high (20% of GDP) and the low (14.5%, coinciding with the tax revenues in 2015 and 2019) government budget. We limit our comparison for the cases of absence of inequality aversion ($e = 0$) and 'extreme' inequality aversion ($e = 2$).

In Appendix D.8 we also compare the optimal tax rates between the higher and the lower government revenue constraints, for those two levels of inequality aversion. All optimal tax rates increase when the government budget constraint is tightened. When $e = 2$, the ranking of optimal tax rates is the same under both government budget constraints, while the taxes on three pairs of good switch rank, when $e = 0$. Even then, no fundamental changes take place in the tax structure.

[37] This amounts to VAT revenues from the household sector equalling 172.6 billion CFA, or 3.5% of GDP, and total tax revenue equalling 14.5% of GDP, which is about the same level as in 2019, see Section 2.2.

[38] We also did some analyses with an intermediate level of tax revenues equalling 18% of GDP, but do not report them in the paper, as all qualitative results remained unaltered.

Figure 12: Difference in average welfare gain w.r.t. level of government revenues



(a) difference in avg. welfare gain per decile (CFA) (b) Difference in relative welfare gain per decile (%)

Note: The figures show for each decile the difference in the average welfare change from the baseline tax structure to optimal tariffs for low (total tax revenues GDP ratio equal to 14.5%) and high (total tax revenue GDP ratio equal to 20%). The left hand panel contains the differences in levels (CFA). The right hand panel contains the differences in welfare changes relative to the respective baselines. Black lines are for absence of inequality aversion ($e = 0$), grey lines apply to $e = 2$.
Averages and deciles are calculated for the population of individuals. Deciles are constructed on the basis of baseline welfare, and are therefore not necessarily composed of the same persons in both the low and high tax revenue case. The averages of relative gains (right hand panel) are calculated as the average gain of all individuals within a decile divided by the average welfare level of individuals within that decile (Section B.3).

Figure 12 shows the differences in welfare changes between baseline and optimum for both government budget constraints, across the initial welfare distribution. Deciles are (slightly) differently composed under the low and high government budget (see the discussion on the budget shares in both cases in Appendix C.2). For each decile, the difference in the average change in welfare from a switch to the optimum is given. Black lines refer the case of no inequality aversion, and grey lines to the case where $e = 2$. The left hand panel contain the figures in levels, the right panel contain relative differences (percentage gain or loss with respect to baseline level).

The black lines reveal that the average gain (loss) is in(de)creasing in the height of the government budget. In levels, this higher gain is relatively flat for the first five deciles, and increases for higher deciles. In relative terms, though, it is decreasing up to the fifth decile, and relatively flat afterwards. It is still overall positive. This means that the loss incurred by raising the government budget is higher under the baseline tax structure (one rate and exempted goods) than under the optimal policy. It might be tempting to conclude that a higher government budget allows for larger gains from a switch the current tax structure with one rate, and a number of exempted goods, to an optimal tax structure. A look at the results for higher inequality aversion (the grey lines) gives a more versatile picture for the lower deciles, with even a negative average for the fourth decile, meaning that gains from switching to the optimum are on average larger for the lower budget, or losses smaller. Notice that even under high inequality aversion, the individuals who gain more or lose less in levels (CFA) from a switch to the optimum under a high than under a low government budget belong to the higher deciles.

A closer look at the results learns that also here, these average differences in welfare changes per decile hide quite a lot of heterogeneity throughout. Table 10 divides the sample into seven groups: (1) those who win

Table 10: Government budget and heterogeneity in amount of welfare gain/loss

Distribution of the sample across different classes (%)		
	Inequality aversion	
Class	$e = 0$	$e = 2$
(1) Winner under 14.5 -loser under 20% of GDP	0.7	1.0
(2) Loser under 14.5, loss increases under 20	38.0	19.3
(3) Loser under both 14.5 and 20% of GDP but loss smaller under 20%	4.4	34.6
(4) Unaffected in both 14.5 and 20% of gdp	0.1	0.1
(5) Winner under both 14.5 and 20% GDP but gain decreases under 20%	1.7	19.4
(6) Winner under both 14.5 and 20% GDP, gain increases under 20%	53.4	24.0
(7) Loser under 14.5, winner under 20% of GDP	1.6	1.7

Note: Each individual in the sample is subdivided into one of seven classes according to her loss or gain pattern from a switch of the baseline structure to optimal taxes : (1) those who win from the switch under a low budget, but lose under the high budget; (2) those who lose under both government budget constraints, but lose more under the high budget; (3) those who lose under both government budget constraints, but lose less under the high budget; (4) those who are unaffected; (5) those who gain under both government budget constraints, but gain less under the high budget; (6) those who gain under both government budget constraints, but gain more under the high budget; and (7) those who lose under the low budget, but win under the high budget. The figures in the table represent the *sample* distribution across the seven classes.

from the switch under a low budget, but lose from the switch under the high budget; (2) those who lose under both government budget constraints, but lose more under the high budget; (3) those who lose under both government budget constraints, but lose less under the high budget; (4) those who are unaffected; (5) those who gain under both government budget constraints, but gain less under the high budget; (6) those who gain under both government budget constraints, but gain more under the high budget; and (7) those who lose under the low budget, but win under the high budget. The table reproduces some results from the earlier analysis (see Table 7), and shows that these results continue to hold at a lower government budget. Adding the classes (5), (6), and (7), we obtain the percentage of winners from a switch from existing policy to optimal rates to be equal to a majority of 56.8% when there is no inequality aversion, and a minority of 45.1% when inequality aversion is high ($e = 2$).[39] For the low budget (total tax revenues equal to 14.5% of GDP) the corresponding figures are 55.9% and 44.3% respectively, obtained by adding the classes (5), (6), and (1). So, a majority is gaining when there is no inequality aversion, while the reverse holds when inequality aversion is high, and this results seems to be unrelated to the size of the government budget. Nevertheless, the percentage of winners seems to slink when the budget is lower. Actually, Table 10 shows that in absence of inequality aversion, 53% of the individuals in the sample gain more from a switch of existing to optimal taxes under the high budget than under the low budget. But, no less than 38% loses under both government budgets, and even more so under the higher budget. Under high inequality aversion, the largest group is the one composed of those who lose under both government budgets, but lose less under

[39] The deviation with the 58.9% and 46.4%, respectively, reported in Table 7 is due to the fact that the figures in Table 10 are at the sample level. No inference for the population as whole is aimed at here. Qualitatively the conclusions are the same anyhow.

the higher government budget. Almost 40% of the sample experiences either a loss from the switch from baseline to optimal taxes that is higher under the high government budget than under the low one, or they experience a smaller gain from that switch with a larger budget than with a low.

We conclude that the level of the budget constraint has almost no effect on structure of optimal indirect tax changes. We reaffirm the conclusions of the analysis with the higher budget: optimal indirect taxes entails winners and losers when compared with the existing tax structure. The amount of winners and the average gain tend to increase slightly with government budget, though at the decile level this not a general result.

6 Conclusion

Current VAT policy in West Africa consists of imposing a single rate, but several commodities are exempted. With the exemption of certain commodities governments aim to reach the social objective of a more equitable distribution of the tax burden. The question of equitable tax reforms becomes even more important in the light of the ongoing debate on Domestic Resource Mobilisation in developing countries, that is the objective to raise more means through tax revenues in order to improve public good provision. More specifically, the United Nations as well as the West African Economic and Monetary Union (WAEMU) advocate that tax revenues should reach 20% of GDP in those countries. We use a many-person Ramsey type of optimal indirect taxation model to derive principles of alternative tax policies that might do better in terms of combining equity and efficiency objectives of taxation. In such a model the equity-efficiency trade-off of taxation is assessed through the choice of a social welfare function, that is maximised with respect to taxes under the condition of a government budget constraint. Our version model of the optimal indirect tax framework incorporates the distinguishing feature of many developing countries that a considerable part of consumption goods are not obtained through purchases on the formal market, but, for example stem from own produce or are received as gifts. These auto-consumed goods cannot (easily) be taxed, but do contribute to individual welfare. We present an individual demand model that accounts for substitution effects between market varieties and auto-consumption varieties of consumption goods. The presence of commodities that cannot be taxed plays an important role in the insight we derive that uniform indirect taxes are not optimal, even in the absence of any inequality aversion in the social welfare function. Furthermore, we exploit micro-data on expenditure in order to calibrate the preference parameters underlying our demand model. We as such allow for preference heterogeneity, possibly correlated with the people's welfare level. Especially for food, the category which still takes the biggest bite out of people's budget in developing countries, we observe a distinction between commodities predominantly consumed by poorer and richer agents. We finally show how optimal tax results with a fairly detailed, but practically non-manageable number of tax rates, can serve as a guideline for determining a limited set of commodity groups, to arrive as such to an implementable maximal number of potentially different tax rates.

We apply our framework to the case of Benin, using the household budget survey (Enquête Modulaire Intégrée sur les Conditions de Vie des Ménages) of 2015, collected by National Institute of Statistics (INSAE). Our analysis mainly focuses on a comparison of the welfare obtained under optimal taxes with the welfare when the current policy of one standard rate with a list of exempted goods is maintained. We do this, first, under the assumption that the government budget has to be risen such that the UN-WAEMU objective of a tax revenues to GDP ratio of 20% is reached, and then apply a sensitivity analysis for Benin's actual government, which equalled 14.5% of GDP in 2015. We develop a bootstrap method to construct confidence intervals around estimated welfare effects.

We highlight six results from the empirical analysis. First, we show how the the presence of untaxable commodities and differences in household structure entail a deviation from uniform taxation in an optimum for a welfare function without inequality aversion. Second, our results illustrate the equity-efficiency trade-off: in the absence of inequality aversion, government sets indirect taxes so that total (or average) welfare is maximised. As inequality aversion rises, commodities on average more intensely preferred by individuals living in households with higher equivalised incomes, tend to be taxed higher. The differences between highest and lowest rates (which are negative when inequality aversion is positive). In return, gains for individuals belonging to households with lower equivalised incomes are more substantial, but overall welfare is lower than in the case of zero inequality aversion. A further analysis of the welfare effects by administrative departments illustrates that our results stand to reason: average welfare gain tends to be higher for poorer departments when inequality aversion increases. Third, we find that up to a substantial level of inequality aversion level, a statistically significant majority of the individuals would gain from switching to optimal taxes. On the contrary, optimal taxes for the highest level of inequality aversion we used, are rejected by a majority, though this result is not statistically significant at the 5% level. Fourth, we find winners and losers in all welfare deciles, due to preference heterogeneity within those deciles. Fifth, we show that when restricting the number of tax rates to a maximum of four rates, one can come fairly close to the theoretical optimum with a much higher number of different tax rates (23 in our application). Finally, our results turn out to be qualitatively unchanged when the government budget is set at the current level of 14.5% of GDP. The amount of winners and the average gain tend to increase slightly with the government budget. This means that when the government budget is raised, people tend to lose more under the existing policy of one standard rate and a fixed list of exempted goods, than under the application of optimal taxes. However, this result again hides a lot of heterogeneity.

Our modelling strategy was to isolate the principles governing optimal indirect taxation from their interaction with other tax instruments, the income tax in the first place. Furthermore we limited the scope of the redistributive role of indirect taxation, by imposing homothetic preferences, so that the usual argument to tax more luxuries and less necessities is not valid in our framework. The redistributive role of indirect taxes is therefore limited to the degree in which preferences are correlated with income. This implies necessarily that any optimal indirect tax structure will entail winners and losers across the whole income or welfare distribution, as long as this correlation is not perfect.

Since the seminal paper of Atkinson and Stiglitz (1976), it is well known that under an optimal direct tax scheme, the principles governing optimal indirect taxation fundamentally change. Indirect taxes serve then in the first place to relax the incentive constraints limiting the progressive nature of the income tax. By making cheaper the consumption preferred by the rich, they are stimulated to work more, earn more money, and therefore pay more taxes in favour of the poorer persons. However, these results were obtained under the assumption of identical preferences. Some recent results (Gauthier and Henriet, 2018, Spiritus, 2022) suggest that under heterogeneous preferences, a limited distributive role of indirect preferences is safeguarded, depending on the correlation of preferences and income. Future research is need to quantify these theoretical results.

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Appendix to
"Welfare effects of indirect tax policies in West Africa"

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A VAT in WAEMU

Table A.1 gives more information on the application of reduced rates, next to the standard rate, by WAEMU countries, after this has been allowed for since 2008.

Table A.1: Current VAT policy in WAEMU

Country	standard rate	exemption and zeros rates	reduced rate
Benin	18	yes	NO
Burkina Faso	18	yes	10
Côte d'Ivoire	18	yes	9
Mali	18	yes	5
Niger	19	yes	5 & 10
Senegal	18	yes	10
Togo	18	yes	10

Note: Data for all countries except Togo, stem from Thorton's international Indirect Tax Guide: https://www.grantthornton.global/en/insights/indirect-tax-guide/international-indirect-tax-guide/; for Togo, we consulted: https://www.lloydsbanktrade.com/en/market-potential/togo/taxes. Guinée-Bissau only introduced VAT in 2023, replacing a sales tax.

B Additional methodology

B.1 Individual household consumption behaviour

In general, a household is assumed to maximise a (strictly increasing) utility function $u(\mathbf{x})$, subject to a budget constraint, $\mathbf{q}'\mathbf{x} = y$, where $\mathbf{q}$ is the vector collecting consumer prices q_k for commodity k, and y household's income. The solution is known as the set Marshallian demand functions $d_k(\mathbf{q}, y)$.

Filling out these solutions in the budget equation and differentiating with respect to a commodity price q_k yields:

$$\sum_l q_l \frac{\partial d_l(\mathbf{q}, y)}{\partial q_k} = -d_k(\mathbf{q}, y). \tag{A.1}$$

This equation is known as the adding-up condition of demand.

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Functional specifications of the paper

- Utility function:

$$u^{\text{CCD}}(\mathbf{x}) = \prod_g \left(\sum_s \delta_{g,s}^{1-r_g} x_{g,s}^{r_g} \right)^{\frac{\alpha_g}{r_g}}, \tag{A.2}$$

  where

  - $r_g = \frac{\sigma_g - 1}{\sigma_g}$, with $\sigma_g \in [0, \infty)$ being the elasticity of substitution between market and auto–consumed types of the good g ($r_g < 1$). The elasticity of substitution is the percentage change of $x_{g,a}/x_{g,m}$ in response to a percentage change in the marginal rate of substitution between a and m;
  - $\delta_{g,s}$ is a distribution parameter indicating the relative intensity of preference for the s type of good g, with $\sum_s \delta_{g,s} = 1$;
  - α_g is the Cobb–Douglas share parameter, and will turn out to be the expenditure share of good g (sum of expenditures on on market and auto-consumption variety of a commodity g over the sum of expenditures on all commodities, market goods and auto-consumption).

- Marshallian demand function for commodity g, s:

$$d_{g,s}^{\text{CCD}}(\mathbf{q}_g; y) = \frac{\alpha_g \delta_{g,s} y}{\phi_g(\mathbf{q}_g)^{1-\sigma_g} q_{g,s}^{\sigma_g}}, \tag{A.3}$$

  where

  - $\phi_g(\mathbf{q}_g) = \left(\sum_s \delta_{g,s} q_{g,s}^{1-\sigma_g} \right)^{\frac{1}{1-\sigma_g}}$, a CES price index;
  - α_g can be verified to be the expenditure share of good g and can be read off from the data;
  - for a given value of σ_g, $\delta_{g,s}$ can be read off from the data as follows: $\delta_{g,a} = \left(1 + \frac{e_{g,m}}{e_{g,a}} \left(\frac{q_{g,a}}{q_{g,m}} \right)^{1-\sigma_g} \right)^{-1}$;
  - σ_g cannot be immediately read off from the data, and should be fixed by the researcher. We assume it is not household specific and equal to 0.5 for all commodities g, and we will therefore denote it by σ.

- Indirect utility function:

$$v^{\text{CCD}}(\mathbf{q}, y) = y \prod_g \left(\frac{\alpha_g}{\phi_g(\mathbf{q}_g)} \right)^{\alpha_g}. \tag{A.4}$$

- Expenditure function:

$$e^{\text{CCD}}(\mathbf{q}; U) = U \prod_g \left(\frac{\phi_g(\mathbf{q}_g)}{\alpha_g} \right)^{\alpha_g}. \tag{A.5}$$

- Money Metric Utility function:

$$MMU^{\text{CCD}}(\mathbf{q}, y; \mathbf{q}_{\text{ref}}) = y \prod_g \left(\frac{\phi_g(\mathbf{q}_{\text{ref},g})}{\phi_g(\mathbf{q}_g)} \right)^{\alpha_g}. \tag{A.6}$$

- Individual welfare metric:

$$m^{\text{CCD}}(\mathbf{q}, y; \mathbf{q}_{\text{ref}}) = \frac{MMU^{\text{CCD}}(\mathbf{q}, y; \mathbf{q}_{\text{ref}})}{\theta}, \tag{A.7}$$

  with θ denoting the household equivalence scale.

B.2 Social welfare, government budget, optimal taxes

- Social welfare function:

$$W(\mathbf{t}) = \sum_h n_h \frac{\left(m_h^{\text{CCD}}(\mathbf{q}, y_h; \mathbf{q}_{\text{ref}})\right)^{1-e}}{1-e}, \tag{A.8}$$

  with $e \geq 0$, the degree of inequality aversion.

– Government budget:

$$R(\mathbf{t}) = \sum_g t_g \sum_h \frac{\alpha_{g,h}\delta_{g,m,h}y_h}{\phi_{g,h}(\mathbf{q}_g)^{1-\sigma} q_{g,m}^{\sigma}} \geq \bar{R}. \tag{A.9}$$

– Optimal taxes should satisfy (necessar) first order conditions of the maximisation problem (max) in the main text:

$$\lambda = -\frac{\partial W/\partial t_g}{\partial R/\partial t_g}, \text{ for all } g, \tag{A.10}$$

with:

– λ: the Lagrange multiplier associated the government budget restriction (A.9);

– $-\frac{\partial W}{\partial t_g} = \sum_h \beta_h(\mathbf{t})\, d^{\text{CCD}}_{g,m,h}(\mathbf{q}_g, y_h) = \sum_h \beta_h(\mathbf{t}) \frac{\alpha_{g,h}\delta_{g,m,h}y_h}{\phi_{g,h}(\mathbf{q}_g)^{1-\sigma} q_{g,m}^{\sigma}}$, where

$$\begin{aligned} \beta_h(\mathbf{t}) = \frac{\partial W}{\partial y_h} &= \left(\frac{y_h}{\theta_h}\prod_g\left(\frac{\phi_{g,h}(\mathbf{q}_{\text{ref},g})}{\phi_{g,h}(\mathbf{q}_g)}\right)^{\alpha_{g,h}}\right)^{-e} \cdot \prod_g\left(\frac{\phi_{g,h}(\mathbf{q}_{\text{ref},g})}{\phi_{g,h}(\mathbf{q}_g)}\right)^{\alpha_{g,h}} \cdot \frac{n_h}{\theta_h} \\ &= \left(\frac{y_h}{\theta_h}\left(\frac{\Phi_h(\mathbf{q}_{\text{ref}})}{\Phi_h(\mathbf{q})}\right)\right)^{-e} \cdot \frac{\Phi_h(\mathbf{q}_{\text{ref}})}{\Phi_h(\mathbf{q})} \cdot \frac{n_h}{\theta_h}, \end{aligned} \tag{A.11}$$

with $\Phi_h(\mathbf{q}) = \prod_g (\phi_{g,h}(\mathbf{q}_g))^{\alpha_{g,h}}$;

– $\frac{\partial R}{\partial t_g} = \sum_h \frac{d^{\text{CCD}}_{g,m,h}(\mathbf{q}_g, y_h)}{\phi_{g,h}(\mathbf{q}_g)^{1-\sigma} q_{g,m}^{\sigma}} \left(\phi_{g,h}(\mathbf{q}_g)^{1-\sigma} q_{g,m}^{\sigma}\left(1-\sigma\frac{t_g}{q_{g,m}}\right) - (1-\sigma)\,\delta_{g,m,h}\,t_g\right)$.

B.3 Construction of quantiles, averages, and confidence intervals

Once individual welfare is calculated, we construct quantiles, that is, we divide the population in q equally sized groups, such that the first group consists of the poorest q% of the population, the next group contains the q% of the population which is better off than the first group but worse of than the other $100 - 2q$% of the population, and so forth. For individual welfare we construct deciles (groups of 10% of the population), though we sometimes use other quantile values. The q-th quantile value is the value below which q% of the population is situated.

Since our welfare measure (see Equation A.7) is an individual one, we consider mostly the population of individuals living in Benin at the moment of survey, as our reference population. This means that statistics will be drawn using weights which sum up to population size.[1]

For some concepts it might be more natural though, to draw statistics at the level of the population of households. For example, when one looks at the budget share of a good (the percentage of the budget spent to that good), it may make more sense to talk about the average household budget share spent on food, of the households to which the poorest 10% of individuals belong, rather than about the average household budget share spent on food, across all individuals belonging to that poorest decile. Average shares, for example budget shares of expenditures on a certain good, can either mean the average of that share over a number of observations, or the average of the numerator of the share, expenditures on that good, over the average of the denominator (the average budget), that is, the ratio of averages. The former is an outlier sensitive statistic. Especially when groups are not very big, the latter may therefore sometimes be preferred. When we talk below about quantiles and averages, we will always specify which quantile or average we mean: with respect to the population of individuals, or with respect to the population of households; and average shares or the ratio of averages.

Statistical inference is made by means of the bootstrap method. We create 500 new samples of the same size as the original one by drawing randomly with replacement from the original sample. The number of 500 replications

[1] The dataset we use has as unit of observation a household. Weighting with individuals is then implemented by drawing statistics using household weights provided by INSAE (which can inflate statistics to the household level) times the household size.

was fixed by doing some robustness checks with 100, 200, 300, 400, and 500 draws, after which confidence intervals became rather stable.

For each sample we first determine a new baseline by fixing the tax rate that raises the same government revenue as the our baseline for the original sample. Remember that this baseline government revenue is determined such that the UN objective of tax revenues to attain 20% of GDP. Then we perform for each of the six values of inequality aversion optimal taxes and compare the resulting welfare levels with those of the corresponding baseline. The 95% confidence interval around the point estimates is then fixed by selecting for twelfth lowest and thirteenth highest value of each of the 500 calculations of the that statistic.

C Data

C.1 Composition of commodity aggregates

The present section gives detailed information of the composition of the different commodity aggregates we used at the most detailed level we have available in the the data (COICOP 6 digits). The 23 aggregates are constructed using a somewhat finer grid than the COICOP 2 digit classification (for example housing is split into rents and utilities and maintenance). Moreover, as explained in the main text, we distinguish between commodities that are taxed according to the rules in vigour in 2015, and those that are exempt from VAT. For some categories, all its components are taxed (for example, 'Catering and accommodation'), or all are exempted (Health).

Finally, for food we distinguish between 'food rich' and 'food poor'. This distinction was based on two pieces of information. First, we investigated for the market varieties of the food, the pattern of the budget shares across the welfare deciles, in the data.[2] We took care that in the aggregate the budget share of the 'food rich' groups is increasing across the welfare distribution, and the other way around for the poor. One can verify that in Table C.2 below. Second, for each of the food aggregates we also investigated the share of total consumption of that good by different welfare groups (see the notion of *distributional characteristics* of a commodity, introduced by Feldstein, 1972). Of courses the poor consume of (almost) all commodities less than the rich. But we verified that for the 'food poor' aggregates, the share in total consumption of these commodity groups of the lowest two welfare deciles is above their average of the shares in total consumption for all commodity groups, and below the average in total consumption of the richest two deciles. For the 'food rich' aggregates, the share in total consumption of these commodity groups of the lowest two welfare deciles is below their average of the shares in total consumption for all commodity groups, and above the average in total consumption of the richest two deciles.

This brings us to 23 commodity groups, of which the composition is given in the next table. For the commodity names, we use the original labels of the survey, which are in French.

[2] We stress again that budget shares of commodities might change with the tax structure and therefore are not necessarily the same in the optimum, as compared what is observed in the data. The same holds true for the welfare deciles, the composition of which may change with tax rates. This is discussed further in Section D.5.

Table C.1: Detailed overview of the composition of the commodity groups

Food rich

Food rich taxed: Riz importé, Couscous de blé, Macaroni, Spaghetti, Autres pattes alimentaires, Biscuit industriel, Pattisserie et viennoiserie, Biscuits, gâteaux, Poulet congelé, Canard congelé, Dinde congelé, Morceaux de poulet, Saucisson, Corned beef, Conserve de porc, Conserve de boeuf, Conserve de poulet, Conserves, autres viandes et préparatif, Maquereau et chinchard congelé, Crabes de lagune, Escargots de lagune, Crabes de mer, Escargots de mer, Homard et crevette, Langouste, Autres produits frais de la mer, Boite de sardine, Boite de thon, Autres conserves poissons, Lait entier pasteurisé, Lait entier concentré sucré ou non, Lait écremé, Lait en poudre, Autres laits, Crême fraiche, Yaourt fabrication industrielle, Lait caillé, Margarine, Huile d'arachide, Huile de coton, Autres matières grasses, Orange, Mandarine, Citron, Ananas, Banane douce, Papaye, Avocat, Pomme, Pastèque melon, Datte, Concentré de tomate, Frites et chips, Farine d'igname, Sucre en morceaux, Bonbons, Miel raffiné, Glace, Sirop et mélasse, Chocolat à croquer ou en patte, Mayonnaise, Vinaigre, Lait infantile (Guiguoz), Cérélac, Farigallia, Nestum, Autres aliments pour bébé.

Food rich exempt: Maïs en épi frais, Mil, Riz local, Autres céréales non transformes, Maïs en patte, Farine de mil, Céréales grillés, Fécule de pomme de terre, Tapioca/gari, Autres farines et semoules, Patte alimentaire locale cuite (abolo), Pain de blé local artisanal, Pain de blé industriel en baguette, Autres pains, Bœuf sur pied (vivant), Viande de bœuf fraîche sans os, Viande de bœuf séchée, Abats et tripes de bœuf, Autres viandes de bœuf, Viande de mouton ou de chèvre fraîche, Abats et fripes de mouton ou de chèvre, Porc sur pied (vivant), Viande de porc fraîche, Volaille sur pied (vivante), Morceaux de volaille, Gibier, Capitaine, Bar frais, Sardinelles sardines et anchois fraiches, Poisson frais Appolo, Poisson frais Sosso, Carpe fraiche, Silure (silivi), Dorade, Autres poissons frais, Maquereau et chinchard fumé, Bar fumé, Sardinelles fumés, Sardinelles séchés, Silure fumée, Dorade fumée, Yaourt fabrication traditionnelle, Œuf frais de poule, Autres œufs, Patte d' arachide locale, Tomate fraîche, Aubergine verte, Carotte, Haricot vert, Courges, Autres légumes frais en fruits ou racines, Salade verte locale (laitue), Epinard, Choux vert, Ndolé (bitter-leaves ou feuilles amères), Feuille de manioc, Haricots secs, Pois secs, Arachide décortiquée, Sésame décortiqué, Banane plantain, Manioc, Igname, Pomme de terre tubercule, Patate douce, Taro, Macabo, Manioc râpé, Manioc déshydraté (en boules ou en mo), Autres tubercules, Canne à sucre, Miel naturel, Aïl persil céleri et basilic, Gingembre.

Food poor

Food poor taxed: Jambon, Museau de porc, Autres charcuteries, Pilchard, Fromage, Autres produits laitiers, Beurre (alimentaire), Autres produits dérivés de beurre, Huile de palme, Huile de soja, Huile d'olive, Huile de karité, Autres huiles, Pamplemousse, Mangue, Goyave, Autres fruits frais, Noisettes, Noix de Coco, Noix de cajou, Autres fruits secs, Sucre en poudre, Autres sucres, Chewing-gum, Autres confiseries, Moutarde et ketchup, Bouillon alimentaire en cube (Maggi, Jumbo), Autres épices et condiments.

Food poor exempt: Maïs en grains crus, Sorgho, Fonio, Farine de maïs, Farine de sorgho, Farine de manioc (y compris Attiékè), Biscuit artisanal, Beignet à base de farine de blé, Beignet à base d'autres céréales, Viande de bœuf fraîche avec os, Mouton ou chèvre sur pied (vivant), Viande de mouton ou de chèvre sêche, Autres viandes de mouton ou de chèvre, Viande de porc séchée, Abats et tripes de porc, Autres viandes de porc, Autres volailles, Insectes ou chenilles, Serpent et reptiles, Maquereau et chinchard séché, Dorade séchée, Poissons salés, Autres poissons fumés ou séchés, Lait frais liquide non traité, Graines de palme traditionnelles, Oignon frais, Gombo frais, Feuille de gombo, Feuille de patate, Feuilles gluantes (adémè ou crincrin), Feuille de baobab, Autres légumes frais en feuille, Conserves de légumes secs, Autres oléagineux (arachide gri), Autres légumes secs, Autres tubercules, Bâton de manioc, Piment, Poivre et poivron, Sel.

Non alcoholic beverages

Non alcoholic beverages taxed: non existent.

Non alcoholic beverages exempt: Café, Thé, Milo, Ovaltine, Matinal, Autres produits cacaotés, Infusion (tisane), Autres cafés thés etc, Jus de fruit artisanal, Eau de source (potable), Glaçon, Autres boissons non alcoolisées artisanales, Eau gazeuse, Eau minérale en bouteille, Boisson gazeuse aromatisée (coca, fanta), Jus de fruit industriel, Autres boissons non alcoolisées industrielles.

Alcoholic beverages, tobacco and narcotics

Alcoholic beverages, tobacco and narcotics taxed: Whisky, Gin, Apéritifs non à base de vin, Eaux-de-vie ou liqueur locale, Autre liqueur industrielle, Vin industriel et vermouth, Apéritif à base de vin, Vins mousseux (champagne), Bière industrielle, Tabac local (à priser, à chiquer, etc), Cigarettes locales ou produites sous licence, Cigarettes importées, Cigares, Noix de cola, Autres stupéfiants.

Alcoholic beverages, tobacco and narcotics exempt: Vin de palme et de rafia, Autres boissons fermentées, Bière artisanale.

Clothing and footwear

Clothing and footwear taxed: Tissu pagne, Autres tissus en coton, Tissu synthétique, Autres tissus, Chemise homme (y compris chemisette), Gandoura, boubou et saharienne homme, Pantalon et culotte homme, Veste homme, Costume homme, Ensemble homme, Autres vêtements de dessus homme, Slip homme (toute forme de caleçon), Chaussette homme, Tee shirt homme, Vêtement de nuit homme, Autres sous-vêtements et bonneterie homme, Robe et jupe, Pantalon et culotte femme (culotte), Ensemble femme (tailleur, veste,), Gandoura, boubou et pagne femme, Chemise en tissu pour femme, Vêtement de sport (shorts, jogging), Autres vêtements de dessus femme, Slip et caleçon femme (string), Jupon et collants, Tee shirt femme, Soutien gorge, Vêtement de nuit (robe de chambre), Autres vêtements de dessous femme, Vêtements pour bébé (layette), Chemisette chemise tricot et pull-over, Robe et jupe fillette, Pantalon culotte et short garçon, Ensemble pour enfant (veste, costume), Gandoura boubou et enfant, Sous vêtement et vêtement de nuit enfant, Autres vêtements enfants, Tenues scolaires jeune homme, Tenues scolaires jeune fille, Tenues scolaires enfant (3 à 13 ans), Mouchoir et foulard en tissu, Ceinture, Couche bébé en tissu, Chapeau bonnet ou chéchia, Perruque, Cravate et noeud, Mercerie (fil à coudre, aiguilles, bou), Autres articles vestimentaires, Confection costume homme, Confection pantalon homme, Confection chemise homme, Réparation vêtement homme, Location de vêtement homme, Autre confection homme, Confection robe et jupe, Confection ensemble femme, Réparation vêtement femme, Location de vêtement femme, Autre confection femme, Confection chemise enfant, Confection pantalon enfant, Confection robe enfant, Confection jupe enfant, Confection ensemble garçon, Confection ensemble fille, Réparation vêtements enfant, Location vêtements enfant, Autres confection vêtements enfant, Nettoyage à sec de vêtement, Blanchissage, Pressing de vêtement, Teinture des vêtements et tissus, Chaussure en cuir homme, Chaussure synthêtique homme (cahoutchouc), Chaussure de tennis basket ou football, Sandale pour homme, Autres chaussures et accessoires (languet), Chaussure en cuir femme, Chaussure synthétique femme (cahoutchouc), Chaussure de tennis basket ou football, Sandale pour femme, Autres chaussures et accessoires (languet), Sandale pour enfants, Chaussure en cuir enfant, Chaussure synthétique (cahoutchouc), Chaussure de tennis basket ou football, Autres chaussures accessoires et articles, Ressemelage complet, Cirage et nettoyage de chaussure, Autres réparations et locations.

Clothing and footwear exempt: non existent.

Housing rent

Housing rent taxed: non existent.

Housing rent exempt: Loyer de maison d'habitation, Loyer de terrain.

Housing utilities and maintenance

Housing utilities and maintenance taxed: Ciment, Tôle, Fer à béton, Peinture, Chaux vive, Sable, Carreaux, Robinet, Petites pièces de plomberie (tuyaux), Autres produits pour entretien et réparation, Main d'œuvre pour réparation courante, Main d'œuvre pour renouvellement, Main d'œuvre pour petits travaux de maintien, Autres services d'entretien du logement, Facture d'eau, Location de compteur, Eau achetée en bidon seau baril etc, Autres dépenses connexes (redevances), Enlèvement et traitement des ordures, Reprises des eaux usées, Vidange fosse septique, Gardiennage, Jardinage, Autres services payant liés au logement, Autres dépenses connexes, Pétrole lampant, Autres combustibles liquides, Charbon de bois, Autres combustibles.

Housing utilities and maintenance exempt: Consommation d'électricité, Gaz, Bois de chauffage, Sciure/copaux de bois.

Furnishings and household equipment

Furnishings and household equipment taxed: Nappes serviettes de table et serviettes, Draps couvertures couvre-lit, Moustiquaires, Tissus pour rideau, Réparation d'articles de ménage, Autres articles de ménage en textile, Cafétières électriques, Ventilateur mobile, Plaques chauffantes, Fer à repasser, Moulinette (moulinex), Autres appareils electroménagers, Fer à repasser à charbon, Fourneau, Rechaud à pétrole ou à gaz, Réparation d'appareils électroménage, Réparation d'un groupe électrogène, Réparation d'un congélateur ou réfrigerateur, Réparation d'un ventilateur mobile, Réparation de fer à repasser, Réparation d'autres appareils ménager, Assiettes, Couverts (couteau, fourchette, cuiller), Verres, Bol et tasse, Réparation de vaisselle, Autres vaisselles, Casserole, Marmite, Poèle, Calebasses et jarres, Cocottes, Réparation d'ustensiles de cuisine, Autres ustensiles de cuisine, Lampe à pétrole pression ou à gaz, Seau ou cuvette, Poubelle, Bouteille thermos glacière, Autres ustensiles de ménage, Scies marteau tournevis etc, Pelle râteau brouette arrosoir etc, Machette et houe, Echelles et escabeaux, Gongs poignées et serrures, Ampoule tube fluorescent Lampes de poche et piles électriques, Autres petits accessoires électriques, Autres outillages, Eau de Javel, Savon de ménage en morceaux, Lessives en poudre ou liquides, Insecticide et tortillon anti-moustique, Articles en papier ou carton (mouchoirs), Produits de cirage (Kiwi), Désinfectant (Crésyl, raticide), Allumettes bougies ou mèches de lampe, Torchons et éponge de ménage serpiaire, Autres articles de ménage non durables, Boy bonne cuisinier, Jardinier, Chauffeur de véhicule personnel, Autre personnel domestique, Blanchisserie pressing de linge, Location de meubles et d'articles ménage, Services ménagers (désinfection), Autres services ménagers.

Furnishings and household equipment exempt: non existent.

Health

Health taxed: non existent.

Health exempt: Aspirine, Nivaquine, Quinimax, Vaccins, Bactrim, Chloroquine, Paracetamol, Autres médicaments modernes, Herbe pour paludisme, Anti hémoroïde, Antitussif, Vermifuge, Pansement gastrique, Antibiotiques, Autres médicaments traditionnels, Mercurochrome, Alcool ou teinture de pansement, Autres produits pour pansements, Seringue à jeter, Thermomètre médical, Préservatifs et autres contraceptifs, Autres produits pharmaceutiques, Consultation d'un généraliste, Consultation d'un gynécologue, Consultation d'un pédiatre, Consultation d'autres spécialistes, Autres services des médecins, Consultation d'un dentiste, Consultation d'un spécialiste ou auxil, Frais de pose des prothèses dentaires, Autres services des dentistes, Radiographie, Analyse de sang, Analyse d' urine, Analyse de celles, Autres analyses, Service d'un infirmier, Consultation d'un médecin traditionnel, Consultation d'un marabout, Autres services des auxiliaires médicales, Hospitalisation, Soins hospitaliers, Intervention chirurgicale, Frais de maternité, Autres services des hospitaux.

Transport

Transport taxed: Pneu pour automobile, Chambre à air pour automobile, Batterie pour automobile, Bougie pour automobile, Pneu pour vélo ou moto, Chambre à air pour moto, Bougie pour moto, Autres pièces détachées, Essence super, Essence ordinaire, Essence mélange, Gas-oil, Huile à moteur, Autres carburants et lubrifiants, Vidange graissage d'une voiture, Vidange graissage d'une moto, Lavage, Réparation d'un pneu de voiture, Réparation d'un pneu de moto, Pose de pièces de rechange et d'access, Taillerie, Autres réparations et entretiens de véhicule, Frais de parking, Leçon auto-école, Examen de permis de conduire, Permis de conduire, Contrôle technique, Location de véhicule sans chauffeur, Autres services relatifs aux véhicules, Transport de passagers et de bagages passagers, Transport par train de tourisme, Taxi-auto course en ville, Télé-taxi, Transport en commun, Transport longue distance par route, Autres transports routiers, Transport par avion de tourisme, Transport transfrontaliers de passagers, Autre transport fluvial, Transport combiné de tourisme, Services de déménagement, Services de porteur, Consignation, Expédition de bagages, Autres services de transports.

Transport exempted: Peage, Taxi-moto.

Communication

Communication taxed: Achats de timbres, Envoi de colis personnels, Frais d'envoi de mandat postal, Achat de carte de téléphone fixe, Achat de carte de téléphone mobile, Autres achats de cartes téléphoniques, Communication téléphonique à l'unité, Frais d'abonnement téléphonique fixe, Frais d'abonnement téléphonique mobil, Facture téléphonique fixe, Facture téléphonique mobile, Frais d'installation de téléphone fix, Frais de télécopie ou fax, Autres services de téléphone et télé, Frais d'abonnement internet, Frais de connexion à internet, Utilisation de messagerie électronique, Autres frais divers de connexion internet.

Communication exempt: non existent

Recreation and culture

Recreation and culture taxed: Pellicule photo, Cassette enregistrée, Cassette vierge, Disquette vierge, Disquette enregistré, CD-ROM vierge, CD-ROM enregistré, Disque, Autres supports d'enregistrement, Réparation appareils réception enregistrement, Réparations d'équipement photographique, Réparation du matériel de traitement, Ludo echec dame carte etc., Jeux video, Jouets, Feux d'artifice, Guirlandes et décorations pour arbre, Autres jeux et jouets, Ballon, Raquette, Boules, Tente et accessoires connexes, Chaussures spéciales, Autres articles de sport, Fleurs et feuillages naturels ou artifices, Plantes arbustes arbrisseaux, Engrais compost, Terreaux, Frais de livraison des fleurs et plantes, Autres produits pour jardins, Chat, Oiseau, Achat d'aliments de produits vétérin, Collier du chien et du chat, Niche cage à oiseau ou litière du chat, Toilettage des animaux de compagnie, Dressage, Vaccinnation et traitement des animaux, Droit d'entrée au stade, Droit d'entree dans une piscine, Salle de gymnase, Service de guide de montagne touristique, Autres services récréatifs et sportif, Droit d'entrée dans une salle de ciné, Droit d'entrée au théâtre, Droit d'entrée au concert, Droit d'entrée en boîte de nuit, Droit d'entrée à une bibliothèque, Abonnement et redevance à des chaînes, Services de photographe, Locations de cassettes à but culturel, Autres services culturels, Billet de loterie nationale, Billet de PMU, Autres jeux de hasard, Journal quotidien privé local, Journal hebdomadaire privé local, Autres presses et périodiques, Catalogues, Imprimé publicitaires, Affiches publicitaires, Carte postale, Calendrier, Carte de vœux cartes de visite, Cartes géographiques et globes, Autres presse et imprimés divers, Cahier, Cartable, Agenda, Enveloppes, Bloc-notes carnets de note, Livres comptables, Autres articles de papeterie, Trousse, Autres fournitures de bureau, Pélérinages, Excursions et circuits touristiques.

Recreation and culture exempt: Livres scolaires enseignement maternelle, Livres scolaires enseignement primaire, Livres scolaires enseignement secondair, Livres scolaires enseignement supérieure, Autres livres scolaires, Atlas, Dictionnaire, Album pour photo, Bande dessinée, Reliure des ouvrages, Autres livres, Journal quotidien officiel, Journal hebdomadaire officiel, Journal mensuel, Crayons, Stylos, Ardoise locale, Craies, Instruments de géométrie, Articles de dessin, Colles à papier et adhésifs, Cartouche d'encre pour imprimante.

Education

Education taxed: non existent.

Education exempted: Frais de scolarité jardin d' enfants, Frais de scolarité dans une école primaire, Cours d'alphabétisation, Frais de répétition des élèves en primaire, Autres frais liés à l'enseignement primaire, Frais de scolarité dans une école secondaire, Frais de répétition des élèves en secondaire, Enseignement secondaire extrascolaire, Autres frais liés à l'enseignement secondaire, Frais de scolarité dans un institut post-secondaire, Autres frais d'enseignement post-secondaire, Frais de scolarité dans le supérieur, Autres frais liés l'enseignement supérieur, Cours particuliers non récréatifs, Formation professionnelle, Autres services d'enseignement.

Catering and accommodation

Catering and accommodation taxed: Bière artsanale dans un bar, Bière industrielle dans un bar, Sucrerie dans un bar, Liqueur dans un bar, Petit déjeuner pris à l'extérieur, Dèjeuner pris à l'extérieur, Diner pris à l'extérieur, Autres consommations à l'extérieur, Autres consommations à l'extérieur, Services de restauration des cantines, Chambre d'hôtel motel auberge, Pensionnats, Résidences universitaires, Autres services d'hébergement.

Catering and accommodation exempt: non existent.

Other non services

Other non services taxed: Coupe homme, Coupe dame, Défrisage des cheveux, Tresse, Manucure ou pédicure, Massage à des fins non thérapeutiques, Autres services de coiffure, Autres services de beauté et soins, Rasoir électrique, Tondeuse électrique, Séchoir à main, Casque séchoir, Réparation des appareils électriques, Autres apparels électriques pour soins, Rasoir non électrique, Tondeuse non électrique, Lame de rasoir et de tondeuse, Ciseaux, Peigne brosse (à cheveux et à dents), Bigoudis, Réparations et autres articles pour les soin de cheveux, Savon de toilette, Savon médicinal, Lait et huile de toilette, Dentifrice, Parfums et eaux de toilette, Déodorants corporels, Produits de beauté (vernis rouge à lèvre), Couches jetables pour bébé, Papier hygiénique, Autres articles pour les soins corporel, Valise, Sac de voyage, Sac à main, Lunettes solaires, Parapluies, Porte-monnaie et portefeuilles, Articles pour fumeurs, Articles pour bébés (poussettes sié), Réparation des effets personnels, Autres effets personnels.

Other non services exempt:

Other services

Other services taxed: Frais de crêche, Autre frais de protection sociale du ménage, Prime d'assurance éducation, Assurance vol, Assurance dégâts des eaux, Assurance maladie, Assurance d'accident privé, Autres assurances maladie, Assurance Automobile, Assurance motcyclette, Autres assurances transport, Frais effectivement facturés par les b Autres services d'intermédiation, Frais de mouture de céréales, Autres frais de mouture, Montant versé à des conseillers juridiques, Montant versé à des services de pompe, Montant versé à des agences immobilières, Autres frais divers sur prestations, Légalisation d'une pièce, Frais de photocopie et de reprographie, Autres services.

Other services exempt: Frais d'établissement des actes d'établissement, Autres frais d'établissement d'autres, Frais de parution d'annonce.

For most of these commodity aggregates, an auto-consumed variety exists. Exceptions are *education* and *other services*. For 'Housing rents' the auto-consumption variety consists of the imputed rents of owner-occupied dwellings.

C.2 Budget shares

Tables C.2 and C.3 contain the budget shares of different commodities by deciles of individual welfare and overall, as constructed from the original data, given the policy in vigour at that time (2015), that is a basic VAT-tariff of 18% while some goods are exempt. Section C.1 contains the definitions of our commodity aggregates.

For auto-consumption and gifts received, the reported monetary amounts are assumed to be exclusive of VAT, and are thus evaluated at producer prices. The idea is that these goods can if wanted be sold on the market at producer price, and therefore should be included as part of the global budget of the households. The budget shares are calculated as the sum of expenditures on a particular commodity g, s of households whose members belong to a particular decile or overall, divided by total expenditures on market goods and auto-consumption of those households (whose members belong to a particular decile or overall).

Tables C.4 and C.5 contain the budget shares of different commodities by deciles of individual welfare and overall, for the baseline with which we will compare results from the optimal taxation exercises. this baseline retains the structure of indirect taxation as is, with a basic tariff and a number of commodities that are exempt. The basic tariff is increased from 18 to 25.56% in order to meet the UN objective to raise total tax revenues to 20% of GDP. Auto-consumption and gifts are treated as in the original data case. The budget shares are calculated as the sum of expenditures on a particular commodity g, s of households whose members belong to a particular decile or overall, divided by total expenditures on market goods and auto-consumption of those households (whose members belong to a particular decile or overall).

Overall budget shares on varieties who belong to the exempt categories are not changing as compared to the corresponding budget shares calculated form the data as reported in Tables C.2 and C.3. The differences across deciles for those goods are solely due to the fact that the deciles are differently composed in both cases (individual welfare with 18% tariff for market varieties of taxed commodities in the data case *versus* 25.56% in the baseline simulation). The budget shares of the market variety of the taxed good categories increase, while those of the corresponding auto-consumption varieties decreases, when compared to the original data. The reverse holds for quantities consumed (decreases for the market variety of taxed commodities, and increases for corresponding auto-consumption variety). This corresponds to what is to be expected from the demand equations (see Equation A.3).

Table C.2: Budget share market by decile and total (% of total expenditures: market + auto) – Data

Commodity	**Decile**										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**
Food rich t	3.59	4.01	4.62	5.21	5.81	6.30	6.65	7.45	8.06	10.27	7.80
Food rich e	9.35	10.63	12.95	14.11	16.32	17.38	17.31	17.92	18.04	18.82	17.27
Food poor t	8.84	6.82	6.32	6.18	5.51	5.41	5.00	4.76	4.25	3.32	4.59
Food poor e	10.78	12.57	12.98	13.00	11.59	10.61	9.79	8.72	7.99	7.65	9.24
Non alcoh. bev. t	0.62	0.58	0.61	0.54	0.65	0.48	0.51	0.62	0.53	1.07	0.73
Alcoh. bev. & tob. t	1.37	1.30	1.15	0.74	0.74	0.65	0.56	0.53	0.60	0.92	0.77
Alcoh. bev. & tob. e	0.25	0.19	0.20	0.10	0.15	0.10	0.11	0.13	0.06	0.12	0.12
Clothing t	4.79	4.27	4.07	3.81	3.89	3.85	3.88	3.72	3.60	4.17	3.94
Housing rent e	0.28	0.70	0.69	0.64	0.91	1.02	1.28	1.73	1.60	1.73	1.40
Housing: utilities t	2.28	2.76	3.11	3.30	3.13	3.43	3.15	3.04	2.75	2.25	2.78
Housing utilities e	0.99	1.86	1.58	1.68	1.89	1.52	1.74	1.66	1.77	1.80	1.73
Furnishings & equipm. t	1.58	1.71	1.74	1.56	1.59	1.51	1.30	1.26	1.18	1.32	1.37
Health e	3.16	3.47	3.25	2.84	3.18	2.94	3.19	3.00	2.89	2.70	2.93
Transport t	5.97	5.28	6.15	6.38	6.18	6.37	6.63	6.77	7.27	8.09	7.10
Transport e	0.44	0.61	0.76	0.77	0.76	0.75	0.89	0.88	1.03	0.97	0.89
Communication t	2.63	2.56	2.97	3.28	3.88	4.09	4.16	4.81	4.97	5.15	4.51
Recreation, culture t	0.56	0.38	0.40	0.33	0.34	0.38	0.38	0.37	0.37	0.39	0.38
Recreation, culture e	0.11	0.17	0.21	0.25	0.23	0.28	0.29	0.31	0.31	0.25	0.27
Education e	2.88	2.09	1.87	1.80	2.03	2.28	2.65	2.48	3.01	3.88	2.93
Catering and accomm. t	7.65	8.50	8.63	10.77	11.03	11.41	12.74	13.10	13.70	13.68	12.56
Others non serv. t	1.95	1.69	1.87	1.89	1.88	1.91	1.82	1.82	1.78	1.88	1.85
Other services t	3.29	3.37	3.28	2.65	2.24	1.90	1.60	1.25	1.05	0.84	1.49
Other services e	0.00	0.01	0.01	0.00	0.00	0.02	0.00	0.00	0.02	0.00	0.01
Total market	73.39	75.52	79.40	81.82	83.94	84.58	85.65	86.33	86.84	91.28	86.63

Note: Deciles are constructed on the basis of the individual welfare measure (equivalised money metric utility, Equation 6) evaluated in the observed situation. Each decile contains 10% of the population of individuals (see Section B.3). Averages are calculated as mean household expenditures on a commodity g, s over mean total household expenditures on auto-consumption plus market goods (see Section B.3). Commodities followed by a ‘t’ are currently taxed at 18%. Those followed by an ‘e’ are currently exempt.

Table C.3: Budget share auto-consumption by decile and total (% of total expenditures: market + auto) – Data

Commodity	**Decile**										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**
Food rich t	0.93	0.70	0.53	0.79	0.69	0.81	0.84	0.79	1.05	0.66	0.78
Food rich e	3.12	3.56	3.05	2.98	3.82	4.03	4.08	4.39	4.28	2.69	3.54
Food poor t	0.31	0.39	0.46	0.35	0.39	0.27	0.25	0.14	0.13	0.07	0.19
Food poor e	12.91	12.51	9.83	7.69	5.34	4.71	4.02	3.49	3.06	1.57	3.96
Non alc. bev. t	0.05	0.03	0.03	0.02	0.04	0.04	0.04	0.09	0.07	0.04	0.05
Alcoh. bev. & tob. t	0.12	0.07	0.08	0.06	0.07	0.07	0.09	0.09	0.08	0.08	0.08
Alcoh. bev. & tob. e	0.02	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.01	0.02	0.02
Clothing t	0.64	0.82	0.76	0.71	0.69	0.62	0.54	0.53	0.40	0.29	0.48
Housing rent e	4.20	3.72	3.68	4.16	3.76	3.38	2.89	2.55	2.30	2.21	2.77
Housing utilities t	0.06	0.13	0.11	0.09	0.09	0.08	0.07	0.05	0.04	0.04	0.06
Housing utilities e	0.36	0.81	1.10	0.78	0.64	0.58	0.46	0.22	0.12	0.05	0.31
Furnishings & equipm. t	0.01	0.00	0.02	0.01	0.01	0.01	0.01	0.02	0.01	0.03	0.02
Health e	0.00	0.01	0.01	0.02	0.00	0.00	0.01	0.00	0.01	0.02	0.01
Transport t	0.03	0.01	0.02	0.03	0.00	0.03	0.02	0.08	0.03	0.06	0.04
Transport e	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01
Communication t	0.00	0.08	0.01	0.02	0.01	0.03	0.02	0.03	0.03	0.02	0.02
Recreation, culture t	0.00	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.02
Recreation, culture e	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01
Education e						non existent					
Catering and accomm. t	3.68	1.52	0.80	0.35	0.44	0.62	0.92	1.14	1.44	0.81	0.97
Other non serv. t	0.00	0.00	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.02	0.01
Other services t	0.16	0.08	0.09	0.07	0.03	0.06	0.03	0.01	0.03	0.01	0.03
Other services e						non existent					
Total auto	26.61	24.48	20.60	18.18	16.06	15.42	14.35	13.67	13.16	8.72	13.37

Note: Deciles are constructed on the basis of the individual welfare measure (equivalised money metric utility, Equation 6) evaluated in the observed situation. Each decile contains 10% of the population of individuals (Section B.3). Averages are calculated as mean household expenditures on a commodity g, s over mean total household expenditures on auto-consumption plus market goods (see Section B.3). Commodities followed by a 't' are those for which the corresponding market variety is taxed at 18%. Those followed by an 'e' are those for which the corresponding market variety is exempt.

Table C.4: Budget share market by decile and total (% of total expenditures: market + auto) – Baseline

Commodity	**Decile**										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**
Food rich t	3.63	4.07	4.73	5.24	5.78	6.32	6.66	7.55	8.04	10.25	7.81
Food rich e	9.18	10.63	12.67	14.11	16.37	17.17	17.14	18.02	17.90	18.99	17.27
Food poor t	9.02	6.83	6.72	5.94	5.48	5.49	4.93	4.76	4.23	3.33	4.60
Food poor e	10.80	12.42	12.74	13.06	11.65	10.51	9.85	8.68	8.03	7.67	9.24
Non alcoh. bev. t	0.60	0.62	0.60	0.55	0.64	0.49	0.52	0.61	0.54	1.06	0.73
Alcoh. bev. & tob. t	1.43	1.31	1.15	0.73	0.75	0.63	0.59	0.53	0.60	0.92	0.77
Alcoh. bev. & tob. e	0.25	0.19	0.19	0.09	0.16	0.09	0.12	0.13	0.07	0.12	0.12
Clothing t	4.80	4.31	4.12	3.84	3.88	3.84	3.93	3.78	3.61	4.16	3.95
Housing rent e	0.28	0.63	0.72	0.64	0.93	1.01	1.27	1.76	1.60	1.72	1.40
Housing: utilities t	2.32	2.74	3.14	3.25	3.19	3.41	3.14	3.05	2.77	2.24	2.78
Housing utilities e	0.98	1.80	1.58	1.71	1.88	1.59	1.69	1.66	1.77	1.80	1.73
Furnishings & equipm. t	1.58	1.73	1.75	1.54	1.60	1.50	1.34	1.25	1.17	1.32	1.37
Health e	3.17	3.37	3.32	2.83	3.20	2.89	3.16	3.02	2.89	2.71	2.93
Transport t	6.02	5.64	6.15	6.45	6.24	6.32	6.71	6.79	7.29	8.01	7.10
Transport e	0.45	0.60	0.77	0.75	0.72	0.75	0.95	0.89	0.98	0.98	0.89
Communication t	2.70	2.54	2.98	3.39	3.95	4.09	4.37	4.64	5.01	5.10	4.51
Recreation, culture t	0.56	0.38	0.39	0.33	0.33	0.39	0.39	0.38	0.37	0.39	0.38
Recreation, culture e	0.11	0.16	0.20	0.24	0.24	0.27	0.30	0.31	0.31	0.25	0.27
Education e	2.88	2.11	1.82	1.83	2.01	2.26	2.63	2.49	3.01	3.89	2.93
Catering and accomm. t	7.99	8.73	8.66	11.17	10.75	11.74	12.84	12.96	13.79	13.55	12.57
Others non serv. t	1.93	1.73	1.85	1.89	1.93	1.90	1.79	1.85	1.80	1.86	1.85
Other services t	3.36	3.34	3.26	2.64	2.25	1.89	1.60	1.26	1.05	0.84	1.49
Other services e	0.00	0.01	0.01	0.00	0.00	0.02	0.01	0.00	0.02	0.00	0.01
Total market	74.04	75.90	79.50	82.21	83.94	84.57	85.92	86.39	86.85	91.16	86.67

Note: Deciles are constructed on the basis of the individual welfare measure (equivalised money metric utility, Equation 6) evaluated in the simulated baseline (basic tariff 25.56%, exempt goods as in legacy of 2015). Each decile contains 10% of the population of individuals (Section B.3). Averages are calculated as mean household expenditures on a commodity g, s over mean total household expenditures on auto-consumption plus market goods (see Section B.3). Commodities followed by a 't' are taxed at 25.56%. Those followed by an 'e' are exempt.

Table C.5: Budget share auto-consumption by decile and total (% of total expenditures: market + auto) – Baseline

Commodity	**Decile**										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**
Food rich t	0.94	0.69	0.52	0.77	0.63	0.82	0.81	0.79	1.03	0.66	0.77
Food rich e	2.92	3.48	3.14	2.89	3.66	4.13	3.94	4.37	4.24	2.77	3.54
Food poor t	0.27	0.40	0.46	0.33	0.38	0.27	0.25	0.14	0.13	0.07	0.19
Food poor e	12.89	12.16	9.70	7.49	5.64	4.55	4.03	3.48	3.13	1.59	3.96
Non alc. bev. t	0.04	0.03	0.02	0.02	0.04	0.04	0.04	0.09	0.06	0.05	0.05
Alcoh. bev. & tob. t	0.12	0.07	0.08	0.06	0.07	0.07	0.09	0.08	0.08	0.08	0.08
Alcoh. bev. & tob. e	0.02	0.02	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.02	0.02
Clothing t	0.64	0.79	0.75	0.68	0.68	0.61	0.53	0.52	0.39	0.28	0.47
Housing rent e	4.14	3.75	3.60	4.11	3.76	3.46	2.81	2.60	2.28	2.22	2.77
Housing utilities t	0.06	0.12	0.12	0.09	0.08	0.08	0.06	0.05	0.04	0.04	0.06
Housing utilities e	0.38	0.78	1.11	0.76	0.65	0.58	0.45	0.23	0.10	0.06	0.31
Furnishings & equipm. t	0.01	0.00	0.02	0.01	0.01	0.01	0.01	0.02	0.01	0.03	0.02
Health e	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.01	0.00	0.02	0.01
Transport t	0.03	0.01	0.02	0.03	0.00	0.03	0.03	0.08	0.03	0.06	0.04
Transport e	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01
Communication t	0.00	0.08	0.01	0.02	0.01	0.03	0.02	0.03	0.03	0.02	0.02
Recreation, culture t	0.00	0.01	0.01	0.00	0.01	0.02	0.02	0.02	0.02	0.01	0.02
Recreation, culture e	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01
Education e						non existent					
Catering and accomm. t	3.34	1.62	0.81	0.38	0.39	0.62	0.93	1.05	1.49	0.80	0.96
Other non serv. t	0.00	0.00	0.01	0.02	0.01	0.02	0.01	0.01	0.00	0.02	0.01
Other services t	0.16	0.09	0.08	0.07	0.03	0.06	0.03	0.01	0.03	0.01	0.03
Other services e						non existent					
Total auto	25.96	24.10	20.50	17.79	16.06	15.43	14.08	13.61	13.15	8.84	13.33

Note: Deciles are constructed on the basis of the individual welfare measure (equivalised money metric utility, Equation 6) evaluated in the simulated baseline (basic tariff 25.56%, exempt goods as in legacy of 2015). Each decile contains 10% of the population of individuals (Section B.3). Averages are calculated as mean household expenditures on a commodity g, s over mean total household expenditures on auto-consumption plus market goods (see Section B.3). Commodities followed by a 't' are those for which the corresponding market variety is taxed at 25.56%. Those followed by an 'e' are those for which the corresponding market variety is exempt.

D Additional results

D.1 Optimal tax structure

Table D.1 contains for each inequality inequality level the rank of the commodities' tax rates. 'Other services e', for example, is the commodity bearing the lowest tax rate in absence of any inequality aversion (4.2%), while it is taxed at the third highest rate (55.3%) when when inequality aversion is high ($e = 2$). The table contains the values used to construct Figure 4 of the main text. The values of the optimal tax rates are reported in Table 5. Notice that an increase or decrease in the tax rank of a commodity, when inequality rises, does not necessary imply that the corresponding tax rate increases. The tax rate on 'Other services e' decreases from 4.2% when $e = 0$ to 0.2% when $e = 0.5$, while the former is the lowest tax rate when $e = 0$, while the later is only the third lowest when $e = 0.5$.

Table D.1: Optimal indirect tax structure: ranks of taxes and inequality aversion

	Inequality aversion					
Commodity	$e = 0$	$e = 0.50$	$e = 0.75$	$e = 1.25$	$e = 1.50$	$e = 2.0$
Housing rent e	23	23	23	23	23	23
Non alcoh. bev. t	22	22	22	21	21	18
Transport e	21	20	19	17	15	8
Catering and accomm. t	20	18	18	20	20	19
Alcoh. bev. & tob. t	19	10	8	5	5	6
Communication t	18	19	20	19	17	13
Food rich t	17	21	21	22	22	17
Housing utilities t	16	9	10	11	11	14
Housing utilities e	15	14	13	13	12	15
Alcoh. bev. & tob. e	14	4	3	3	3	4
Other non serv. t	13	13	12	10	9	7
Clothing t	12	12	11	9	8	9
Food rich e	11	16	16	18	19	20
Health e	10	7	7	6	6	2
Transport t	9	15	15	14	16	16
Furnishings & equipm. t	8	6	6	7	7	12
Food poor e	7	5	4	4	4	5
Education e	6	17	17	15	14	10
Recreation, culture t	5	8	9	8	10	11
Recreation, culture e	4	11	14	16	18	22
Food poor t	3	2	2	2	2	1
Other services t	2	1	1	1	1	3
Other services e	1	3	5	12	13	21

Note: The numbers in the table reflect the rank (one is the lowest tax rate, and 23 the highest) of the optimal tax rate of that commodity according to each of the simulations, which differ only in the degree of inequality aversion.

D.2 Average welfare gains

Tables D.2 and D.3 contain the values underlying the blue lines of Figures 5 and 6 of the main text.

Table D.2: Inequality aversion and average welfare gain: overall and by decile (CFA)

	Average change in welfare: CFA					
	Inequality aversion					
Decile	**e=0**	**e=0.5**	**e=0.75**	**e=1.25**	**e=1.5**	**e=2**
1	**1297**	**2740**	**3410**	**4684**	**5313**	**6144**
2	**1369**	**3919**	**5019**	**6841**	**7524**	**7468**
3	**1648**	**4740**	**5997**	**7920**	**8535**	**7787**
4	**1799**	**4563**	**5541**	**6695**	**6769**	**4123**
5	**1132**	**3320**	**3946**	**4288**	**3884**	-159
6	**1790**	**3193**	**3342**	**2636**	1627	-4464
7	**1878**	**2134**	**1670**	-256	*-1882*	*-9780*
8	**2083**	518	-959	*-5023*	*-7812*	*-19058*
9	**3316**	-1017	*-3969*	*-10969*	*-15283*	*-31471*
10	**5289**	*-9838*	*-18086*	*-35408*	*-45352*	*-80617*
All	**2160**	**1426**	**590**	*-1862*	*-3671*	*-12008*

Note: Deciles are constructed on the basis of the individual welfare measure (equivalised money metric utility, Equation 6) evaluated in the baseline (two tariffs: exempt and 25.56%, thus reaching the UN tax revenue objective of 20% of GDP). Each decile contains 10% of the population of individuals (Section B.3). Averages are calculated at the individual level. Boldface figures are significantly positive at the 5% level; italics are significantly negative. Significance levels are calculated by means of a 500 replications bootstrap.

Table D.3: Inequality aversion and average welfare gain (%): overall and by decile

	Average change in welfare: %					
	Inequality aversion					
Decile	**e=0**	**e=0.5**	**e=0.75**	**e=1.25**	**e=1.5**	**e=2**
1	**1.8**	**3.9**	**4.9**	**6.7**	**7.6**	**8.8**
2	**1.0**	**2.9**	**3.7**	**5.0**	**5.5**	**5.5**
3	**0.9**	**2.6**	**3.3**	**4.4**	**4.7**	**4.3**
4	**0.8**	**2.0**	**2.4**	**2.9**	**3.0**	**1.8**
5	**0.4**	**1.2**	**1.4**	**1.5**	**1.4**	-0.1
6	**0.5**	**1.0**	**1.0**	**0.8**	0.5	-1.3
7	**0.5**	**0.5**	**0.4**	-0.1	*-0.5*	*-2.4*
8	**0.4**	0.1	-0.2	*-1.0*	*-1.5*	*-3.7*
9	**0.5**	-0.1	*-0.6*	*-1.6*	*-2.2*	*-4.6*
10	**0.4**	*-0.8*	*-1.4*	*-2.8*	*-3.6*	*-6.4*
All	**0.5**	**0.3**	**0.1**	*-0.5*	*-0.9*	*-2.9*

Note: Deciles are constructed on the basis of the individual welfare measure (equivalised money metric utility, Equation 6) evaluated in the baseline (two tariffs: exempt and 25.56%, thus reaching the UN tax revenue objective of 20% of GDP). Each decile contains 10% of the population of individuals (Section B.3). Averages are calculated as average gain over average baseline welfare (see Section B.3) and these averages are calculated at the individual level.
Boldface figures are significantly positive at the 5% level; italics are significantly negative. Significance levels are calculated by means of a 500 replications bootstrap.

D.3 Winners and losers

Table D.4 contains the percentage of losers with respect to the baseline (two tariffs: exempt and 25.56%, guaranteeing to reach the UN tax revenue objective of 20% of GDP) per decile of baseline welfare, for different values of inequality aversion. The blue lines of Figure 8 report the corresponding percentages of winners (that is 100 *minus* the values reported in the table).

Table D.4: Inequality aversion and percentage of losers: overall and by decile

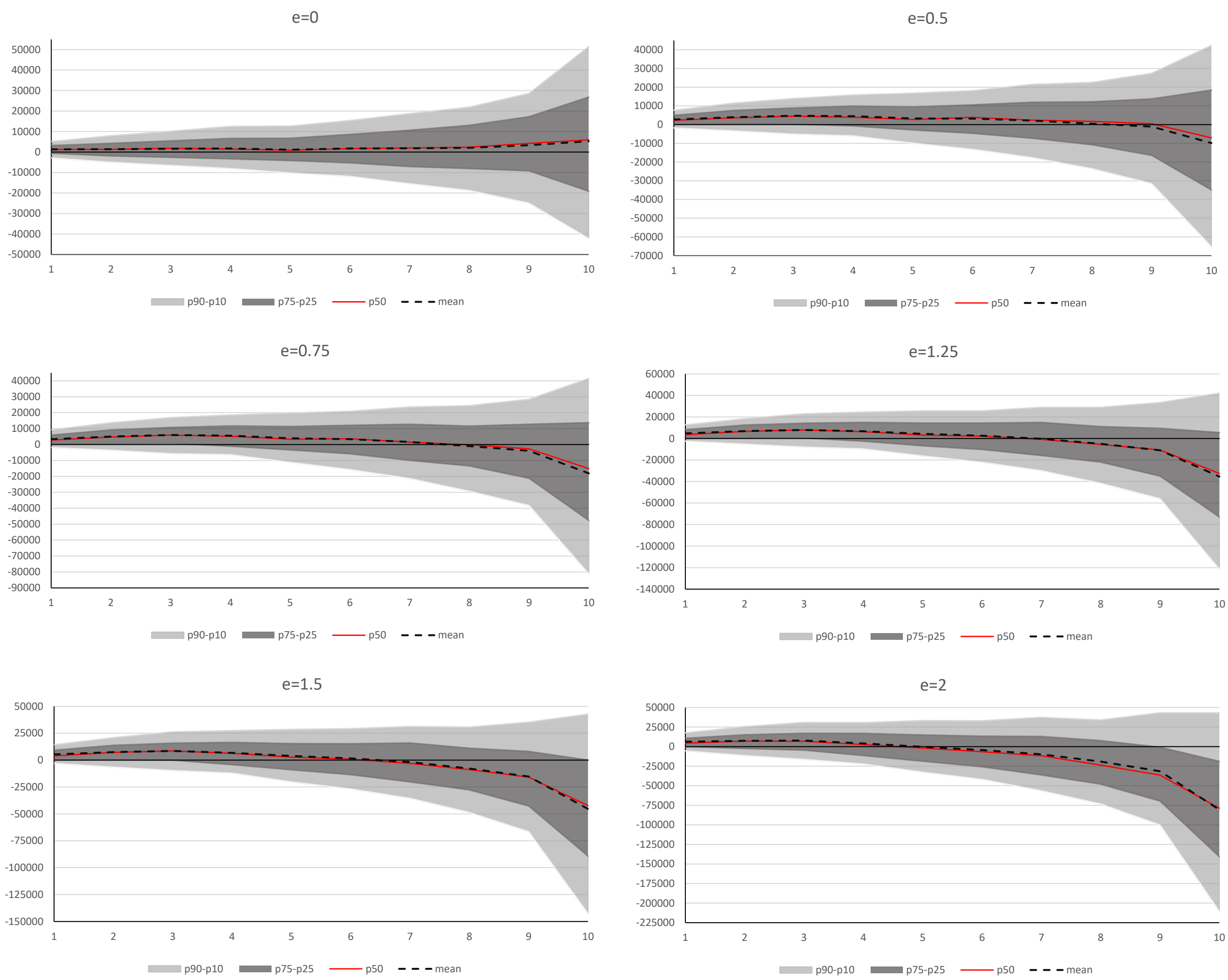
	Percentage of losers					
	Inequality aversion					
Decile	**e=0**	**e=0.5**	**e=0.75**	**e=1.25**	**e=1.5**	**e=2**
1	*32.2*	*22.6*	*21.3*	*23.5*	*23.2*	*25.7*
2	*38.6*	*22.6*	*21.8*	*23.1*	*24.5*	*31.1*
3	*38.4*	*23.5*	*22.4*	*23.6*	*25.3*	34.2
4	*42.1*	*29.5*	*29.1*	*32.9*	*34.6*	44.0
5	*44.9*	*35.9*	*37.1*	*39.9*	*44.1*	53.2
6	*42.8*	*37.4*	*39.1*	*46.1*	48.4	59.1
7	*43.7*	*43.6*	*46.1*	52.0	**54.9**	**63.1**
8	*44.0*	*46.2*	50.2	**58.1**	**62.4**	**69.5**
9	*41.5*	49.6	**54.9**	**65.0**	**67.9**	**75.3**
10	*43.1*	**58.3**	**64.2**	**71.1**	**75.0**	**80.6**
All	*41.1*	*36.9*	*38.6*	*43.5*	*46.0*	53.6

Note: Deciles are constructed on the basis of the individual welfare measure (equivalised money metric utility, Equation 6) evaluated in the baseline (two tariffs: exempt and 25.56%, guaranteeing to reach the UN tax revenue objective of 20% of GDP). Each decile contains 10% of the population of individuals (Section B.3). A cell shows the percentage of the population belonging to that decile (or overall) which loses from applying the optimal indirect tax tariff for a given degree of inequality aversion (columns) when compared to their baseline individual welfare level. Boldface figures are significantly higher than 50% at the 5% significance level; italics are significantly lower than 50%. Significance levels are calculated by means of a 500 replications bootstrap.

D.4 Heterogeneity of welfare gains within deciles

Figure D.1 is the counterpart for welfare changes in levels of Figure 7 in the main text (see Section 5.2). These figures illustrate the within decile distribution of welfare gains and losses from a switch of the baseline (two tariffs: exempt and 25.56%, guaranteeing to reach the UN tax revenue objective of 20% of GDP) to the optimal tax structure. Generally, the medians follow a similar course as the means, and we refer to the discussion of Figure 5 in the main text. For lower values of inequality aversion the within decile distribution is skewed toward higher values than the median (the mean tends to be somewhat higher than the median), and reversely for higher deciles (mean lower than median). Contrary to the corresponding figure for the relative changes (Figure 7), within decile diversity is increasing in baseline decile ranks: the gap between the hardest losers and the best winners is widening across deciles for all values of inequality aversion.

Figure D.1: Within decile quantile values of welfare changes



Note: The vertical axis reports the, within each baseline welfare decile, quantile values and means of welfare changes (CFA) from a switch of the baseline (two tariffs: exempt and 25.56%, guaranteeing to reach the UN tax revenue objective of 20% of GDP) to the optimal tax structure. Each panel is for a different value of inequality aversion. The dashed lines connect the mean welfare change within each decile and correspond to the blue lines of Figure 5 of the main text. The red lines connect the median value of the welfare change within each baseline decile. The dark grey areas are bounded by the first and third quartile value within each baseline decile. The light grey areas are bound by the first and ninth decile of the welfare differences within each baseline.

D.5 Transition matrices

Tables D.5- D.6 show for each decile in the baseline, the percentage of persons in deciles 1 to 10 for each of the 6 optimal indirect tax simulation (each corresponding to a different value of inequality aversion). We see more people tend to jump from one decile to another when inequality aversion increases. People are predominantly jumping to neighbouring deciles, and decile movements occur more in the middle of the distribution than at the outer deciles.

Table D.5: Transition matrices

Welfare decile baseline	**Optimal indirect tax simulation**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
					$e = 0$					
1	9.70	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.29	9.14	0.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.58	8.76	0.65	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.65	8.66	0.69	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.70	8.70	0.61	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.61	8.67	0.73	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.72	8.70	0.58	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.58	9.02	0.40	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	9.25	0.35
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.35	9.65
					$e = 0.5$					
1	9.59	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.41	8.96	0.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.63	8.50	0.85	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.87	8.32	0.82	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.82	8.44	0.75	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.75	8.45	0.80	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.80	8.54	0.66	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.66	8.88	0.46	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.46	9.16	0.37
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.37	9.63
					$e = 0.75$					
1	9.52	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.48	8.81	0.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.71	8.31	0.97	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.98	8.06	0.98	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.98	8.18	0.85	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.84	8.22	0.93	0.01	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.93	8.33	0.75	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.76	8.72	0.52	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.51	9.09	0.39
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	9.61

Note: Deciles are constructed on the basis of the individual welfare measure (equivalised money metric utility, Equation 6). Rows are deciles in the baseline (two tariffs: exempt and 25.56%, guaranteeing the UN tax revenue objective of 20% of GDP); columns are deciles when applying the optimal indirect taxes. Each panel refers to a different degree of inequality aversion. Cells show the percentage of people belonging to decile k (row) in the baseline and to decile l in the indirect tax simulation.

Table D.6: Transition matrices

Welfare decile baseline	**Optimal indirect tax simulation**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
					$e = 1.25$					
1	9.40	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.60	8.46	0.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.94	7.82	1.19	0.04	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	1.23	7.52	1.25	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	1.28	7.47	1.24	0.01	0.00	0.00	0.00
6	0.00	0.00	0.00	0.01	1.24	7.49	1.25	0.01	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	1.27	7.68	1.05	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	1.06	8.24	0.69	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.70	8.79	0.51
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.51	9.49
					$e = 1.5$					
1	9.35	0.63	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.65	8.29	1.03	0.02	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	1.07	7.53	1.32	0.07	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	1.40	7.17	1.43	0.01	0.00	0.00	0.00	0.00
5	0.00	0.00	0.01	1.48	7.06	1.42	0.03	0.00	0.00	0.00
6	0.00	0.00	0.00	0.01	1.44	7.09	1.42	0.03	0.01	0.00
7	0.00	0.00	0.00	0.00	0.01	1.47	7.33	1.19	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.01	1.22	7.98	0.79	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.81	8.59	0.60
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60	9.41
					$e = 2$					
1	9.15	0.80	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00
2	0.82	7.77	1.35	0.06	0.01	0.00	0.00	0.00	0.00	0.00
3	0.03	1.40	6.72	1.65	0.14	0.06	0.00	0.00	0.00	0.00
4	0.00	0.02	1.83	6.23	1.76	0.16	0.01	0.00	0.00	0.00
5	0.00	0.00	0.08	1.92	6.07	1.81	0.12	0.00	0.01	0.00
6	0.00	0.00	0.00	0.13	1.95	6.04	1.81	0.06	0.01	0.00
7	0.00	0.00	0.00	0.00	0.07	1.90	6.45	1.52	0.06	0.00
8	0.00	0.00	0.00	0.00	0.00	0.03	1.62	7.20	1.14	0.01
9	0.00	0.00	0.00	0.00	0.00	0.00	0.01	1.22	7.91	0.85
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.87	9.14

Note: Deciles are constructed on the basis of the individual welfare measure (equivalised money metric utility, Equation 6). Rows are deciles in the baseline (two tariffs: exempt and 25.56%, guaranteeing the UN tax revenue objective of 20% of GDP); columns are deciles when applying the optimal indirect taxes. Each panel refers to a different degree of inequality aversion. Cells show the percentage of people belonging to decile k (row) in the baseline and to decile l in the indirect tax simulation.

D.6 Restricted optimal tax rates

We ran simulations for restricted optimal taxation (see the last paragraph of Section 3.3) for inequality aversion $e = 0$ and $e = 2$. After running the unrestricted optimal tax program, we ranked goods from high to low optimal tariffs, and subdivided them into four categories: those with high, middle high, middle low, and low tariffs. The groups are separated by a horizontal bar in Table D.7. This grouping is different for the case $e = 0$ and $e = 2$. Next, we re-ran the optimal tax program under the additional constraint that the tax rates for commodities belonging to the same group should be identical. We did not impose however any order on these tax rates. That is, we allowed that goods belonging to the group with highest tax rates in the unrestricted program, should bear the highest tax rate in the unrestricted one also. But it turns out that this hierarchy is respected in the optimum, as one could expect.

Table D.7: Restricted *versus* unrestricted optimal tax rates (%)

e=0			e=2		
Commodity	23 rates	4 rates	Commodity	23 rates	4 rates
Housing rent e	26.2	22.9	Housing rent e	111.4	55.2
Non alcoh. bev. t	20.6	22.9	Recreation, culture e	71.2	55.2
Transport e	20.1	22.9	Other services e	55.3	55.2
Catering and accomm. t	16.0	15.4	Food rich e	51.2	55.2
Alcoh. bev. & tob. t	15.9	15.4	Catering and accomm. t	50.3	55.2
Communication t	15.4	15.4	Non alcoh. bev. t	47.9	35.4
Food rich t	14.9	15.4	Food rich t	46.9	35.4
Housing utilities t	14.8	15.4	Transport t	31.4	35.4
Housing utilities e	14.4	15.4	Housing utilities e	30.0	35.4
Alcoh. bev. & tob. e	14.0	15.4	Housing utilities t	27.7	35.4
Others non serv. t	13.9	12.9	Communication t	21.0	35.4
Clothing t	13.8	12.9	Furnishings & equipm. t	17.2	15.3
Food rich e	13.6	12.9	Recreation, culture t	16.4	15.3
Health e	13.1	12.9	Education e	11.9	15.3
Transport t	12.5	12.9	Clothing t	3.5	-23.7
Furnishings & equipm. t	12.5	12.9	Transport e	-1.9	-23.7
Food poor e	11.8	12.9	Others non serv. t	-4.7	-23.7
Education e	11.5	12.9	Alcoh. bev. & tob. t	-4.7	-23.7
Recreation, culture t	10.6	8.5	Food poor e	-14.8	-23.7
Recreation, culture e	10.0	8.5	Alcoh. bev. & tob.e	-15.4	-23.7
Food poor t	9.0	8.5	Other services t	-23.1	-23.7
Other services t	6.0	8.5	Health e	-34.4	-23.7
Other services e	4.2	8.5	Food poor t	-45.0	-23.7

Note: The 23 rates cases are the optimal tax rates for inequality aversion $e = 0$ and $e = 2$, and correspond to the first and last column of Table 5. Commodities are ordered such that they are ranked from high to low optimal tax rates for the cases with 23 rates. The columns for the cases of 4 rates contain the optimal taxes obtained by regrouping commodities into 4 classes on the basis of the corresponding results for the 23 rates cases.

Table D.8: Welfare gains and winners: restricted versus unrestricted

Baseline decile	Welfare change (CFA)		Relative welfare change (%)		Winners (%)	
	e=0	**e=2**	**e=0**	**e=2**	**e=0**	**e=2**
1	-63	-690	-0.09	-0.90	40.7	46.9
2	-148	66	-0.11	0.05	29.8	54.8
3	-174	-56	-0.09	-0.03	30.4	56.8
4	-180	136	-0.08	0.06	32.4	53.9
5	-114	218	-0.04	0.08	40.7	53.6
6	-38	-318	-0.01	-0.10	46.0	51.6
7	11	105	0.00	0.03	49.7	53.6
8	168	80	0.03	0.02	57.7	52.7
9	192	-35	0.03	-0.01	56.7	48.0
10	237	9706	0.02	0.82	53.9	55.5
All	-11	922	0.00	0.23	43.8	52.8

Note: The first two columns denote the difference in average welfare gain between the restricted optimal taxation (4 tariffs) and the unrestricted optimal taxation (23 tariffs), per *baseline* welfare decile (standard rate of 25.56%, thus guaranteeing to reach the UN tax revenue objective of 20% of GDP, with the list of exempted goods as in 2015) and overall. The next two columns contain the corresponding average relative relative gains or losses from a switch from the unrestricted to the restricted optimum, calculated as the average gain over the mean welfare levels in the unrestricted optimum (see Appendix B.3). The last two columns contain the percentage of winners in each decile and overall, for the same switch from unrestricted to restricted taxation.

Whereas we concentrated in the main text on differences with the baseline policy for both the restricted and unrestricted optima, Table D.8 compares the restricted (maximum 4 rates) optimum with the corresponding unrestricted cases directly. Deciles remain, however, constructed on the basis of the baseline policy simulation. The first two columns of the table represent the change in average welfare level for each baseline decile, when switching from the unrestricted (maximum 23 tariffs) to the restricted case (maximum 4 rates) for $e = 0$ (first column) and $e = 2$ (second column). These columns correspond to the differences between the first two columns of Table 9. The next two columns contain the relative gains or losses from a switch from the unrestricted to the restricted optimum, expressed as the average gain or loss divided by average welfare in the unrestricted optimum. These figures numerically slightly deviate from the differences between the third and fourth columns of Table 9), because the denominator there is the baseline policy average welfare. Qualitatively both give the same information though. The last two columns represent the percentage of winners when switching from the unrestricted to the restricted optimum. Notice that is not equal to the difference between the last two columns of Table 9, which contains the percentage of winners of the unrestricted and restricted case with respect to the baseline policy. One can, for example, win with respect to baseline in both, the restricted and unrestricted case, but one is either a winner or a loser when comparing the unrestricted with the restricted optimum.

In absence of inequality aversion there is an average loss of welfare of only 11 CFA. Limiting the diversification of the tax rates to a tractable number of at most four rates, allows to come reasonably close to the welfare optimum without restrictions. A closer look at the distribution of this small loss across deciles learns that the losses are primarily born by people belonging to the lower deciles. There are both, more people loosing in the lower six deciles than in the highest three deciles (see column 5 of the table), and welfare changes with respect to unrestricted optimal taxation are on average negative within those deciles. But not everybody loses from such a restriction. On the contrary, a considerable majority in the highest three deciles is even gaining under the restricted policy, as compared to the unrestricted one. This might be explained by the fact that smaller losses are caused when designing the tax such that goods on average more intensely preferred by the people with initially lower levels of welfare become more expensive, than when one makes goods on average more intensely preferred by the originally better off more expensive. Given that correlation between welfare and preferences is not perfect, there will be losers and winners everywhere in the welfare distribution. But as losses and gains in levels are usually bigger among the better off, it is more efficient to put the burden of the overall loss on the persons with preferences shared more commonly among the poorer persons. However, given that the differences in welfare between restricted and unrestricted optima are small, it is not clear whether the percentages of winners and losers from switching from the restricted to the unrestricted optimum are very stable.

Potentially even more surprisingly, the switch to a more restricted tax structure in presence of high inequality aversion ($e = 2$) causes an average *gain* in welfare of more than 900 CFA. Even more so, a majority of persons is gaining from the switch from unrestricted to restricted taxation in this case. If we look at the impact across the initial welfare distribution, we see that losses are on average largest for the persons belonging to the lowest decile in the baseline, and average gains for those in the baseline top decile are no less than 9706 CFA. When inequality aversion is high, one wants to give up average welfare in exchange for a transfer of welfare from those with high welfare to poorer persons in terms of welfare. When one restricts the number of tax rates such an objective becomes more difficult to obtain. But then this loss in redistributive power can only be minimised by overcompensating the richer ones as they have a lower weight in the welfare function. Given the small differences in welfare gains and losses between the restricted and unrestricted case, we should again warn that, also in the case of high inequality aversion, these results might not be statically relevant.

D.7 Departments

Tables D.9–D.11 report the values underlying Figure 9–11 of the main text.

Table D.9: Average welfare gain by department (CFA)

	Inequality aversion					
Departement	**e=0**	**e=0.5**	**e=0.75**	**e=1.25**	**e=1.5**	**e=2**
Mono	-1508	242	600	214	-685	-5195
Atacora	3219	6911	8556	11332	12284	10837
Alibori	6522	9477	10717	13002	14226	15418
Couffo	1676	6327	8231	11087	11869	9903
Borgou	4665	6162	6624	7268	7504	5530
Donga	1179	1625	1319	-100	-1169	-5443
Zou	-754	1542	1881	1005	-370	-7445
Atlantique	1958	-3583	-6770	-13680	-17755	-32324
Plateau	899	2663	2578	480	-1807	-11778
Collines	4377	4781	4258	1969	39	-9164
Oueme	1677	-4276	-7875	-16155	-21356	-40403
Littoral	-2324	-18486	-26738	-43152	-52077	-81496

Note: The figures represent the average welfare differences in levels (CFA) between the application of the optimal tax and the baseline simulation (two tariffs: exempt and 25.56%, guaranteeing to reach the UN tax revenue objective of 20% of GDP). Rows represent average gains of a given department for different levels of inequality aversion (columns).

Table D.10: Relative average welfare gain by department (%)

	Inequality aversion					
Departement	**e=0**	**e=0.5**	**e=0.75**	**e=1.25**	**e=1.5**	**e=2**
Mono	-0.6	0.1	0.2	0.1	-0.3	-2.0
Atacora	1.2	2.6	3.3	4.3	4.7	4.1
Alibori	2.3	3.4	3.8	4.7	5.1	5.5
Couffo	0.6	2.2	2.8	3.8	4.0	3.4
Borgou	1.4	1.8	2.0	2.2	2.2	1.6
Donga	0.3	0.5	0.4	0.0	-0.3	-1.6
Zou	-0.2	0.4	0.4	0.2	-0.1	-1.8
Atlantique	0.4	-0.8	-1.5	-3.1	-4.0	-7.3
Plateau	0.2	0.6	0.6	0.1	-0.4	-2.6
Collines	0.9	1.0	0.9	0.4	0.0	-1.8
Oueme	0.3	-0.7	-1.4	-2.8	-3.7	-7.0
Littoral	-0.3	-2.3	-3.3	-5.4	-6.5	-10.2

Note: The figures represent the relative average welfare differences in levels (CFA) between the application of the optimal tax and the baseline simulation (two tariffs: exempt and 25.56%, guaranteeing to reach the UN tax revenue objective of 20% of GDP). Relative average welfare differences are calculated as average welfare differences over baseline average welfare differences. Rows represent relative average gains of a given department for different levels of inequality aversion (columns).

Table D.11: Percentage of winners by department

	Inequality aversion					
Departement	**e=0**	**e=0.5**	**e=0.75**	**e=1.25**	**e=1.5**	**e=2**
Mono	41.2	67.1	68.6	65.1	62.6	52.8
Atacora	71.2	84.5	85.9	84.4	83.6	78.3
Alibori	76.9	82.5	80.8	80.1	78.2	74.3
Couffo	58.4	76.4	79.3	81.0	79.8	70.7
Borgou	72.2	73.0	71.2	66.9	66.5	61.0
Donga	64.0	67.1	66.6	62.2	60.7	56.9
Zou	44.6	64.4	66.1	62.6	58.9	47.2
Atlantique	52.6	45.9	39.9	30.9	26.5	18.0
Plateau	53.9	58.0	57.1	51.9	48.5	38.4
Collines	64.7	66.8	64.0	57.1	53.4	42.8
Oueme	51.0	44.2	40.2	28.5	24.1	15.5
Littoral	43.8	26.1	19.0	11.5	9.7	6.4

Note: The figures represent the percentage of winners from a switch of the baseline simulation (two tariffs: exempt and 25.56%, guaranteeing to reach the UN tax revenue objective of 20% of GDP) to the optimal taxes. Rows represent percentage of winners in a given department for different levels of inequality aversion (columns).

D.8 Current government revenue versus tax augmentation

In the present section, we compare the optimal taxes of low (tax revenues to GDP ratio equal to 14.5%) versus high government budget (20% of GDP) for the cases $e = 0$ and $e = 2$. All optimal tax rates increase when the government budget constraint tightens. The ranks of the tax rates are however unaffected when $e = 2$, and the taxes of only three pairs of goods switch rank in the case where $e = 0$ ('furnishings and equipment t' and 'transport t'; 'Food rich t' and 'housing utilities t'; and 'alcoholic beverages and tobacco t' and 'catering and accommodation t'). Rank switches only occur between originally adherent pairs of goods. The optimal tax structure turns out to be fairly robust with respect to the required government budget level.

Table D.12: Optimal taxes rates and global government budget

Inequality aversion	$e = 0$			$e = 2$	
	Government budget			Government budget	
Commodity	20.0% of GDP	14.5% of GDP	Commodity	20.0% of GDP	14.5% of GDP
Other services e	4.2	0.3	Food poor t	-45.0	-46.9
Other services t	6.0	2.6	Health e	-34.4	-36.7
Food poor t	9.0	5.3	Other services t	-23.1	-26.2
Recreation, culture e	10.0	6.1	Alcoh. bev. & tob. e	-15.4	-18.6
Recreation, culture t	10.6	6.7	Food poor e	-14.8	-17.9
Education e	11.5	7.5	Alcoh. bev. & tob. t	-4.7	-8.4
Food poor e	11.8	7.7	Others non serv. t	-4.7	-8.1
Furnishings & equipm. t	12.5	8.6	Transport e	-1.9	-5.2
Transport t	12.5	8.5	Clothing t	3.5	-0.4
Health e	13.1	9.2	Education e	11.9	8.0
Food rich e	13.6	9.4	Recreation, culture t	16.4	12.1
Clothing t	13.8	9.7	Furnishings & equipm. t	17.2	12.8
Others non serv. t	13.9	9.9	Communication t	21.0	16.8
Alcoh. bev. & tob. e	14.0	10.2	Housing utilities t	27.7	23.2
Housing utilities e	14.4	10.3	Housing utilities e	30.0	25.2
Housing utilities t	14.8	10.7	Transport t	31.4	26.7
Food rich t	14.9	10.7	Food rich t	46.9	41.8
Communication t	15.4	11.3	Non alcoh. bev. & tob. t	47.9	42.6
Alcoh. bev. & tob. t	15.9	11.9	Catering and accomm. t	50.3	44.9
Catering and accomm. t	16.0	11.8	Food rich e	51.2	45.6
Transport e	20.1	15.8	Other services e	55.3	49.8
Non alcoh. bev. & tob.t	20.6	16.2	Recreation, culture e	71.2	64.8
Housing rent e	26.2	21.3	Housing rent e	111.4	104.4

Note: Optimal tax rates [%] for $e = 0$ under high and low government budget (column 2 and 3)), and, similarly, for inequality aversion $e = 2$ (columns 5 and 6). Goods are ranked from low to high taxes under the higher budget, for each level of inequality aversion separately. Grey background coloured rates are those that cause a rank reversal in the optimal tax structure between low and high government budget. The optimal tax rates in columns 2 and 5 are the same as those in columns 2 and 7 of Table 5.

D.9 Regression analysis

In the main text we described the welfare effects of optimal indirect taxation along different dimensions. We illustrated the distribution of absolute and relative welfare gains, and the percentage of winners and losers – all compared with respect to the baseline – across baseline welfare deciles and departments. In the present section we report how these dimensions can contribute to explain the obtained results.

Thereto, we regress the absolute and relative welfare gain, and the probability to become a winner on these variables, controlling for preference heterogeneity. In this way we want to isolate the effect of initial inequality in the welfare distribution and differences in consumption patterns and/or availability of commodities across departments and/or residential environment (urban *versus* rural), from the effect of preferences on welfare gains and the probability to gain or lose from a an optimal tax design.

More specifically we regress welfare gains in levels and relative to baseline welfare, and we estimate a discrete choice model for the probability to gain on the following set of common explanatory variables:

- a set of dummies for the baseline welfare deciles (the first decile is the reference category);
- a set of preference parameters. More specifically, the budget shares α_g, except for 'education e' and 'other services e', were included;
- the ratio of household size over household equivalence scale, n_h/θ_h;
- department dummies (Alibori being the reference category); and
- a residential environment dummy (rural being the reference category).

Not all α_g parameters can be included because they are perfectly collinear, as they sum to one. As a consequence, the estimated coefficients of the α_g variables have no meaning *per se*. They serve solely as a control such that the decile dummies take up mainly the effect of the initial welfare distribution, not being confounded by other factors differing across deciles. That is also the reason for the inclusion of the other explanatory variables, which all in one way or another play a role in the welfare model. We present and discuss only the coefficients of the baseline welfare decile dummies in the sequel. These are interpreted as the effect of the baseline welfare distribution *per se*, after netting out the effect of preference heterogeneity that is correlated with preference heterogeneity, and other confounding factors.

Table D.13 contains the results for the OLS regression with the welfare gain in levels as dependent variable. One can best compare these results with the unidimensional averages by decile reported in Figure 5 and Table D.2. When inequality aversion is absent, the coefficients for the dummies of the lower deciles is irregularly hovering around 3200 to 4600 CFA and there is a considerable jump only from the ninth to the tenth decile. The main difference with the unidimensional analysis of the main text is however the large and significant difference between the first decile and all the others, something not observed in the undimensional analysis.

When inequality aversion increases, the inverse U-shaped pattern from the undimensional analysis reappears, but the top is reached at higher deciles than in the unidimensional analysis. Actually, the top is in decile 7 for lower values of inequality aversion, and in decile 6 for inequality aversion $e \geq 1.5$.

Unexpectedly, the (not reported) coefficient of n_h/θ_h is rising with inequality aversion and significantly negative for $e = 0$.

Table D.14 reports the OLS regression results with the welfare gain relative to the baseline welfare as dependent variable. The pattern emerging from the regression coefficients is not in line with the corresponding unidimensional description reported in Figure 6 and Table D.3. More in particular, the decreasing pattern of relative welfare gains across deciles for positive values of inequality aversion is not reflected in the coefficients. The loss of the tenth decile

Table D.13: OLS regression: welfare gain

Baseline	Inequality aversion					
decile	**e=0**	**e=0.5**	**e=0.75**	**e=1.25**	**e=1.5**	**e=2**
2	3259.1***	4539.7***	5248.3***	6973.9***	8102.8***	10288.7***
3	3665.6***	6172.4***	7445.8***	10193.5***	11763.8***	14404.6***
4	3475.3***	7537.8***	9486.3***	13342.6***	15342.7***	18534.2***
5	4116.5***	9086.3***	11396.1***	15783.4***	17926.8***	20702.8***
6	4360.4***	10034.7***	12590.3***	17275.9***	19476.0***	21981.5***
7	4319.9***	10289.6***	12859.1***	17300.3***	19193.1***	20199.7***
8	4618.2***	10004.9***	12162.9***	15606.7***	16878.3***	15554.8***
9	5317.4***	9386.2***	10698.4***	12169.9***	12251.9***	6805.5***
10	9565.6***	4467.8***	1185.3	-6446.7***	-11377.0***	-34358.9***

Note: The dependent variable is the individual welfare gain from a switch of the baseline simulation (two tariffs: exempt and 25.56%, guaranteeing to reach the UN tax revenue objective of 20% of GDP) to the optimal taxes. Explanatory variables are: (1) dummies for the baseline welfare deciles (1 for the dummy of the decile to which the individual belongs, and zero otherwise; the first decile is the reference category); (2) preference parameters (budget shares α_g, except for 'education e' and 'other services e'); (3) department dummies; (4) residential environment dummy (urban *vs.* rural); and (5) the household size over household equivalence scale ratio, n_h/θ_h. The table only reports the estimated coefficients for the decile dummies. $N = 19920$; $^{*}\,p < 0.05$; $^{**}\,p < 0.01$; $^{***}\,p < 0.001$.

Table D.14: OLS regression: relative welfare gain

Baseline	Inequality aversion					
decile	**e=0**	**e=0.5**	**e=0.75**	**e=1.25**	**e=1.5**	**e=2**
2	-0.0403	-0.215***	-0.323***	-0.594***	-0.793***	-1.533***
3	-0.118*	-0.287***	-0.401***	-0.702***	-0.923***	-1.703***
4	-0.130*	-0.260***	-0.363***	-0.665***	-0.899***	-1.742***
5	-0.156**	-0.298***	-0.409***	-0.725***	-0.968***	-1.841***
6	-0.133*	-0.263***	-0.365***	-0.656***	-0.879***	-1.679***
7	-0.157**	-0.319***	-0.434***	-0.744***	-0.975***	-1.803***
8	-0.145*	-0.351***	-0.481***	-0.806***	-1.035***	-1.854***
9	-0.141*	-0.300***	-0.402***	-0.667***	-0.860***	-1.579***
10	-0.0546	-0.222***	-0.324***	-0.580***	-0.762***	-1.420***

Note: The dependent variable is the individual relative welfare gain (welfare gain over baseline welfare level) from a switch of the baseline simulation (two tariffs: exempt and 25.56%, guaranteeing to reach the UN tax revenue objective of 20% of GDP) to the optimal taxes. Explanatory variables are: (1) dummies for the baseline welfare deciles (1 for the dummy of the decile to which the individual belongs, and zero otherwise; the first decile is the reference category); (2) preference parameters (budget shares α_g, except for 'education e' and 'other services e'); (3) department dummies; (4) residential environment dummy (urban *vs.* rural); and (5) the household size over household equivalence scale ratio, n_h/θ_h. The table only reports the estimated coefficients for the decile dummies. $N = 19920$; $^{*}\,p < 0.05$; $^{**}\,p < 0.01$; $^{***}\,p < 0.001$.

is systematically smaller than that of the ninth, and comparable in order of magnitude with that of the second decile. This indicates that the unidimensional analysis might capture some effects which are in fact attributable to the correlation of preferences with welfare levels.

Table D.15: Logit regression: probability to be a winner

Baseline	Inequality aversion					
decile	**e=0**	**e=0.5**	**e=0.75**	**e=1.25**	**e=1.5**	**e=2**
2	-0.0598	-0.141	-0.390**	-0.208	-0.3	-0.698***
3	-0.0704	-0.139	-0.25	-0.134	-0.265	-0.805***
4	-0.238*	-0.0847	-0.279	-0.322*	-0.384**	-0.839***
5	-0.223	-0.221	-0.393**	-0.251	-0.512***	-0.890***
6	-0.191	-0.118	-0.345*	-0.279*	-0.363*	-0.869***
7	-0.244*	-0.251	-0.440**	-0.317*	-0.501***	-0.813***
8	-0.233	-0.137	-0.381**	-0.264	-0.442**	-0.815***
9	-0.189	-0.118	-0.272*	-0.247	-0.389**	-0.839***
10	-0.0993	-0.223	-0.419**	-0.132	-0.467**	-0.795***

Note: The dependent is binary, 1 if the individual gains from a switch of the baseline simulation (two tariffs: exempt and 25.56%, guaranteeing to reach the UN tax revenue objective of 20% of GDP) to the optimal taxes, and zero otherwise. Explanatory variables are: (1) dummies for the baseline welfare deciles (1 for the dummy of the decile to which the individual belongs, and zero otherwise; the first decile is the reference category); (2) preference parameters (budget shares α_g, except for 'education e' and 'other services e'); (3) department dummies; (4) residential environment dummy (urban *vs.* rural); and (5) the household size over household equivalence scale ratio, n_h/θ_h. The table only reports the estimated coefficients for the decile dummies. $N = 19920$; $^{*}\, p < 0.05$; $^{**}\, p < 0.01$; $^{***}\, p < 0.001$.

Table D.15 shows the Logit regression for the binary dependent variable model (win or lose). The coefficients do not replicate the flat parts of the distribution for the lowest three deciles, neither the decreasing pattern beyond the third decile, observed in the panels of Figure 8 corresponding to a positive level of inequality aversion $e < 1.5$. For example, when inequality aversion $e = 0.5$, no significant effects were obtained for the decile dummies, and the point estimates are not monotonously decreasing. For $e \geq 1.5$ coefficients are mostly significantly negative, but they do not exhibit a monotonously decreasing pattern as in the unidimensional representation of the results.

When there is no inequality aversion, the decile dummies hardly generate any significant effect. But we do observe a drop in the percentage of winners from the fourth decile on, in line with the unidimensional picture. The tenth decile is an exception though in the regression analysis.

The regression results seem to indicate that the distribution of the welfare gains and losses in levels is to a certain extent determined by the baseline welfare distribution. The extent to which this indicates that there is a high correlation between preferences and welfare remains an open question. What is sure is that preference heterogeneity within deciles remains sufficiently large to cause more than a quarter of the population to lose from optimal taxes even when designed for a high degree of inequality aversion (see Table D.4). This might also explain why the reported coefficients for the relative gains and the probability to win are much less in line with the unidimensional picture we provided in the main text.