International Microsimulation Association

RESEARCH ARTICLE

Dealing with Residents and Cross-borders in a Tax-benefit Model for Luxembourg

Philippe Liégeois[1]*

[1]Luxembourg Institute of Socio-Economic Research/LISER, Belval, Luxembourg

Abstract The models presented in this paper are intended to contribute to a debate on the impact of hypothetical changes in social security contributions and personal income tax on the distribution of household disposable income and on total public financial revenue from these sources for Luxembourg.Our aim is to take account as far as possible of the non-linearity of socio-fiscal systems and the precise structure of populations, hence the need for microsimulation modelling of both resident and cross-border commuter households. This latter population is involving an essential innovative extension compared with previous assessments. Cross-border commuters are very important in Luxembourg, accounting for over 40% of total employment: 41% in 2017, 43% in 2022.Static microsimulation tools and data are already available for residents (mainly via EUROMOD and EU-SILC), but not for cross-border commuter households. Therefore, there is need for a secondary simulation framework, for example based on EUROMOD and HFCS data (offering some information for cross-border commuters in addition), separately for resident and cross-border commuter households. Such publicly available distributional views on residents and cross-border commuters in countries with high openness where the latter may play an important role in public accounts are not numerous, or even unique in Luxembourg, if we except (expected) imputation-based approaches.The aim of this methodological article is to present the EUROMOD-type models implemented for the resident and cross-border commuter populations in Luxembourg and to highlight the particularities of their construction. Using these tools, we are then able to provide a complementary overview of the two populations "as they are today". Another objective is to provide a toolbox for an immediate overview of tracks for – and impact of – changes in socio-economic policies.Given the important structural differences between resident and cross-border commuter populations in terms of socio-economic status and gross labor and taxable incomes, we show and explain to what extent total revenues from residents are higher than those from cross-border commuters, even considering the relative sizes of the two populations. For the same reason, a change in the socio-fiscal system of policies in Luxembourg could have remarkably different effects between cross-border commuter households and residents. More specifically, these results could also partially serve as a basis for the debate on a pension reform recently launched in Luxembourg.This research was initiated by the *Chambre des Salariés du Luxembourg* (CSL). Consequently, the contents reported here result from exchanges with social partners (not all of whom are familiar with the technicalities of the context). Such a context allowed us to propose an approach more in line with the questions and final expectations of our usual public targets. The present paper also aims to "open the black box", which can lead to contents that are sometimes technical, but accessible to "practitioners" who would like to better understand the underlying forces and rely on these models for subsequent counterfactual analyses.

JEL classification: C63, D31, H24, P43

DOI: https://doi.org/10.34196/ijm.00324

***For correspondence:**
Philippe.Liegeois@liser.lu

Author Keywords: static microsimulation, cross-border workers, EUROMOD, HFCS data, Luxembourg

1. Motivation and context of the paper

The models presented in this article result from the desire of the *Chambre des Salariés du Luxembourg*[1] (hereafter the "CSL") to launch a debate on the impact of hypothetical changes in social contributions and personal income tax (hereafter the "alternatives") on the distribution of household disposable income and on total public financial revenue from these sources for Luxembourg.[2]

Consequently, the contents reported here result from exchanges with social partners (not all of whom are familiar with the technicalities of the context). Such a context allowed us to propose an approach more in line with the questions and final expectations of our usual public targets. The present paper also aims to "open the black box", which can lead to contents that are sometimes technical, but accessible to "practitioners" who would like to better understand the underlying forces and rely on these models for subsequent counterfactual analyses.

Microsimulation techniques are well suited to analyze the distributional impact of changes in the socio-demographic environment (including finding winners and losers) and generate missing information (for example individual taxes and benefits) if it is unknown from other sources. This technique is particularly relevant when the interactions induced by the changes are non-linear, such as those resulting from the application of complex socio-fiscal policies.

The present analysis aims to focus on distributional aspects and total public financial revenues for Luxembourg, hence the need for microsimulation modelling of resident and cross-border commuter households. The latter population implies an extension of the microsimulation models compared with previous assessments. Cross-border commuters are very important in Luxembourg, accounting for over 40% of total employment: 41% in 2017, 43% in 2022.[3]

Consequently, and given the general objectives of the CSL, this research is based on an innovative pair of EUROMOD static microsimulation models,[4] one (updated) for the resident population, the other targeting cross-border worker households and specifically set up for the present study. It is based mainly on the Household Finance and Consumption Survey ("HFCS"),[5] which is available in Luxembourg for both residents and active cross-border households.[6]

There are not many detailed and distributional views on cross-border commuter households in largely open economies, where they can play a significant role in public accounts. And the CSL's request, involving a modelling approach to address issues related to possible policy changes, is quite specific.

As far as Luxembourg or its surroundings are concerned, we can mainly mention a current project by ***Sologon et al., 2023-2026*** who are "*considering the situation of cross-border workers in a cross-national comparison of incomes*", including Luxembourg, and "*develop a spatial microsimulation model of the cross-border region*". Their approach "*relies on combining census data, with EU-SILC* (administrative and HFCS data) *and with an income generation model which incorporates the complexity of the tax-benefit rules of four systems (Luxembourg, Germany, Belgium and France) via the EUROMOD microsimulation model*". This promising development, which involves statistical matching from several sources, could show some synergy with the present study.

Clément et al. (2023) also "*analyze the many facets of cross-border worker flows* [including with regard to Luxembourg]*, identifying similarities and differences from one area to another*". ***Ochmann et al. (2014)*** and the DiW Berlin examine possible alternatives for financing social security in Luxembourg, and their distributional implications for the resident population. Cross-border households are indirectly taken into account through proportional summary keys indicating to what extent they may contribute to the "totals", in case of policy changes, as a proportion of the resident population. A somewhat different concern leads ***Bayenet et al. (2007)*** to examine inter-regional relations in

1. https://www.csl.lu/en/
2. CSL – LISER Project « *Alternative Ways for Funding the Luxembourgish social security system, with distributional effects* ». The full reports by both ***Liégeois (2023a)*** and ***Liégeois (2023b)*** are confidential, the present paper grounding on, and developing, some aspects to be made accessible to a larger audience.
3. ***STATEC (2019)***, page 14, for 2017; ***STATEC (2023)***, page 18, for 2022
4. For detailed explanations on the model, see ***Sutherland and Figari (2013)***.
5. HFCS results from a joint project of EU national central banks and national statistical institutes, providing data improving outcomes for higher income deciles and wealth-related concerns and transfers (https://www.ecb.europa.eu/stats/ecb_surveys/hfcs/html/index.en.html).
6. Collected via a separate survey organized by the *Banque Centrale du Luxembourg* (https://www.bcl.lu/en/index.html) in collaboration with LISER (***Chen et al., 2021***).

Belgium from a normative, historical and economic point of view, as this country generates large flows of workers between highly differentiated regions.

More generally, other useful references for tools and outcomes include ***Edzes et al. (2022)***, ***Sologon et al. (2021)***, ***Drevon et al. (2018)***, ***Mathä et al. (2018)***, ***Van der Valk (2018)***, ***Decoville et al. (2015)***, ***O'Donoghue et al. (2014)***, ***Tanton (2014)***, ***Farrell et al. (2013)***, ***Burlacu and O'Donoghue (2012)***, ***Ballas et al. (2005)*** and ***Clarke (1996)***.

The aim of the present methodological article is to present these EUROMOD-like models set up for the resident and cross-border populations in Luxembourg, to highlight the particularities of their construction and to provide a complementary overview of the two populations as they are "today". Another objective is to provide a toolbox for an immediate overview of tracks for –and impact of– changes in socio-economic policies.

It is structured as follows. First, we briefly describe the EUROMOD models, the microdata that feed these models, the way tax rules are implemented in this bi-regional environment (residents and cross-border commuter households) and the macroeconomic adjustment made necessary by cross-border households not covered by the HFCS microdata (*Section 2*). Next, we examine the effects of the benchmark system of socio-fiscal policies currently in force in Luxembourg on total public financial revenues and on the distribution of net household incomes, for both residents and cross-border commuter households (*Section 3*). We then derive the contribution of tax brackets and households to taxes and illustrate the use of such an apparatus through a basic change in the fiscal policy (*Section 4*) before concluding (*Section 5*).

2. Models, data, fiscal rules and macro adjustment

This methodological section introduces the models used for this analysis, the limitations and adjustments made necessary for the microdata. Then are clarified an important choice relating to the implementation of the tax rules and a final adaptation to take into account this part of the XB population not covered by the HFCS microdata.

2.1. The basic framework: EUROMOD models and HFCS data

When the resident population alone is at stake, EUROMOD may be run on the classical "European Union Statistics on Income and Living Conditions" (EU-SILC) data.[7] Unfortunately, EU-SILC data are not covering cross-borders.

Alternatively, a EUROMOD model is running on the "Household Finance and Consumption Survey" ("HFCS") data for residents.[8] HFCS data are also available in Luxembourg for active cross-border households,[9] that is residing in the Greater Region and involving at least one member working in Luxembourg, hence not embedding all persons covered through the LU social security or fiscal systems.[10] This last survey "*is specifically designed to complement the Luxembourg Household Finance and Consumption Survey*" initially set up for residents only (***Chen et al., 2021***). The overall coverage of both residents and active cross-border households induces us to adopt this HFCS-based framework for the present analysis, yet some comparison with SILC-based outcomes can be maintained sometimes.

Hereafter we use "EUROMOD/SILC", "EUROMOD/HFCS-R" and "EUROMOD/HFCS-XB" to refer either to the EUROMOD models based on SILC or HFCS data, or to the EUROMOD input databases built from the same datasets, depending on the context. For simplicity reasons, we are also referring to "XBs" (cross-borders) as to "active commuter cross-border households" or "all cross-border households", indifferently and depending on the context.

Three waves have been collected up to now for HFCS in Luxembourg: 2013 (income reference year), 2017 and 2020 (not available yet at date of the present analysis). The present analysis is building

7. https://ec.europa.eu/eurostat/web/microdata/european-union-statistics-on-income-and-living-conditions
8. ***Kuypers et al. (2016)***; ***Kuypers et al. (2020)***; , see ***Chen et al. (2020)*** and ***Household Finance and Consumption Network (2020)***.
9. Collected via a separate survey organized by the *Banque Centrale du Luxembourg* (https://www.bcl.lu/en/index.html) in collaboration with LISER (***Chen et al., 2021***) (.
10. The "Greater Region" is covering the territories of Lorraine in France, Wallonia in Belgium, Saarland and Rhineland-Palatinate in Germany as well as the Grand Duchy of Luxembourg (https://www.granderegion.net/en/The-Greater-Region-at-a-Glance).

Table 1. Populations covered by the EUROMOD input databases (*Income year 2017 for all*).

	Number of Residence Households*		Number of Persons	
Database	Unweighted	Weighted	Unweighted	Weighted
EUROMOD/**SILC** input (LU-Resident population)	3,833	252,336	10,493	574,184
EUROMOD/**HFCS-R** input (LU-Resident population)	1,616	226,378	4,333	535,897
EUROMOD/**HFCS-XB** input ("Active" Cross-border households)	2,362	147,380	7,341	418,997

*All persons living in the same dwelling, not to be confused with the "residents" who involve inhabitants of Luxembourg.

on the most recent wave available when the microsimulation tools were designed (2022), that is 2017. Therefore and given our objective to involve the XBs in the analysis as well, we have to update a former version of the EUROMOD/HFCS-R model, to take into account a more recent wave for the HFCS data for residents, namely the 2017 one (income reference year), and more recent policy systems in the EUROMOD model as such, up to 2017**.** And we build a new version of the EUROMOD/HFCS-XB model targeting that additional population.

Note that for dealing with missing information resulting from the HFCS surveys, "*a multiple stochastic imputation strategy has been chosen* [by the designers of the surveys]. *The dataset provides five imputed values (replicates) for every missing value corresponding to a variable entering the composition of household wealth, consumption or income*".[11]

Practically, this implies that an input created for the purpose of microsimulation from HFCS micro-data is composed of 5 datasets, each of them involving the whole sample. Those 5 inputs are simulated and analyzed in turn, generating altogether 5 outputs. Finally, all outcomes shown up in the present paper are, for each variable and unless otherwise mentioned, output means resulting from those multiple outputs.[12]

Finally and for comparative reasons, the EUROMOD/SILC model may be used as well, building here on wave 16 (income reference period: 2017).

Most outcomes in this paper resulting from the "*EUROMOD/SILC and EUROMOD/HFCS models for Luxembourg resident and cross-border populations, version I4.62+ Beta release (3.4.10), in combination with the author's computations*", we are considering this piece of information as implicit for all tables and Graphs where no other mention of sources is explicitly provided.

2.2. The coverage and limits of microdata

Table 1 below is showing up some basic information about the samples retained for the different EUROMOD models, directly depending on the microdata those are grounding on (HFCS-R 2017/wave 3 and HFCS-XB 2017/wave 3). For comparative concerns, we also add some information derived from the EU-SILC data, hence the well-established EUROMOD/SILC model.

The discrepancy between the weighted number of persons covered through the EU-SILC data, on one side, and HFCS-R data, on the other side, are partially explained only by the international civil servants' households being embedded to a more comprehensive extent in EU-SILC.[13]

11. See ***Household Finance and Consumption Network (2020)***, page 7.
12. In particular, if a Gini coefficient is derived, with values 0.2903, 0.2905, 0.2897, 0.2901 and 0.2899 resulting from the 5 runs of a EUROMOD model we report 0.2901 as an outcome. Alternatively, we could have gathered or averaged *ex ante* the 5 values outputted from EUROMOD/HFCS for the equivalent income, then computing *ex post* the "overall" Gini. But we rather chose to build on procedures available *ex ante* the present study for saving time, what might deserve some deepening *ex post* the study, yet probably not fundamentally changing the outcomes.
13. EU-SILC 2018 data are embedding households involving international civil servants/ICS, what HFCS data do not (unless some ICS being a member of a household selected on another basis).

Another remarkable information in ***Table 1*** is about the dimension of the samples. The number of persons and households interviewed through the HFCS-R survey being lower than under the EU-SILC environment, we may expect by principle outcomes less accurate in terms of background confidence intervals.[14] This could become more noticeable when looking into sub-groups of population, taking into account income deciles, levels of wages, types of households etc.

Even if essential topics like outcomes for higher income deciles and wealth-related concerns and transfers are deeply examined in HFCS-R compared to alternative datasets, some (monetary) variables are sometimes aggregated or missing, compared to EU-SILC. Fortunately, the EUROMOD/SILC model can be adapted anyway to run EUROMOD/HFCS-R.

HFCS-XB data deserve some additional comments as well. Less information is collected, compared to HFCS-R, especially for non-"reference/FKP" household members (for example about the economic activity). Moreover, some variables are missing or have been aggregated in HFCS-XB (for example in relation with Luxembourgish *versus* non-Luxembourgish origin of revenues).[15] This last limitation matters as we need some idea about that part of income leading to social contributions and taxes specifically due to Luxembourg (see *Section 2.3*).

Therefore, we have to impute some missing information in HFCS-XB, which is reported in *Appendix A*.

2.3. Dealing with the fiscal rules applicable to XBs

The outcomes from EUROMOD/HFCS-XB are primarily based on total household incomes, whatever originated from Luxembourg or other countries.

For total revenue regarding Luxembourg, a main concern in case of a change in socio-fiscal rules, we stick to the Luxemburgish tax authority's 2-step computation. Firstly, a global tax rate is derived from EUROMOD for each XB household, considering its total taxable income (whatever the geographical origin of revenues) and Luxembourgish fiscal rules only. Secondly, this rate is applied to income originated from Luxembourg only, to fix the tax due to Luxembourg.

Therefore, we are neither considering foreign socio-fiscal rules nor dealing with separate bilateral fiscal agreements between Luxembourg and surrounding countries,[16] what we refer to as "hypothesis H1" (through the present paper, we emphasize strong or prominent hypotheses regarding XBs by this type of "Hx**"** marker signal, essentially in *Appendix B*). Such a simplifying approach, out of being easily applicable, seems also sufficiently close to real practice and acceptable as a prior step.

2.4. Macro adjustment for XBs uncovered through HFCS data

Leaving aside XB households which do not presently involve any active worker in Luxembourg, for example a couple of Belgian pensioners, may reduce the total public revenue seen as due to Luxembourg. Some social contributions or personal income taxes are then ignored by the present exercise. Therefore, the information is partial and a comparison to other more comprehensive official statistical sources might be difficult.

Therefore, we show in *Appendix B* how, building on outcomes from the EUROMOD/HFCS-R and EUROMOD/HFCS-XB platforms, how we choose to roughly complete the picture to add to social contributions and personal income taxes revenue from those XB households ignored up to now. Such a "macro adjustment" leads, for the reference year 2017, to a supplement of 1.1% for social contributions ([VI]/[IV], ***Table B1***) and 2.7% for the tax on income ([XV]/[TAX/HFCS+], ***Table B2***).

These amounts deserve to be taken into account −and they are− without fundamentally altering the overall picture, given our objectives. But the distributional effects derived from EUROMOD/HFCS-XB are not entirely relevant and are therefore only marginally addressed in this document.

14. This remark does not refer to the "quality" of the survey, which is not at stake here. HFCS data are also involving questions and information about essential topics like wealth-related items which are much more deeply examined in this survey, a clear and useful innovation compared to other studies. For an analysis of confidence intervals in EUROMOD/SILC data for Luxembourg, see ***Liégeois et al. (2011)***.
15. During the interview, a person who is the "*most knowledgeable with the financial situation of the household*"/FKP is designated. This FKP is providing more detailed personal information, needed for an efficient microsimulation exercise, than the other members of the households for whom, therefore, such a useful information may not have been collected.
16. See ***Clément et al. (2023)***, page 20.

3. The Luxembourg's resident and cross-border commuter populations as observed in 2017 (benchmark "STD")

Based on the structure of the resident and "active" XB populations in terms of gross income and household composition, we are able to use microsimulation to determine the social contributions, social benefits and personal income tax for each resident household. We can then derive aggregates in terms of public financial revenue and some information about the distribution of "well-being" throughout the populations, hence finally looking at inequalities (Gini coefficient and Poverty Rates). Consequently and later on, we will be in position to assess the outcome from alternative socio-fiscal policies.

We consider here as an indicator of individual "well-being" the so-called and standard equivalent income which is the ratio between the disposable income of the household (= gross income + social benefits – social contributions – personal income taxes) and a coefficient taking into account the composition hence needs of that household.[17] The equivalent income is determined at the residence household level (all persons belonging to the same dwelling) and then each member of the household is attributed this household value.

In search of a basic reference for our analysis, we explore here the system of socio-fiscal policies actually implemented in Luxembourg in 2017, with regard to both residents and XBs. As we proceed, we are led to highlight a number of fundamentals that may give us the keys to a better understanding of the underlying mechanisms explaining the overall results observed. Therefore, we are building a useful knowledge-base that might be of interest for further analyses of possible alternative socio-fiscal policies.

Our path is structured as follows.

Section 3.1 provides an overview of the resident and XB populations through a set of classical global indicators: total public revenue, "well-being", inequality and poverty.

In *Sections 3.2* and *3.3* and *3.4*, we then open the black box and look for fundamentals (employment status, gross earnings, taxable income and classes of tax) on the basis of which a more in-depth analysis can be carried out. *Section 3.5* is going a step further and takes a look on the whole tax base, the fiscal brackets, the fiscal classes and the types of households composing the resident and active XB populations.

3.1. An overview

Table 2 is gathering such a rich information in the context of our benchmark "STD" which is a picture available for Luxembourg in 2017 (income year), as derived from several microsimulation platforms and additional macro adjustments.

The top lines of ***Table 2*** are reminding the populations covered by the data and simulation models and show the total taxable income before tax allowances (based on EUROMOD variables tinty_s for residents, tinty_lu_s for the XBs) available for Luxembourg. Active XB households are providing an amount that is 40% of the taxable income coming from residents: 7.95 billion € as computed through microsimulation (hence an aggregation of individual results), against 20.04 billion € for residents in 2017 (based on EUROMOD/HFCS-R and XB, see also *Footnote 20*).

Then comes information about the total public revenue for Luxembourg in terms of social contributions (3.71 billion € from residents if HFCS data; 2.03 billion € from XBs), with several sources participating in this total, and taxes on personal incomes (3.44 billion € for residents; 824 million € from XBs), taking into account several tax credits reducing the tax after a prior application of the tax schedule to the tax base. It appears that the overall tax rate on XB income is 824/7,947=10.4%, much lower than for residents (17.2%). We will come back to that downstream.

The next section in ***Table 2*** is reporting several "well-being" and "inequality indices**"** for residents, all dimensions genuinely embedded in an approach undertaken through microsimulation. As seen from ***Table 2*** for residents, the usual sub-groups of households like "*Single with dependents*" or "*Couple with 3 dependents or more*" are facing a well-being much lower than other categories

17. This so-called OECD-modified equivalence scale is attributing a weight of 1 to the first adult, 0.5 to additional persons (aged fourteen or more), and 0.3 per child (aged under fourteen).

Table 2. An overall view of the benchmark "STD" (income year 2017) for resident and XB households.

Data and EUROMOD platforms		SILC	HFCS-R	HFCS-XB *(Active households & LU-incomes only)*
Population covered by the survey (see ***Table 1***), in *persons*		574,184	535,897	418,997
Taxable Income, before Tax allowances, in *millions €* / year (from tinty_s in HFCS-R, or tinty_lu_s for Active XB households)		20,808	20,041	7,947
… out of additional amount from XBs not covered by the survey (for subsequent *macro adjustment*, see *Section 2.4*)				1,109
Public Revenue (in *millions €* / year)				
Social contributions		[I]*	[II]	[III]
		3,914	3,714	2,030
whose	Employee	1,820	1,693	945
	Self-employed	178	221	27
	Others (*Long term care from Social assistance*)	3	3	0
	Employers	1,710	1,667	1,059
	Credited (*Replacement income, Social assistance, Pensions*)	202	130	0
… out of additional amount from XBs not covered by the survey (for *macro adjustment*)				62
Personal Income Tax		[VII]	[VIII]	
		3,289	3,439	824
	Implicit Tax Rate on Tax Base (tinty_s – tinta_s, or LU versions if XBs), before Tax Credits		20.9%	14.4%
	Global Tax Rate (after Tax Allowances & Credits) = Income Tax / Taxable Income, on average		17.2%	10.4%
… out of additional amount from XBs not covered by the survey (for *macro adjustment*)				115
⇒ **Total Public Revenue** (before *macro adjustment*)		7,203	7,153	2,855
Inequalities				If *All Incomes*
Gini				
	Relative = Abs / (2*Avg)	0.2524	0.2993	0.1940
	Absolute (in € / month)	1,701	2,103	1,088
	Average (in € / month)	3,371	3,513	2,804
Poverty				
	Line (in € / month)	1,790	1,770	1,564
	Rate	11%	13%	2%
	by Type of Residence Household:			
	Single (<65)	14%	16%	1%
	Single (65+)	8%	9%	2%
	Single with dependent(s)	31%	18%	0%
	Couple - 0 dep	6%	5%	2%
	Couple - 1-2 dep	11%	18%	2%
	Couple - 3+ dep	14%	21%	2%
"**Well-being**", as equivalized income (all in € / month), on average				If *All Incomes*
All		3,371	3,513	2,804
1st Decile		1,574	1,472	1,635
by Type of Residence Household:				
	Single (<65)	3,308	3,249	2,828
	Single (65+)	3,215	3,440	2,878
	Single with dependent(s)	2,473	2,661	2,530
	Couple - 0 dep	3,922	4,150	3,194
	Couple - 1-2 dep	3,117	3,292	2,768
	Couple - 3+ dep	2,673	2,826	2,353

*The references [I], [II], ... refer to ***Table B1*** and ***Table B2*** (*Appendix B*)

of population. This is complementarily illustrated for those sub-groups by a higher level of poverty (18% and 21%, if EUROMOD/HFCS-R environment). The poverty risk represented here is the share of population below 60% of the median equivalent income, a threshold called the "poverty line", also shown in ***Table 2***.

Another indicator is telling something about the unequal distribution of well-being throughout the population: the inequality Gini coefficient. As summarized in ***Vergnat et al. (2022)***, this coefficient is an index with a value between 0 and 1 (0.2993 in Luxembourg in 2017, based on EUROMOD/HFCS-R). It increases if inequalities in equivalent incomes become greater (zero would indicate perfect equality; the same income for all). It is equal to the absolute Gini index (the average absolute difference between incomes, 2,103 EUR/month) divided by twice the average equivalent income (3,513 EUR/month).[18]

We are not commenting the levels of well-being, poverty and Gini resulting from the EUROMOD/HFCS-XB platform for XB active households. This population is partial only, compared to the usual reference involving a whole (resident) population, hence comparisons more hazardous, as already mentioned earlier. And what will be at stake at that moment will be the *changes* in several indicators, on top of absolute values given here as basic references.

In the same vein but for other reasons, we are not commenting outcomes from EUROMOD/SILC, also for the resident population (international civil servants' households included). Differences may be important in comparison to results obtained through EUROMOD/HFCS-R, especially when having a look on sub-groups, less numerous in terms of survey observations (see for example the risk of poverty

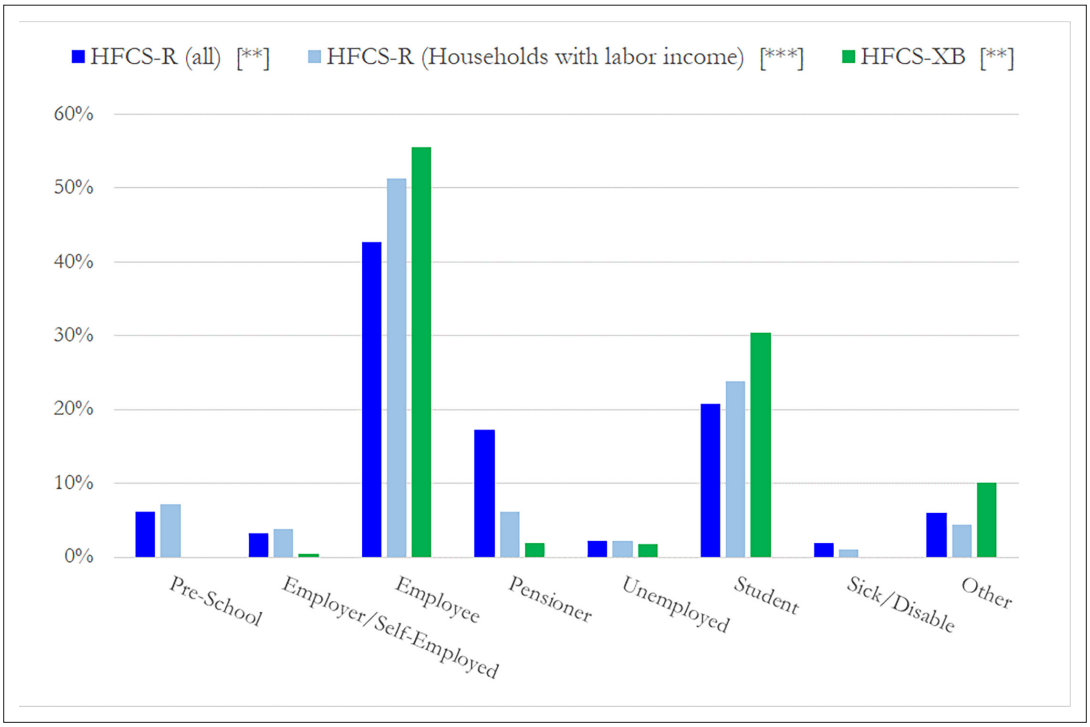

Figure 1 Share of the whole population (in % of the total population in 2017), based on its employment (social-economic) status*

*Mean over all 5 imputations (see *Section 2.1*) – **EUROMOD/HFCS-XB is dealing only with households in which at least one member is a XB worker, that is presently active in Luxembourg, whereas EUROMOD/HFCS-R is targeting the whole Luxembourgish resident population – ***(yem + yse) > 0 over the residence household

18. These two indicators are not concerned with the same notion of inequality; the first measures the relative differences in equivalent income between members of a population, while the second refers to the absolute differences in equivalent income between them. The relative Gini index will not change if equivalent income increases in the same proportion for all (scale invariance), even though this increase would change the absolute gap and thus the absolute Gini. Conversely, if equivalent income increases by the same absolute amount for all, the absolute Gini will not change (translation invariance); the gap in income between individuals remains constant, while the relative Gini will change.

for *Single with dependents*, quite high through SILC). Those gaps might deserve a deeper analysis in future times.

However, we note that total public revenue, as derived from the two platforms, are close each other, embedding a lower level of social contributions through EUROMOD/HFCS-R (-5%), partially compensated by more income taxes (+5%).

Finally, ***Table 2*** is embedding some additional information related to the macro adjustment for XBs uncovered through HFCS data as introduced in *Section 2.4*.

3.2. Employment status, gross labor income and public pensions

Figure 1 shows how the resident and active XB populations of Luxembourg are spread based on their so-called "employment" status in 2017, that is their socio-economic status at large as referenced to in the EUROMOD environment.

As mentioned earlier, "active" XBs are gathering all XB households embedding at least one worker presently active in Luxembourg. Therefore, the active XB population cannot be compared as such with the resident one. A more appropriate basis for comparison might be to concentrate, on the resident side, to households reporting some labor income only. This sub-resident population is also shown up in ***Figure 1*** as a matter of comparison.

The employees and pensioners represent altogether a little less than 60% of the whole resident population. Therefore, we can expect larger effects of changes when these groups are affected. On the contrary, an alternative targeting the self-employed is likely to show smaller overall effects (this group is still lighter in HFCS-XB).

Obviously, the share of pensioners is much more limited when considering the active XB households (2%, against 17%), even if we compare "active" sub-groups (2%, against 6%). Let's also mention that observed differences may also result from some kind of misclassification, the information we are building on through HFCS-XB being limited, as mentioned earlier. An indication of that is the share of "other" statuses in HFCS-XB, much larger than in HFCS-R (10%, against 4% to 6%).

Figure 2 examines the share of employees, employers/self-employed and pensioners, the most prominent categories in the employment statuses (out of students and "others"), based on their gross labor and public pension earnings compared to the Minimum Social Wage (MSW = 1998.59 EUR per month in 2017), a key social parameter in Luxembourg. We consider here thresholds at 2*MSW, 5*MSW and above, which may play an important role in some alternatives. Self-employment and pension incomes are both examined for residents only, those categories being less represented in HFCS-XB (cf. ***Figure 1***).

Unsurprisingly, self-employed residents enjoy higher average incomes from work than employees.[19] They more often exceed the 5*MSW essential threshold (18% compared with 7%). Pensions of residents, on the other hand, are rarely as high, due in particular to the rules governing the capping of pensions in Luxembourg.

Finally, we underline higher wages for XBs, when generated through their activity in Luxembourg compared to all sources taken together: 3,881 €/month, on average from Luxembourg, against 3,442 €/month when all wages considered (***Figure 2A***). Nevertheless, despite average wages from Luxembourg being 13% higher than the general mean for XBs, those Luxembourgish-based salaries remain 16% lower than the residents' ones.[20] In the same vein, 64% of the XB employees benefit from a Luxembourgish salary less than twice the MSW, what is the situation for 55% of the resident employees only.

19. Nevertheless, such comparisons may be biased. Let's remind that for self-employed, part of the employer's social contributions are considered as incorporated in the gross incomes as reported in the raw microdata, whereas they still have to be added-up to such gross levels for employees (to reach sometimes called "gross-gross" levels).
20. Such a disequilibrium between labor earnings for XBs and residents, at the advantage of the latter, is confirmed in ***Chen et al. (2020)***, page 44. ***Clément et al. (2023)***, chapter 2, are also giving an insight about the underlying determinants (education attainment, nature of jobs, etc) that can explain those discrepancies between the residents and XB workers.

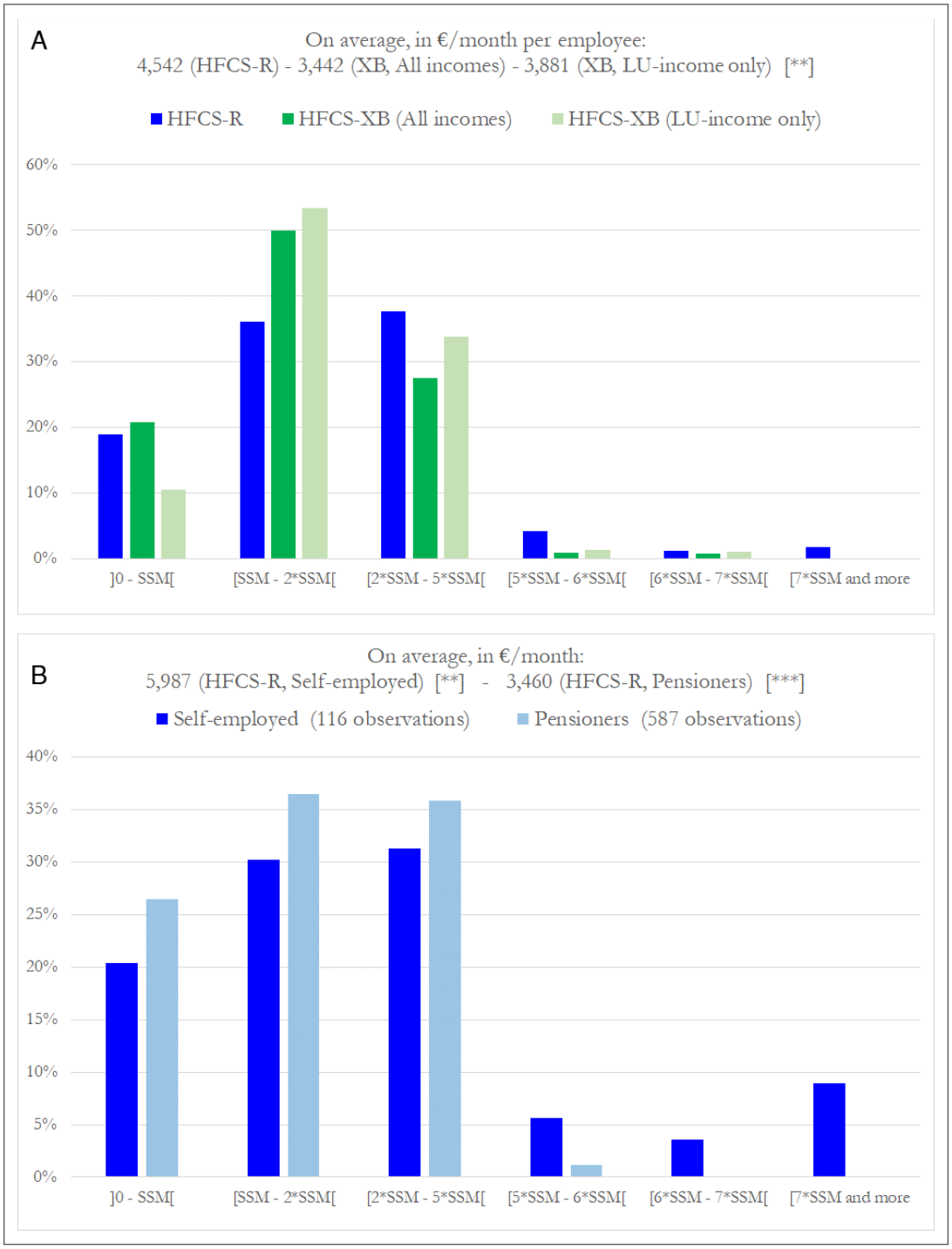

Figure 2 **[A]** Share of EMPLOYEES, based on their earnings compared to the MSW, in % of employees with positive (>0) labor earnings [*] (MSW = 1998.59 EUR / month in 2017). **[B]** Share of RESIDENT SELF-EMPLOYED AND PENSIONERS, based on their earnings compared to the MSW, in % of self-employed and pensioners with positive (>0) earnings [*] (MSW = 1998.59 EUR / month in 2017)

[A] [*] Mean over all 5 imputations (see *Section 2.1*), except for averages that are valid for imputation 1 only. The averages are whatever the working time (part-time and full-time workers altogether), which partially explains discrepancies with ***Clément et al. (2023)*** outcomes on pages 50 on. – [**] The "*All incomes*" columns involve all XB employees with positive employment income (yem > 0 and "employee", as referred to in EUROMOD through the labor economic status variable "les" == 3); "*LU-income only*" is dealing with that part of XB population earning employment income from Luxembourg (yem_lu > 0), the latter group being embedded in the former one,

Figure 2 continued on next page

hence a sub-group of it ♦ **[B]** [*] Mean over all 5 imputations (see *Section 2.1*), except for averages that are valid for imputation 1 only – [**] yse > 0, "self-employed/employer", as referred to in EUROMOD through the labor economic status variable "les" == 1 or 2 – [***] il_taxpen > 0, "pensioners", as referred to in EUROMOD through the labor economic status variable "les" == 4

3.3. The components of the total taxable income for Luxembourg

We can now go a step further in the derivation of the total taxable income (simulated EUROMOD/HFCS variables "tinty_s", or "tinty_lu_s" if considering Luxembourgish revenues only). Those amounts can be examined at the individual or fiscal household level.

Table 3 describes the components of the total taxable income in Luxembourg. Note that figures in ***Table 3*** can hardly be compared horizontally between residents and XBs. Those figures involve the whole population and are most often means per person, hence with an impact of the structure of households on outcomes, whereas previous results were given by worker or pensioner at stake, like in ***Figure 2***.

For residents, the salaries and pensions are by far the most prominent sources for the taxable income tinty_s. Remarkably, incomes from capital (interest, dividends, etc.) and property are reported

Table 3. The components of the taxable income, in *€/month* [*].

Component (EUROMOD variable)	Meaning	HFCS-R		HFCS-XB†			
				All incomes		LU-income	
		Avg ‡	**% of total**	**Avg ‡**	**% of total**	***Avg ‡***	***% of total***
tinty_IT_s	Taxable income, by fiscal household §	5,392		4,537		*3,492*	
tinta_IT_s	Tax allowances, by fiscal household §						
tinty_s	Taxable income, by person	3,116	100%	2,054	100%	*1,581*	*100%*
bsacm_s	Social assistance	58	1.9%	22	1.1%	*0*	*0.0%*
il_repl	Replacement income	10	0.3%	0	0.0%	*0*	*0.0%*
il_taxpen	Taxable pensions	626	20.1%	19	0.9%	*0*	*0.0%*
yem	Employee gross income	2,047	65.7%	1,894	92.3%	*1,544*	*97.7%*
yiy	Interest, dividends, profit from capital investments in unincorporated business	16	0.5%	18	0.9%	*14*	*0.9%*
ypp	Pension from private pension plans	43	1.4%	0	0.0%	*0*	*0.0%*
ypr	Income from property	128	4.1%	79	3.8%	*0*	*0.0%*
ypt	Regular inter-household cash transfers received	16	0.5%	0	0.0%	*0*	*0.0%*
yse	Gross income from self-employment	172	5.5%	22	1.1%	*22*	*1.4%*

*Mean over all 5 imputations (see *Section 2.1*)

†Averages for "*All incomes*" and "*LU-Income*" are considering the whole surveyed population

‡Mean = (weighted) total / number of persons or fiscal households in 2017

§A fiscal household is gathering persons considered as to be taxed jointly on income, taking into account the relevant fiscal rules

at a level similar to the one from self-employment (4.6% of the taxable income from capital and property, against 5.5% for self-employed). This deviates from classical outcomes from EUROMOD/SILC

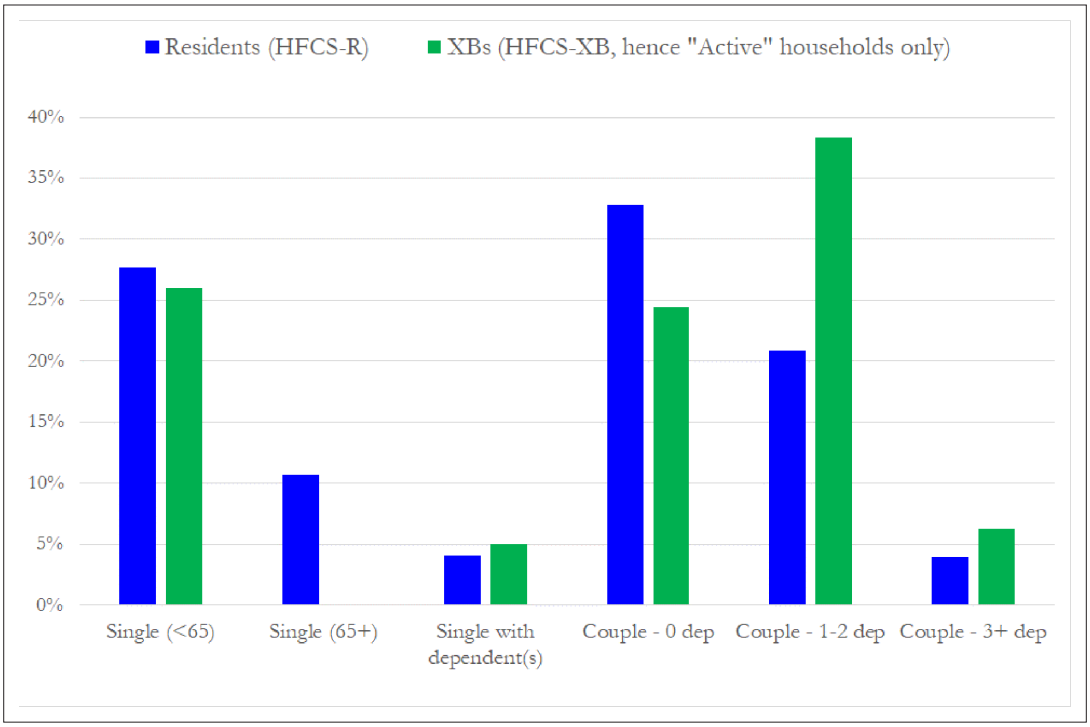

Figure 3 Share of households across the TYPES OF HOUSEHOLDS, as resulting from EUROMOD/HFCS-R and EUROMOD/HFCS–XB (Outcome from *imputation 1* only – see *Section 2.1*)

data which are showing up a much lower proportion for those incomes (***Liégeois et al., 2011***). In the same vein, given the objectives of HFCS surveys, pensions from private plans are now visible with a participation to the taxable income by 1.4% (close to 0% in SILC).

On the XB-side, the taxable income composed from the survey is mainly attributable to wages (92.3%). Other components, often "0", are in line with both some limitations in survey data and imputations operated as reported in ***Table A1***. ***Table 3*** is also showing which part of the taxable income is composed of Luxembourgish revenues: 77% on average (1,581 € / 2,054 €).

However and given the relative dimensions of residents and XB populations shown in ***Table 1***, we have already an indication from ***Table 3*** that the macro or total taxable income prevailing for XBs (and Luxembourgish revenue) is about 40% of the one for residents,[21] as reported more precisely through the in ***Table 2*** (7,947 millions € / 20,041 millions €, when ignoring macro adjustment).

3.4. The tax base, the classes of tax, the types of households and fiscal brackets

Grounding on the taxable income, we are now in position to derive the personal income tax for Luxembourg through microsimulation. What are the main ingredients for that?

At the level of a tax household, the tax deducted from the taxable income of fiscal households depends on i) the tax base, i.e. the taxable income EUROMOD variable "tinty_s" from which are deducted the tax allowances "tinta_s" (including social security contributions themselves), ii) the tax brackets to which are allocated specific tax rates (discussed in *Section 4* below) and iii) the "class of tax" prevailing for that household.

21. For residents through HFCS-R data: 535,897 persons * 3,116 €/month * 12 = 20,04 billions €/year; for XBs as covered through the HFCS-XB data: 418,997 * 1,581 €/month * 12 = 7,95 billions €/year (see also ***Table 2*** for totals).

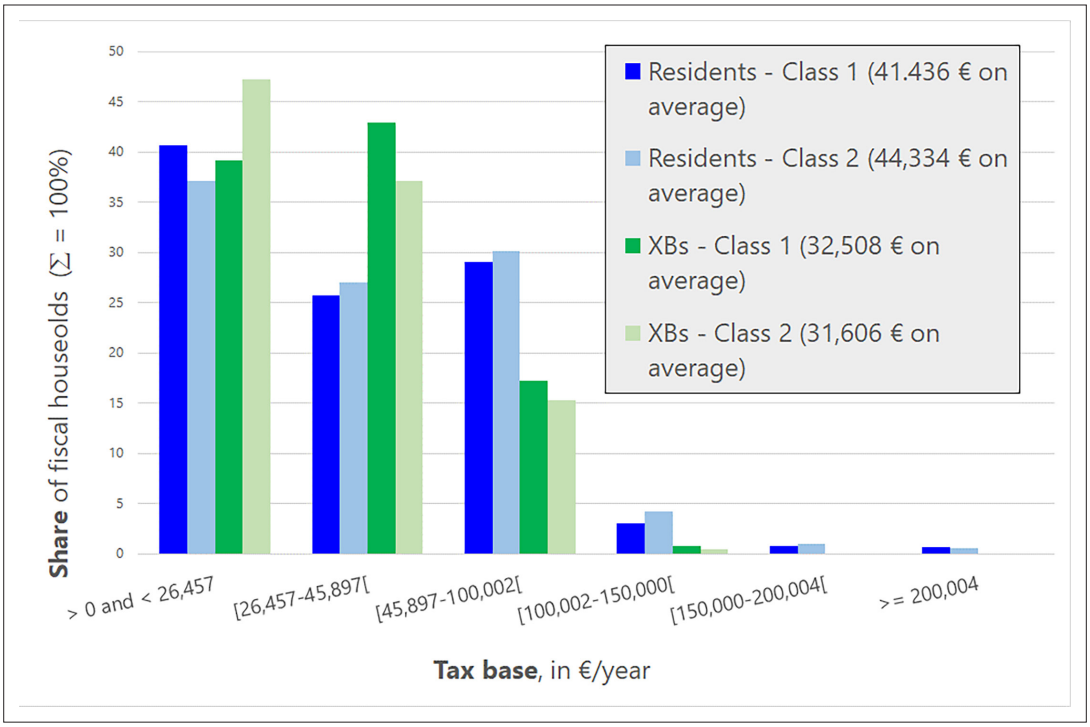

Figure 4 Share of Fiscal Households across the FISCAL BRACKETS, based on their YEARLY TAX BASE [*], if >0 and CLASS-1 (single without dependents) or CLASS-2 households (couples), resulting from EUROMOD /HFCS-R and EUROMOD / HFCS-XB

Note to the reader: it should be understood from the "27%" seen for bracket [26,457-45,897] for resident couples (class-2 fiscal households) that 27% of those households are experiencing a tax base situated between 52,914 €/ year (twice 26,457) and 91,794 €/year, given that this tax base is divided by 2 in Luxembourg before applying the tax schedule for computing the tax on income (finally multiplied by 2 for an effective value). [*] Mean over all 5 imputations (see *Section 2.1*).

The classes of tax can be identified as "0" (basically, single with dependents or aged ≥ 65), "1" (single without dependents and aged < 65) and "2" (couples). ***Table 4*** tells more about the share of fiscal households across those classes. Still, the populations covered through HFCS-R and HFCS-XB surveys differing structurally, we can hardly compare figures horizontally. However, we can partially explain the relatively high proportion of "class 0" fiscal households in the resident population by the presence of many single households aged 65 or more see ***Figure 3***), hence classified in "class 0".

Table 4. Share of fiscal households across the classes of tax (in % of Fiscal Households) as resulting from EUROMOD/HFCS-R and EUROMOD/HFCS–XB (mean over all 5 imputations – *Section 2.1*)

	Proportions, in % of Fiscal Households	
Class of Tax	HFCS-R	HFCS-XB (*Active Households*)
0	17%	9%
1	47%	38%
2	37%	54%

* Mean over all 5 imputations (*Section 2.1*)

Finally, we show in ***Figure 4*** the share of fiscal households across several fiscal brackets, under EUROMOD/HFCS-R and EUROMOD/HFCS-XB. We focus on class-1 and class-2 households only, the most frequent types encountered (see ***Table 4***).

To fix the ideas, we select the brackets available in the EUROMOD models for the income year 2017 and that may play a prominent role in alternatives examined downstream: brackets [1-9], that correspond to [0€-26,457€, yearly]; [10-19] ⇒ [26,457€-45,897€]; 20 ⇒ [45,897-100,002]; 21 ⇒

[100,002-150,000]; 22 ⇒ [150,000-200,004]; and 23 ⇒ ≥ 200.004 (for the original tax brackets, see ***Islam et al., 2020***).

As was expected based on an examination on gross incomes behind the scene (see ***Figure 2***), tax bases are more concentrated on lower brackets in the XB population. We can show that this statement remains true even if comparing only to Luxembourgish fiscal households experiencing a positive labor income (either from employment or self-employment).

On the other side of the income spectrum, the highest brackets (more than 100.002 EUR for the gross taxable earnings) are gathering a little part of the fiscal households: 5.7% if considering resident couples ; 0.4% for (active) XBs.

4. The contribution of fiscal brackets and households to (a change in) taxes

We are now undertaking a practical exercise that can be seen as a starter for downstream analyses and comments, including in relation with alternative socio-fiscal policies.

Why such a difference between the overall implicit tax rate on the tax base (taxable income *minus* tax allowances), between the resident population and the XBs one: 20.9% against 14.4% (the latter when considering LU-incomes only, see ***Table 2***). Both populations basically facing the same socio-fiscal system of policies, those differences should be mainly explained by the structure of earnings pertaining to each population. To clarify those differences, we derive an approximation of the implicit tax rate for resident and active XB fiscal households separately.

Starting from the distribution of those households across the fiscal brackets (copied for example from ***Figure 4***), we may consider two approaches (an initial request by the CSL, indeed).

The first view is relevant for understanding the role of each *fiscal bracket* in the total funding, whoever is concerned by this fiscal bracket. For example, all fiscal households with a positive tax base are dealing with the first fiscal bracket as summarized in ***Figure 4*** (0-26,457 €), which may make this bracket an important player in the computation of total income taxes despite the tax rates applicable at that level being low. Therefore and through such a view, we see easily to what extent a change in rate applicable to a given bracket may impact the total receipt (*Section 4.1*).

The second view is focusing on the role of the *fiscal households* themselves in the total funding. For that purpose, fiscal households are ranked based on their tax base and then gathered in the corresponding fiscal brackets. For each bracket, we then derive the income tax generated from the collection of households corresponding to that bracket due to their tax base. This view is relevant for understanding which households are paying what, based on the level of tax base (*Section 4.2*).

We are then briefly illustrating that analytical framework while analyzing the effects of an alternative to the fiscal policy in force in 2017 (*Section 4.3*).[22]

4.1. The role of fiscal brackets in the total fiscal revenue

Let's first examine the role of each fiscal bracket in the total funding, whoever is concerned by this bracket.

With such a perspective in mind, ***Table 5*** *[A] (Upper Part)* is showing up how deriving an approximation of the overall tax rate for class-2 resident fiscal households. For sake of illustration, we focus here on this category of households which generates by far the largest proportion of income tax in Luxembourg.

Starting from the classification of those households across the fiscal brackets (copied from ***Figure 4***) in column [a], we derive for each bracket the share of fiscal households concerned by this specific bracket (column [b], obviously 100% for the lowest bracket) and, subsequently, the sum of tax bases specifically impacted by that bracket, in column [f].

Note that the "27%" seen in column [a] for the bracket [26,457-45,897] should be understood as 27% of class-2 resident fiscal households experiencing a tax base situated between 52,914 €/year (twice 26,457) and 91,794 €/year (see the "note to reader" in ***Figure 4***).

The 0.5% of fiscal households belonging to the highest bracket (≥ 200,004 €/year, hence an original tax base exceeding 400,008 €/year) generate (405,658-200,004) * 0.5 = 102,827 € of income to be

22. More applications can be found in ***Liégeois (2024)***.

International Journal of Microsimulation 2025; 18(2): 94–123 DOI: https://doi.org/10.34196/ijm.00324

Table 5. [A - Upper Part] The impact of fiscal brackets (whatever the households' tax base behind) in the overall implicit tax rate on personal income for class-2 resident fiscal households (couples) – An approximation based on EUROMOD/HFCS-R ♦ [B - Lower Part] The impact of fiscal brackets (whatever the households' tax base behind) in the overall implicit tax rate on personal income for class-2 active XB fiscal households – An approximation based on EUROMOD/HFCS-XB.

Part [A] – RESIDENTS) Fiscal Bracket (in €)	**Share of Fiscal Households within the bracket, in p.p. (see Figure 4) [a]**	**Percent of Fiscal Households impacted by that bracket * [b] = [b>] + [a]**	**Mean Tax Base for that bracket [c]**	**Lower limit for that fiscal bracket (€, *yearly*) [d]**	**Income from tax payers belonging to that bracket, above the Minimum level of Fiscal Bracket [e] = [c] - [d]**	**Σ of Tax Bases impacted by that Bracket, *for 100 fiscal households* (€, *yearly*) [f] = [a] * [e] + [b>] * ([d>] - [d])**	***Approximate* Marginal Tax** Rate (+/- mean tax **rate over the bracket †) (2017 STD system) [g]**	**Income Tax from that Tax Bracket, *for 100 fiscal households* (€, *yearly*) [h] = [f] * [g]**	**% of income Tax from that Tax Bracket [i] = [h] / [k]** **and Avg % tax below =[k] / [j]**
> 0 and < 26,457	37.1	100	17,976	0	17,976	*2,330,900*	6.2%	144,944	17%
[26,457-45,897[	27	62.9	35,848	26,457	9,391	950,689	28.6%	271,611	31%
[45,897-100,002[	30.1	35.8	63,520	45,897	17,623	840,398	39.0%	327,755	38%
[100,002-150,000[	4.2	5.7	119,684	100,002	19,682	157,891	40.0%	63,156	7%
[150,000-200,004[	1	1.5	167,270	150,000	17,270	43,312	41.0%	17,758	2%
≥ 200,004	0.5	0.5	4,05,658	200,004	205,654	110,230	42.0%	46,297	5%
		Total Tax Bases [j], for 100 fiscal households ⇓						Total Tax [k]	(Avg % Tax: 19.7%)‡
			4,433,421					871,521	

Part [B] – XBs	[a]	[b]=[b>]+[a]	[c]	[d]	[e]= [c] - [d]	[f] = [a] * [e] +[b>] * ([d>] - [d])	[g]	[h] = [f] * [g]	[i] = [h] / [k] *(Avg =[k] / [j])*
> 0 and < 26,457	47.2	100	19,199	0	19,199	*2,303,022*	6.3%	144,668	35%
[26,457-45,897]	37.1	52.8	34,668	26,457	8,211	609,230	28.3%	172,392	42%
[45,897-100,002]	15.3	15.7	60,455	45,897	14,558	243,819	39.0%	95,089	23%
[100,002-150,000]	0.4	0.4	111,375	100,002	11,373	4,549	40.0%	1,820	0%
[150,000-200,004]	0	0		150,000			41.0%		
≥ 200,004	0	0		200,004			42.0%		
		Total Tax Bases [j], for 100 fiscal households ⇓						Total Tax [k]	*(Avg % Tax: 13.1%)* §
			3,160,620					*413,969*	

* [b>]" refers to the value of [b] for the fiscal bracket above the present one (e.g. [150,000-200,004[, as for bracket [100,002-150,000[)

† Approximate weighted mean tax rate over the Fiscal Bracket: for example in Part [A], "28.6%" = (([a]/100*28%) + ([b]-[a])/100*((20%+38%)/2)) / ([b]/100), where 28% is the tax rate at [c]-income and 20%/38% are the tax rates at the extremes of this fiscal bracket

‡ 20.9% on average, all fiscal classes considered for HFCS-R in 2017, including a 7% (mainly) or 9% Tax for Unemployment fund ⇒ about 19.5% without it

§ 13.8% on average, all fiscal classes considered for HFCS-XB in 2017, including a 7% (mainly) or 9% Tax for Unemployment fund ⇒ about 12.9% without it

taxed based on the highest rate (42%, [g]), for 100 fiscal households and on average, hence an income tax of 43,187 € coming from that highest bracket for 100 households (46,297 € if avoiding rounding factors).[23]

The reasoning is similar for the second highest bracket [150,000-200,004], but the sum of taxable incomes here concerned is 1.0 * (167,270-150,000) from those households belonging to the 2nd highest bracket + 0.5 * (200,004-150,000) from those households belonging to the brackets above the present one (hence here the 1st highest bracket) = 42,272 € (43,312 € in [f], without rounding errors), hence a marginal income tax from that bracket equal to 17,758 € ([h]). Going on with the lowest brackets, we finally get a total income tax of 871,521 € ([k]), which drives to an overall tax rate of 871,521 € / 4,433,421 € = 19.7%.

This general outcome may be compared to the figure shown up in ***Table 2*** and coming from the microsimulation, which is 20.9% (tax rate after tax allowances, but before tax credits). Taking into account that this latter value incorporates some participation to the unemployment fund (7% to 9%, depending on the level of gross tax base; *cf.* ***Islam et al. (2020)***, Section 2.6), our approximate value of 19.7% is not that far from the one observed for all fiscal households: 19.5%, after a rough evaluation of the contribution to the unemployment fund (cf. [‡] in ***Table 5***).[24]

A lesson to keep in mind from that exercise is that the lowest brackets play a prominent role in the accumulation of income tax. In our example, 48% of the income tax are generated through fiscal brackets below 45,897 €/year. We are specifically mentioning "fiscal bracket" and not "income bracket" as those lowest brackets are concerned with households benefitting from higher incomes as well. The first level retained here, below 26,457 €/year, yet facing the lowest marginal rate, is dealing with a large tax base, hence a return which remains appreciable (17% of the total).

Therefore, an average increase of 1 percentage point for the tax rates applicable to the fiscal brackets below 45,897 €/year would provide 4% of additional taxes from class-2 fiscal households: 1% * (2,330,900 € + 950,689 €) = 32,816 € per year for 100 fiscal households, derived from variations in [f] * [g] = [h]).

On the other side of the distribution, 7% of the tax are coming from the brackets above 150,000 €/year (*2 for original tax bases).

Table 5 *[B] (Lower Part)* is performing the same kind of approximation, but for the class-2 active XB fiscal households.[25]

Starting from the share of fiscal households across the fiscal brackets mentioned in ***Figure 4*** we are reaching a total income tax of 413,469 € in 2017 ([k] in ***Table 5***, for 100 class-2 households, on average), out of a tax base of 3,160,620 € ([j]), hence an overall implicit tax rate approximated to 13.1% for class-2 households. This is close to the 12.9% resulting from the microsimulation (roughly corrected for the unemployment fund, cf. [§] in ***Table 5***).

The conclusion is here straightforward: the distribution of incomes, more concentrated on the lower brackets for XBs, compared to residents, drive to a reduced average tax rate: 13.1% against 19.7% for residents, that is 6.6 p.p. lower. On top of this, the lowest brackets, below 45,897 € (*2), are now concentrating 77% of the income tax (48% for residents).

23. The figure "110,230 €" shown up in column [f], rather than 102,827 € roughly computed here, comes from rounding errors in presentation, "0.5" in [a] being indeed in the background "0.536".
24. Note that during this approximation exercise, we had to fix marginal tax rates for the several brackets shown up here, sometimes gathered compared to the real tax schedule. For such a bracket as [150,000-200,004], this is obvious given that this bracket is incorporated as such in the real tax schedule. For an intermediate one like [26,457-45,897], we had to combine "manually" several marginal rates (see [†] in ***Table 5***), building on the marginal rates observed, the ranges of incomes considered in the real tax schedule and the mean tax base corresponding to households belonging to that specific bracket ([c]).
25. We can mention a specificity for that population, compared to the resident one. The exercise undertaken here is based on total incomes for XBs, whatever coming from Luxembourg or from other countries, given that the tax rate is fixed on that basis by principle (and as a first approximation, probably the only one possible at this stage), before being applicable on a fiscal household level to the income originated from Luxembourg to derive the income tax due to this country specifically (see *Section 2.3*). Therefore, our reference of 13.8% mentioned below ***Table 5B*** in [§] results from the tax on total XB income and differs a little from the 14.4% reported in ***Table 2*** for XBs, valid for LU-incomes only.

4.2. The role of fiscal households in the total fiscal revenue

Let's now turn to the role of the fiscal households themselves (gathered by sub-groups, depending on their tax base) in the total funding, taking into account all the fiscal brackets these households are concerned with.

Table 6 are summarizing the exercise in the same vein as for ***Table 5***, for class-2 resident fiscal households, then active XB fiscal households. The derivation of total income taxes being more common and made explicit through the table headers, we are not detailing this path anymore.

Let's just remind that some outcomes, if directly computed from the tables as shown up here, may deviate from what is visible, due to rounded values in the presentation. For example, the second line in column [e] in ***Table 6A*** would lead, based on figures made visible in the table, to 26,457 * 7.5% = 1,984 €, and not 1,975 €. This results from the rate applicable in the background, which is 7.465% rather than 7.5% as shown up for clarity in the table. The total amount of tax could also show some differences compared to outcomes in ***Table 5***, again explained by other kinds of approximations implemented while deriving all those tables.

We can see from ***Table 6A*** that the class-2 resident fiscal households whose yearly tax base is greater than 100,002 EUR (*2), representing about 6% of the class-2 fiscal households (column [a]), are providing 33% of the total personal income tax coming from class-2 ([i]). And the tax due to the *brackets* above 100,002 EUR represents only about 14% of that total amount (***Table 5A***). This is a classical expression of the progressive nature of the personal income taxation which is also emphasized through column [j].

We are providing ***Table 6B***, dealing with class-2 active XB fiscal households (and total incomes, not limited to LU-ones), just for illustration and will not comment it.

4.3. An alternative fiscal policy

We are finally briefly illustrating that analytical framework through an application in ***Table 7*** provided for class-2 resident fiscal households.

Let's consider an alternative to the fiscal policy in force in 2017, with fiscal brackets unchanged but higher rates applied for the highest brackets: 40% over [45,897€-100,002€] (rather than 39%), 42% over [100,002-150,000] (rather than 40%), 44% over [150,000-200,004] (rather than 41%), and 46% for the bracket above 200,004€ (rather than 42%). The role of fiscal households in the total fiscal revenue is here at stake (similarly to ***Table 6***).

We derive through the ***Table 7*** an approximation of the average tax on personal income as resulting from the EUROMOD/HFCS-R framework for class-2 resident fiscal households (gathered by sub-groups, depending on their tax base). This approximation (20.2%, to be compared to 19.8% in ***Table 6A*** for the benchmark STD), despite partial compared to fiscal households taken altogether, is quite close to what is more precisely derived from the microsimulation model for all resident households: 21.4% (see [***]), downsized here to 20.0% if the unemployment fund contribution is deducted.

This represents an increase by 0.5% (21.4%-20.9%) if building on more precise microsimulation outcomes, including the contribution to the unemployment fund, 0.4% (20.2%-19.8%) through the present approximation for class-2 resident households, without the contribution to the unemployment fund.

As is expected given the nature of the alternative fiscal policy, we can see that high income households are now contributing more intensively to the whole funding than before the change. This intensity of contribution is 0.35 and 0.41 for class-2 resident fiscal households earning more than 150,000 EUR (*2) /year (***Table 7***, column [j]), rather than 0.33 and 0.38 in the benchmark STD (***Table 6B***). The progressivity of taxation is obviously reinforced through such an alternative.

The conclusions (not developed here) are qualitatively similar for class-2 active XB fiscal households. However, the effects of the alternative fiscal policy are quite lighter, in line with a distribution of gross tax base less concentrated on higher tax brackets for XBs (see ***Figure 4***). We can show that the approximate average tax rate is now 13.4%, to be compared to 13.3% in ***Table 6B*** for the benchmark STD.

Finally, ***Table 8*** is partly replicating ***Table 2*** for a more general overview of outcomes, separately for residents and for active XB households. We are not commenting here this table. Let's mention only higher total revenue and tax rates, with social contributions logically unchanged. The well-being is reduced for highest deciles (see the 9th Decile) and the reinforced progressivity of the fiscal schedule

International Journal of Microsimulation 2025; 18(2): 94–123 DOI: https://doi.org/10.34196/ijm.00324

Table 6. [A - Upper part] The impact of the fiscal households, given their tax base bracket, in the overall implicit tax rate on personal income for class-2 resident fiscal households (couples) – An approximation based on EUROMOD/HFCS-R ♦ [B - Lower Part] The impact of the fiscal households, given their tax base bracket, in the overall implicit tax rate personal income for class-2 ACTIVE XB fiscal households (couples) – An approximation based on EUROMOD/HFCS-XB.

Part [A] – RESIDENTS) **Fiscal Bracket** (in €)	**Share of Fiscal Households** within the bracket, in p.p. [a]	**Mean Tax Base for that Bracket** [b]	**Lower limit Fiscal bracket** (€, yearly) [c]	Approximate **Marginal Tax Rate if Income reaching the Upper limit of the Tax Bracket** * (2017 STD system) [d]	Tax receipt per Fiscal Household if Tax Base = lower limit of this Tax Bracket (€/year) † [e] = [e<] + [d<] * ([c] - [c<])	Tax receipt per Fiscal Household whose Tax Base lays within this Tax Bracket (€/year) [f] = [e] + [d] * ([b] - [c])	**Tax receipt for ALL Fiscal Households** whose Tax Base lays within this Tax Bracket, if considering 100 fiscal households on the whole (€/year) [g] = [a] * [f]	**% of Income Taxes from Fiscal Households belonging to this Tax Bracket** [i] = [g] / [h]	Intensity of Contribution to Personal Income Taxes [j] = [g] / ([a] * [b])
> 0 and < 26,457	37.1	17,976	0	7.5%	0	738	27,400	3%	0.04
[26,457-45,897[	27	35,848	26,457	29.0%	1,975	4,605	124,534	14%	0.13
[45,897-100,002[	30.1	63,520	45,897	39.0%	7,613	14,486	436,218	50%	0.23
[100,002-150,000[	4.2	119,684	100,002	40.0%	28,714	36,586	154,833	18%	0.31
[150,000-200,004[	1	167,270	150,000	41.0%	48,713	55,793	53,338	6%	0.33
≥ 200,004	0.5	405,658	200,004	42.0%	69,214	155,589	83,396	9%	0.38
	Total Tax Bases [k], for 100 fiscal households ⇓						**Total Tax** [h]		*(Avg % Tax: 19.8%)* ‡
		4,433,421					*879,719*		
Part [B] – XBs	[a]	[b]	[c]	[d]	[e] = [e<] + [d<] * ([c] - [c<])	[f] = [e] + [d] * ([b] - [c])	[g] = [a] * [f]	[i] = [g] / [h]	[j] = [g] / ([a] * [b])
> 0 and < 26,457	47.2	19,199	0	7.5%	0	952	44,964	11%	0.05
[26,457-45,897[	37.1	34,668	26,457	29.0%	1,975	4,274	158,632	38%	0.12
[45,897-100,002[	15.3	60,455	45,897	39.0%	7,613	13,290	202,832	48%	0.22
[100,002-150,000[	0.4	111,375	100,002	40.0%	28,714	33,263	13,305	3%	0.3
[150,000-200,004[	0		150,000	41.0%	48,713				
≥ 200,004	0		200,004	42.0%	69,214				
	Total Tax Bases [k], for 100 fiscal households ⇓						**Total Tax** [h]		*(Avg % Tax: 13.3%)* §
		3,160,620					*419,733*		

* Approximate weighted mean tax rate over the Fiscal Bracket: for example, "29.0%" = (20% + 38%) / 2

† "[c<]" refers to the value of [c] for the Fiscal Bracket below the present one (e.g. [100,002-150,000[, as for bracket [150,000-200,004[)

‡ 20.9% on average, all Fiscal Classes considered for HFCS-R in 2017, including a 7% (mainly) or 9% Tax for Unemployment fund ⇒ about 19.5% without it

§ 13.8% on average all Fiscal Classes included for HFCS-R in 2017, including a 7% (mainly) or 9% Tax for Unemployment fund ⇒ about 12.9% without it

International Journal of Microsimulation 2025; 18(2): 94–123 DOI: https://doi.org/10.34196/ijm.00324

Table 7. Amending the personal income taxes - The impact of the fiscal households, given their *tax base bracket*, in the overall implicit tax rate on personal income for class-2 resident fiscal households (couples) – An approximation based on EUROMOD/HFCS-R.

Fiscal Bracket (in €)	**Share of Fiscal Households** within the bracket, in p.p. [a]	**Mean Tax Base for that Bracket** [b]	**Lower limit Fiscal bracket** (€, yearly) [c]	Approximate **Marginal Tax Rate *if Income reaching the Upper limit of the Tax Bracket*** * (2017 STD system) [d]	Tax receipt ***per Fiscal Household* if Tax Base = *lower* limit of this Tax Bracket** (€/year) † [e] = [e<] + [d] * ([c] - [c<])	Tax receipt per Fiscal Household whose Tax Base lays within this Tax Bracket (€/year) [f] = [e] + [d] * **([b] - [c])**	**Tax receipt for ALL Fiscal Households** whose Tax Base lays **within this Tax Bracket**, if considering 100 fiscal households on total (€/year) [g] = [a] * [f]	**% of Income Taxes from Fiscal Households belonging to this Tax Bracket** [i] = [g] / [h]	**Intensity of Contribution** to Personal Income Taxes [j] = [g] / ([a] * [b])
> 0 and < 26,457	37.1	17,976	0.00	7.5%	0	738	27,400	3%	0.04
[26,457-45,897[	27.0	35,848	26,457	29.0%	1,975	4,605	124,534	14%	0.13
[45,897-100,002[	30.1	63,520	45,897	40.0%	7,613	14,662	441,525	49%	0.23
[100,002-150,000[	4.2	119,684	100,002	42.0%	29,255	37,521	158,789	18%	0.31
[150,000-200,004[	1.0	167,270	150,000	44.0%	50,254	57,852	55,307	6%	0.35
≥ 200,004	0.5	405,658	200,004	46.0%	72,255	166,856	89,435	10%	0.41
		Total Tax Bases [j], for 100 fiscal households ⇓						Total Tax [k]	*(Avg % Tax: 20.2%)* ‡
			4,433,421					*896,990*	

* Approximate weighted mean tax rate over the Fiscal Bracket: for example, "29.0%" = (20% + 38%) / 2

† "[e<]" refers to the value of [c] for the Fiscal Bracket below the present one (e.g. [100,002-150,000[, as for bracket [150,000-200,004[)

‡ 21.4% on average, all Fiscal Classes considered for HFCS-R in 2017, including a 7% (mainly) or 9% Tax for Unemployment fund ⇒ about 20.0% without it

Table 8. An overall view of the benchmark "STD" and an alternative fiscal policy for Residents and XBs (income year 2017).

		EUROMOD models (out of MACRO adjustment)			
		EUROMOD /HFCS-R		**EUROMOD/ HFCS-XB (Active households)**	
		STD	**Alternative policy**	**STD**	**Alternative policy *(LU-Incomes only)***
Population covered by the surveys		535,897		418,997	
Taxable Income, before Tax allowances (for XBs, LU-incomes only) in *millions €* / year [a + b]		**20,041**		**9,056**	
a] Covered by the surveys (for XBs, LU-incomes only)		20,041		7,947	
b] Additional amount not covered by the XB survey				1,109	
Total Public Revenue (in millions € / year)					
Social contributions [c + d]		**3,714**	**3,714**	**2,092**	**2,092**
c] Resulting from the microsimulation (based on HFCS surveys)		3,714	3,714	2,030	2,030
d] Contribution for XBs *not covered* by the HFCS-XB survey (evaluated based on b] and while hypothesizing that those persons are all retired)				62	62
Personal Income Tax [e + f]		**3,439**	**3,517**	**939**	**947**
e] Resulting from the microsimulation (based on HFCS surveys)		3,439	3,517	824	832
f] Additional tax from XBs *not covered* by the HFCS-XB survey (evaluated based on b] while hypothesizing that the tax rate applicable is the one determined for the covered households after tax credits [*])				115	
and Tax Rates					
Global Tax Rate on Tax Base, before Tax Credits, on average and through the HFCS surveys		20.9%	21.4%	14.4%	14.5%
[*] Global Tax Rate, after Tax Credits, through the HFCS surveys [e/a]		17.2%	17.5%	10.4%	10.5%
⇒ *Total Revenue*	Through the surveys, LU-incomes only for XBs [c + e] (in millions € / year)	7,153	7,231	2,855	2,862
	With macro adj., for XBs [c + d + e + f]			3,032	3,039
	General (Residents + XBs, including macro adjustment) (in millions € / year)	STD: 10,185		Alternative: 10,270	
Inequalities					
Gini				All *Incomes*	
	Relative = Absolute gap / (2*Average)	0.2993	0.2966	0.1940	0.1934
	Absolute gap, on average (in € / month)	*2,103*	*2,074*	*1,088*	*1,084*
	Average well-being (in € / month)	*3,513*	*3,496*	*2,804*	*2,802*
Poverty				All *Incomes*	
	Line (in € / month)	1,770	1,768	1,564	1,564
	Rate	13%	13%	2%	2%
"Well-being", as equivalized income (all in € / month), on average				All *Incomes*	
All		3,513	3,496	2,804	2,802
1st Decile		1,472	1,472	1,635	1,635
9th Decile		4,943	4,923	3,820	3,816

evoked earlier is driving to lower inequalities (Gini). However, the poverty line and rate are quite stable, under such a change in fiscal policy affecting the highest income brackets. The XBs being less represented in those higher levels of gross incomes (see Table 9 ***Figure 4***) are also marginally affected only by the change.

5. Conclusions

This document is based on the desire of the *Chambre des Salariés du Luxembourg*/CSL to benefit from an additional and innovative tool for analysing the distributive aspects and total public financial revenue resulting from alternative socio-fiscal policies in place or to be designed. This implies taking into account as far as possible the non-linearity of socio-fiscal systems and the precise structure of populations, hence the need for microsimulation modelling of both residents and cross-border commuter households.

The cross-border commuter population plays a more important role in Luxembourg (and on public finance) than in most other developed countries, and is therefore definitely worth incorporating. The new light shed on Luxembourg by this article required the updating of an older version of a EUROMOD model using HFCS microdata for the resident population and the creation of a new model for cross-border commuters. The constraints inherent in microdata led us to opt for 2017 (year of income) as the year of analysis for this document.

Given the important structural differences between resident and cross-border commuter households in terms of socio-economic status as well as gross labor income and taxable incomes, we show and explain why total revenues from residents are higher than those from cross-border commuter households, even when the relative sizes of the two populations are taken into account. For the same reason, a change in the socio-fiscal system of policies in Luxembourg could have remarkably different effects between cross-border commuters and residents.

In considering the tools used in this paper and some of the results of the analysis, the reader should keep in mind some aspects.

Firstly, the models developed here do not address non-parametric tracks which, for example, would change the nature of the income taken into account for calculating social security contributions or taxes (consumption would be such another basis). Sologon *et al.* (2023-2026) and the EUROMOD network as a whole (but only for residents, as far as the latter is concerned) are currently developing ways of taking into account other sources of tax such as consumption in a complementary manner.

Second and as is well known, some changes in socio-fiscal policies that can be addressed through the current modelling environment could lead us to a real world that deviates from our restricted (so-called "static") analytical framework. A significant increase in social security contributions would have an impact on the cost of labor and more generally on the partial equilibrium of the labor market. The results of the models developed here should therefore be seen as a first exploration of the immediate underlying implications in terms of the distribution of household disposable income and total public financial revenues. These might also be completed through a micro-macro linkage.

More significant changes may also raise concerns about the general equilibrium implications (for example at the level of public interventions made possible downstream thanks to new budget revenues) and the feasibility of reforms in political terms, not to mention longer-term dynamic expectations (in terms of population, migration, labor, etc.).

However, all these relevant questions were clearly outside the scope of this initial request from the CSL, the main motivation of which was to provide a toolbox allowing to have an immediate overview of the possibilities and to open up avenues for further reforms and analyses.

Building on the current apparatus, alternative socio-economic policies have already been examined for several months by the CSL, with an interest in new possible avenues for financing social security in Luxembourg, while involving all the populations concerned, including cross-border workers, and keeping in mind possible feedback effects. This makes it possible to clarify the priorities and select the preferred avenues.

Moreover, we can nowadays observe that these indicative results might serve as a starting information set for longer-term explorations (including through dynamic microsimulations, cf. ***Liégeois and Genevois, 2015***), in particular in the context of a reform of pension rules currently under debate in Luxembourg.

We hope that this document will respond to the concerns of stakeholders for more transparency in data processing and model construction, while allowing a greater number of professionals to have access to an overview, a need reminded for example by ***Blond-Hanten and Thomas (2014)*** for Luxembourg.

ORCID iD
Philippe Liégeois https://orcid.org/0000-0003-2329-5609

Acknowledgements

The research presented in this paper is part of a study initiated and financed by the Chambre des Salariés du Luxembourg (CSL). Numerous exchanges with experts (social partners) enabled us to provide an approach more in line with the questions and final expectations of our usual public targets. Yet the present paper mentioning Philippe Liégeois as sole author, its outcomes result from a larger network.The developments presented here are initially based on the model EUROMOD/SILC version I4.62+ Beta release (3.4.10). Originally maintained, developed and managed by the Institute for Social and Economic Research (ISER), since 2021 EUROMOD is maintained (with regard to resident populations), developed and managed by the Joint Research Centre (JRC) of the European Commission in Seville, in collaboration with EUROSTAT and national teams from the EU countries (including LISER for Luxembourg).The EUROMOD/HFCS-R model is building on the same core version as EUROMOD/SILC, yet running on HFCS data rather, and was developed for its base versions (socio-fiscal policies up to 2017) by Jonas Boone, Johannes Derboven, Sarah Kuypers and Gerlinde Verbist, from the University of Antwerp, together with Francesco Figari, from the Università degli studi del Piemonte orientale. An extension to the new EUROMOD/HFCS-XB model, involving microdata related to cross-borders for Luxembourg, has been set up by Johannes Derboven, in collaboration with Philippe Liégeois. A specific documentation for extending EUROMOD/HFCS-XB to all cross-borders, through macro adjustments, was also gathered by Anasse El Maslohi, from LISER. Even if HFCS results from a European-wide effort, Michael Ziegelmeyer from the Banque Centrale du Luxembourg, and Carla Martins from LISER, more specifically but among many others, have indirectly supported the present study through their expertise in those data for Luxembourg.
We are also grateful to the editor of the International Journal of Microsimulation and two anonymous referees for many stimulating suggestions. Obviously and meanwhile, the results developed here and their interpretation are the author's sole responsibility at this stage.

Funding

This research was carried out as part of the project "Alternative Ways for Funding the Luxembourgish social security system, with distributional effects » (2022-2023) funded by the Chambre des Salariés du Luxembourg/CSL under agreement dated 18 July 2022.

Conflict of Interest

No competing interests reported.

Data and code availability

The analysis builds on data from [i] the "European Union Statistics on Income and Living Conditions" (EU-SILC) survey Wave 16, available for scientific research upon request to EUROSTAT, [ii] the third wave of the Eurosystem Household Finance and Consumption Survey (HFCS) for residents, available for scientific research upon request to the European Central Bank, [iii] the third wave of the Luxembourg Household Finance and Consumption Survey for Cross-Border Commuters (for access requests, contact the Luxembourg Institute of Socio-Economic Research at dataservice@liser.lu or marc.schneider@liser.lu) and [iv] the EU-wide micro-simulation model EUROMOD (I4.62+ Beta release / 3.4.10) available upon request to the EU-Joint Research Center in Seville. Details of STATA routines for the creation of the EUROMOD input datasets from HFCS raw data and specific policy codes are available from the author upon request.

References

Ballas D, Rossiter D, Thomas B, Clarke G, Dorling D. 2005. *Geography Matters. Simulating the Local Impacts of National Social Policies*. York: Joseph Rowntree Foundation.

Bayenet B, Capron H, Liégeois P (Eds). 2007. *L'espace Wallonie-Bruxelles. Voyage Au Bout de La Belgique*. Bruxelles : De Boeck.

Blond-Hanten C, Thomas A. 2014. [Stakeholders and expertise: obstacles, expectations and dissemination]. Work Package D of the Progress Project MiDLAS. LISER.

Burlacu IS, O'Donoghue C. 2012. [Differential Welfare State Impacts for Frontier Working Age Families]. IZA Discussion Paper No 6734. Bonn: IZA.

Chen Y, Mathä TY, Pulina G, Schuster B, Ziegelmeyer M. 2020. The Luxembourg Household Finance Consumption Survey: Results from the third wave. [BCL working papers 142].

Chen Y, Mathä TY, Pulina G, Ziegelmeyer M. 2021. The Luxembourg Household Finance Consumption Survey: Results from the third wave. [BCL working papers 154].

Clarke GP (Ed). 1996. *Microsimulation for Urban and Regional Policy Analysis*. Pion.

Clément F, Belkacem R, Pigeron-Piroth I, Wille C (Eds). 2023. *Le Travail Frontalier En Europe / Cross-Border Work in Europe - Réalités et Défis / Realities and Challenges*. Larcier - Luxembourg.

Decoville A, Durand F, Feltgen V. 2015. [Opportunities of cross-border cooperation between small and medium cities in Europe]. Luxembourg: Ministère du développent durable, Département de l'aménagement du territoire.

Drevon G, Gerber P, Klein O, Enaux C. 2018. Measuring Functional Integration by Identifying the Trip Chains and the Profiles of Cross-Border Workers: Empirical Evidences from Luxembourg. *Journal of Borderlands Studies* **33**: 549–568. DOI: https://doi.org/10.1080/08865655.2016.1257362

Edzes AJE, van Dijk J, Broersma L. 2022. Does cross-border commuting between EU-countries reduce inequality? *Applied Geography* **139**: 102639. DOI: https://doi.org/10.1016/j.apgeog.2022.102639

Farrell N, Morrissey K, O'Donoghue C. 2013. Creating a spatial microsimulation model of the Irish local economy. Tanton R, Edwards K (Eds). *Spatial Microsimulation: A Reference Guide for Users*. Dordrecht: Springer. DOI: https://doi.org/10.1007/978-94-007-4623-7_7

Household Finance and Consumption Network. 2020. [Household Finance and Consumption Survey: Methodological report for the 2017 wave]. ECB Statistics Paper, N°35.

Islam N, El Maslohi A, Genevois A-So. 2020. EUROMOD Country Report for Luxembourg, 2017-2020. LISER and University of Essex. https://euromod-web.jrc.ec.europa.eu/resources/country-reports/f3-onwards/I30plus

Kuypers S, Figari F, Verbist G. 2016. The Eurosystem Household Finance and Consumption Survey: A New Underlying Database for EUROMOD. *International Journal of Microsimulation* **9**: 35–65. DOI: https://doi.org/10.34196/ijm.00142

Kuypers S, Boone J, Derboven J, Figari F, Verbist G. 2020. Enhancing microsimulation analysis of wealth-related policies in EUROMOD. *International Journal of Microsimulation* **13**: 5–26. DOI: https://doi.org/10.34196/IJM.00223

Liégeois P, Berger F, Islam N, Wagener R. 2011. Cross-validating administrative and survey datasets through microsimulation. *International Journal of Microsimulation* **4**: 54–71. DOI: https://doi.org/10.34196/ijm.00045

Liégeois P, Genevois A-S. 2015. [LuDMi– Dynamic Microsimulation Model for Luxembourg]. Technical report. EU-PROGRESS MiDLAS Project (2013-2015), 81 pages (LISER).

Liégeois P. 2023a. Alternative Ways for Funding the Luxembourgish social security system, with distributional effects – Final Report involving both LU-Residents and Cross-border Households analyzed using Static EUROMOD HFCS-based Models. . LISER and CSL, mimeo, confidential.

Liégeois P. 2023b. Financement du système de sécurité sociale luxembourgeois – Analyse statique exploratoire de pistes alternatives, avec effets redistributifs, impliquant à la fois les ménages résidents et frontaliers – Modèles EUROMOD/HFCS – Synthèse pour un public élargi. [LISER, CSL and partners, mimeo (confidential].

Liégeois P. 2024. Dealing with complexity when assessing alternative systems for financing social security in Luxembourg, taking into account cross-border households and distributional aspects. [LISER and CSL, mimeo, confidential].

Mathä TY, Porpiglia A, Ziegelmeyer M. 2018. Wealth differences across borders and the effect of real estate price dynamics: Evidence from two household surveys. *Journal of Income Distribution®* **26**: 1–35. DOI: https://doi.org/10.25071/1874-6322.40360

Ochmann R, Blömer M, Haan P, Müller K-U, Tomasch E. 2014. Studie zu alternativen Finanzierungsansätzen für die Sozialversicherungssysteme Luxemburgs", Deutsches Institut für Wirtschaftsforschung (DIW Berlin). https://www.csl.lu/app/uploads/2021/02/2014-04-01_diw-finanzierungsansatze-2.-endbericht.pdf

O'Donoghue C, Morrissey K, Lennon J. 2014. Spatial Microsimulation Modelling: a Review of Applications and Methodological Choices. *International Journal of Microsimulation* **7**: 26–75. DOI: https://doi.org/10.34196/ijm.00093

OECD. 2023. OECD Data Explorer. http://stats.oecd.org/Index.aspx

Sologon DM, Van Kerm P, Li J, O'Donoghue C. 2021. Accounting for differences in income inequality across countries: tax-benefit policy, labour market structure, returns and demographics. *The Journal of Economic Inequality* **19**: 13–43. DOI: https://doi.org/10.1007/s10888-020-09454-7

Sologon DM, O'Donoghue C, Andreoli F, Gerber P, Licheron J, Montes Vinas A, Paccoud A. 2023-2026. Spatial Economics of Income Distribution Across Borders: Drivers of Spatial Inequalities Using Microsimulation. LISER

(on-going project). https://liser.elsevierpure.com/fr/projects/spatial-economics-of-income-distribution-across-borders-drivers-o

STATEC. 2019. *Le Luxembourg En Chiffres*. Statistiques.lu : le portail des statistiques. https://statistiques.public.lu/fr/publications/series/luxembourg-en-chiffres/2019/luxembourg-en-chiffres.html

STATEC. 2023. *Le Luxembourg En Chiffres*. Statistiques.lu : le portail des statistiques. https://statistiques.public.lu/fr/publications/series/luxembourg-en-chiffres/2023/luxembourg-en-chiffres-2023.html

Sutherland H, Figari F. 2013 EUROMOD: the European Union tax-benefit microsimulation model. *International Journal of Microsimulation* **6**: 4–26. DOI: https://doi.org/10.34196/ijm.00075

Tanton R. 2014 A Review of Spatial Microsimulation Methods. *International Journal of Microsimulation* **7**: 4–25. DOI: https://doi.org/10.34196/ijm.00092

Van der Valk J. 2018. Border region data collection – Final report. Brussels: European Commission. Directorate-General for Regional and Urban Policy.

Vergnat V, D'Ambrosio C, Liégeois P. 2022. The Distributive Impact of the Luxembourg Tax-Benefit System: A More Comprehensive Measurement. *Public Finance Review* **50**: 436–483. DOI: https://doi.org/10.1177/10911421221113842

Appendix A

Imputing missing information in HFCS-XB

Some information is missing in the second wave of HFCS-XB (income year 2017), compared to HFCS-R and what seems necessary for the microsimulation exercise. The present Appendix is summarizing the imputations resulting from such missing variables.

Logically, a household member's labor income (which is not separated between employment or self-employed income in HFCS-XB), if this person is by elsewhere identified as an employee (resp. self-employed), is considered as employment income "yem" (resp. "yse"). Other income variables were imputed based on averages derived from the resident population, or even simply set to "0" if either limited in size or when no relevant information is available by elsewhere.

Table A1. Final imputations in HFCS-XB, *ex ante* EUROMOD.

EUROMOD Variable		Imputation		Origin **(in % of total)**		
Name	***Content***	***in % of (yem + yse) at household level***	***if another base***	***From LU***	***From ABROAD***	Remarks
poa	Old-age Pension	20.3% if 1 pensioner in the household, 42.5% for *each* pensioner if more than 1, and 0.2% if no pensioner		0	100%	0.2% if no pensioner preferred to "0", in conformity to HFCS-R
psu	Survival Pension		0	0	0	Incorporated in the imputation of "poa"
xmp	Maintenance payment		0	0	0	Lower amounts
yiy	Investment income	1.9%		In conformity with proportions in HXG0100*x* (total gross household income, separated based on its origins, LU *versus* other countries altogether)		May come from LU or other capital investments
yot	Other income by children < 16	1.3%		0	100%	Mainly from children, hence from "home"
ypp	Private pension		0	0	0	Lower amounts (in LU !)
ypr	Property income	4.1%		0	100%	"Properties" supposed from ABROAD

Departing from those simple treatments, a more sophisticated imputation is implemented for pension incomes, which are not reported as such in HFCS-XB.[26] We remind that those pensioners are not that numerous in HFCS-XB which are targeting active XB households. If a household member is identified as a retired person, we attribute to this inactive person an amount of pension income in proportion of the total work income in the household. Those proportions are those observed for the resident population (HFCS-R), in households with working members, and depending on the number of pensioners in the residence household.

Finally, a decision about the share of incomes coming from LU-sources and from other countries has to be made.

26. A priori, the HFCS "HXG0100*x*" variables (total gross household income, all sources) could serve as a basis for deriving some information related to pension incomes. However, many inconsistencies were observed between those variables and incomes derived separately from several sources during the same survey, hence the choice to not build on HXG0100x at that level.

Table A1 is summarizing the adaptations undertaken to complete the HFCS-XB original survey data with information relevant for microsimulation and the objective of our study.

Additionally, in particular with regard to the demographic structure of the databases (age, education, ...), the reader can refer to other available documentation.[27]

27. ***Islam et al. (2020)*** for some information about the data with regard to the EUROMOD/SILC model, for HFCS-R data, ***Chen et al. (2021)*** for HFCS-XB, all for Luxembourg. For EUROMOD/HFCS-R more generally (2nd Wave), the reader can refer to ***Kuypers et al. (2016)*** and for HFCS-R, see also "Household Finance and Consumption Network" (2020).

Appendix B

Consolidating Macro Outcomes for XBs uncovered by the HFCS-XB survey

Leaving aside those XB households which do not presently involve any active worker in Luxembourg may reduce the total public revenue due to Luxembourg, compared to what has been identified up to now, whatever in terms of social contributions or personal income taxes ignored.

We show now how, building on outcomes from the EUROMOD/HFCS-R and EUROMOD/HFCS-XB platforms, we choose to roughly complete the picture to add to social contributions and personal income taxes revenue from those XB households ignored up to now, what we call a "macro adjustment". ***Table B1*** (for social contributions), ***Table B2*** (for the income tax) and ***Table B3*** (for the global consolidation) are summarizing the point.

Table B1 is first consolidating outcomes in relation with social contributions (*section [C]*). The first column on left is mentioning references ([I], [II], ...) that may be used later on in the computations. Percentages are emphasized through specific markers: [%1], [%2], ... An intermediate column is complementarily explaining the details of the computations undertaken.

We complete the information collected up to now in a structured way: *[C.1]* is consolidating past results, *[C.2]* is completing for uncovered XB households through macro adjustments and *[C.3]* is summing up outcomes for social contributions.

[C.1] is reminding past results (see ***Table 2***): 3.71 billion € have been identified for social contributions from residents through the EUROMOD/HFCS microsimulation, on top of 2.03 billion € from active XB households, that is 5.75 billion € on total in 2017 (reference "*[IV]*", also referred to as *[SC/HFCS+]*, "+" for underlying the contents in terms of aggregation between resident and active XB outcomes).

[C.2] is hypothesizing that XB households not covered by the HFCS-XB survey, yet having a socio-fiscal link with Luxembourg, are mainly composed of pensioners (hypothesis H2 – for the notation, see *Section 2* and H1 regarding bilateral fiscal agreements). If considering that pensions received by the retired members of the XB active households are coming from countries out of Luxembourg (a strong but maybe sole possible positioning and approximation in a first step, H3), the pensions going to otherwise uncovered pensioners correspond to what Luxembourg is offering as pensions to all XBs. Those are approximatively evaluated as 1.11 billion € in 2017 (*[V]*, source: IGSS and author's computation) and give rise to the payment of social contributions for health in-kind at the level of 2.8% (*2, taking into account personal contributions and credited ones H4), that is 62 million € additional (*[VI]*).

On the whole, *[C.3]* is concluding that total social contributions paid to Luxembourg amount to 5.81 billion €, based on EUROMOD/HFCS data and microsimulation platforms, our hypotheses Hx and a final macro adjustment (*[SC/HFCS++]*, "++" for underlying the contents in terms of aggregation between resident and *all* XB households).

Table B1. Macro adjusting outcomes for dealing with missing XB households, uncovered up to now through the EUROMOD/HFCS (and SILC) data and platforms – Social contributions.

C] SOCIAL CONTRIBUTIONS				
Reference	Component		Computation information	Value *(in Millions €/year or %)*
[I]	From model platforms (cf. ***Table 2***)	SILC (Social contributions)		3,914
[II]		HFCS-R (Social contributions)		3,714
		⇒ HFCS-R [II], in % of SILC [I]	= [II] / [I]	94.9%
[III]		HFCS-XB (Social contributions for Active households & LU-incomes only)		2,030
[%1]		⇒ HFCS-XB [III[, in % of HFCS-R [II]	= [III] / [II]	54.7%
[SC/HFCS+] == [IV]	⇒ **C.1]** Social contributions for **populations covered through** HFCS-R & XB **surveys**		= [II] + [III]	5,745
[SC/SILC+]	Alternatively, Residents/SILC + XBs in % of SILC		= [I] * (1 + [%1])	6,054
		⇒ *[SC/HFCS+], in % of [SC/SILC+]*		94.9%
	C.2] MACRO Correction for Social Contributions from gross income from **XBs not covered by the HFCS/XB survey**			
[V]	**Additional gross LU-income from XBs not covered by the HFCS/XB survey**, based on Pensions paid to XBs from Luxembourg in 2017 (considered as the LU-taxable income for that sub-population), whereas Pensions received by XBs covered by the HFCS survey are considered as from foreign origin only			1,109
[VI]	⇒ Additional contribution for XBs not covered by HFCS surveys (considering 2.8% * 2 of contributions for Health In-Kind, as for pensioners)		= [V] * 5.6%	62
[%2]	⇒ Total Social Contributions from XBs, *in % of SC from RESIDENTS*		= ([III] + [VI]) / [II]	56.3%
[SC/HFCS++]	⇒ **C.3] TOTAL SOCIAL CONTRIBUTIONS**, if considering All XBs, including those not covered by the HFCS/XB survey on top *(based on HFCS)*		= [IV] + [VI] = [II] + [III] + [VI]	**5,807**
	Alternatively, if based on SILC, completed by HFCS data for XBs		= [I] * (1 + [%2])	6,120

As a matter of validation, we might compare this amount to external statistics, like from OECD (tax revenue in 2017, "*2000 Social security contributions*": 6.13 billion €), but it appears extremely difficult to find external sources fully comparable to what has been taken into account in the present data and microsimulation platforms.[28] Therefore, and for the time being, we refer to this reference as an indication that our simulation outcomes do not seem too far from the "real" world (5.81/6.13=95%) and might be a good basis for the analysis of *changes* in the of socio-fiscal system of policies. Other experiments to validate microsimulation models sometimes show much larger differences (see ***Islam et al., 2020***, Annex 2, for EUROMOD/SILC).

The next step is dealing with adjustments of the total personal income taxes (*section [T], **Table B2***). Still, the task is divided into 3 steps.

28. ***OECD (2023)***.

Table B2. Macro adjusting outcomes – Personal income taxes.

T] PERSONAL INCOME TAX (as for LU-Incomes, unless otherwise mentioned)				
Reference	Component		Computation information	Value *(in Millions €/ year or %)*
[VII]	From model platforms (cf. ***Table 2***)	SILC (Personal Income Tax)		3,289
[VIII]		HFCS-R (Personal Inc Tax)		3,439
		⇒ HFCS-R, in % of SILC	= [VIII] / [VII]	105%
[IX]		HFCS-XB (Personal Income Tax for Active households & LU-incomes only)		824
[%3]	⇒ HFCS-XB, in % of HFCS-R		= [IX] / [VIII]	24%
[TAX/HFCS+]	⇒ **T.1]** Personal Income Taxes for **populations covered through** HFCS-R & XB **surveys**		= [VIII] + [IX]	4,263
[TAX/SILC+]	Alternatively, Residents/SILC + XBs in % of SILC		= [VII] * (1 + [%3])	4,077
		⇒ *[TAX/HFCS+] in % of [TAX/SILC+]*		104.6%
	T.2] MACRO Correction for Personal Income Tax from gross income of XBs not covered by the HFCS/XB survey			
[X]	T.2.1] Total Taxable Income of HFCS-XBs (covered by the survey, LU-Incomes only), before Tax Allowances		= EUROMOD variable "tinty_lu_s" (on average) * 12 * HFCS-XBs Population in 2017 / 1,000,000	7,947
[XI]	Total Tax Allowances for XBs/HFCS (LU-incomes)		= EUROMOD variable "tinta_lu_s" (on average) * 12 * HFCS-XBs Population in 2017 / 1,000,000	1,627
[XII]	Income Tax for HFCS-XBs *before* Tax credits (LU-Incomes)		= "tin_lu_s" (/ year & for whole covered population)	911
[XIII]	⇒ Implicit Tax Rate on Tax Base for HFCS-XBs, *before* Tax Credits		= [XII] / ([X] - [XI])	14.4%
[XIV]	Total Tax Credits for HFCS-XBs		= [XII] - [IX]	87
[%4]	⇒ HFCS-XBs' Global Tax on Taxable Income, *after* Tax Credits, LU-Incomes only		= [IX] / [X]	10.4%
	T.2.2] Additional gross income from XBs *not covered by the HFCS/XB survey*, based on Pensions paid to XBs from Luxembourg in 2017		[V]	1,109
[XV]	⇒ **Total Tax on Income for XB households not covered by the HFCS/XB survey**, *if Residents' average rate [%4] applied*		= [V] * [%4]	115
[XVI]	& Equivalent computation taking into account Tax Allowances and Tax Credits		= ([V] - [XI] * [V]/[X]) * [XIII] - ([XIV] * [V]/[X])	115
[%5]	⇒ Total *Income Tax from ALL XBs*, in % of Tax from RESIDENTS		= ([IX] + [XV]) / [VIII]	27.3%
[TAX/ HFCS++]	⇒**T.3] TOTAL TAXES**, if considering All XBs, including those not covered by the HFCS/XB survey on top		= [TAX/HFCS+] + [XV]	**4,378**

[T.1] is gathering previous outcomes (see ***Table 2***) and conducting to a total of 4.26 billion € in 2017 (*[TAX/HFCS+]*).

The macro adjustment, in *[T.2]* is more demanding. *[T.2.1]* is first reminding several indicators, including the average global tax after tax credits (10.4%), which are consistent with ***Table 2***. Then, *[T.2.2]* is starting from additional gross income attributed to the uncovered XBs (the same amount *[V]* as for social contributions, H5) and considering that income taxes for that sub-group might correspond, on average, to the ones derived for the covered XBs (another strong hypothesis, H6), that is here 10.4% * 1,109 million € = 115 million € additional (*[XV]*).

Finally, *[T.3]* is summing up those results, leading to a total amount of personal income taxes from (all) XBs equal to 4.38 billion € (*[TAX/HFCS++]*).

As a matter of validation, we might compare this amount to external statistics, like from OECD (tax revenue in 2017, "*1100 Taxes on income, profits and capital gains of individuals*": 5.06 billion €), but it appears here again to be extremely difficult to find external sources fully comparable to what has been taken into account in the present data and microsimulation platforms.[29] For the time being, we refer to this reference as an indication that our simulation outcomes do not seem fully out of the scene (4.38/5.06 = 87%) compared to what can be commonly achieved through microsimulation. Anyway, this might also be a good basis for the analysis of changes in the of socio-fiscal system of policies, coming next.

All those considerations lead, in *section [R]* of ***Table B3***, to total revenue from social contributions and personal income taxes amounting to 10.19 billion € (*[TOT/HFCS++]*), as derived from EUROMOD/HFCS-R, EUROMOD/HFCS-XB, macro adjustments and author's working hypotheses H1 to H6. This amount corresponds to 10.19 / (6.13 + 5.06) = 91% of (supposed) comparable external sources.

Table B3. Macro adjusting outcomes for dealing with missing XB households, uncovered up to now through EUROMOD/HFCS – overall consolidation.

R] TOTAL PUBLIC REVENUE: SOCIAL CONTRIBTIONS and PERSONAL INCOME TAXES **as for LU accounts (hence from LU Incomes) & including ALL Cross-border households (whatever active or not) & Residents**			
Reference	Component	Computational information	Value *(in Millions €/year or %)*
[TOT/ HFCS++]	Total Public Revenue from Residents/HFCS + ALL XBs, if through HFCS data and models	= [SC/HFCS++] + [TAX/ HFCS++]	10,185
[TOT/ SILC++]	Alternatively, Residents/ SILC + ALL Cross-Borders considered through an additional % (derived from HFCS)	= [I] * (1 + [%2]) + [VII] * (1+ [%5])	10,307
	⇒ *[TOT/HFCS++] in % of [TOT/SILC++]*		98.8%

We conclude this *Appendix* by mentioning that we could have opted for another strategy for the derivation of total public revenue: working basically with EUROMOD/SILC, computing from EUROMOD/HFCS platforms ratios between XB outcomes and the ones for residents, when relevant, and applying those ratios to EUROMOD/SILC results for deriving total amounts. This approach has been implemented in *Tables B*. It leads to a total amount of 10.31 billion € (*[TOT/SILC++]*), rather than 10.19 billion € mentioned earlier. Those outcomes are remarkably close each other (a 1.2%-gap).

29. ***Islam et al. (2020)***, *Section 4* for classical validation outcomes of EUROMOD/SILC.