Accounting for Changes in the Distribution of Household Income by its Sources

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Abstract
We develop a copula-based decomposition method to account for changes in the distribution of disposable income between two points in time. This method allows us to explore how changes in the marginal distributions of different income components and their dependence structure affect the distribution of total disposable household income over time. The method consists in constructing a counterfactual distribution of total disposable income for the case where the distribution of a given income component (or several of them) had remained unchanged between the initial and the final period. The difference between the actual and counterfactual distributions can then be assigned to the effect of changes in corresponding income components. The method also makes it possible to integrate higher order interactions and accommodate changes in covariates. We present an application of the proposed methodology to explain the change in the income distribution in Luxembourg between 1987 and 2010.

Keywords: temporal changes in income distribution; copula-based decomposition; income components

JEL classification codes: D31 ; D33 ; C14.

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1. Introduction

Many industrialized countries have experienced sharp changes in the distribution of total household income over recent decades (OECD, 2011). Widening the gap between low-income and high-income families, they have resulted in the rise of income inequality, poverty and polarization indexes. Inspection of household income sources is useful to understand factors behind these changes. Analysing the relative importance of various income sources, such as earnings, capital income, social transfers or taxes helps to uncover the contribution of each source towards the level and dispersion of total income in the society as well as to identify the main drivers of their evolution over time. This approach has a long history (see, e.g. Shorrocks (1982), Lerman and Yitzhaki (1985)) and has been used recently, for instance, by Larrimore (2013) to assess the extent to which the growth in inequality in the United States since the late 1970s has been affected by changes in earnings, employment or mating behaviour, or by García-Peñalosa and Orgiazzi (2013) to analyse the relative importance of the changes in market income, taxes and transfers in the evolution of inequality over three decades in six different high-income countries.

Most of the existing menagerie of analytical methods for the analysis of income sources is limited to particular ad hoc indices of inequality (Jenkins and Van Kerm, 2009).[1] Given that household disposable income is the sum of a set of income components (e.g. pre-tax income sources as well as social security transfers, taxes and social insurance contributions), this approach consists in assessing the contribution of each income source to overall inequality. According to Sastre and Trannoy (2002), the traditional approach to the decomposition of inequality by factors can take two forms. Within what they refer to as the 'global methods', the contribution of each source is computed for all pre-determined components and the sum of these contributions add up to the inequality to be explained. Examples of such methods are Shorrocks (1982)'s decomposition rule or Lerman and Yitzhaki (1985)'s decomposition method. By contrast, in the context of 'local methods', the contribution of one specific income source is computed using a before/after calculation: each source contribution is then equal to the difference between overall inequality and the inequality obtained when the income component is not taken into account (see among other, Cowell and Jenkins (1995), Jenkins (1995), Cancian and Reed (1998), Burtless (1999), Fuest

[1] Note, however, that a method of decomposition by income source for the Sen index of poverty was proposed by Mussard and Pi Alperin (2011) and for the indexes of polarization by Araar (2008) and Deutsch et al. (2013).

et al. (2010) for various applications and Lerman (1999) or Mussard (2007) for reviews of this literature).

'Global' and 'local' methods share some limits. First, these methods focus on specific distributional measures providing little evidence about changes that occur along the income distribution. In some cases, however, it might be important to know what happens where in the distribution. For example, the distribution might become more unequal over time because of the increased dispersion in its upper tail, lower tail or both. Second, focus on specific summary measures makes these methods dependent on the index chosen: Shorrocks (1982) relies on the square of the coefficient of variation while Lerman and Yitzhaki (1985) rely on the Gini coefficient. Contribution of income components to the overall inequality may then be sensitive to the index used.

Investigating the possibility of finding a method allowing to decompose the change in the income distribution by income sources while not being limited to the decomposition of a specific summary measure is therefore of interest. Most available density decomposition techniques focus on the evaluation of the effects of compositional shifts in the population structure on the overall change in earnings (DiNardo et al., 1996; Rothe, 2012) or total income distribution (Biewen and Juhasz, 2012; Peichl et al., 2012).[2]

In the framework of inequality, Jenkins and Van Kerm (2005) propose a formal non-parametric method to decompose the overall change in the income distribution by population subgroups using the density function. In a similar spirit, Fournier (2001), Daly and Valletta (2006), Fiorio (2011) and Larrimore (2013) decompose changes in total income distribution by income sources. Building on the work of Burtless (1999), they use rank-preserving exchange to account how shifts in marginal distributions of different income components have affected the distribution of total income between two points in time.[3] The main limitation of these studies is that they do not explicitly account for interrelationship between different income components. The latter is especially important in the decomposition framework (Rothe, 2012; Biewen, 2013) providing the only way to identify unique contributions of different factors to the overall change in the outcome of interest.

[2] Apart from the mentioned semi-parametric decomposition methods, there is a stream in the literature which uses regression-based techniques to decompose changes in the total income distribution over time (see Hyslop & Mare, 2005; Cowell and Fiorio, 2011). The main limitation of these techniques is that they heavily rely on parametric assumptions and, hence, are prone to misspecification bias.

[3] The method foresees construction of the counterfactual income distribution by assigning to individuals with certain ranks in one period incomes to which their ranks would entitle them in another period.

In this paper we implement a decomposition method which allows us to explore how changes in the marginal distributions of different income components and their dependence structure underlie the distribution of total disposable household income over time. The method takes advantage of the copula representation of the joint distribution of income components making it possible to construct a set of counterfactual distributions of total disposable income which would have prevailed if the marginal distributions of various income components or their dependence structure had remained unchanged between two points in time. The difference between the actual and counterfactual distributions can then be assigned to the contribution of corresponding income components (or the dependence structure between them) to the overall change in the distribution of disposable income.

Our method extends the works of Burtless (1999), Fournier (2001), Fiorio (2011) and Larrimore (2013) in several ways. First of all, it provides a formal framework for flexible semi-parametric decomposition of temporal changes in income distribution. Along with the effects induced by changes in marginal distributions of different income components, it also makes it possible to account for statistical and rank correlations between these components and therefore isolate their contributions to the overall change in income distribution. This provides a formal solution to the problem of 'sharing rule' stressed by Shorrocks (1982) which arises when income components are correlated with each other.[4] Second, our decomposition method provides a formalized framework for combining individual attributes and income source decomposition. Building on the definition of conditional copula and re-weighting procedure proposed by DiNardo, Fortin and Lemieux (1996), it allows us to identify changes in marginal distribution of income components within different population subgroups and evaluate how changes in the population structure affect income distribution over time.

We apply the proposed methodology to explain the change in the income distribution in Luxembourg between 1987 and 2010, using the Luxembourg socio-economic panel 'Liewen zu Lëtzebuerg'. Over the past 25 years, Luxembourg has experienced a remarkable growth based primarily on the flourishing of the financial sector, together with other service activities such as information and communication technologies (STATEC, 2003). This high economic growth, as well as the presence of an efficient redistribution system, induced an

[4] This issue is especially relevant for the income components representing earnings of household heads and their spouses. These two components are usually found highly correlated and there is also documented evidence that an increase in their correlation has resulted into substantial shifts in the distribution of total household income in a number of countries (see, for example, Burtless (1999), Fournier (2001) and Larrimore (2013)).

improvement of the overall living standards of the resident population between the mid-1980s and 2010 (Osier, 2012). However, following the trend of other developed countries, during the same period of time the distribution of total disposable income became more spread and shifted to the right resulting in higher inequality and poverty rates in the country (Fusco et al., 2013). This evidence makes Luxembourg an interesting case to study, since alongside the rising dispersion of incomes, levels of living have increased substantially. Henceforth, we explore how compositional shifts in different income components (labor, capital, transfer income etc.) have affected the distribution of total household income and its summary measures over time. One striking feature of Luxembourg is the massive inflow of skilled migrants in the recent decades. Such a change in the structure of the migrant population is likely to have contributed to the evolution of the income distribution and will be incorporated in our analysis.

The paper is structured as follows. Section 2 presents the proposed decomposition methodology while Section 3 describes data used for its empirical application. Section 4 summarizes the changes in the distribution of total disposable income and its components in Luxembourg between 1987 and 2010. Section 5 provides the results of the decomposition exercise and Section 6 concludes.

2. A copula based decomposition approach

The proposed decomposition approach builds on copula theory and standard density decomposition techniques which involve estimation of re-weighting function in the spirit of DiNardo, Fortin and Lemieux (1996).

Consider a hypothetical population of N individuals consisting of two sub-groups where each sub-group is observed only at one point in time $t \in \{0, 1\}$. Each individual i ($i=1, \ldots, N$) receives income from different income sources $k=1, \ldots, K$ (e.g, earnings, capital, public transfers etc.) which form a set of mutually exclusive income components, y_k, so that:

$$y_i^t = \sum_{k=1}^{K} y_{ik}^t \tag{2.1}$$

The cumulative distribution function (CDF) of total income, $F(y)$, in time period t can then be estimated by integrating the joint probability density function (PDF) of all income components, $g(y_1, \ldots, y_k)$ in that period, over the region $y_1 + \ldots + y_k \leq y$:

$$F^{t}(y)=\Pr[Y_1+...+Y_k\le y\,|\,T=t]=\int_0^{y}...\int_0^{y-y_1-...-y_{k-1}} g^{t}(y_1,...,y_k)dy_1...dy_k \qquad (2.2)$$

According to Sklar's theorem (Sklar, 1959), the joint CDF of income components, $G(y_1, \ldots, y_k)$, can be expressed as a function of their marginal CDFs $(F_{y1}(y_1), \ldots, F_{yk}(y_k))$ and a dependence structure between them called copula, C:

$$G^{t}(y_1,...,y_k)=C^{t}(F^{t}_{y_1}(y_1),...,F^{t}_{y_k}(y_k))\,. \qquad (2.3)$$

Hence, we can re-write Equation (2.2) as:

$$F^{t}(y)=\Pr[Y_1+...+Y_k\le y\,|\,T=t]=\int_0^{y}...\int_0^{y-y_1-...-y_{k-1}} dC^{t}(F^{t}_{y_1}(y_1),...,F^{t}_{y_k}(y_k)) \qquad (2.4)$$

The copula, C^t, in Equations (2.3) and (2.4) is simply a joint CDF of k uniformly distributed variables r $(r_1,\ldots, r_k)$ where each variable contains information about the ordered positions of individuals (individual ranks) in the distribution of a given income component, $y_{k,}$:

$$y_k=F^{-1,t}_{y_k}(r_k)\,,\quad 0<r_k<1 \qquad (2.5)$$

where $F^{-1,t}_{y_k}$ is the generalized inverse of $F^{t}_{y_k}$, or so called quantile function, for income component y_k. Equation (2.3) can be equivalently expressed as:

$$C^{t}(r_1,...,r_k)=\Pr[R_1\le r_1,...,R_k\le r_k\,|\,T=t]=G^{t}(F^{-1,t}_{y_1}(r_1),...,F^{-1,t}_{k}(r_k)) \qquad (2.6)$$

where C^t is the k-dimensional CDF defined on the unit square [0,1].

The estimation of copula specified in Equation (2.6) requires identification of unique ranks within each income component so that $r_{1k} \le r_{2k} \ldots \le r_{nk}$. This is straightforward for continuously distributed variables without ties, but less so when several individuals in the sample score the same in certain income components. In this case, identification of unique ranks requires additional assumptions. One of the possible solutions, which is also used in this paper, is to apply random rank assignment to tied observations. This might slightly change the dependence structure between income components but the overall bias will be kept at minimum. Another alternative might be to rank individuals with tied observations in one income component according to their scores in other income components. For example, if two individuals have the same size of capital income, then the higher rank is assigned to the individual who also score higher in other income components (assumption of maximum inequality). In a similar way, it is possible to assign higher ranks in one income component to those individuals who score lower in other income components (assumption of minimum inequality).

Consider that apart from income components, there is a vector $X = (X_1, \ldots, X_j)$ with the domain Ω_X attached to each individual observation. This vector contains variables capturing socio-economic characteristics of individuals with their joint CDF denoted as $H(X)$. Given that the marginal distributions of different income components might depend on these characteristics, the CDF of total income has to be identified conditionally on X:

$$F^t_{y|X}(y \mid X) = \int_0^y \ldots \int_0^{y-y_1-\ldots-y_{k-1}} dC^t_{|X}(F^t_{y_1|X}(y_1 \mid X), \ldots, F^t_{y_k|X}(y_k \mid X) \mid X) \qquad (2.7)$$

Denote that $F^t_{y|X}(y \mid X)$ is the conditional CDF of total income given X and $C^t_{|X}$ is the conditional copula defined as:

$$C^t_{|X}(r_1, \ldots, r_k) = G^t_{|x}(F^{-1,t}_{y_1|X}(r_1 \mid X), \ldots, F^{-1,t}_{k|X}(r_k \mid X) \mid X) \qquad (2.8)$$

By the law of total probability, the CDF of total income can be estimated by integrating conditional CDFs given X over the distribution of X:

$$F^t(y) = \int_{\Omega_X} \int_0^y \ldots \int_0^{y-y_1-\ldots-y_{k-1}} dC^t_{|X}(F^t_{y_1|X}(y_1 \mid X), \ldots, F^t_{y_k|X}(y_k \mid X) \mid X) \cdot dH^t(X) \qquad (2.9)$$

Equation (2.9) provides a formalized framework for decomposing the change in the distribution of disposable income between two points in time - a base period (*t = 0*) and a final period (*t = 1*):

$$\Delta F(y) = F^{(1)}(y) - F^{(0)}(y) =$$

$$\int_{\Omega_X} \int_0^y \ldots \int_0^{y-y_1-\ldots-y_{k-1}} dC^{(1)}_{|X}(F^{(1)}_{y_1|X}(y_1 \mid X),\ldots,F^{(1)}_{y_k|X}(y_k \mid X) \mid X) \cdot dH^{(1)}(X) -$$

$$- \int_{\Omega_X} \int_0^y \ldots \int_0^{y-y_1-\ldots-y_{k-1}} dC^{(0)}_{|X}(F^{(0)}_{y_1|X}(y_1 \mid X),\ldots,F^{(0)}_{y_k|X}(y_k \mid X) \mid X) \cdot dH^{(0)}(X)\,. \qquad (2.10)$$

From Equation (2.10) it follows that the change in the CDF of total income over time can be potentially generated by three sources: (i) changes in the distribution of population sub-groups, *H(X)*; (ii) changes in the marginal CDFs of income components within each population sub-group, $F^t_{y1|X}$, … , $F^t_{yk|X}$, and (iii) changes in the dependence structure of the income components, $C^t_{|X}$:

$$\Delta F(y) = \Theta(\Delta F^{(0,1)}_X(y) + \Delta F^{(0,1)}_M(y) + \Delta F^{(0,1)}_D(y)) \qquad (2.11)$$

The first argument in Equation (2.11) captures the contribution of the shifts in the population structure whereas the second and the third terms stand for the contributions of changes in the marginal CDFs of income components and their dependence structure correspondingly. In what follows, we present a detailed decomposition framework which makes it possible to identify these three components and break them further down into a set of sub-components.

2.1. Changes in the population structure

To account for changes in the population structure between two points in time, we take advantage from the reweighting procedure developed by DiNardo, Fortin, Lemieux (1996). It makes it possible to derive a counterfactual CDF of total income which would have prevailed in the final year had the distribution of population subgroups remained the same as it was in the base year, $F^C_X(y)$:

$$F_X^C(y) = \int_{\Omega_X} \int_0^{y} \ldots \int_0^{y-y_1-\ldots-y_{k-1}} dC_{|X}^{(1)}(F_{y_1|X}^{(1)}(y_1 \mid X),\ldots,F_{y_k|X}^{(1)}(y_k \mid X) \mid X) \cdot dH^{(0)}(X)\,, \qquad (2.12)$$

Following DiNardo et al. (1996), this counterfactual distribution can be estimated by reweighting the actual CDF of income in period *t=1* with a reweighting factor, *Ψ*, which accounts for the change in the CDF of covariates between period 0 and 1:

$$\cdot \; = \frac{dH^0(X)}{dH^1(X)} = \frac{dF(X \mid t=0)}{dF(X \mid t=1)} \qquad (2.13)$$

Using the Bayes' rule, Equation (2.13) can be re-expressed as a product of two ratios – the ratio of conditional probabilities to observe individual *i* with a given set of characteristics *X* in periods *t=0* and *t=1*, and the ratio of unconditional probabilities to be observed in periods *t=1* and *t=0*:

$$\cdot \; = \frac{\Pr(t=0 \mid X)}{\Pr(t=1 \mid X)} \cdot \frac{\Pr(t=1)}{\Pr(t=0)} \qquad (2.14)$$

The difference between the actual (Equation 2.9) and counterfactual (Equation 2.12) CDFs of total income in the final year captures the contribution of the shift in the population structure to the overall change in the CDF of disposable income ($\Delta F_X^{(0,1)}(y)$).

Note that the reweighting factor, *Ψ*, in Equation (2.14) captures the shift in the joint distribution of covariates and does not partition the overall compositional effect into contributions attributable to each characteristic separately. However, the joint CDF of *X* can be easily disentangled into a sequence of conditional CDFs using the chain rule with the subsequent calculation of a set of weights and their application to obtain a sequence of counterfactual distributions.[5]

2.2. Changes in the marginal distributions of income components

Equation (2.9) makes it possible to estimate the counterfactual distribution of total income which would have prevailed if the marginal distributions of all income components

[5] For a detailed description of the procedure see DiNardo, Fortin, Lemieux (1996).

within each population subgroup had not changed between the base and the final year. To do that, the marginal CDFs of income components within each population subgroup in the final period have to be replaced with the corresponding CDFs in the base year keeping the dependence between income components and the structure of the population unchanged:

$$F_M^C(y) = \int_{\Omega_X} \int_0^y \dots \int_0^{y-y_1-\dots-y_{k-1}} dC_{|X}^{(1)}(F_{y_1|X}^{(0)}(y_1 \mid X),\dots,F_{y_k|X}^{(0)}(y_k \mid X) \mid X) \cdot dH^{(1)}(X) \qquad (2.15)$$

The difference between the actual (Equation 2.9) and counterfactual (Equation 2.15) CDFs of total income in the final period yields the contribution of the change in the marginal CDFs of all income components taken together to the change in the CDF of total income ($\Delta F_M^{(0,1)}(y)$).

The overall marginal effect, $\Delta F_M^{(0,1)}(y)$, can then be further partitioned into a set of components capturing direct contributions of changes in the conditional marginal CDFs of income sources to the overall change in income CDF (first order effects) and contributions resulting from all possible interactions between these marginal CDFs (higher order effects)[6]:

$$\Delta F_M^{(0,1)}(y) = \sum_{k=1}^{K} \Delta F_{M_k}^{(0,1)} + \sum_{j \in C_2^k} \Delta F_{M_j}^{(0,1)} + \dots + \sum_{j \in C_{k-1}^k} \Delta F_{M_j}^{(0,1)} + \Delta F_{M_{all}}^{(0,1)} \qquad (2.16)$$

The first term on the right-hand side of Equation (2.16) represents the sum of the direct contributions of *k* income components to the change in the CDF of total income. The second term summarizes the contributions of all possible two-way interactions between *k* income components. It is followed by the sum of contributions attributable to all possible higher order interactions with the last term representing a *k*-way interaction between all income sources, $\Delta F_{M_{all}}^{(0,1)}$.

The first-order effects can be identified by constructing *k* counterfactual situations for period *t=1* replacing in each case the conditional marginal CDF of only one income component to its analog in period *t=0* while keeping the marginal CDFs of all other income

[6] Copula representation of the joint CDF of income components allows separating their marginal CDFs from the rank correlation across sources (dependence structure). It does not, however, eliminate statistical correlation between different income components.

components and the dependence structure between them unchanged. For example, doing this exercise for income component y_1 will yield:

$$F^C_{M_1}(y) = \int_{\Omega_X} \int\limits_0^{y} \ldots \int\limits_0^{y-y_1-\ldots-y_{k-1}} dC^{(1)}_{|X}(F^{(0)}_{y_1|X}(y_1 \mid X),\ldots,F^{(1)}_{y_k|X}(y_k \mid X) \mid X) \cdot dH^{(1)}(X) \qquad (2.17)$$

The difference between the actual (Equation 2.9) and counterfactual (Equation 2.17) CDFs of total income in the final period captures the contribution of the change in the marginal distribution of this specific income component to the distributional change of total income ($\Delta F^{(0,1)}_{M1}$).

In a similar way we can derive the contributions attributed to interactions between marginal CDFs of income components. For example, to calculate the contribution of the two-way interaction between the marginal CDFs of y_1 and y_2 given X we have to (1) construct a counterfactual situation of what would have been the CDF of total income if the conditional marginal CDFs of both y_1 and y_2 had remained the same in the final period as they were in the base period, and (2) calculate the contribution itself by taking the difference between the actual and counterfactual CDFs and subtracting from this difference direct contributions induced by y_1 and y_2.

2.3. Changes in the copula (dependence structure)

The contribution of copula to the change in the distribution of total disposable income can be derived by constructing the counterfactual situation in which the dependence structure between all income components would have remained at its level in a base period while all other factors had changed over time. Mathematically, such a counterfactual will take the following form:

$$F^C_D(y) = \int_{\Omega_X} \int\limits_0^{+\infty} \ldots \int\limits_0^{y-y_1-\ldots-y_{k-1}} dC^{0}_{|X}(F^{1}_{y_1|X}(y_1 \mid X),\ldots,F^{1}_{y_k|X}(y_k \mid X) \mid X) \cdot dH^{1}(X) \qquad (2.18)$$

The difference between the actual (Equation 2.9) and counterfactual (Equation 2.18) CDFs of total income in the final period captures the contribution of the change in the dependence structure between income components to the overall change in the distribution of disposable income. Although the size of this contribution relatively to other factors is important, it does not tell us much about the interplay between the ranks of separate income components which might be of interest.

2.4. Further ceteris paribus decomposition

Although the decomposition method proposed above provides a flexible framework for the analysis of underlying sources of distributional changes, it does not possess the property of exact decomposition. In other words, the sum of 'ceteris paribus' effects (when only one factor is moved back to the base year while all other factors remain at the level of final year) do not result into the overall change in the CDF of disposable income between two points in time. This is induced by the interplay between three groups of sources considered: (i) changes in the population structure; (ii) changes in marginal CDF of income components within each population subgroup and their interactions; (iii) changes in the dependence structure of income components.

The issue can be solved by disentangling all possible interaction effects between the three groups of factors. This is the strategy that has been followed in the application of the proposed method in order to explain the change in the distribution of disposable income in Luxembourg between 1987 and 2010.

3. Data

The analysis is performed with data from the *Socio-Economic Panel "Liewen zu Lëtzebuerg"* (PSELL). This is an annual representative longitudinal survey which collects data on income and living conditions of individuals and private households residing in Grand Duchy of Luxembourg. Apart from questions about demographic and socio-economic characteristics of individuals and their households, it also includes questions about total household income and its components which is important for studying the contribution of different income sources to the change in the distribution of total income over time. The PSELL consists of three independent but consecutive panels: PSELL I (1985-1994), PSELL II (1995-2002) and PSELL III (2003-onwards). In this paper we use data for the years 1987 and 2010 which contain income information for the periods May 1986 – April 1987 and January – December 2009 correspondingly.

Although the design of PSELL1 and PSELL3 is very similar, there are a number of important differences between the two panels which should be accounted for. The most substantial one in the context of the paper is availability of gross income components. While in PSELL3 both gross and net components of income are collected, only net incomes were initially recorded in PSELL1. Information on gross income components is, however, important for identification of the contributions of taxes and transfers to the overall change in the distribution of disposable income. Therefore, we take advantage from the availability of simulated gross values of income components for 1987. These components have been derived using the algorithm of the reverse simulation of tax burden (see Berger et al., 2001, Immervoll & O'Donoghue, 2001) which is usded for EUROMOD type of simulations.[7] To test for potential bias in the simulation outcomes, we compared the distributions of simulated and reported income components (both are available) in 2010 but did not find substantial divergence in their patterns.

Since individuals not affiliated with the national social security system (mostly international civil servants) were not interviewed within PSELL 1, we also exclude them from PSELL 3 to make two datasets comparable. The sample size accounts 4905 individuals for 1987 and 13045 individuals for 2010.

To perform decomposition of total income by income sources, we partition total net household income in six components:

$$\text{Total net income} = E_h + E_s + E_o + CI + ST - ITC \qquad (3.1)$$

where E_h represents gross earnings of household head, E_s gross earnings of spouse, E_o gross earnings of other household members, *CI* capital income, *ST* social transfers (including pensions), *ITC* income taxes and social security contributions. This specification allows us to analyze in detail the interplay between the earnings of spouse's and also to retrieve the contributions of taxes and transfers to distributional changes. Household head is defined according to the rules of the tax-benefit system in Luxembourg: in couple-headed households the man is considered to be the head while in single-headed households the head of the household can be either a man or a woman. All income components are equalized with the square root of the number of individuals living in household, expressed in Euros and adjusted for prices of 2005.

[7] The general idea of the algorithm is to find in the iterative way the value of household gross income which after the deduction of all simulated taxes and contributions will be equal (or close enough) to the actual net income recorded in the data.

4. Changes in the distribution of total disposable income and its components in Luxembourg between 1987 and 2010

Figure 4.1 depicts the adaptive kernel density estimates of the distribution of total net equivalized household income in Luxembourg in 1987 and 2010.[8] In both years the distribution was skewed to the right, but the 2010 distribution became more dispersed compared to the one in 1987. The widening of the income distribution, however, was not the same in its upper and lower tails. Whereas income disparity in the lower tail also increased between 1987 and 2010, it is the upper tail of the distribution which especially thickened over time.

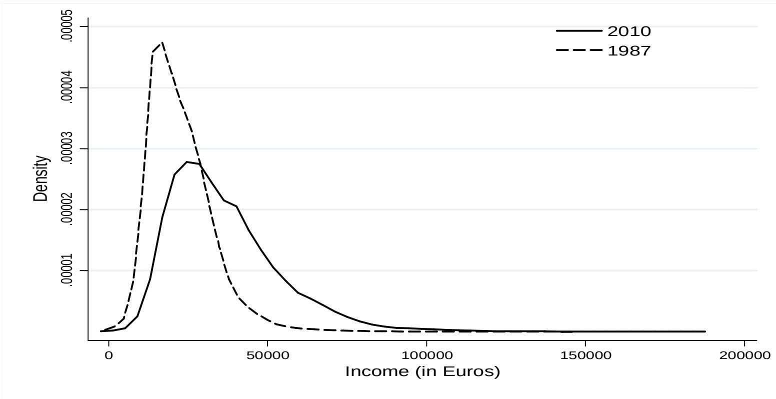

Figure 4.1. Probability density estimates of the total net household equivalized income in Luxembourg for 1987 and 2007

Note: PSELL 1 and PSELL 3, cross-sectionally weighted data. Income values are in prices of 2005.

Figure 4.2 provides further evidence about the development of the distribution of total income between 1987 and 2010 by plotting income values across different income quantiles – the so-called Pen's Parade. The quantile function for 2010 lies above the quantile function for 1987 which means that the real income grew for all income quantiles between 1987 and 2010 with especially profound growth being recorded in the upper quantiles of the income distribution.

[8] For a description of the adaptive kernel density estimation procedure see Van Kerm (2003).

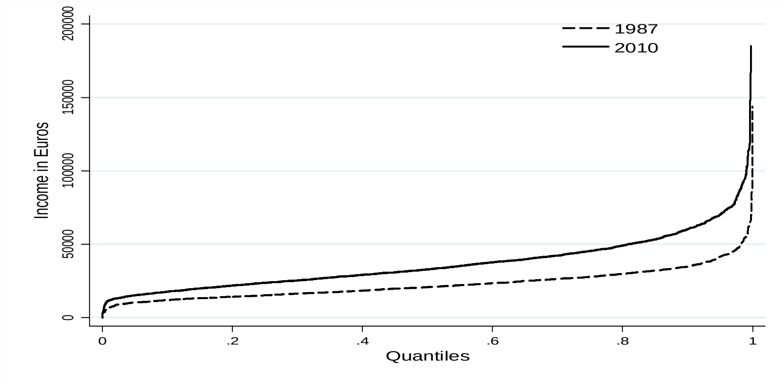

Figure 4.2. Quantile functions of total net equivalized income in Luxembourg between 1987 and 2010

Note: PSELL 1 and PSELL 3, cross-sectionally weighted data. Income values are in prices of 2005.

Table 4.1 presents summary measures for income distributions depicted in Figures 4.1 and 4.2. We focus on standard polarization, inequality and poverty indexes – Gini and Theil coefficients, percentile income ratios, and the percentage of individual living below the poverty line defined as 60% of median income in the society. In addition, we provide mean and median income values in each year in order to quantify the growth of income and improvement of standards of living over time.

Table 4.1. Changes in income dispersion and poverty indexes in Luxembourg between 1987 and 2010

Indexes	1987	2010	Change (2010 to 1987)	
			Absolute	Relative, %
Mean income	22728.04	37284.52	+14556.48	+ 64.04
Median income	20894.39	32885.66	+11991.27	+ 57.39
Standard deviation	10973.05	23213.67	+12240.62	+111.55
P90/P10	2.904	3.400	+0.496	+ 17.08
P90/P50	1.669	1.834	+0.165	+ 9.89
P50/P10	1.740	1.854	+0.114	+ 6.55
Gini	0.241	0.273	+0.032	+ 13.28
Theil index	0.098	0.135	+0.037	+ 37.75
Poverty rate (%)	11.62	14.40	+2.78	+ 23.92

Source: PSELL 1 and PSELL 3, cross-sectionally weighted data.

Table 4.1 shows that all income dispersion measures increased between 1987 and 2010. The larger increase in the mean than in the median income provides the first numerical evidence that the distribution of disposable equivalent income became more spread and unequal over time. The evolution of percentile income ratios gives a notion in what parts of the distribution this dispersion occurred. During the period studied, the ratio of the 90th and the 50^{th} percentiles of income distribution has increased by almost 10% while the ratio of the 50^{th} and the 10^{th} percentiles only by 6.5%. Such trends resulted into the increase of Gini and Theil indexes (by 13.28% and 37.75% correspondingly) and increase in relative income poverty (by 2.78 percentage points).

In the text which follows we focus on uncovering the underlying factors of the described trends in income distribution and its summary measures in Luxembourg. To get the first feeling about the potential contributions of different income sources to the change in the distribution of disposable income, Figure 4.3 below displays evolution of the CDFs of different income sources between 1987 and 2010.

Turning to the earnings-related components first, we can see that there has been a substantial shift in employment patterns of the households over the recent twenty five years. While the share of household with the head engaged in gainful employment remained almost the same, the shares of households with employed spouses and other members did change over time. In 1987 around 23% of individuals lived in households with an employed spouse, in 2010 this figure was around 39%. By contrast, the share of individuals living in households with other than head and spouse employed members declined from 31 to 12% making this income source even more unequally distributed among households. Looking at dispersion, one can conclude that while earnings of household spouses have increased along the distribution, the increase in the earnings of household heads and other household members disproportionally benefited those in the upper parts of the corresponding distributions.

Figure 4.3 also reveals that the shares of individuals living in households which receive social benefits and pay taxes did not change substantially between 1987 and 2010. However, the changes in the size of benefits and taxes were not proportional for individuals located in different quantiles of their distributions. For example, all benefits beneficiaries enjoyed the increase in real values of benefits but this increase was more pronounced for the upper percentiles than for the lower ones. On the one hand, this can be seen as a result of the expansion of policies targeting low-income households which are also expected to result in the decline of income inequality and poverty measures. On the other hand, it might also be a result of more generous pension schemes in 2010 compared to 1987. Similarly, the shift in the quantile functions for the paid taxes and social security contributions signifies that all households were paying higher taxes in 2010 than in 1987. However, the size of the taxes increased to larger extent for top income tax payers than for those who used to pay relatively low taxes. This is expected to have an equalizing influence on the total income distribution.

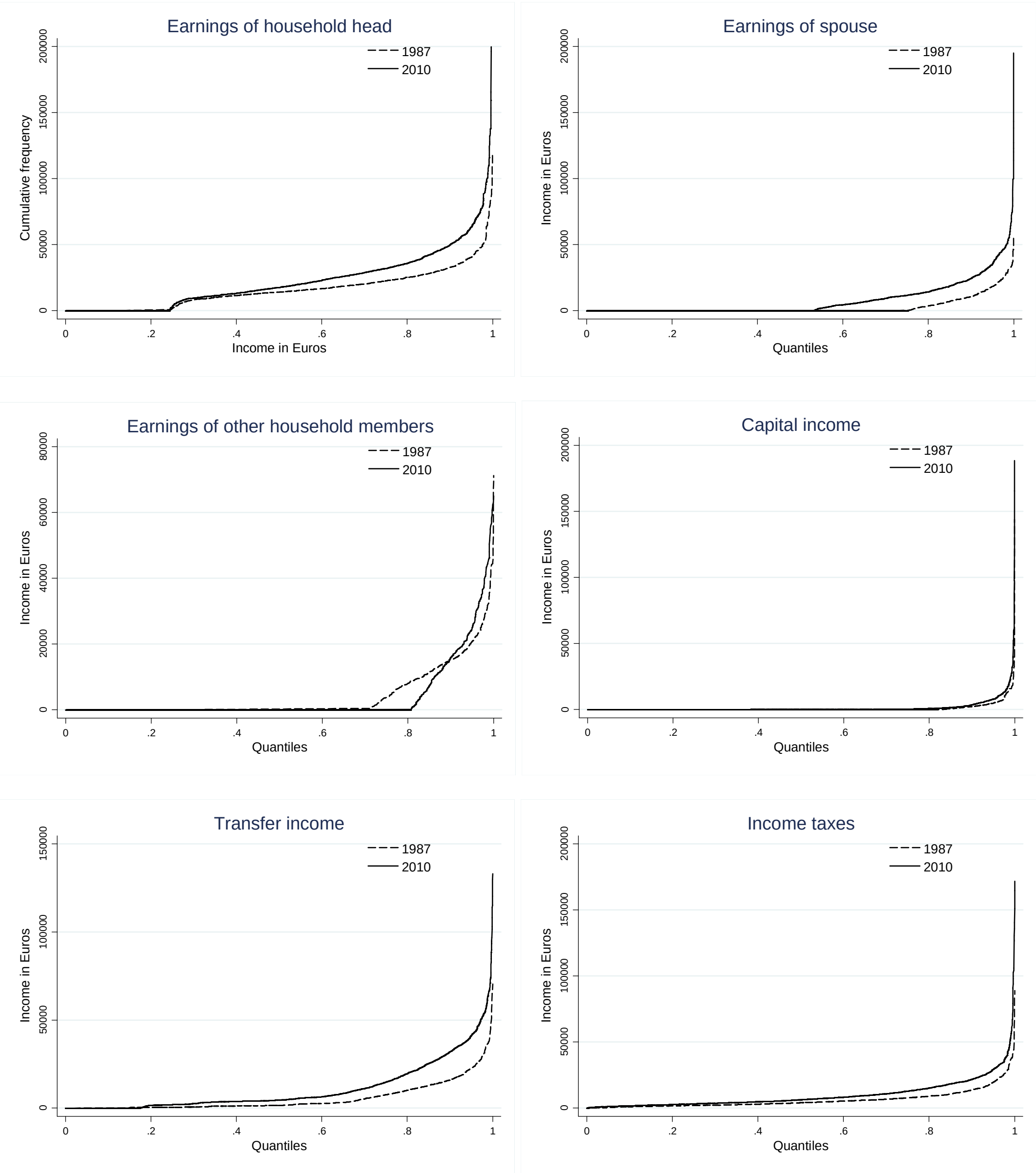

Figure 4.3. Changes in the marginal distributions of different income sources in Luxembourg between 1987 and 2010

Note: PSELL 1 and PSELL 3, cross-sectionally weighted data. Income values are in Euros expressed in prices of 2005.

5. Decomposition results

In this part of the paper we present the decomposition results of the change in the distribution of total household equivalent income and its summary measures in Luxembourg between 1987 and 2010. In line with what has been written in Section 3, we consider the contributions of three groups of factors: (i) changes in the population structure; (ii) changes in the marginal distributions of different income sources within the population sub-groups, and (iii) changes in the dependence structure between marginal CDFs of income sources. To get a better understanding of the interplay between (i), (ii) and (iii) and arrive at the exact ceteris paribus decomposition in which the contributions of different components sum up to the overall change in total income distribution independently on the order of decomposition, we also calculate interactions between these three groups of factors. The results of the decomposition for selected distributional measures are presented in Table 5.1 below and discussed in the text which follows.

Table 5.1. Decomposition results of inequality and poverty indexes in Luxembourg between 1987 and 2010

Decomposition components	**P90/P10**	**P90/P50**	**P10/P50**	**Gini index**	**Poverty rate**
1. Population structure	**+0.168**	**+0.102**	**+0.004**	**+0.0105**	**-0.081**
2. Marginal CDFs of income components including:					
(i) Direct contributions:					
Earnings of household head	+0.198	+0.041	-0.020	+0.0050	+1.095
Earnings of spouse	+0.089	+0.020	-0.008	-0.0024	-0.169
Earnings of other household members	+0.148	+0.087	+0.003	+0.0063	-0.082
Capital income	+0.024	+0.027	+0.004	+0.0023	-0.089
Transfer income	-1.682	-0.271	+0.123	-0.0780	-8.816
Income taxes	-0.204	-0.070	+0.011	-0.0060	-0.660
Sum of all direct contributions	-1.427	-0.166	+0.113	-0.0728	-8.721
(ii) Interactions:					
Second-order interactions:					
Earnings of head and spouse	-0.025	-0.145	-0.042	-0.0082	+2.280
Earnings of head and others	-0.036	-0.005	+0.004	+0.0050	+0.037
Earnings of head and capital income	-0.024	-0.025	-0.003	-0.0011	-0.415
Earnings of head and transfer income	+0.879	+0.006	-0.078	+0.0225	+4.896
Earnings of head and taxes	+0.100	+0.032	-0.005	+0.0171	+0.201
Earnings of spouse and other household members	+0.058	+0.017	-0.006	+0.0041	+0.645
Earnings of spouse and capital income	+0.050	+0.003	-0.007	+0.0011	+0.364
Earnings of spouse and transfer income	+0.333	-0.007	-0.026	+0.0015	+0.666
Earnings of spouse and taxes	-0.023	+0.010	+0.007	+0.0045	-0.248
Earnings of other members and capital income	-0.020	-0.026	-0.005	+0.0001	+0.077
Earnings of other members and transfer income	+0.165	-0.037	-0.019	+0.0013	+1.720
Earnings of other members and taxes	+0.007	-0.003	-0.002	-0.0006	-0.005
Capital and transfer income	-0.053	-0.044	-0.005	-0.0036	-0.061
Capital income and taxes	+0.026	-0.005	-0.005	-0.0001	+0.183
Transfer income and income taxes	-0.026	+0.005	-0.005	+0.0101	+0.305
Sum of all second-order interactions between components	+1.411	-0.224	-0.197	+0.0537	+11.645
Sum of all higher-order interactions between components	+0.145	+0.434	+0.077	+0.0320	-2.706
Sum of all contributions induced by marginal CDFs of income components and their interactions	**+0.129**	**+0.044**	**-0.007**	**+0.0129**	**+0.218**
3. Dependence structure (copula)	**+0.046**	**+0.050**	**+0.008**	**+0.0074**	**+0.805**
4. Interaction between population structure and marginal CDFs of income components	**-0.181**	**-0.057**	**+0.011**	**-0.0097**	**-0.716**
5. Interaction between population structure and copula	**-0.170**	**-0.062**	**+0.008**	**-0.0048**	**-0.724**
6. Interaction between marginal CDFs and copula	**+0.364**	**+0.052**	**-0.050**	**+0.0237**	**+3.471**
7. Interaction between population structure, marginal CDFs of income components and copula	**+0.207**	**+0.054**	**-0.015**	**+0.0048**	**+0.284**
Total change due to all factors (1 through 7)	**+0.563**	**+0.183**	**-0.041**	**+0.0391**	**+3.257**

Note: Decomposition is based on PSELL 1 and PSELL 3 cross-sectionally weighted data. The contributions are expressed in absolute terms with the sign showing the direction of the contribution of a given income component to the overall change in the corresponding inequality measure. All possible interaction effects were calculated separately and then summed up into groups (based on predicted values). The calculations of indexes themselves are based on the predicted income values.

Changes in the population structure

Changes in the population structure in Luxembourg are mainly driven by the increased highly skilled migration from both EU and non-EU countries (Fusco et al., 2013). Between 1987 and 2010 the share of individuals without Luxembourgish citizenship increased almost twice in the country and reached 42.5%. In the performed decomposition exercise, we have tried to identify the contribution of this trend to the change in the distribution of total disposable income and its summary measures. It is done by constructing a counterfactual distribution of total income which would have prevailed in Luxembourg if the structure of population in terms of migration background had remained at its 1987 level. Figure 5.1 below plots this counterfactual distribution against actual distributions of total disposable income (based on predicted values) for 1987 and 2010. It shows that had the migration composition of population remained the same as it was in 1987, the quantile function of total income would have been above the actual quantile function in 2010. Although being relatively small, the difference is more pronounced in the middle of the distribution implying that incomes of individuals located in this part of the distribution would have been higher, had the migration composition of the population remained at its 1987 level.

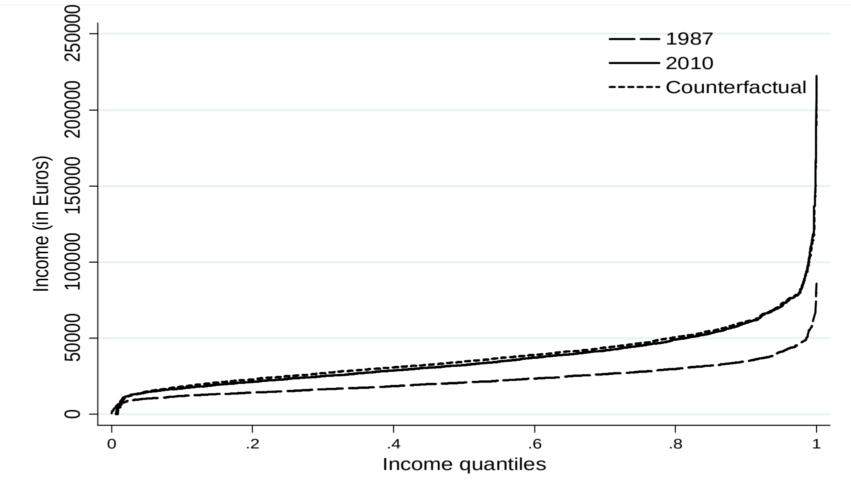

Figure 5.1. Contribution of the change in the population structure to the shift in the distribution of total disposable income in Luxembourg between 1987 and 2010

Graphical evidence from Figure 5.1 is supported numerically by the decomposition results provided in Table 5.1. More specifically, the shift in migration composition of Luxembourgish population has contributed to the increase in the discrepancy of incomes between the 90th and the 10th percentiles of income distribution as well as between its 90th and 50th percentiles. For these two indexes, the unequalizing contribution of migration was the highest compared to other two groups of factors – changes in marginal CDFs of income components and their dependence structure. The Gini index would have also been 0.0105 points lower than it actually was in 2010 under the 1987 population structure. At the same time, the contribution of the shift of migration to the change in P50/P10 index is very small which signifies that this factor has induced larger dispersion of incomes of the individuals located in the middle and upper parts of the income distribution. This can be partially explained by the very specific composition of migrants in Luxembourg, who are mainly highly-qualified well-paid employees.

Changes in marginal CDFs of income components

Figure 5.2 depicts the overall contribution of the change in marginal CDFs of income components to the shift in the distribution of disposable income in Luxembourg between 1987 and 2010. The counterfactual distribution in Figure 5.2 shows the quantile function of total disposable income which would have prevailed in 2010 if the marginal CDFs of all income components had remained at their 1987 level.

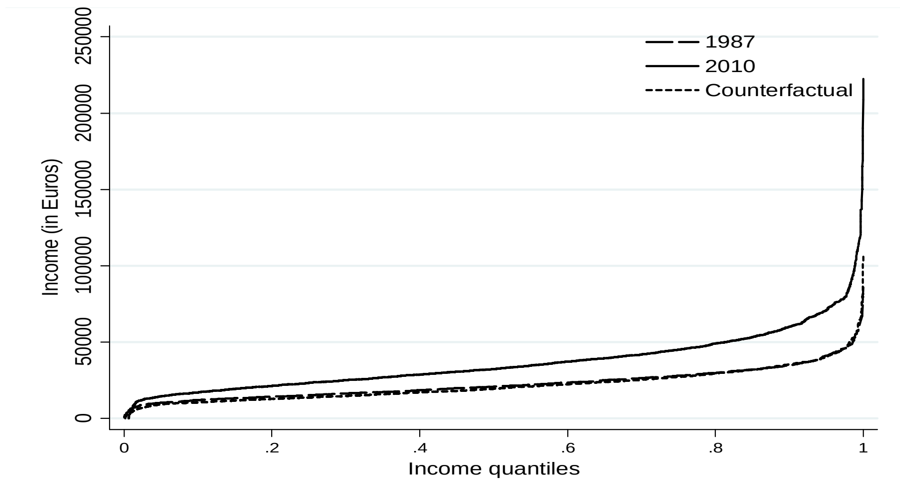

Figure 5.2. Contribution of the change in marginal CDFs of all income components to the shift in the distribution of total disposable income in Luxembourg, 1987-2010

Figure 5.2 shows that if the marginal distributions of all income components had remained at the level of 1987, the shape of the distribution of total disposable income in 2010 would have been very similar to the one actually observed in 1987. This being said, the distribution of total income would have been more equal in 2010 if the marginal CDFs of income sources within each population sub-group remained unchanged. Indeed, turning to the decomposition results in Table 5.1 we can see that the shift in marginal CDFs of all income components taken together has resulted into a substantial increase in all income inequality and poverty indexes.

In order to uncover the contribution of the marginal CDF of each income component to the change in the distribution of total income, we perform detailed ceteris paribus decomposition. In this decomposition, the actual marginal distribution of each income component in 2010 is switched to its values in 1987 holding the marginal distributions of all other sources, their interdependence and population structure unchanged. It allows us to derive a counterfactual distribution of total equivalent income that would have prevailed in Luxembourg in 2010 if the marginal distribution of only one income component had remained at the level of 1987 while all other factors had changed in a way they did in reality.

Figure 5.3 gives the first insight into the contributions of different income components to the change in the total income distribution in Luxembourg over time. By comparing the plots where actual quantile functions are depicted against counterfactual ones for earnings components, we can see that the earnings of household head have the most pronounced influence on the change in the shape of the distribution of total disposable income over time. If the marginal distribution of this income component had remained at the level of 1987, the distribution of total income in 2010 would have been more equal. The shift in the total income distribution induced by changes in the CDF of household head earnings was especially profound in the area of upper income quantiles signifying that the growth of individual earnings was not the same along the income distribution. It is mainly individuals with incomes in the upper tail of the total income distribution who benefited the most over time. Although to a smaller extent, the shift in the CDF of spouses' earnings also have reflected on the distribution of total disposable income lifting it up in 2010.

In contrast to earnings of household heads and spouses, changes in the earnings of other household members and capital income did not impose substantial visual shifts in the distribution of total income. Remarkably, that a small change in the distribution of total income induced by the shift in earnings of other household members took place only in the upper tail of the distribution slightly increasing the incomes of individuals located there.

Figure 5.3 shows that the changes in the marginal CDFs of benefit income and income taxes are two other factors which substantially influenced the shape of income distribution over time. Had the marginal distribution of transfers remained at its 1987 level, the growth of incomes in the lowest quantiles would have been substantially smaller and the distribution itself would have been more unequal. A similar trend would have been observed if the marginal distribution of taxes had not changed since 1987. The size of paid income taxes and social security contributions increased to a larger extent for individuals in the upper tail of total income distribution making it more equal.

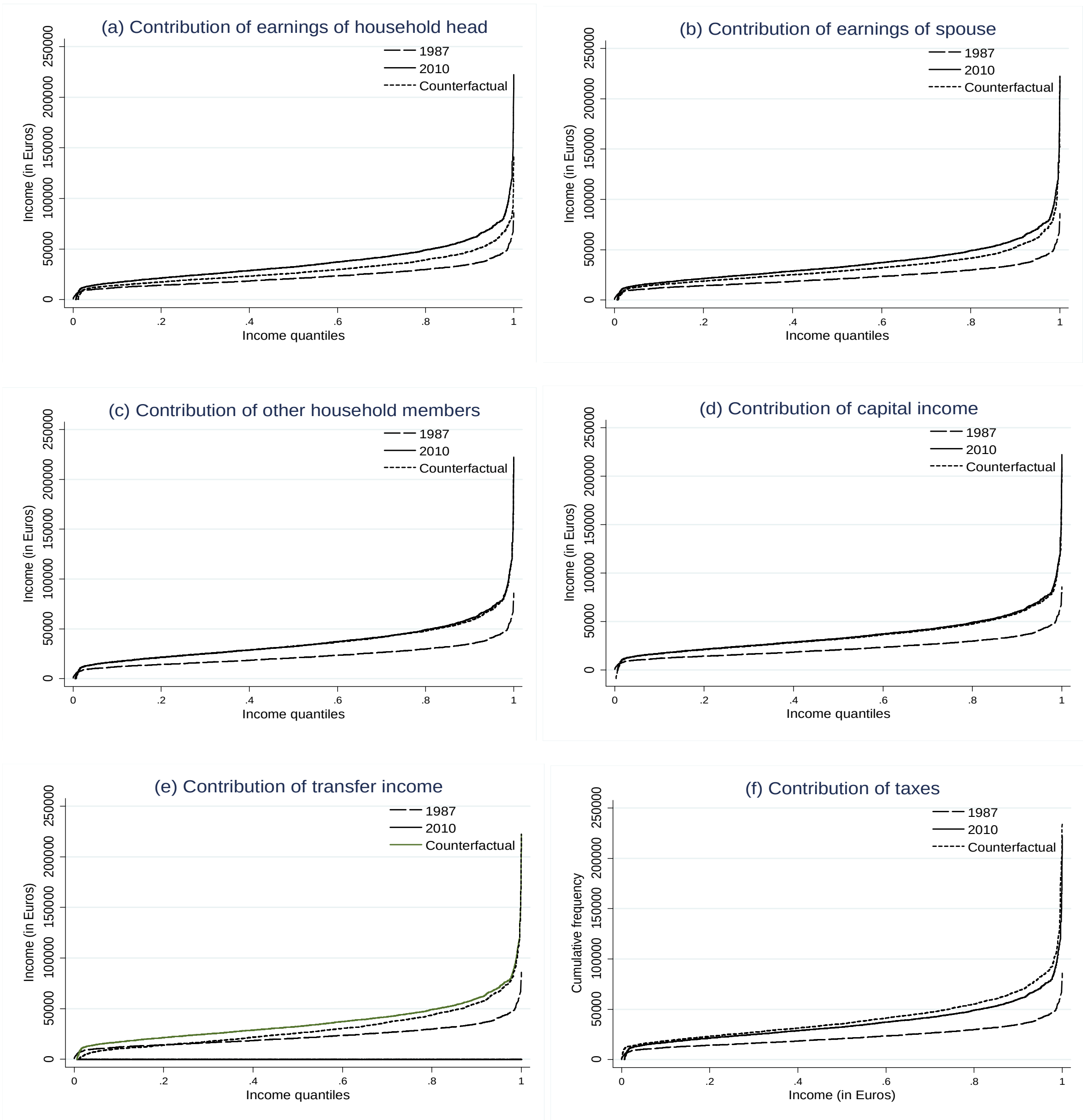

Figure 5.3. Ceteris paribus contributions of the changes in the marginal CDFs of income sources to the shift in the distribution of disposable income in Luxembourg, 1987-2010

Table 5.1. quantifies the contributions of the mentioned income sources to the change in the summary measures of the distribution of total income. Looking at the size and direction of the contributions attributable to different income components, we can see that the shifts in the marginal CDFs of earnings of household head and other members of household as well as in capital income are associated with the increase in income inequality in 2010. Had the marginal distributions of these components remained the same as in 1987, these indexes would have been lower in 2010 other things being equal. The shift in the marginal CDF of the earnings of spouses also contributed to the unfavourable changes in all percentile ratios, but no similar effect is found for the Gini index. In fact, the change in the marginal CDF of this income source has resulted in the decrease of the Gini coefficient, but the size of the contribution is very small. Remarkably, that the changes in the marginal CDFs of earnings components have affected relative poverty rate differently than inequality measures. While earnings of household head contributed to the increase in poverty, earnings of household spouse and other members of the household resulted into the reduction of the poverty rate. This might be explained by the fact that the applied poverty rate is defined in relative terms using the median income which is not sensitive to the increased income dispersion in the upper tail of income distribution.

In contrast to labor-related income components and capital income, shifts in the marginal distributions of benefits and taxes have strong equalizing effect on all inequality and relative income poverty measures. Compared to earnings and capital income, the contributions of these two income sources are much larger for all distributional measures except of P90/P50 ratio for which the effect of earnings of other household members was more pronounced than the change in the marginal distribution of income tax.

Table 5.1 also shows how important it is to account for interaction effects while decomposing the change in the distribution of total disposable income by income source. If we look at the sum of the ceteris paribus contributions of all income sources, we would see that taken together they have contributed to the decrease in all income inequality and poverty measures over time. However, this equalizing contribution is cancelled out as soon as we account for interactions between income sources which, on average, have disequalizing effects for all inequality and poverty measures. In the case of sequential decomposition, these interactions would coincide with the main effects of income sources providing misleading information about the direction of their contributions.

Another advantage of looking at interactions between marginal CDFs of income sources lies in the ability to detect the interplay between income values between different income sources. For example, ceteris paribus changes in the marginal CDFs of earnings of household head, spouse and other members have resulted in the increase of income dispersion measured with the P90/P10 index. However, these effects are partially eliminated by the two-way interactions between these income sources.

Changes in the dependence structure (copula)

Figure 5.4 below provides the contribution of the change in the dependence structure between income components to the overall change in the distribution of disposable income in Luxembourg. Had the copula remained unchanged since 1987, the distribution of total disposable income would have been very close to the one actually observed in 2010.

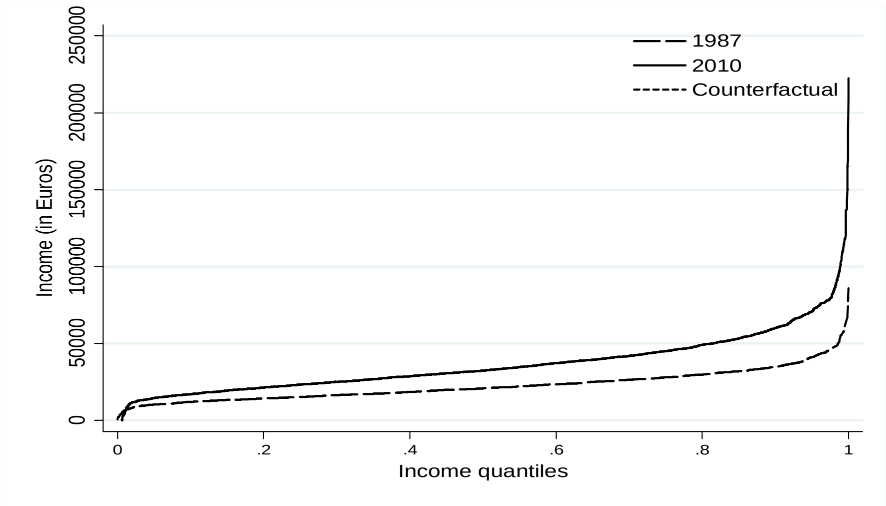

Figure 5.4. Copula contribution to the change in the distribution of total disposable income in Luxembourg, 1987-2010

The results of the detailed decomposition in Table 5.1, however, only partially confirm graphical evidence. In line with the graphical evidence they show a relatively small contribution of the copula to the changes in P90/P10 and P90/P50 indexes and the Gini coefficient. At the same time, the change in copula over time imposed a sound contribution to the increase in P10/P50 ratio and the relative poverty rate which are especially sensitive to what is going on in the lower part of the income distribution. While the contribution is small but equalizing for the P10/P50 index, it is relatively big and negative for the poverty rate.

Other things being equal, the change in the copula induced 0.8 percentage points increase in the poverty rate. This implies that the rank correlation between different income sources (dependence structure) has become even more unfavourable for individuals located in the lowest quantiles of the income distribution as it used to be before. In other words individuals who score low in one income source also tend to score low in other income sources, and this relationship becomes more profound over time.

Changes in the interplay between population structure, marginal CDFs of income components and copula

Table 5.1 also presents the contributions of the interactions between three groups of factors underlying the change in the overall distribution of total equivalent income discussed above, i.e. the change in the population structure, changes in the marginal CDFs of income components and their dependence structure. The size of these contributions shows that they are not trivial for explaining the change in inequality and poverty measures over time. In most cases it is larger than the size of contributions attributable to three groups of factors if they are considered separately from each other. All in all, interaction between population structure and marginal CDFs of income sources as well as the interaction between population structure and copula have equalizing effect on inequality and poverty indexes. This might be considered as the evidence that the shift in the migration composition of the population, if considered together with the changes in the marginal CDFs and copula, has an equalizing contribution to the income inequality measures and yields the decrease in poverty. Contrarily, the interaction between marginal CDFs of income components and copula as well as the three-way interaction between all income sources have disequalizing contribution to the overall change in the distributional summary measures.

6. Conclusions

This paper proposes a copula-based decomposition method which makes it possible to partition the overall change in total distribution of household equivalent income into three sets of contributions induced by: (i) changes in the population structure, (ii) changes in the marginal CDFs of different income sources and their interactions, and (iii) changes in the dependence structure between different income sources. The empirical application of the method is demonstrated with data from the PSELL in order to explain the change in the distribution of total disposable income in Luxembourg between 1987 and 2010.

The main results show that, other things being equal, changes in the population structure (captured as a change in the migration composition of the population) have contributed to the increase in income inequality and poverty measures in Luxembourg over time. Similar evidence is also found for changes in the marginal CDFs of income components taken together as well as for the change in copula. A detailed breakdown of the total change in marginal CDFs of income sources into a set of direct and indirect contributions reveals that the changes in the marginal CDFs of earnings of household heads and other members of household have contributed to the increase in inequality and poverty in Luxemburg. Contrarily, shifts in the marginal CDFs of benefit income and income taxes have a sound equalizing contribution to the overall change in the distribution of disposable income. The decomposition exercise also shows the importance of accounting for interactions between the marginal CDFs of income sources as well as between three major groups of contributing factors mentioned above.

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