CIRCLE Working Paper n. 3

A simple subgroup decomposable measure of downward (and upward) income mobility

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July 2018

Work Package 2: Intergenerational insurance of income and care risks
Task 2.1: The changing patterns of income mobility by age cohorts in EU countries

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A simple subgroup decomposable measure of downward (and upward) income mobility

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Abstract

We propose a subgroup decomposable class of income mobility measures with good axiomatic properties by adapting the concept of "individual income gap between two moments in time" to a framework that is traditionally used in the measurement of poverty and deprivation. This framework is explicit in incorporating the necessary judgements about how to aggregate individual income gaps by making use of the indices with best normative properties within the poverty literature. This strategy allows us to provide intuitive and simple measures of downward (and upward) mobility that consider incidence, intensity and inequality of income gaps and are easy to comprehend and communicate to policy makers. Moreover, these measures are consistent with a simple and intuitive graphical device. As an empirical illustration of the use of this class of measures, we present an analysis of downward income mobility for different age groups in three EU countries using the European Union Survey of Income and Living Conditions (EUSILC) longitudinal data from 2004 up to 2015.

Keywords: directional income mobility, decomposability, European Union.

JEL codes: D31, D63, I30.

Acknowledgements: The support of the JPI MYBL (Project "Care and Income Redistributive Cycles in the Lives of the Europeans" - CIRCLE project PCIN-2016-089 JPI MYBL) is gratefully acknowledged.

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1. Introduction

Recent evidence on the impact of the crisis on the European Union shows that changes in income inequality and poverty have been relatively small despite the macroeconomic heterogeneity of the recession across different economies (Jenkins *et al.*, 2013). However, for a more complete evaluation of how individual well-being has changed it is also crucial to analyse if there have been significant changes in individuals' chances to scale up or lose ground in the income ladder. Evidence for the US shows that the prevalence of income losses in the last two decades grew significantly already before the crisis (Hacker et al. 2010, 2014; Dynan et al., 2012). In the European context, Ayala and Sastre (2008), Van Kerm and Pi Alperin (2013) and Cantó and Ruiz (2015) underline that in some EU countries disposable incomes are particularly volatile in time. For instance, in the case of Spain during the recession a very large part of the population lost more than 25% income from one year to the next, more than in any other EU country in the same period.

The concept of mobility is a multidimensional one (Fields and Ok, 1999) and traditionally studies concentrate on one of its different aspects. This generally tends to make any comparison of the results obtained quite confusing. A recent key contribution aiming to clarify the economic and wellbeing meaning of different notions of income mobility for a given society is Jäntti and Jenkins (2015). These authors underline, as in Jenkins (2011), that income mobility between two or more moments in time can be understood as the dimension of four different issues: positional changes in the income distribution, income growth (or income movement), inequality reduction or risk/uncertainty.

Regarding the first two of these concepts, the actual *direction* of the movement (either upwards or downwards) is a crucial issue that provides important information on the social desirability of mobility. In general, *directional* measures of income distance in the literature are understood as those that treat income increases differently from income decreases. Nonetheless, aggregate measures frequently combine upward and downward mobility to provide a comprehensive aggregate measure of income mobility for any society. However, this characteristic may not be enough to make these measures meaningful in terms of evaluating the social desirability of mobility..

Some papers such as Ferretti and Ganugi (2013) have proposed families of indices of a directional nature with axiomatically desirable properties when the interest is that of measuring mobility as positional change in the distribution. However, to the best of our knowledge, there are no other relevant proposals of directional measures for other mobility concepts such as income growth or income movement. This is probably because, in general, the contributions to this area have focussed on income growth measures that construct comprehensive mobility measures. These measures aim to consider both upward and downward mobility together searching for dominance conditions to rank growth processes (Trede, 1998; Ravallion and Chen, 2003; Van Kerm, 2009; Bourguignon, 2011; Jenkins and Van Kerm, 2011; Demuyck and Van der Gaer, 2012; Palmisano and Peragine, 2015; Palmisano and Van der Gaer, 2016; Jenkins and Van Kerm, 2016).

We believe that, in a period of a deep recession (high growth) even if positional change may be relevant, the immediate negative (positive) perception of a loss (gain) is more related to a concept of mobility that is genuinely more "absolute" than "relative". This means it is most meaningful to measure gains and losses of income (absolute mobility or dollar-based mobility as in Fields, 2008) rather than focussing on changes in income shares or positions in the income distribution. In fact, some recent papers on the improvement of Social Welfare measures have argued in favour of following Prospect Theory and incorporating in the individual utility functions two concepts that can be, to some extent, captured by a measure of absolute mobility: income-reference dependence and loss aversion (Jäntti et al., 2013).

Additionally, absolute mobility measures can consider the *prevailing* direction of income changes avoiding the assumption of a one to one (or some similar) compensation of opposite direction movements. Therefore, we believe that the experience of an income loss by one individual cannot be compensated by the gain of another and so there is a need for an adequate directional measure that focusses separately on these changes and is essentially based on the idea of "individual income gap" (individual income growth). This is in line with a recent contribution by Jenkins and Van Kerm (2016) on the large interest in the assessment of individual income growth so that we can clearly show who are the gainers and the losers and who provide some distribution-sensitive assessments of mobility.

More precisely, we believe that the experience of a change in individual income between two moments in time (income gap) can be advantageously analysed in the framework of the measurement of poverty and deprivation. In fact, other research lines such as Jenkins (1994) and Del Río et al. (2011) have used a similar framework using "wage gaps" to analyse gender wage discrimination by studying the "individual wage discrimination experience" which is the gap between a female wage and the wage of an otherwise identical male. In the income mobility field, we can use the individual distance of incomes between two moments in time as a genuinely individual income gap (or ratio if expressed as a growth rate) so that income mobility incidence, dimension (intensity) and distribution would play a crucial role when quantifying the aggregate level of either upward or downward mobility in any society.

In this setting, we would need to consider two key issues in measuring directional income mobility: (1) how to identify which individuals suffer from (enjoy) downward (upward) mobility and in what quantity; and (2) how to sum up their income gaps using indices that verify a set of desirable normative properties. Naturally, positive and negative income distances, gains and losses, cannot be considered together in the same aggregate measure, because mobility is a strictly individual experience. Indeed, a pure individual positive wellbeing experience cannot be "compensated" by any other person's negative one. This is a similar idea to that of the focus axiom in poverty research and has been used in the literature on individual gender wage discrimination to analyse wage gaps by measuring only the distance between male and female wages when the former is higher (Del Río et al., 2011). In the case of gender wage gaps empirical results show that only a negligible number of males obtain lower wages than females (given otherwise similar attributes), so only female wage gaps are relevant. In contrast, in the case of income mobility both upward and downward moves may be empirically relevant, so we propose to examine both positive and negative income changes using the same approach, but in a separate way.

Additionally, not only the measurement of the incidence of upward and downward income mobility is of interest, also intensity and inequality in each of these directions are relevant dimensions to consider. Moreover, measures should allow researchers to study which are the socioeconomic or demographic subgroups that suffer downward income changes or enjoy upward mobility. As Jenkins and Van Kerm (2011) rightly underline "*Another important topic for future research is closer examination of patterns of income growth for subgroups within the population*". For instance, Ayala and Sastre (2008) who study income mobility in five EU countries in the second half of the nineties, find that mobility was significantly different by age groups, so that young household heads (together with individuals in single-parent households) experienced the greatest income fluctuations, even if the intensity of this instability varied greatly across countries. More recently, Cantó and Ruiz (2015) find one of the main determinants of the probability of suffering income losses, both in the US and Spain, was the individual's age cohort. The young and middle-aged groups are more likely to lose incomes compared to individuals from older ones. In addition, Aristei and Perugini (2015) have concluded that the levels and determinants of short-term mobility differ remarkably in the various institutional models across Europe, particularly regarding household composition, demographic attributes, education levels and job positions. In this setting, there is a clear need that a measure of income mobility is subgroup decomposable making it simple to identify the main characteristics of downward and upward movers while taking into consideration both the incidence, intensity and inequality of the phenomenon.

In this paper, we propose a class of mobility measures that has important advantages. First, it is directional because it quantifies upward separately from downward mobility avoiding compensation between different individual's gains and losses. Second, it can identify the relevance of all three important dimensions of the individual mobility experience: incidence, intensity and inequality. Third, its properties allow researchers to evaluate mobility across population subgroups in a coherent way. Fourth, the proposed class of mobility measures is consistent with a simple but complete and very informative graphical device that allows for further intuitive and detailed analysis of the distribution of income losses (gains) for different population subgroups. Finally, its simple structure facilitates comprehension and eases communication with policy makers without leaving any desirable axiomatic properties aside. Probably, the price to pay for its simplicity is that, in its current form, it does not include a social preference for pro-poor income growth. However, as stated in Van Kerm and Pi Alperin (2013), our measure gives relatively more importance in our analysis to the currency gains or losses of individuals with lower incomes. This makes comparisons of growth figures more meaningful, especially when comparing individuals with different income levels, and more importantly in the illustration of this paper, when comparing aggregate values for countries with diverse income levels.

As an empirical illustration of the proposed class of mobility measures, we present an analysis of income mobility for different age groups in three EU countries during a decade. We use the EUSILC longitudinal data from 2004 up to 2015. Our preliminary results reveal that our class of measures is particularly useful to show (both cardinally and in a graph) how remarkably the level and dimension of downward income mobility and its components (incidence, intensity and inequality) differ between age groups in the same country and for the same group across countries.

The paper is organized as follows. In the second section, we review the literature on *directional* income mobility focusing on the most recent contributions to the topic. In the third section, we present our subgroup decomposable income mobility measure, discuss its axiomatic properties and we then detail the graphical device linked to it in the following section. The fifth section includes an empirical illustration showing how useful our measure is to compare downward mobility incidence, intensity and inequality both cardinally and graphically by subgroups, providing a detailed comparison of downward income mobility by age groups in three European countries for a decade. The last section concludes.

2. A brief discussion of the relevant literature on income mobility measures

A relevant strand of the literature has emphasized the adequacy of using pure measures of positional change to assess income mobility. This is mainly because the results on the distinction between exchange (re-ranking) and structural (growth) mobility generally show that the main driver of short-term mobility is re-ranking (Ruiz-Castillo, 2004, Van Kerm, 2004), which may be linked to that fact that relevant distributional changes are generally slow.[1]

However, given that individuals are known to be strongly sensitive to changes in their incomes, particularly if they imply income losses (loss aversion), another relevant strand of the literature that has made significant advances in recent years is that related to a concept of mobility as *individual income growth* as noted by Jäntti and Jenkins (2015). These authors underline that "*Mobility as individual income growth refers to an aggregate measure of the changes in income experienced by each individual within the society between two moments in time, where the individual-level changes might be gains or losses*". A mobility measure is *directional* if it considers the difference between an income increase and an income decrease so that income increases count positively and

[1] See D'Agostino and Dardanoni (2009). A recent contribution improving the properties of some relevant indices of this rank-based approach is Bossert et al. (2016).

income decreases count negatively. This could generally imply that "*one would want the former to represent an improvement in circumstances and the latter a deterioration*" (Jäntti and Jenkins, 2015). However, as these same authors note the main issue is how to aggregate gains and losses in the social calculus because the evaluation of society's wellbeing requires weighting up the gains and losses of different individuals and this may be a controversial issue.

As Jäntti and Jenkins (2015) underline the most well-known aggregate measure of income movement is due to Fields and Ok (1996, 1999).[2] These authors proposed an aggregate measure of income growth, which is the mean change in log incomes and takes the form:

$$m_n(x,y) = \mathrm{c}\left[\frac{1}{n}\sum_{i=1}^{n}|log(y_i) - log(x_i)|\right] = \mathrm{c}\left[\frac{1}{n}\sum_{i=1}^{n}|d_i|\right]$$

where society consists of n individuals, c is a normalizing constant which may be set equal to one and the vector of incomes at the initial moment is $X = (x_1, x_2, x_3, \dots, x_n)$ while the vector of incomes sometime later is $Y = (y_1, y_2, y_3, \dots, y_n)$ and d_i is a vector of distances between incomes in the second and the first moment in time. This measure gives us a flavour of the stability of absolute incomes in a society and, if transformed into a more general directional movement measure, it considers that the same absolute movement experienced by a poorer individual is more desirable.

Fields and Ok (1999) index fulfils a set of adequate axiomatic properties and assures that overall income growth in a society is the average of individuals' income growth. However, if we use this approach as some welfare evaluation of mobility in a society, we would be assuming that an individual's loss is equally important than an individual gain of the same dimension.

Recent advances in this area are papers such as Demuyck and Van der Gaer (2012) or Jenkins and Van kerm (2016) who make sound proposals to include two relevant issues in one mobility class of measures: the dimension of individual income growth and the individual position in the pre-movement income distribution. Jenkins and Van kerm (2016) consider a social preference for pro-poor income growth while Demuyck and Van

[2] See Appendix 2 for a reference of the connection between our family of measures and that of Fields and Ok.

der Gaer (2012) add the idea of “priority for lower growth”. This implies that “aggregate (income) growth should increase more when additional income growth is allocated to individuals with lower income growth than when it is allocated to individuals with higher income growth”. More recently, Creedy and Gemmell (2017) apply the insights of poverty analysis to income growth measures of mobility to construct an interesting new graphical device by which, unfortunately, one cannot easily identify incidence, intensity or inequality in a directional way.

Some other papers such as Ferretti and Ganugi (2013) have proposed directional measures of mobility with axiomatically desirable properties within a concept of mobility related to positional changes in the distribution. These measures aim to grasp the prevailing direction of income transitions between income groups (e.g. deciles, quintiles, etc.) in each society and are functions of a transition matrix defined for the corresponding two moments in time. The absolute value of the indices measures the intensity of this relative mobility and its sign represents the prevailing direction towards improvement or worsening of the transitions between states in that society. These authors propose a normalized index of mobility that is essentially a weighted sum of the frequencies of movement between states and in a more refined formulation, researchers can consider choosing different weights for jumps of the same magnitude but different starting position and different non-linear weights to the actual magnitude of the jump.

Even if we think that this is an interesting strand of research, we believe that the immediate perception of income mobility for an individual is not so strongly linked to the transition between two groups but more to the experience of having an income gain or loss. Moreover, when aggregating income gaps into a whole society, an individual gain or loss should not be compensated by the gain or loss of another individual. There is a need for a focus on the incidence and dimension of “individual income distance or gap” (individual income growth) and the subsequent natural construction of an adequate aggregate (social) directional measures of upward and downward income mobility with good axiomatic properties. Our proposal aims to identify the three dimensions of downward and upward income gaps: incidence, intensity and inequality and to provide a simple decomposable measure that provides insights into the nature of income mobility by demographic or socioeconomic groups.

3. A subgroup decomposable income mobility measure

The aim of this paper is to discuss and propose a normative framework for the empirical study of income mobility as movement differentiating upward and downward mobility. This framework is going to be based on the literature on poverty and deprivation that provides us with aggregate indicators that are explicit in incorporating the necessary judgements about how to aggregate individual income gaps. We consider that making good use of the indices with best normative properties within the poverty and deprivation literature we can adequately provide a subgroup decomposable measure of downward (and upward) mobility with adequate axiomatic properties.

In this context, we will adapt the family of poverty indices proposed by Foster et al. (1984) and construct a downward (upward) mobility index based on the relative income gap. This gap is determined by the ratio of the difference between an individual threshold (equal to her income in the first moment in time) and the level of individual income reached in the second moment in time, and the individual threshold.

Let $x \in \mathbb{R}^n_{++}$ be a vector of individual incomes and suppose that some dynamic process transforms it into $y \in \mathbb{R}^n_{++}$. Let $\Gamma_i = \frac{x_i - y_i}{x_i}$ be the relative income gap of the ith individual; let Q be the set of downward movers, $q = q(x, y)$ the number of individuals with downward mobility (income falls or losses) and $n = n(y)$ the total number of individuals in the population. Consider a mobility measure DM_α for $\alpha \geq 0$ defined by:

$$DM_\alpha(x, y) = \frac{1}{n} \sum_{i \in Q} \left(\frac{x_i - y_i}{x_i} \right)^\alpha = \frac{1}{n} \sum_{i \in Q} \Gamma_i^{\alpha}$$

The downward mobility measure is a weighted sum of the individual relative income falls of those who experience income losses. The weights are the relative income decrease itself. Unlike Demuynck ad Van der Gaer (2012) our weights do not depend on the rank order in the distribution of the individual relative change nor on the individual rank order in the base-year distribution as in Jenkins and Van kerm (2016), we opt for a convex transformation of the individual relative income change before aggregating. This is an alternative way to attach greater weights to greater downward movements, and therefore implies taking value judgements into account. Consequently, this measure shows sensitivity towards greater relative losses and considers inequality in the distribution of individual mobility (measured by individual income change rates) within a population for $\alpha > 1$.

For $\alpha = 0$ the measure DM_0 is the proportion of individuals that experience income falls, that we may call *incidence* of losses or *incidence* of downward mobility, H.

$$DM_0(x,y) = \frac{q}{n} = H$$

while DM_1 is the renormalization of the mean relative income loss:

$$DM_1(x,y) = \frac{1}{n}\sum_{i\in Q}\Gamma_i = \frac{1}{n}\sum_{i\in Q}\frac{x_i - y_i}{x_i} = H\frac{1}{q}\sum_{i\in Q}\frac{x_i - y_i}{x_i}$$

If we denote the mean relative income loss per downward mover as *intensity* of losses or *intensity* of downward mobility, $L = \frac{1}{q}\sum_{i\in Q}\frac{x_i - y_i}{x_i}$, then

$$DM_1(x,y) = HL$$

For $\alpha = 2$

$$DM_2(x,y) = \frac{1}{n}\sum_{i\in Q}\Gamma_i^{\,2} = \frac{1}{n}\sum_{i\in Q}\left(\frac{x_i - y_i}{x_i}\right)^2$$

As the variance of the relative income losses, Var_D, is:

$$Var_D\left(\frac{x_i - y_i}{x_i}\right) = \frac{1}{q}\sum_{i\in Q}\left(\frac{x_i - y_i}{x_i}\right)^2 - \left(\frac{1}{q}\sum_{i\in Q}\frac{x_i - y_i}{x_i}\right)^2$$

we can write,

$$\begin{aligned} DM_2(x,y) &= H\,Var_D\left(\frac{x_i - y_i}{x_i}\right) + H\left(\frac{1}{q}\sum_{i\in Q}\frac{x_i - y_i}{x_i}\right)^2 = H\left[\left(Var_D\left(\frac{x_i - y_i}{x_i}\right) + L^2\right)\right] \\ &= HL^2\left[1 + VC_D^{\,2}\right] \end{aligned}$$

where VC_D is the coefficient of variation of the relative income losses. Therefore, DM_2 includes a well-known inequality measure, the square coefficient of variation, that is the generalized entropy index when the parameter $\alpha = 2$. Therefore, this parameter α can be viewed as a measure of loss aversion: a larger α gives greater emphasis to the greatest relative losses. As α becomes very large DM_α approaches the "Rawlsian" measure which considers only the situation of the individual with the greatest loss. Symmetrically, the same reasoning can be used to propose a further index of upward mobility UM_α, we will detail its definition in Appendix 1.

The DM_α family of measures resembles the index of relative mobility proposed by Schluter and Van der Gaer (2011) but differently from theirs (which focusses on the amount of mobility in moving form distribution x to y) we make a distinction between downward or upward mobility. We focus on either downward or, alternatively, on upward mobility, one at a time, so we could also say that we impose a more restrictive property of "focus" on those who experience income losses (gains) while disregarding the upward (downward) movements. This does not mean that our measures are necessarily independent of the existence of upward movements but we do require that these upward movements are not considered when measuring aggregate downward movements. We consider that an individual's downward (upward) movement cannot be counterbalanced by upward (downward) movements of others. Only when focusing on downward movements can we provide a family of measures that incorporates information about the proportion of downward movers (incidence), mean relative income loss of downward movers (intensity) and the inequality of relative income losses of downward movers (inequality).

The DM_α family satisfies the following axioms:

*1. Focus. F*or all $x, y, z \in \mathbb{R}^n_{++}$, $DM_\alpha(x, y) = DM_\alpha(x, z)$ whenever z is obtained from y by an income change of a non-downward mover. That is, $DM_\alpha(x, y)$ is not concerned about what happens to non-downward movers.

This property derives from the expression of the index that only accounts for downward movements.

2. Continuity. $DM_\alpha(\Gamma)$ is a continuous function for any vector of relative income changes in its domain.

This property guarantees that small changes in relative income losses do not lead to large changes in our downward mobility index.

*3. Anonymity. F*or all $x, y, x', y' \in \mathbb{R}^n_{++}$ $DM_\alpha(x, y)$ is symmetric $DM_\alpha(x, y) = DM_\alpha(x', y')$ whenever x', y' are obtained after applying the same permutation of downward movers on x and y.

This property guarantees that the index does not favour any particular downward mover.

*4. Replication invariance. F*or all $x, y, x', y' \in \mathbb{R}^n_{++}$ $DM_\alpha(x, y) = DM_\alpha(x', y')$ whenever x', y' are obtained after applying the same k-replication on downward movers on x and y.

This is a technical property that allows for comparisons between distributions of different size.

5. *Monotonicity*. Given the vector $x = \{x_1, \dots, x_i, \dots, x_j, \dots, x_q, \dots, x_n\} \in \mathbb{R}^n_{++}$ and $y = \{y_1, \dots, y_i, \dots, y_j, \dots, y_q, \dots, y_n\} \in \mathbb{R}^n_{++}$ consider any $\mathcal{E} \in \mathbb{R}$ such that $x^{\mathcal{E}(i)} = \{x_1, \dots, x_i + \mathcal{E}, \dots, x_j, \dots, x_q, \dots, x_n\} \in \mathbb{R}^n_{++}$, and $y^{\mathcal{E}(i)} = \{y_1, \dots, y_i - \mathcal{E}, \dots, y_j, \dots, y_q, \dots, y_n\}$. For all $i \in Q$, and all $x, y \in \mathbb{R}^n_{++}$ $DM_\alpha(x,\ y^{\mathcal{E}(i)}) > DM_\alpha(x,\ y)$ and $DM_\alpha(x,\ y) > DM_\alpha(x^{\mathcal{E}(i)},\ y)$. This property is satisfied for $\alpha \geq 1$.

This property refers to downward movement intensity, so that a worsening in the downward movement yields a higher value of the index. Therefore, ceteris paribus, the lower the final income is the greater the downward mobility index will be, and similarly the greater the initial income, the greater the downward mobility index will be.

6. *Concern about greater downward moves*[3]. Given the vector of relative income changes, $\Gamma_i = \frac{x_i - y_i}{x_i}$, arranged in ascending order $\Gamma = \{\Gamma_1, \dots, \Gamma_i, \dots, \Gamma_j, \dots, \Gamma_q, \dots, \Gamma_n\}$ consider any $\pi > 0$ such that $\Gamma(\pi_i) = \{\Gamma_1, \dots, \Gamma_i + \pi, \dots, \Gamma_j, \dots, \Gamma_q, \dots, \Gamma_n\}$ and $\Gamma(\pi_j) = \{\Gamma_1, \dots, \Gamma_i, \dots, \Gamma_j + \pi, \dots, \Gamma_q, \dots, \Gamma_n\}$. For all $i, j \in Q$, $i < j$, $DM_\alpha(\Gamma(\pi_i)) < DM_\alpha(\Gamma(\pi_j))$. This property is satisfied for $\alpha > 1$.

This property implies inequality aversion with respect to the distribution of individual income losses. The allocation of any additional downward income change increases the index more if it is allocated to an individual with a greater initial downward movement.

The proof is evident because in $DM_\alpha(\Gamma_i) = F\left[\frac{1}{n}\sum_{i \in Q} \phi(\Gamma_i)\right]$, $\phi(\Gamma_i) = {\Gamma_i}^\alpha$ is a convex function of Γ_i. This property is derived from the fact that the weights of income losses depend on each individual's relative income losses.

The index satisfies other properties:

[3] Jäntti and Jenkins (2013) ask a key question related to this "why should we be concerned about the inequality of individual growth rates independently of incomes in the initial period?" (page 63). We would argue that given that it is most likely that a large income loss will take place at the lowest part of the income distribution, and recalling our definition of income change, $\frac{x_i - y_i}{x_i}$, our measures consider that an equal absolute income change has a larger impact on downward mobility. This is because the relative income fall is larger the smaller initial income is. Therefore, our approach is giving more importance to and income fall of the poor.

1. Individualistic and additive in relative income changes. For all $x, y \in \mathbb{R}^n_{++}$, $DM_\alpha(x,y)$ is the sum of individual relative income changes for a person with income x_i in the initial period and y_i in the final period.

$DM_\alpha(x,y) = \frac{1}{n}\sum_{i\in Q}\left(\frac{x_i - y_i}{x_i}\right)^\alpha$ only depends on the individual's own incomes and not on other downward movers' incomes.

*2. Scale invariance. F*or all $x, y, \in \mathbb{R}^n_{++}$ and $\lambda > 0$ $DM_\alpha(x,y) = DM_\alpha(\lambda x, \lambda y)$

3. Decomposition by population subgroups. Consider that the population is divided in G subgroups. Let index the group by g. Let P be a partition of the set $N = \{1,\dots,n\}$ in G subsets of individuals and let $\wp$ denote the set of all such possible partitions of N. For each group g of size n^g, the income vectors are partitioned into (x^g, y^g). For all $P \in \wp$

$$DM_\alpha(x^1, x^2, \dots, x^G, y^1, y^2, \dots, y^G) = \sum_{g=1}^{G} \frac{n^g}{n} DM_\alpha^g(x^g, x^g)$$

This property allows to decompose our overall downward mobility index into that of subgroups according to any socio-demographic characteristics of interest. This feature is particularly interesting to identify if some population subgroups are experiencing more downward mobility than others in order to help policy makers to design effective and consistent anti-downward mobility strategies. This property can also be used to account for the contribution of each population subgroup to overall downward mobility.

4. Concern about downward movement of poorer individuals. Given the vector $x = \{x_1, \dots, x_i, \dots, x_j, \dots, x_q, \dots, x_n\} \in \mathbb{R}^n_{++}$ and $y = \{y_1, \dots, y_i, \dots, y_j, \dots, y_q, \dots, y_n\} \in \mathbb{R}^n_{++}$ consider $\pi > 0$, $\pi < y_i$, $\pi < y_j$, such that $y(\pi_i) = \{y_1, \dots, y_i - \pi, \dots, y_j, \dots, y_q, \dots, y_n\}$ and $y(\pi_j) = \{y_1, \dots, y_i, \dots, y_j - \pi, \dots, y_q, \dots, y_n\}$ all arranged in ascending order of initial incomes, and $\Gamma_i = \Gamma_j$. For all $i, j \in Q$, $DM_\alpha(x, y(\pi_i)) > DM_\alpha(x, y(\pi_j))$. This property is satisfied for $\alpha \geq 1$.

That is, given two downward movers with the same income change, the same additional absolute reduction in income between the two moments in time increases the index more if it is allocated to an individual who initially had a lower income. Therefore, our index is more sensitive to the losses of the poorest individuals.

Proof:

$DM_\alpha(x, y(\pi_i)) > DM_\alpha\left(x, y(\pi_j)\right)$ is satisfied because.

$$DM_\alpha(x, y(\pi_i)) = DM_\alpha(x, y) - \left(\frac{x_i - y_i}{x_i}\right)^\alpha + \left(\frac{x_i - y_i + \pi}{x_i}\right)^\alpha$$

$$DM_\alpha\left(x, y(\pi_j)\right) = DM_\alpha(x, y) - \left(\frac{x_j - y_j}{x_j}\right)^\alpha + \left(\frac{x_j - y_j + \pi}{x_j}\right)^\alpha$$

Therefore, because of the $\Gamma_i = \Gamma_j$ and $x_i < x_j$

$$DM_\alpha(x, y(\pi_i)) - DM_\alpha\left(x, y(\pi_j)\right) = \left(\Gamma_i + \frac{\pi}{x_i}\right)^\alpha - \left(\Gamma_i + \frac{\pi}{x_j}\right)^\alpha > 0$$

Therefore, our measure of aggregate individual downward income mobility satisfies reasonable normative properties.

4. A graphical device for downward mobility analysis

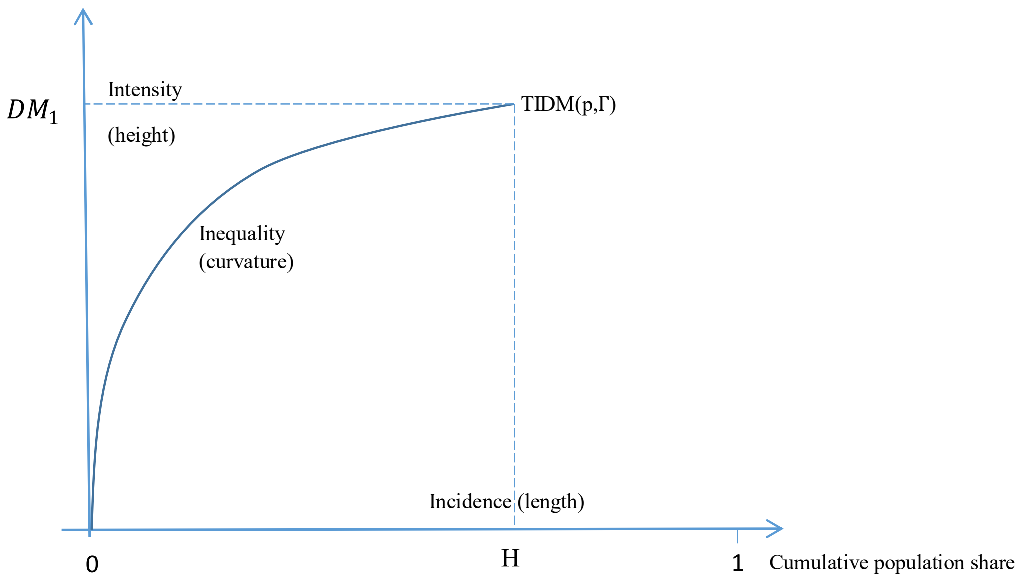
In this section we discuss the characteristics of an interesting graphical device for the analysis of downward (upward) mobility that is analogous to *Three I's of Poverty* (TIP) curves in poverty analysis (Jenkins and Lambert, 1998). These curves are based on relative income losses and provide a revealing picture of downward mobility and its distribution. We construct downward mobility profiles and develop some dominance criteria to rank downward mobility distributions according to their downward mobility level. The name of the curve, *Three I's of Downward Mobility* (TIDM) curve, is derived from its ability to simultaneously represent and summarize three aspects of downward mobility: incidence, intensity and inequality.

Curves are obtained by ranking relative income losses, $\Gamma_i = \frac{x_i - y_i}{x_i}\ \forall\ i \in Q$, in descending order (greatest losses first), cumulating the relative income losses per individual and plotting them. Values of the curve are defined in the interval [0, H] and only for downward movers.

The TIDM curve is denoted by TIDM(p, Γ) where $0 \leq p \leq 1$ and p represents the cumulative proportion of individuals in the population ranked in descending order of relative income losses. The curve plots against p the sum of the first p percent Γ-values divided by the total number of individuals in the population, n, once they have been ranked from larger to smaller relative (downward) income changes. Thus, TIDM$(0, \Gamma)$=0 and $\mathrm{TIDM}(\frac{\mathrm{k}}{\mathrm{n}}, \Gamma) = \frac{1}{n}\sum_{i=1}^{k}\frac{x_i - y_i}{x_i}$ for integer values k<q and at intermediate points $\mathrm{TIDM}(\mathrm{p}, \Gamma)$ is determined by linear interpolation. Therefore, $\mathrm{TIDM}(\mathrm{p}, \Gamma)$ is a positive, increasing and concave function of p, where the slope at each given percentile is equal to the mean relative income loss experienced by individuals in that particular percentile.

The shape of a TIDM curve provides us with very useful information. The incidence of downward mobility i.e. proportion of downward movers, H, is represented by the value of p, in the horizontal axis, which graphically corresponds to the point in the x-axis where the TIDM curve reaches its maximum height. The mean relative income loss is represented by the maximum height of the TIDM curve and is a measure of the intensity of downward movements. The inequality of income losses in the population considered is captured by how sharply curved the curve is, i.e. by the curve's concavity. If downward movers were to experience the same relative income losses, the TIDM curve would be a straight line with slope equal to the mean income loss. The more unequal the relative income losses are the more sharply curved the TIDM will be.

Figure 1. The TIDM curve and the three I's of downward movement



The extreme cases of the TIDM curve are as follows. The maximum downward mobility in a given population is when all individuals lose all their income, this means that in the final period all of them have zero income[4] and therefore the dimension of the relative income loss would take the value 1 for all the population. In this case the TIDM

[4] We assume all individuals in the society have non-negative incomes.

curve is the bisector of the first quadrant, that is the 45º line from the origin with slope one and with vertical intercept one at p=1. Its shape would be analogous to the Lorenz curve in the case of maximum equality. At the other extreme, when there are no downward movers in a population, the curve is defined over the empty interval and there is no curve.

Regarding dominance in TIDM curves, we are able to establish an ordering of relative income losses profiles by non-intersecting TIDM curves. Moreover, they allow researchers to identify how income gaps are distributed in a population, so that one can evaluate the relevance of large income drops versus medium or small ones. Consequently, these curves provide an extremely valuable additional information to that the DM_α family of measures in order to interpret the nature of downward mobility in any population of interest. Obviously, it is also possible to use them to compare income mobility across time and across countries, regions, or any other population sub-group, as we will show in a simple empirical illustration in the following section using longitudinal data for three European countries.

Definition of dominance in downward mobility. Given two relative income losses profiles, Γ^a and Γ^b, we would say that Γ^a dominates Γ^b in downward mobility sense, $\Gamma^a >_{DM} \Gamma^b$, if $\Gamma^a \neq \Gamma^b$ and $TIDM(p, \Gamma^a) > TIDM(p, \Gamma^b)$ for any $p \in [0,1]$

This dominance is linked to the axioms previously mentioned.[5] We can establish a relationship between dominance in downward mobility sense and the set of indices of downward mobility that satisfy the axioms mentioned. This is done in the inequality and poverty analysis, where there are valuable theorems that establish a relationship between the income distribution ranking obtained by "three 'I's of poverty" (TIP) or Lorenz's dominance criteria and those obtained by complete poverty and inequality indices compatible with those criteria (Jenkins and Lambert, 1998). In this sense, by using a minimal set of judgments, we will be able to identify particular cases where the downward movement distribution ranking is independent of the index chosen, since all indices yield the same result. This makes our analysis of downward movement significantly more robust.

Theorem For any pair of income losses profiles, Γ^a and Γ^b,

[5] Given initial incomes, dominance still holds if all downward movers experience an identical proportional income change.

$$\Gamma^a >_{DM} \Gamma^b \Leftrightarrow DM(\Gamma^a) > DM(\Gamma^b) \text{ for any } DM(.) \in DM^*,$$

where DM^* is the set of indexes that satisfy the, focus, continuity, anonymity, replication invariance, monotonicity and concern about greater downward mover axioms. That is, DM^* is the class of downward mobility indices in the form:

$$DM \quad = F\left[\frac{1}{n}\sum_{i\in Q}\phi(\Gamma_i)\right],$$

with $\phi(o) = 0$ and $\phi'(\Gamma_i) > 0$ and $\phi''(\Gamma_i) > 0$ for all $\Gamma > 0$. Then, a higher TIDM curve leads to a higher downward mobility index for an extensive set of downward movement indices.

Symmetrically, the same reasoning can be used to propose a curve of upward mobility TIUM, we detail its definition in Appendix 1.

5. An empirical illustration: the incidence and intensity of income mobility by age groups in Spain, Italy and Belgium.

In this section, we show the advantages of our approach in measuring the incidence, intensity and inequality of downward mobility in different countries by age groups during the last decade in three EU countries: Spain, Italy and Belgium. We will first compare the aggregate upward and downward mobility levels in the three countries to compare the phenomenon in each society. Secondly, given the empirical evidence on the relevant role of age groups in determining the opportunities to scale up or fall down the income ladder in many EU countries (particularly during the recession period) we will compare the levels of income mobility by age groups. In this way, we will show the advantage of the decomposability property of our income mobility class of indices. Both Italy and Spain would be included in the cluster of Mediterranean countries following Amable (2003) models of capitalism and in the more traditional classification of welfare systems by Esping-Andersen (1990). Belgium instead would be included in the continental European economies together with Austria, France, Norway, The Netherlands and Luxembourg.

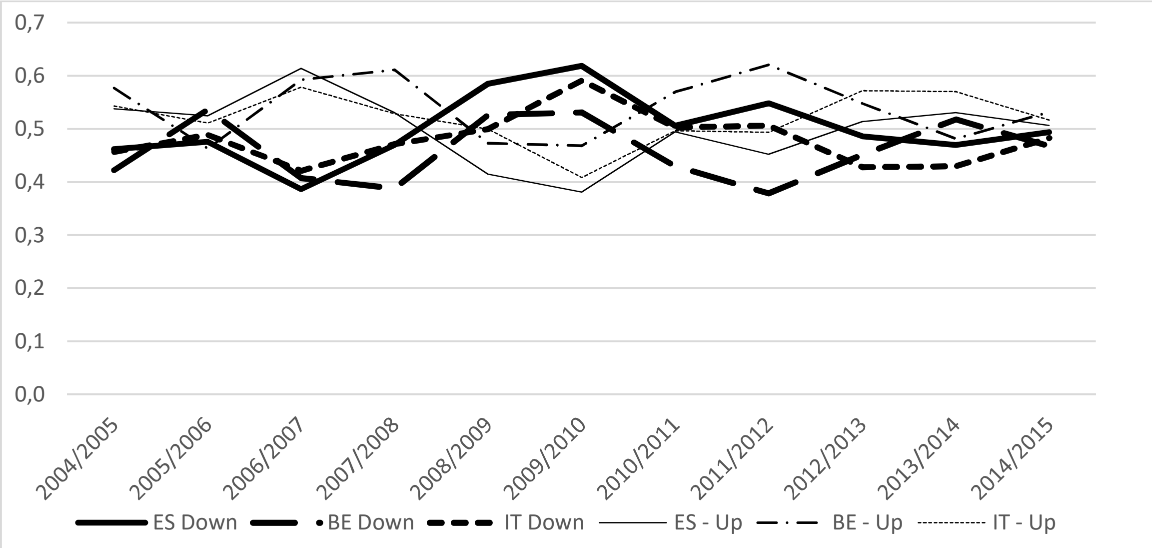
We exploit the longitudinal structure of the EU-SILC database undertaken by Eurostat for 27 EU countries that provides comparable panel data on individuals and households from 2004 to 2015, (the latest year available when closing the writing of this paper). In the case of Spain, we will consider two different periods of analysis: 2004-

2009 and 2009-2015. This is because in 2013 a new methodology for household income measurement was introduced in the Spanish version of EU-SILC to improve the quality of income information and retrospective estimations since 2009 have been made to make data to be comparable. In this new context, administrative records of Social Security and tax databases are now combined with survey information to construct better quality income variables for Spain. This methodological change does not seem to have significantly affected inequality and poverty indicators based on household income even if household income has increased significantly after the new system was introduced (Vega and Méndez, 2014) so we believe that it is wise to consider two different series of analysis for consistence in the case of this country.

For robustness, we have trimmed the tails of the distribution (1% of each tail) as strongly suggested by Cowell and Schluter (1999) due to the sensitivity of income mobility indices to the presence of outliers. Our 2004-2015 database includes, for every couple of years, more than 20,000 observations for Spain, almost 30,000 for Italy and between 8,000 and 9,000 for Belgium (Table 1A, Appendix 3). Our income variable in both moments in time is household equivalized disposable income in euro at constant 2015 prices adjusted for household size using a modified OECD scale. As in Van Kerm and Pi Alperin (2013) and Aristei and Perugini (2015) all estimates are obtained using sampling weights provided by Eurostat that are designed to adjust for attrition and non-response biases. In terms of age groups, we will consider analysing the different trends in three different groups: 35 and below, 36-65, over 65.

Results in Figure 2 and Table 1 clearly show that the incidence of upward and downward income mobility during turbulent economic periods has a kind of mirror trend. That is, when the number of individuals experiencing downward income mobility in a country is relatively high, upward mobility in that country tends to be relatively low and vice versa. This happens in all the three countries analysed. The fact that downward and upward income mobility incidence have opposite trends, may allow researchers to discuss both phenomena focussing only on one of them and then considering the analysis of the other one mostly as a sensitivity check.

Figure 2. Incidence of Upward and Downward income mobility in Spain, Belgium and Italy (DM0): 2004-2015



Source: EU-SILC Longitudinal Data, 2004-2015.

Interestingly, however, during periods of economic growth (such as 2004-2006) and economic recovery (since 2013 onwards), upward and downward mobility incidence levels are much more similar than during recessions (2008-2012). Moreover, some differences between countries are also observable: Spaniards and Italians experienced a relatively high incidence of downward income mobility during the recent crisis (62 percent and 59 percent of individuals were affected) and for a much larger period than the Belgians. Indeed, downward mobility is relatively high in Spain and Italy in the period between 2008 up to 2012 while in Belgium the largest incidence or this phenomenon (53 percent) occurs during 2009 and 2010.

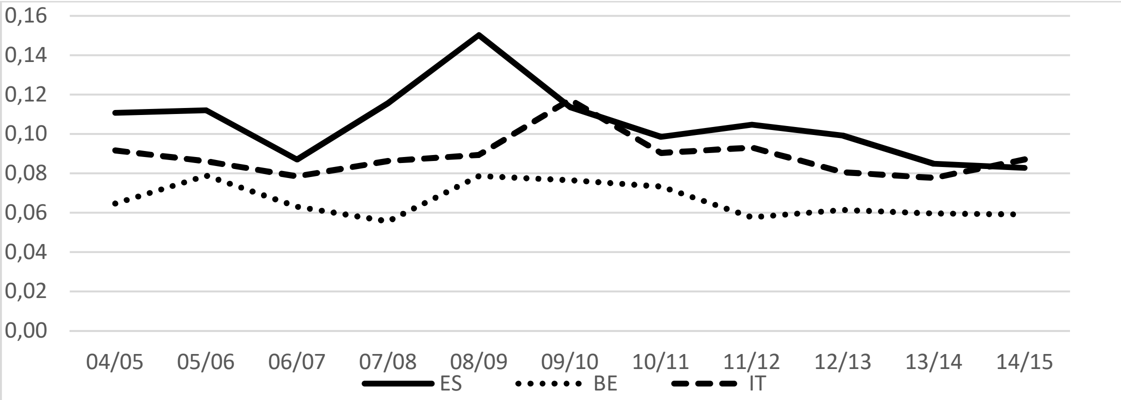
Table 1. Downward income mobility: Spain, Belgium and Italy, 2004-2015.

		04/05	05/06	06/07	07/08	08/09	09/10	10/11	11/12	12/13	13/14	14/15
$DM_0(x,y)$	ES	0.462	0.476	0.386	0.469	0.585	0.619	0.506	0.548	0.486	0.470	0.494
	BE	0.423	0.537	0.407	0.389	0.526	0.531	0.430	0.379	0.452	0.518	0.468
	IT	0.457	0.489	0.421	0.471	0.500	0.591	0.503	0.506	0.428	0.430	0.483
$DM_1(x,y)$	ES	0.111	0.112	0.087	0.116	0.150	0.114	0.099	0.105	0.099	0.085	0.083
	BE	0.065	0.079	0.063	0.056	0.079	0.077	0.073	0.058	0.061	0.060	0.059
	IT	0.092	0.086	0.079	0.086	0.089	0.117	0.090	0.093	0.081	0.078	0.087
$DM_2(x,y)$	ES	0.045	0.045	0.037	0.051	0.075	0.041	0.038	0.038	0.039	0.032	0.032
	BE	0.018	0.024	0.018	0.016	0.020	0.024	0.020	0.017	0.016	0.015	0.013
	IT	0.035	0.032	0.028	0.031	0.031	0.047	0.034	0.035	0.032	0.030	0.035

Source: EU-SILC Longitudinal Data, 2004-2015.

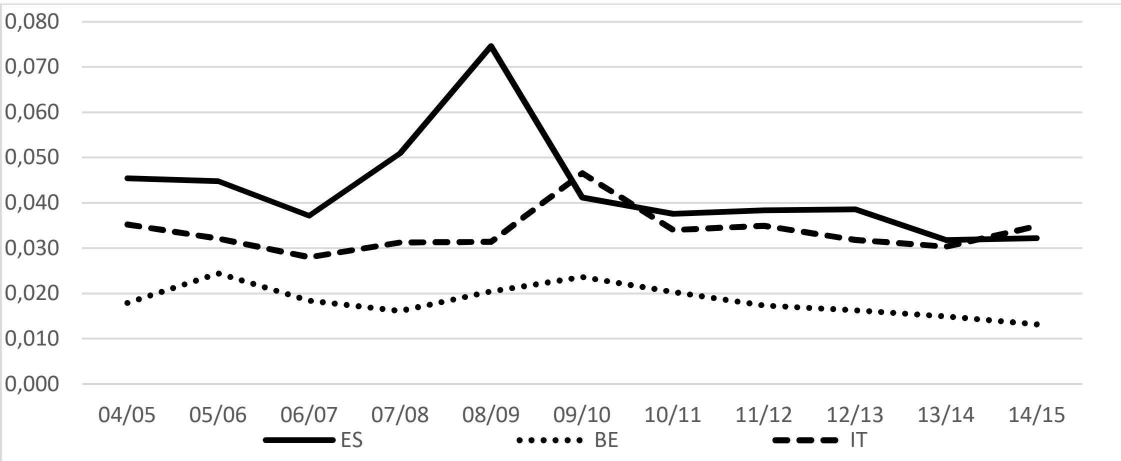
In Figures 3 and 4 we present the results of our downward mobility measure DM_α for $\alpha > 0$ for the whole period of analysis. We represent only the values of the index when $\alpha = 1$ that reflects the product of incidence and intensity of losses and $\alpha = 2$ where all three dimensions of incidence, intensity and inequality of the losses contribute to our downward mobility index. In general, our results show that downward mobility indices for Belgium are always below those for Spain or Italy, whatever the degree of aversion to income losses. In the light of the results, we can conclude that out of the three countries Spain stands out as the one where income losses have a larger negative social impact in the whole period of analysis, either considering only incidence and intensity or, even more so, considering inequality of individual income drops. Spaniards have experienced more downward income mobility than Italians and significantly more than Belgians.

Figure 3. Incidence and Intensity of Downward Income Mobility in Spain, Belgium and Italy (DM1): 2004-2015



Source: EU-SILC Longitudinal Data, 2004-2015.

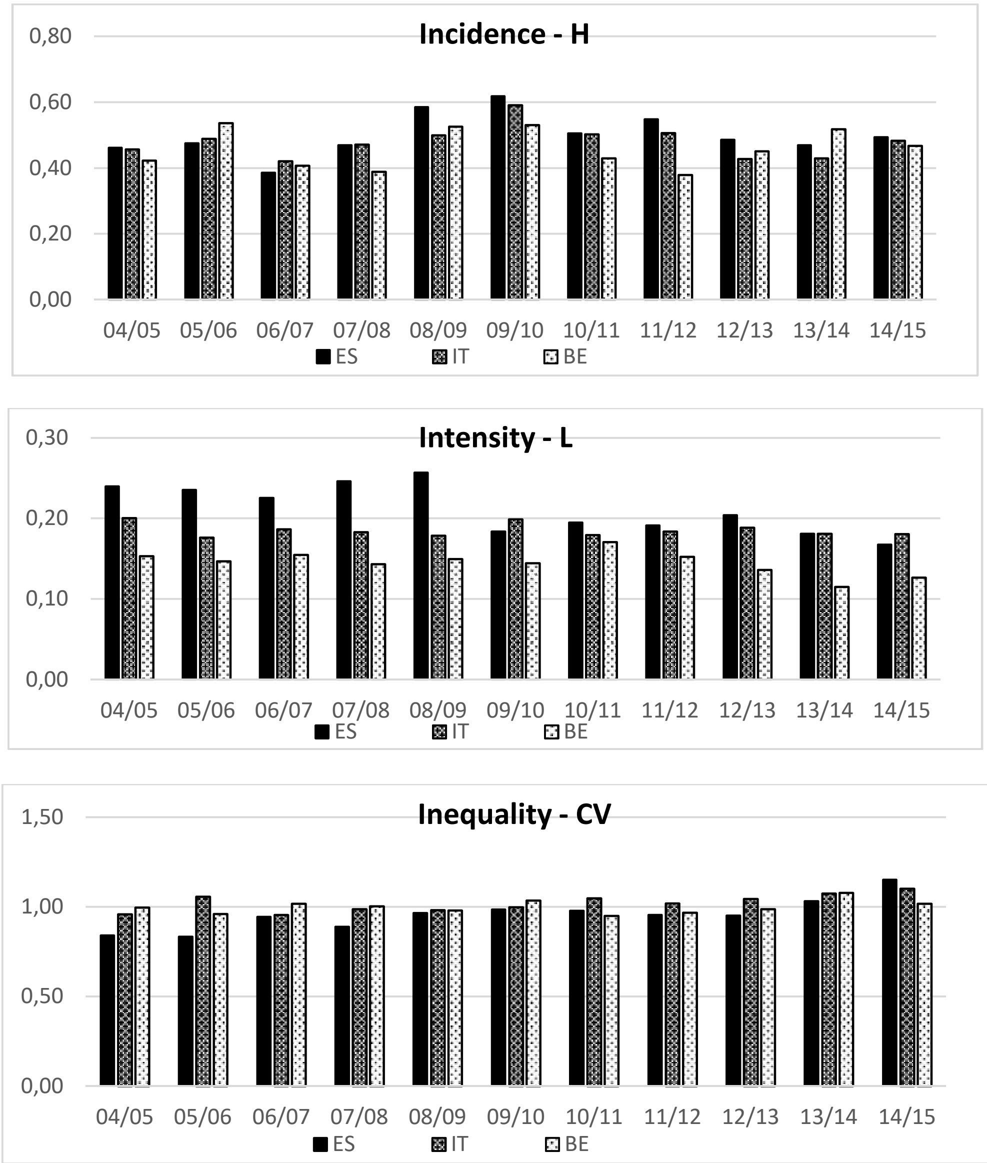
Figure 4. Incidence, Intensity and Inequality of Downward Income Mobility in Spain, Belgium and Italy (DM2): 2004-2015.



Source: EU-SILC Longitudinal Data, 2004-2015.

Interestingly, we can also conclude that income losses linked to the impact of the Great Recession took place in Spain slightly earlier than in Italy or Belgium, our index is much larger in 2008-2009 for Spain as opposed to that of Italy and Belgium that grows in 2009-2010. It is relevant to underline that when we consider a higher sensitivity to greater losses, Spain in 2008-2009 is even in a worse comparative position to the other two countries. Nevertheless, in this setting during the biannual period 2009-2010 Italians suffered more than Spaniards from social welfare reductions due to income losses.

Figure 5. Downward income mobility Incidence, Intensity and Coefficient of Variation: Spain, Belgium and Italy.



Source: EU-SILC Longitudinal Data, 2004-2015.

Our family of indices jointly considers incidence, intensity and inequality measured by the coefficient of variation, however it is most interesting to dedicate some time to analyse each of these dimensions separately for each country and year. In Figure 5 we show the three components of our downward mobility index, $DM_2(x, y)$, for the three countries. Results show that, only considering the incidence of downward moves is not enough to evaluate the social welfare impact of downward income losses in a comprehensive way. For instance, even if in Spain the incidence of downward mobility is generally higher than in Italy or Belgium, using that as a general measure of downward mobility would imply that we would consider Belgium in a worse position than Spain in various years because it has a higher percentage of downward movers in three pairs of years 2005-2006, 2006-2007 or 2013-2014. In a more complete picture, instead, we see that the mean relative income loss (intensity) is consistently higher in Spain than in Belgium (71% higher in Spain in the period 2007 to 2009 and 57% in the period 2013-2014). In contrast, inequality of income losses measured by the coefficient of variation is persistently larger in Belgium than in Spain with the only exception of the 2010-2011 and 2014-2015 periods when exactly the opposite happens (inequality of income losses is a 3% and 13% larger in Spain than in Belgium). This shows that losses are more evenly distributed in Spain, thus a more widespread phenomenon than in Belgium where this phenomenon is less intense and not so widespread.

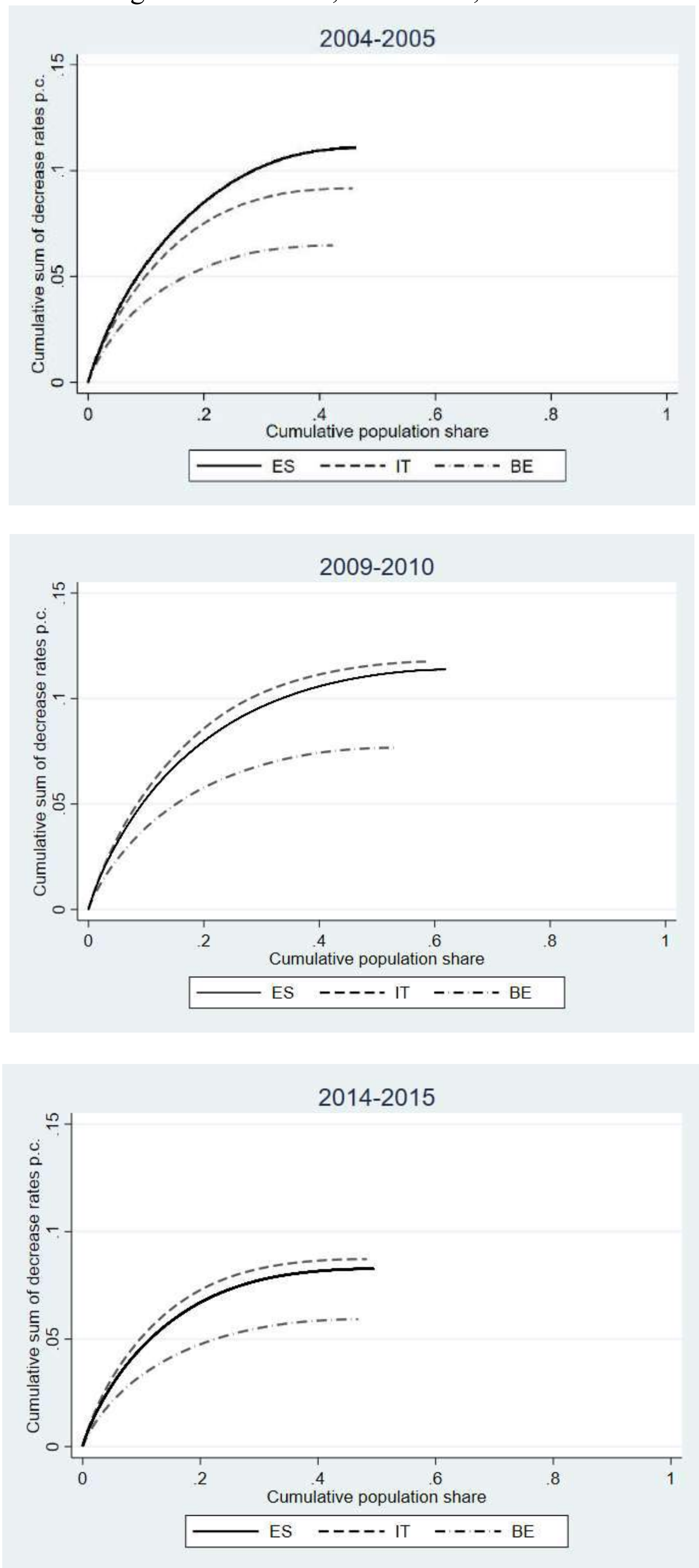
In Italy, inequality of income losses is almost every year over that in Spain and, in some periods, even over that in Belgium meaning that Italians suffer from a rather more unequal distribution of income losses in the population of downward movers. Not without discussion one could consider that, ceteris paribus, this is a worse social outcome.[6]

To establish some robust ordering of relative income losses during this period we use TIDM curves and compare the evolution of downward mobility across time in the three countries considered. These curves are largely informative on the actual distribution of income losses in the population. They provide a much more detailed information on how income losses of different dimensions are distributed compared to income mobility indices. Thus, they are be particularly useful for the interpretation of results when decomposing the population by demographic groups (see more detailed results by country and time and for upward mobility in Figures 3A and 4A in Appendix 3).

Results in Figure 6 show that downward mobility during the boom had a similar incidence on the three countries; approximately 40 percent of the population suffered some income loss from one year to the next. Differences between countries in that period of GDP growth were essentially related to the intensity of the losses (TIDM height). Spaniards suffered from a significantly higher mean relative income loss than Italians or Belgians.

[6] It can be surely debatable that given a fixed level of incidence and intensity of losses a more equal distribution of losses between the losers is a better outcome. In fact, in the poverty literature this value judgment has been also largely debated regarding the distribution of income gaps when using the Foster, Greer and Thorbecke (FGT) measure.

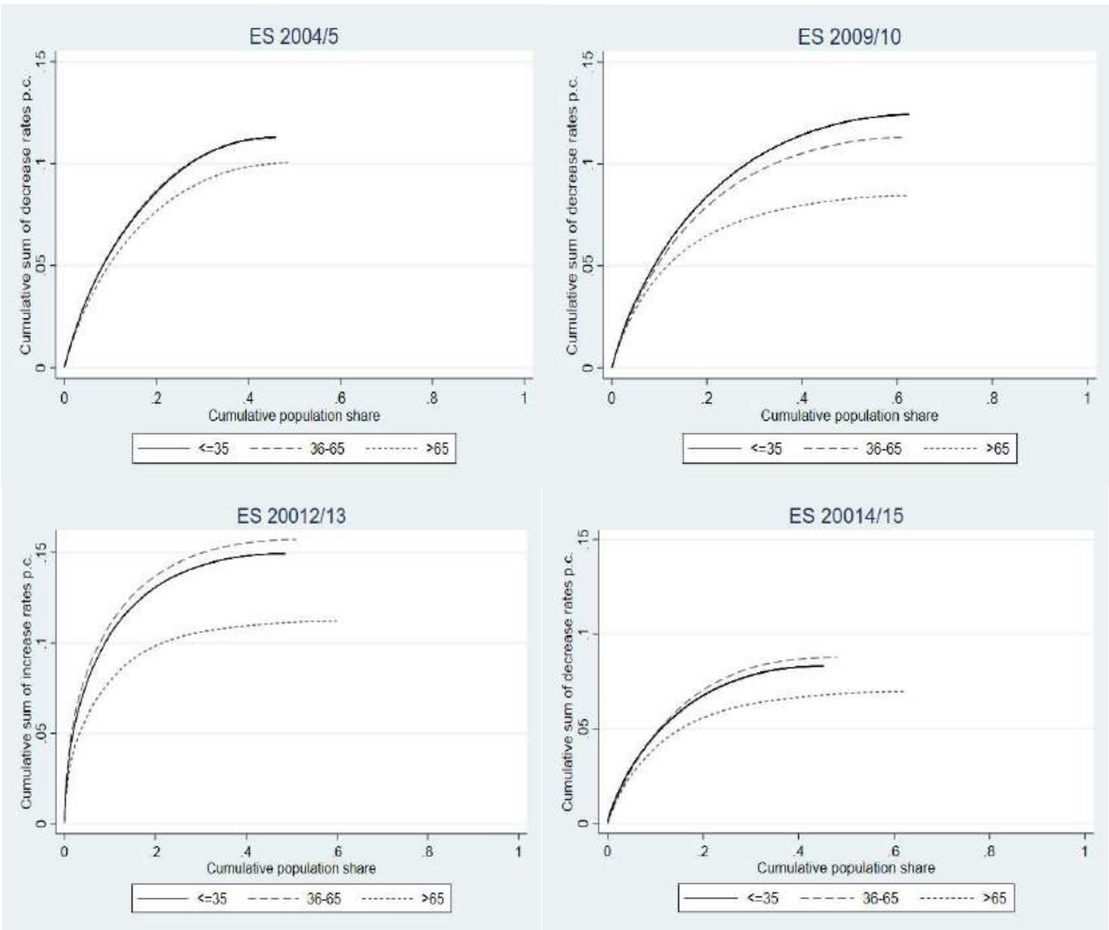
Figure 6. Three I's of Downward Mobility Curves (TIDM) for Spain, Italy and Belgium: 2004-2005, 2009-2010, 2014-2015



Source: EU-SILC Longitudinal Data, 2004-2015.

The Great Recession increased downward income mobility incidence in all three countries but in different magnitudes. Approximately 60 percent of Spaniards and Italians saw their incomes fall while only just over 55 percent of Belgians had a similar experience. However, what makes all three countries most different is the intensity of the losses. Both Italians and Spaniards experienced a much larger mean relative income loss than Belgians. In 2014-2015, in contrast with the two other years, we clearly observe that inequality was smaller in Belgium than in Spain or Italy because the TIDM for the two latter countries increases first with a steeper slope and then from p=0.2 onwards it becomes much flatter.

Figure 7A. Three I's of Downward Mobility Curves (TIDM) for Spain by age group



Source: EU-SILC Longitudinal Data, 2004-2015.

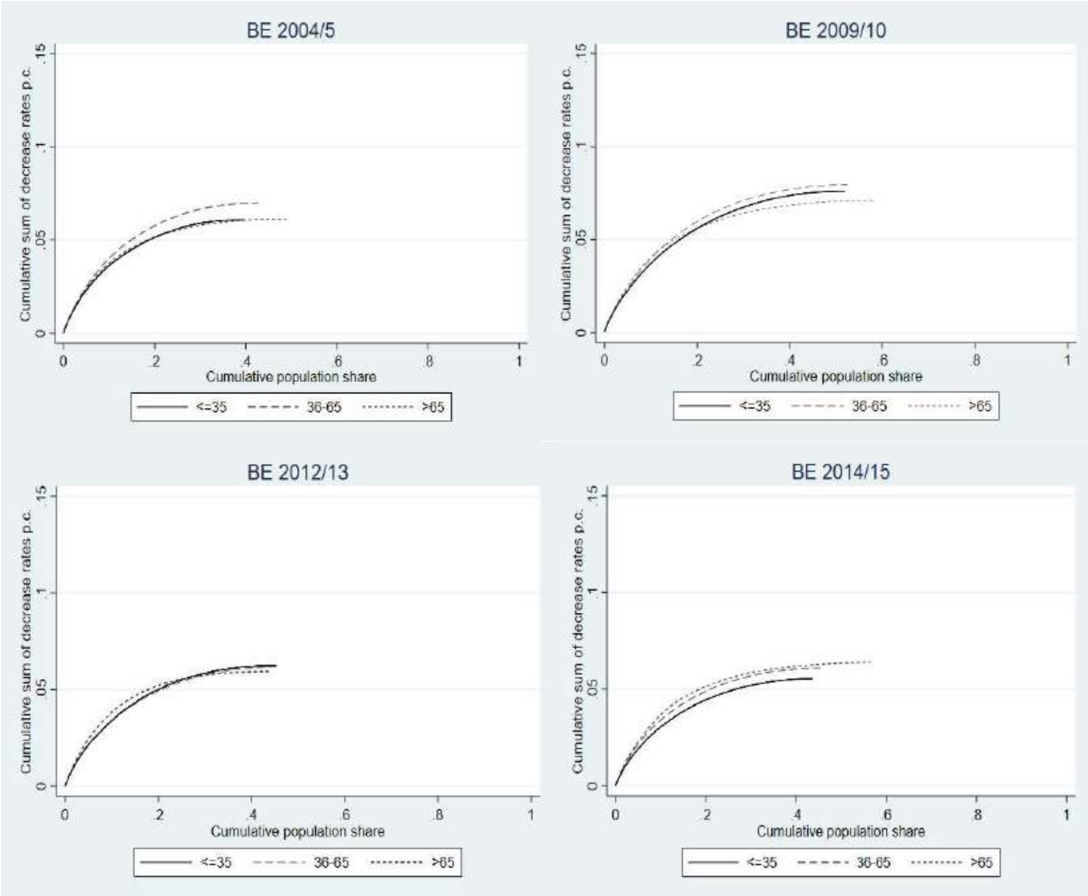
One step forward in the analysis of downward income mobility is to use this class of income mobility measures to study which are the socioeconomic or demographic subgroups that suffer more from downward income changes (or enjoy upward mobility) in different countries at different moments in time taking advantage of its subgroup decomposability. Ayala and Sastre (2008) found that mobility was significantly different by age groups, so that young household heads (together with individuals in single-parent households) experienced the greatest income fluctuations, even if the intensity of this instability varied greatly across countries. Cantó and Ruiz (2015) found that one of the main determinants of the probability of suffering income losses, both in the US and Spain, was precisely the individual's age group. The young and middle-aged groups are more likely to lose incomes compared to older individuals.

With the purpose of analysing the downward income mobility by age groups, we have divided the population in each country in various groups and constructed their TIDM curves. After revising the results for a significantly larger number of age groups, we believe that the differences are mainly observable comparing three key age divisions: 35 and below, 36-65, over 65. Results in Figures 7A, 7B and 7C show some interesting patterns by these three age groups in the countries considered.

We clearly observe that intensity in Spain and Italy is much larger for both young and middle-aged individuals than for those over 65, both during growth periods and recessions. This surprisingly extends the relevant impact of the recession on income changes in these two European countries to a much larger number of individuals that are not exactly what one would call the youngest generation. In Belgium, in contrast, age group differences in income losses are relatively small.

In Spain, the incidence of income losses has grown strongly for all age groups while intensity has mainly grown for the young and middle-aged and not so much for those over 65. We can also observe, in Spain and Italy, that the increases in the incidence of income losses for those over 65 in the second part of the recession (from 2012 onwards) is linked to many individuals who lose small real income quantities. In fact, since 2012, just one third of individuals over 65 that have seen their real incomes fall have suffered from great losses while two thirds have suffered from a small loss. This is not the case for younger individuals in any of these two countries.

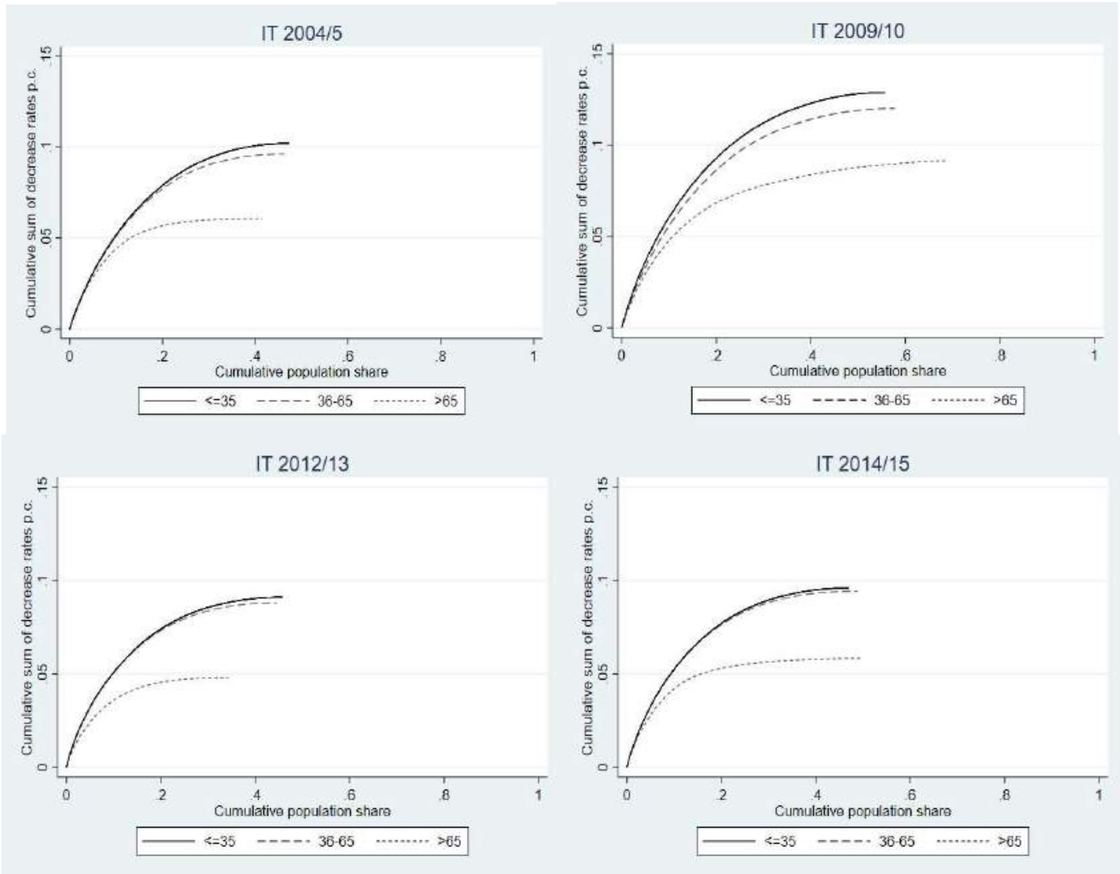
Figure 7B. Three I's of Downward Mobility Curves (TIDM) for Belgium by age group



Source: EU-SILC Longitudinal Data, 2004-2015.

In Belgium, the different age groups have a much more similar experience regarding downward moves. Note that in the 2012-2013 period individuals over 65 had a similar incidence and intensity to that of the rest of the groups but a higher inequality in income gaps, meaning that income drops were particularly different between individuals belonging to the oldest group in this country.

Figure 7C. Three I's of Downward Mobility Curves (TIDM) for Italy by age group



Source: EU-SILC Longitudinal Data, 2004-2015.

Conclusions

In this paper, we propose a subgroup decomposable class of income mobility measures with good axiomatic properties by adapting the concept of "individual income gap between two moments in time" to a framework that is traditionally used in the measurement of poverty and deprivation. This framework is explicit in incorporating the necessary judgements about how to aggregate individual income gaps by making use of the indices with best normative properties within the poverty literature. We believe that, in a period of a deep recession (high growth) even if positional change may be relevant, the immediate negative (positive) perception of a loss (gain) is more related to a concept of mobility that is genuinely more "absolute" than "relative". Therefore, we believe that the experience of an income loss by one individual cannot be compensated by the gain of another and so there is a need for an adequate directional measure that focusses separately on these changes. This is in line with recent contributions on the large interest in the assessment of individual income growth so that we can clearly show who are the gainers and the losers and who provide some distribution-sensitive assessments of mobility.

Our class of measures is directional because it quantifies upward mobility separately from downward mobility avoiding compensation between different individual's gains and losses. Second, it can identify the relevance of all three important relevant dimensions of the individual mobility experience: incidence, intensity and inequality. Third, its properties allow researchers to evaluate mobility across population subgroups in a coherent way. Fourth, the proposed class of mobility measures are consistent with a simple, intuitive and largely informative graphical device, which allows for further intuitive analysis of the incidence and intensity of income changes between two moments in time and for different population subgroups. These curves establish an ordering of relative income losses (gains) when they do not intersect which allows for consistent comparisons of downward (or upward) mobility across time, countries or any other relevant demographic or socio-economic variables. Finally, its simple structure facilitates comprehension and eases communication with policy makers without leaving any desirable axiomatic properties aside.

As an empirical illustration of the proposed class of mobility measures, we present an analysis of downward income mobility for different age groups in three EU countries during a decade. We use the EUSILC longitudinal data from 2004 up to 2015. Our main results reveal that our class of measures is particularly useful to show (both cardinally and in a graph) how remarkably different components of income mobility contribute to the social evaluation of income changes which allows us to identify the weight of each of the three main drivers of income losses (or gains): incidence, intensity and inequality. We can also analyse how these differ between countries along time and by age groups or other individual demographic or socioeconomic characteristics.

In general, our results show that downward mobility indices for Belgium are always below those for Spain or Italy, whatever the degree of aversion to income losses. Spain is in a worse relative position compared to Italy and Belgium if we consider a higher sensitivity to greater losses. Nevertheless, during the biannual period 2009-2010 Italians suffered more than Spaniards from social welfare reductions due to income losses.

Results clearly show that only considering incidence in the analysis of downward income mobility is not enough to evaluate the social welfare impact of losers; if we only looked into incidence, Belgium would be placed in a worse position than Spain in various years while the intensity of income drops in Belgium was largely smaller.

The graphical analysis of downward income mobility using TIDM curves is largely informative on the actual distribution of income losses in any population, particularly when decomposed into different demographic and socioeconomic groups. Income losses are of similar incidence by age groups in all three countries. However, their intensity in Spain and Italy is much larger for young and middle-aged individuals than for older groups. This result suggests that the Great Recession has reduced real incomes up to a much larger group than just the youngest generation. In Italy and Spain, the incidence of income losses for those over 65 is larger than for younger individuals since 2012, however this is linked to the occurrence of many small real income losses to this population subgroup while younger individuals experience fewer but much more intense losses.

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Appendix 1: Upward mobility index and upward mobility curve

Let $\Gamma'_i = \frac{y_i - x_i}{x_i}$ be the relative income change of the ith individual; let Q' be the set of upward movers, $q' = q'(x, y)$ the number of individuals with upward mobility (income gains). Consider a mobility measure UM_α for $\alpha \geq 0$ defined by:

$$UM_\alpha(x, y) = \frac{1}{n}\sum_{i \in Q'}\left(\frac{y_i - x_i}{x_i}\right)^\alpha = \frac{1}{n}\sum_{i \in Q'}\Gamma'^{\alpha}_i$$

The upward mobility measure is a weighted sum of the individual relative income gains of those who experience income gains. The weights are the relative income increase itself. This is an way to attach greater weights to greater upward movements, and therefore implies taking value judgements into account. Consequently, this measure shows sensitivity towards greater gains and takes into account inequality in the distribution of individual mobility (measured by individual income change rates) within a population for $\alpha > 1$.

For $\alpha = 0$ the measure UM_0 is the proportion of individuals that experience income gains, that we may call *incidence* of gains or *incidence* of upward mobility, H'.

$$UM_0(x, y) = \frac{q'}{n} = H'$$

while UM_1 is the renormalization of the mean relative income gains:

$$UM_1(x, y) = \frac{1}{n}\sum_{i \in Q'}\Gamma'_i = \frac{1}{n}\sum_{i \in Q'}\frac{y_i - x_i}{x_i} = H\frac{1}{q}\sum_{i \in Q'}\frac{y_i - x_i}{x_i}$$

If we denote the mean relative income gain per upward mover as *intensity* of gains or *intensity* of upward mobility, $L' = \frac{1}{q}\sum_{i \in Q'}\frac{y_i - x_i}{x_i}$, then

$$UM_1(x, y) = H'L'$$

For $\alpha = 2$

$$UM_2(x, y) = \frac{1}{n}\sum_{i \in Q'}\Gamma'^{2}_i = \frac{1}{n}\sum_{i \in Q'}\left(\frac{y_i - x_i}{x_i}\right)^2$$

As the variance of the relative income gains, Var_U, is:

$$Var_U\left(\frac{y_i - x_i}{x_i}\right) = \frac{1}{q'}\sum_{i\in Q'}\left(\frac{y_i - x_i}{x_i}\right)^2 - \left(\frac{1}{q'}\sum_{i\in Q'}\frac{y_i - x_i}{x_i}\right)^2$$

we can write,

$$UM_2(x,y) = H'\,Var_U\left(\frac{y_i - x_i}{x_i}\right) + H'\left(\frac{1}{q'}\sum\nolimits_{i\in Q}\frac{y_i - x_i}{x_i}\right)^2$$
$$= H'\left[\left(Var_U\left(\frac{y_i - x_i}{x_i}\right) + L'^2\right)\right] = H'L'^2\left[1 + VC_U{}^2\right]$$

where VC_U is the coefficient of variation of the relative income gains. Therefore, UM_2 is associated with a well-know inequality measure, the square coefficient of variation, that is the generalized entropy index when the parameter $\alpha = 2$. Therefore, this parameter α can be viewed as a measure of gain propensity: a larger α gives greater emphasis to the greatest gains. As α becomes very large UM_α approaches the "Rawlsian" measure which considers only the situation of the individual with the greatest gain.

The UM_α family satisfies the following axioms:

*1. Focus. F*or all $x, y, z \in \mathbb{R}^n_{++}$, $UM_\alpha(x,y) = UM_\alpha(x,z)$ whenever z is obtained from y by an income change of a non-upward mover. That is, $UM_\alpha(x,y)$ is not concerned about what happens to non-upward movers.

This property derives from the expression of the index that only accounts for upward movements.

2. Continuity. $UM_\alpha(\Gamma')$ is a continuous function for any vector of relative income changes in its domain.

This property guarantees that small changes in relative income gains do not lead to large changes in our upward mobility index.

*3. Anonymity. F*or all $x, y, x', y' \in \mathbb{R}^n_{++}$ $UM_\alpha(x,y)$ is symmetric $UM_\alpha(x,y) = UM_\alpha(x',y')$ whenever x', y' are obtained after applying the same permutation of upward movers on x and y.

This property guarantees that the index does not favour any particular upward mover.

*4. Replication invariance. F*or all $x, y, x', y' \in \mathbb{R}^n_{++}$ $UM_\alpha(x,y) = UM_\alpha(x',y')$ whenever x', y' are obtained after applying the same k-replication on upward movers on x and y.

This is a technical property that allows for comparisons between distributions of different size.

5. Monotonicity. Given the vector $x = \{x_1, \dots, x_i, \dots, x_j, \dots, x_q, \dots, x_n\} \in \mathbb{R}^n_{++}$ and $y = \{y_1, \dots, y_i, \dots, y_j, \dots, y_q, \dots, y_n\} \in \mathbb{R}^n_{++}$ consider any $\mathcal{E} \in \mathbb{R}$ such that $x^{\mathcal{E}(i)} = \{x_1, \dots, x_i - \mathcal{E}, \dots, x_j, \dots, x_q, \dots, x_n\} \in \mathbb{R}^n_{++}$, and $y^{\mathcal{E}(i)} = \{y_1, \dots, y_i + \mathcal{E}, \dots, y_j, \dots, y_q, \dots, y_n\}$. For all $i \in Q$, and all $x, y \in \mathbb{R}^n_{++}$ $UM_\alpha(x,\ y^{\mathcal{E}(i)}) > UM_\alpha(x,\ y)$ and $UM_\alpha(x,\ y) < UM_\alpha(x^{\mathcal{E}(i)},\ y)$. This property is satisfied for $\alpha \geq 1$.

This property refers to upward movement intensity, so that an increase in the upward movement yields a higher value of the index. Therefore, ceteris paribus, the greater the final income is the greater the upward mobility index will be, and similarly the lower the initial income, the greater the upward mobility index will be.

6. Concern about greater upward moves. Given the vector of relative income changes, $\Gamma'_i = \frac{y_i - x_i}{x_i}$, arranged in ascending order $\Gamma' = \{\Gamma'_1, \dots, \Gamma'_i, \dots, \Gamma'_j, \dots, \Gamma'_q, \dots, \Gamma'_n\}$ consider any $\pi > 0$ such that $\Gamma'(\pi_i) = \{\Gamma'_1, \dots, \Gamma'_i + \pi, \dots, \Gamma'_j, \dots, \Gamma'_q, \dots, \Gamma'_n\}$ and $\Gamma'(\pi_j) = \{\Gamma'_1, \dots, \Gamma'_i, \dots, \Gamma'_j + \pi, \dots, \Gamma'_q, \dots, \Gamma'_n\}$. For all $i, j \in Q'$, $i < j$, $UM_\alpha(\Gamma'(\pi_i)) < UM_\alpha(\Gamma'(\pi_j))$. This property is satisfied for $\alpha > 1$.

This property implies that the allocation of any additional upward income change increases the index more if it is allocated to an individual with a greater initial upward movement.

The proof is evident because in $UM_\alpha(\Gamma'_i) = F\left[\frac{1}{n}\sum_{i \in Q'} \phi(\Gamma'_i)\right]$, $\phi(\Gamma'_i) = {\Gamma'}_i^{\alpha}$ is a convex function of Γ'_i. This property is derived from the fact that the weights of income gains depend on each individual's relative income gains.

The index satisfies other properties:

1. Individualistic and additive in relative income changes. For all $x, y \in \mathbb{R}^n_{++}$, $UM_\alpha(x, y)$ is the sum of individual relative income changes for a person with income x_i in the initial period and y_i in the final period.

$UM_\alpha(x, y)$ only depends on the individual's own incomes and not on other upward movers' incomes.

2. *Scale invariance*. *F*or all $x, y, \in \mathbb{R}^n_{++}$ and $\lambda > 0$ $UM_\alpha(x,y) = UM_\alpha(\lambda x, \lambda y)$

3. *Decomposition by population subgroups.* Consider that the population is divided in G subgroups. Let index the group by g. Let P be a partition of the set $N = \{1, \dots, n\}$ in G subsets of individuals and let $\wp$ denote the set of all such possible partitions of N. For each group g of size n^g, the income vectors are partitioned into (x^g, y^g). For all $P \in \wp$

$$DM_\alpha(x^1, x^2, \dots, x^G, y^1, y^2, \dots, y^G) = \sum_{g=1}^{G} \frac{n^g}{n} UM_\alpha^g(x^g, x^g)$$

This property allows to decompose our overall upward mobility index into that of subgroups according to any socio-demographic characteristics of interest. This feature is particularly interesting to identify if some population subgroups are experiencing more upward mobility than others in order to help policy makers to design effective and consistent anti-upward mobility strategies. This property can also be used to account for the contribution of each population subgroup to overall upward mobility.

4. *Concern about upward movement of poorer individuals*. Given the vector $x = \{x_1, \dots, x_i, \dots, x_j, \dots, x_q, \dots, x_n\} \in \mathbb{R}^n_{++}$ and $y = \{y_1, \dots, y_i, \dots, y_j, \dots, y_q, \dots, y_n\} \in \mathbb{R}^n_{++}$ consider > 0, $\pi < y_i$, $\pi < y_j$, such that $y(\pi_i) = \{y_1, \dots, y_i + \pi, \dots, y_j, \dots, y_q, \dots, y_n\}$ and $y(\pi_j) = \{y_1, \dots, y_i, \dots, y_j + \pi, \dots, y_q, \dots, y_n\}$ all arranged in ascending order of initial incomes, and $\Gamma'_i = \Gamma'_j$. For all $i, j \in Q$, $UM_\alpha(x, y(\pi_i)) > UM_\alpha\left(x, y(\pi_j)\right)$. This property is satisfied for $\alpha \geq 1$.

That is, given two upward movers with the same income change, the same absolute increase in income between the two moments in time increases the index more if it is allocated to an individual who initially had a lower income. Therefore, our index is more sensitive to the gains of the poorest individuals.

Proof:

$UM_\alpha(x, y(\pi_i)) > UM_\alpha\left(x, y(\pi_j)\right)$ is satisfied because.

$$UM_\alpha(x, y(\pi_i)) = UM_\alpha(x,y) - \left(\frac{y_i - x_i}{x_i}\right)^\alpha + \left(\frac{y_i - x_i + \pi}{x_i}\right)^\alpha$$

$$UM_\alpha\left(x, y(\pi_j)\right) = UM_\alpha(x,y) - \left(\frac{y_j - x_j}{x_j}\right)^\alpha + \left(\frac{y_j - x_j + \pi}{x_j}\right)^\alpha$$

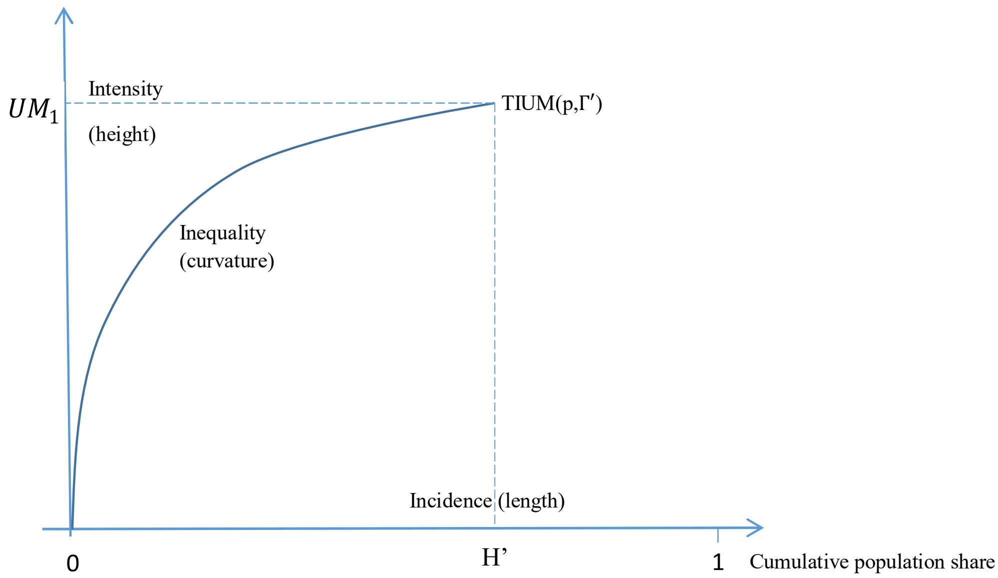
Therefore, because of the $\Gamma'_i = \Gamma'_j$ and $x_i < x_j$

$$UM_\alpha(x, y(\pi_i)) - UM_\alpha\left(x, y(\pi_j)\right) = \left(\Gamma_i + \frac{\pi}{x_i}\right)^\alpha - \left(\Gamma_i + \frac{\pi}{x_j}\right)^\alpha > 0$$

Therefore, our measure of aggregate individual upward income mobility satisfies reasonable normative properties.

The Three I's of upward mobility (TIUM) curve is denoted by TIUM(p, Γ') where $0 \leq p \leq 1$ and p represents the cumulative proportion of individuals in the population ranked in descending order of relative income gains. The curve plots against p the sum of the first p percent Γ'-values divided by the total number of individuals in the population, once they have been ranked from larger to smaller relative (upward) income changes. Thus TIUM$(0, \Gamma)$=0 and TIUM$(\frac{k}{n}, \Gamma')$=$\frac{1}{n}\sum_{i=1}^{k}\frac{y_i - x_i}{x_i}$ for integer values k<q', at intermediate points TIUM(p, Γ') is determined by linear interpolation. Therefore, TIUM(p, Γ') is a positive, increasing and concave function of p, where the slope at each given percentile is equal to the mean relative income gain experienced by individuals in that particular percentile.

Figure A1. The TIUM curve and the three I's of upward movement



Regarding dominance in TIUM curves, we are able to establish an ordering of relative income gains profiles by non-intersecting TIUM curves.

Definition of dominance in upward mobility. Given two relative income gains profiles, Γ'^{a} and Γ'^{b}, we would say that Γ'^{a} dominates Γ'^{b} in upward mobility sense, $\Gamma'^{a} >_{UM} \Gamma'^{b}$, if $\Gamma'^{a} \neq \Gamma'^{b}$ and $TIUM(p, \Gamma'^{a}) > TIDM(p, \Gamma'^{b})$ for any $p \in [0,1]$

We will be able to identify particular cases where the upward movement distribution ranking is independent of the index chosen, since all indices yield the same result. This makes our analysis of upward movement significantly more robust.

Theorem For any pair of income losses profiles, Γ'^{a} and Γ'^{b},

$\Gamma'^{a} >_{UM} \Gamma'^{b} \Leftrightarrow UM(\Gamma'^{a}) > UM(\Gamma'^{b})$ for any $UM(.) \in UM^{*}$,

where UM^{*} is the set of indexes that satisfy the, focus, continuity, anonymity, replication invariance, monotonicity and concern about greater upward mover axioms. That is, UM^{*} is the class of downward mobility indices in the form:

$$UM = F\left[\frac{1}{n}\sum_{i\in Q'} \phi(\Gamma'_{i})\right],$$

with $\phi(o) = 0$ and $\phi'(\Gamma'_{i}) > 0$ and $\phi''(\Gamma_{i}) > 0$ for all $\Gamma > 0$. Then, a higher TIUM curve leads to a higher downward mobility index for an extensive set of downward movement indices.

Appendix 2: Fields and Ok (1999) index as a function of downward and upward mobility indexes

The class of downward mobility indices in the form:

$DM = F\left[\frac{1}{n}\sum_{i\in Q} \phi(\Gamma_{i})\right]$,

has a special case that in which $\widetilde{DM} = \frac{1}{n}\sum_{i\in Q}|lny_{i} - lnx_{i}|$. In the same way $UM = F\left[\frac{1}{n}\sum_{i\in Q'} \phi(\Gamma'_{i})\right]$ has a special case that in which $\widetilde{UM} = \frac{1}{n}\sum_{i\in Q'}|lny_{i} - lnx_{i}|$.

Therefore, the Fields and Ok (1999) index of mobility can be expressed as:

$$FO = \frac{1}{n}\sum_{i=1}^{n}|lny_{i} - lnx_{i}| = \widetilde{UM} + \widetilde{DM}.$$

And the decomposition of the Fields and Ok (1999) index of aggregate income movement as the sum of a component representing income 'growth' for individuals and a residual component that can be interpreted as income 'transfers' between individuals, can be expressed as:

$FO = \frac{1}{n}\sum_{i=1}^{n}|lny_i - lnx_i| = \frac{1}{n}\sum_{i=1}^{n}(lny_i - lnx_i) + 2\frac{1}{n}\sum_{i\in Q}(lnx_i - lny_i)$=$\widetilde{UM} - \widetilde{DM} + 2\widetilde{DM}$

Therefore, the component representing income 'growth' for individuals is $\frac{1}{n}\sum_{i=1}^{n}(lny_i - lnx_i) = \widetilde{UM} - \widetilde{DM}$, while the component income 'transfers' between individuals is $2\frac{1}{n}\sum_{i\in Q}(lnx_i - lny_i)$=$2\widetilde{DM}$

Appendix 3: Additional results

Table 1A. Sample sizes in Spain, Belgium and Italy: 2004-2015

	04/05	05/06	06/07	07/08	08/09	09/10	10/11	11/12	12/13	13/14	14/15
ES	21476	21110	22681	23545	23927	23064	21382	19893	19801	20512	20977
%menor 36	46.1%	46.2%	45.8%	45.8%	45.0%	44.5%	43.0%	42.1%	41.7%	41.3%	39.4%
% 36-65	38.7%	38.9%	39.3%	39.2%	39.6%	40.3%	41.6%	42.1%	42.3%	42.2%	43.5%
% >65	15.2%	15.0%	14.9%	15.0%	15.4%	15.2%	15.4%	15.8%	16.0%	16.5%	17.1%
BE	7722	9023	9491	8793	8748	8675	8627	8537	9093	9091	8991
%menor 36	43.3%	42.7%	42.9%	42.0%	42.1%	41.2%	42.1%	42.3%	42.4%	42.4%	41.6%
% 36-65	41.6%	40.9%	40.7%	41.7%	42.1%	42.1%	41.6%	41.1%	40.9%	40.5%	40.4%
% >65	15.1%	16.4%	16.4%	16.2%	15.9%	16.7%	16.3%	16.5%	16.8%	17.1%	18.0%
IT	35587	34248	33644	33392	31712	27226	28304	27485	28831	29299	25189
%menor 36	38.8%	38.3%	37.7%	37.6%	37.1%	36.6%	35.9%	35.7%	34.8%	34.5%	35.0%
% 36-65	42.2%	42.0%	42.4%	42.1%	42.3%	43.2%	43.5%	43.4%	44.2%	43.6%	43.9%
% >65	18.9%	19.7%	19.8%	20.3%	20.7%	20.2%	20.6%	20.8%	21.0%	21.9%	21.1%

Source: EU-SILC Longitudinal Data, 2004-2015.

Table 2A. Incidence, intensity and inequality of downward income mobility in Spain, Belgium and Italy: 2004-2015

		04/05	05/06	06/07	07/08	08/09	09/10	10/11	11/12	12/13	13/14	14/15
Incidence	ES	0.46	0.48	0.39	0.47	0.59	0.62	0.51	0.55	0.49	0.47	0.49
	BE	0.42	0.54	0.41	0.39	0.53	0.53	0.43	0.38	0.45	0.52	0.47
	IT	0.46	0.49	0.42	0.47	0.50	0.59	0.50	0.51	0.43	0.43	0.48
Intensity	ES	0.11	0.11	0.09	0.12	0.15	0.11	0.10	0.10	0.10	0.08	0.08
	BE	0.06	0.08	0.06	0.06	0.08	0.08	0.07	0.06	0.06	0.06	0.06
	IT	0.09	0.09	0.08	0.09	0.09	0.12	0.09	0.09	0.08	0.08	0.09
Inequality (CV)	ES	0.84	0.83	0.95	0.89	0.97	0.99	0.98	0.96	0.95	1.03	1.15
	BE	1.00	0.96	1.02	1.00	0.98	1.04	0.95	0.97	0.99	1.08	1.02
	IT	0.96	1.06	0.95	0.99	0.98	1.00	1.05	1.02	1.05	1.08	1.10
Inequality (Gini)	ES	0.46	0.45	0.48	0.47	0.48	0.51	0.51	0.50	0.50	0.54	0.54
	BE	0.51	0.50	0.52	0.51	0.50	0.51	0.50	0.51	0.51	0.54	0.51
	IT	0.51	0.55	0.51	0.52	0.51	0.52	0.54	0.53	0.53	0.55	0.56

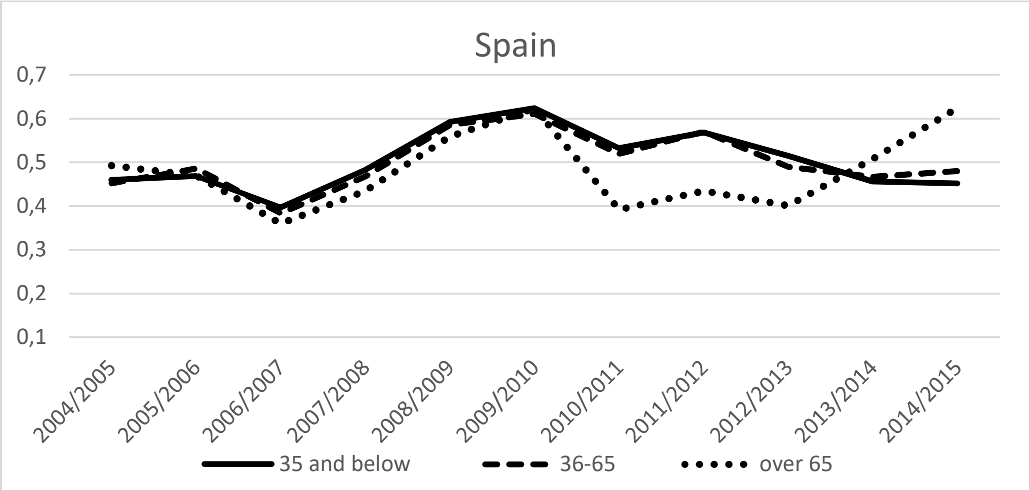
Source: EU-SILC Longitudinal Data, 2004-2015.

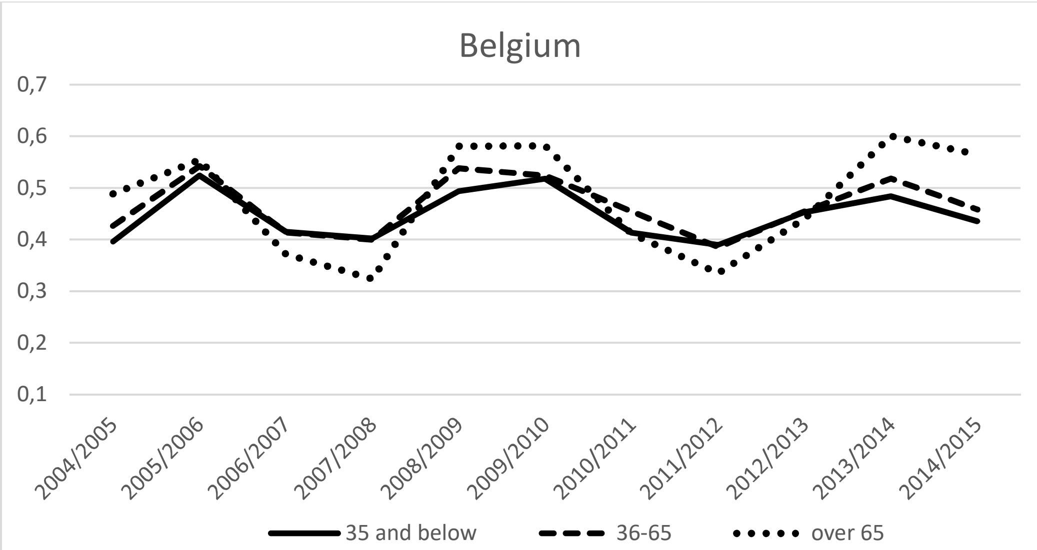
Table 3A. Incidence, intensity and inequality of upward income mobility in Spain, Belgium and Italy: 2004-2015

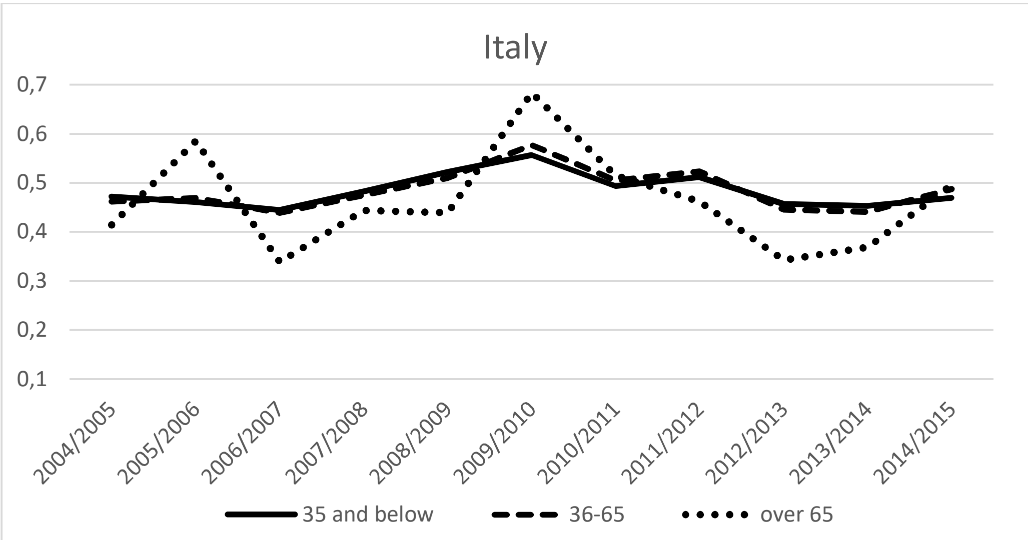
		04/05	05/06	06/07	07/08	08/09	09/10	10/11	11/12	12/13	13/14	14/15
Incidence	ES	0.54	0.52	0.61	0.53	0.41	0.38	0.49	0.45	0.51	0.53	0.51
	BE	0.58	0.46	0.59	0.61	0.47	0.47	0.57	0.62	0.55	0.48	0.53
	IT	0.54	0.51	0.58	0.53	0.50	0.41	0.50	0.49	0.57	0.57	0.52
Intensity	ES	0.29	0.28	0.30	0.24	0.20	0.15	0.15	0.16	0.15	0.17	0.17
	BE	0.13	0.11	0.13	0.15	0.11	0.12	0.12	0.16	0.12	0.10	0.11
	IT	0.18	0.17	0.20	0.17	0.16	0.16	0.18	0.14	0.16	0.16	0.16
Inequality (CV)	ES	1.60	1.61	1.65	1.72	1.90	1.99	1.97	2.05	2.17	2.03	1.99
	BE	1.40	1.61	1.55	1.54	1.47	1.67	1.49	1.81	1.53	1.76	1.46
	IT	1.85	1.65	1.90	1.94	1.99	1.89	1.99	1.99	1.99	2.33	2.06
Inequality (Gini)	ES	0.62	0.63	0.61	0.63	0.66	0.66	0.67	0.69	0.68	0.69	0.68
	BE	0.58	0.62	0.60	0.60	0.61	0.63	0.59	0.63	0.61	0.61	0.59
	IT	0.65	0.63	0.66	0.66	0.67	0.65	0.68	0.67	0.68	0.70	0.68

Source: EU-SILC Longitudinal Data, 2004-2015.

Figure 1A. Evolution in time of the Incidence of downward income mobility by age in Spain, Belgium and Italy (2004-2015)

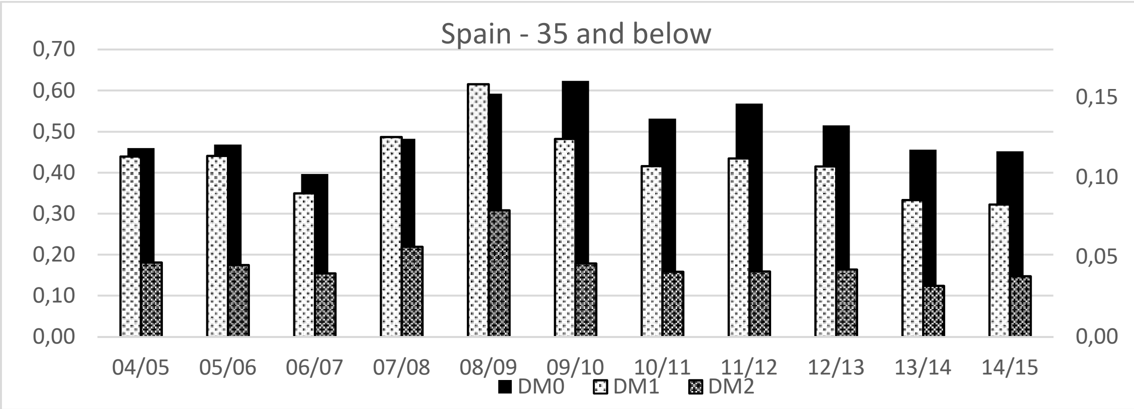


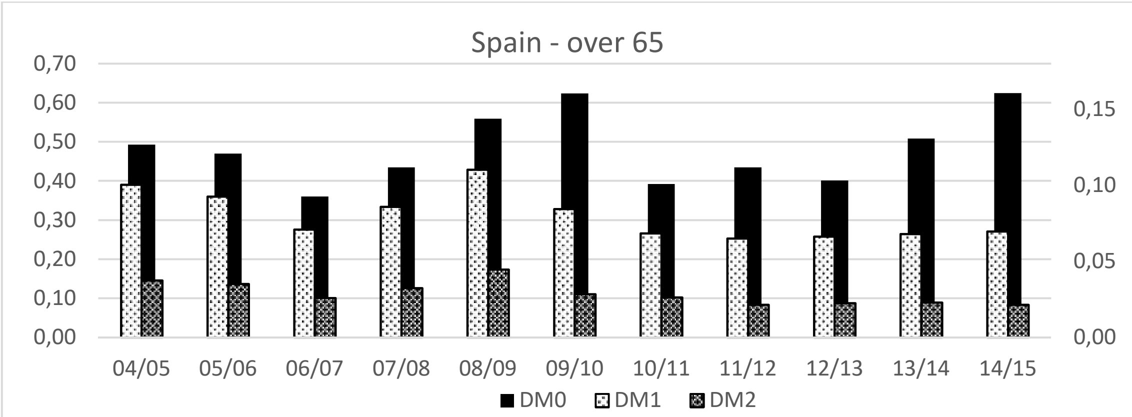


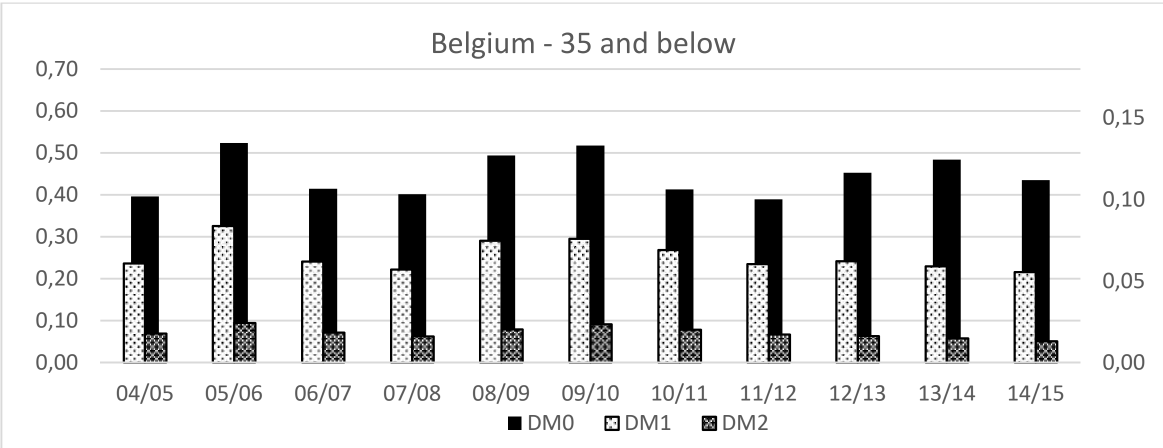


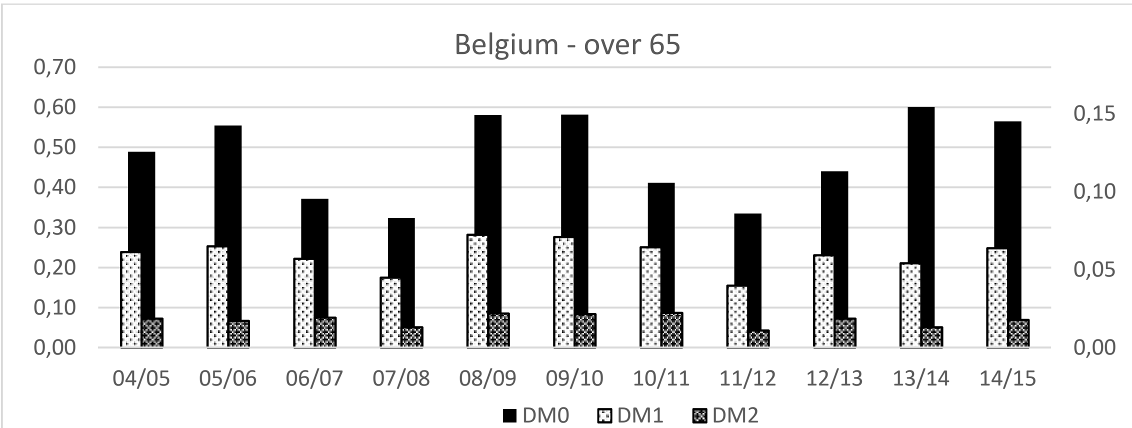
Source: EU-SILC Longitudinal Data, 2004-2015.

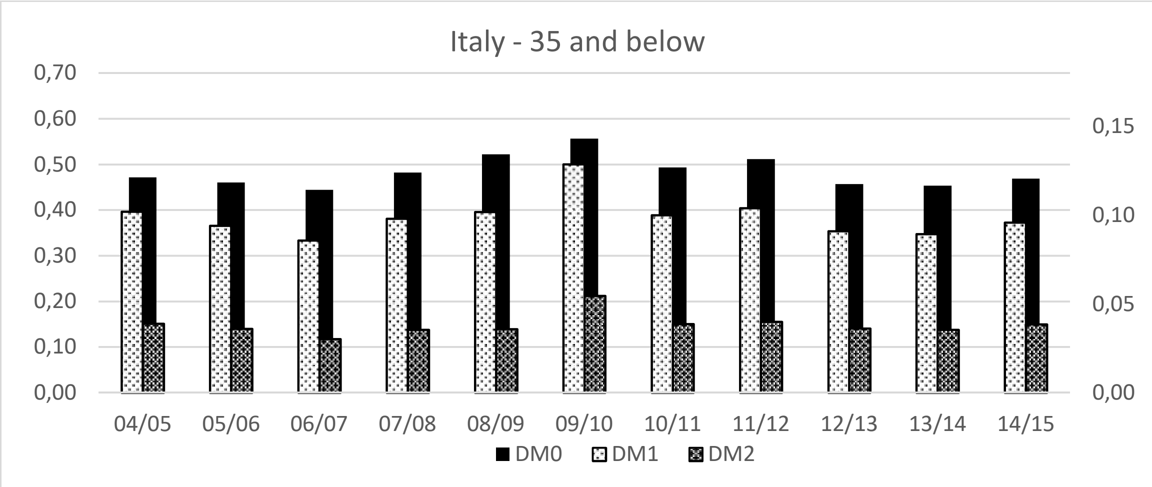
Figure 2A. Downward income mobility indices for Spain, Belgium and Italy: by age group, 2004-2015

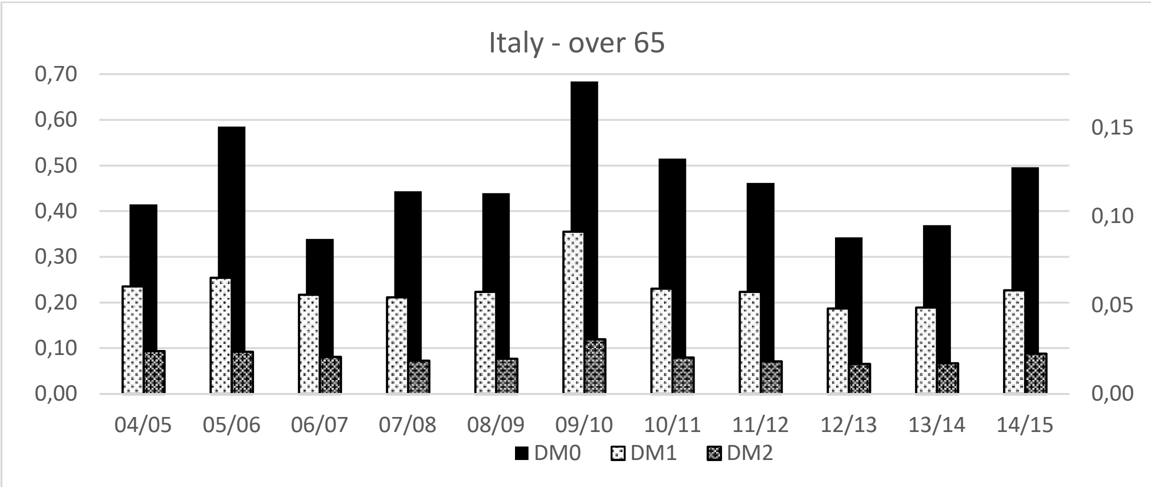






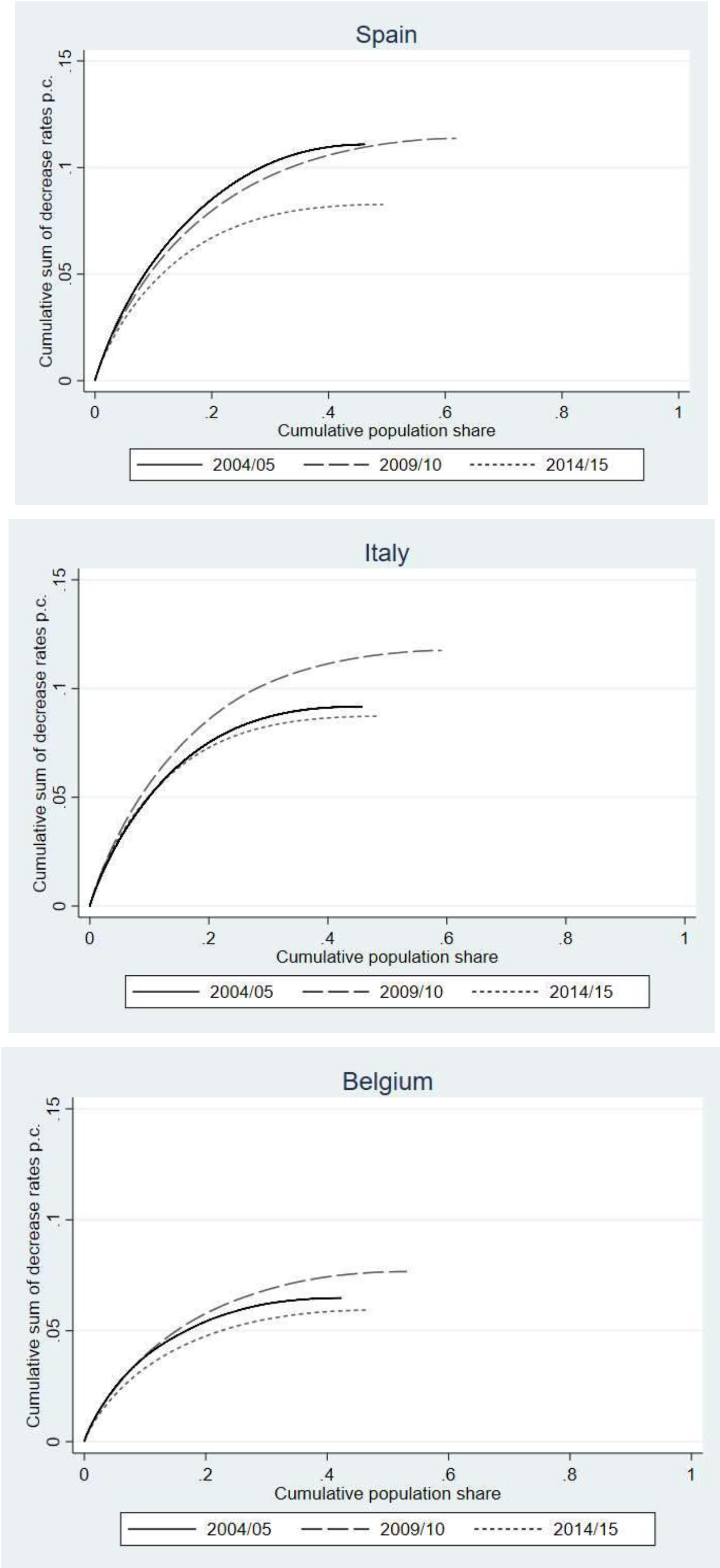






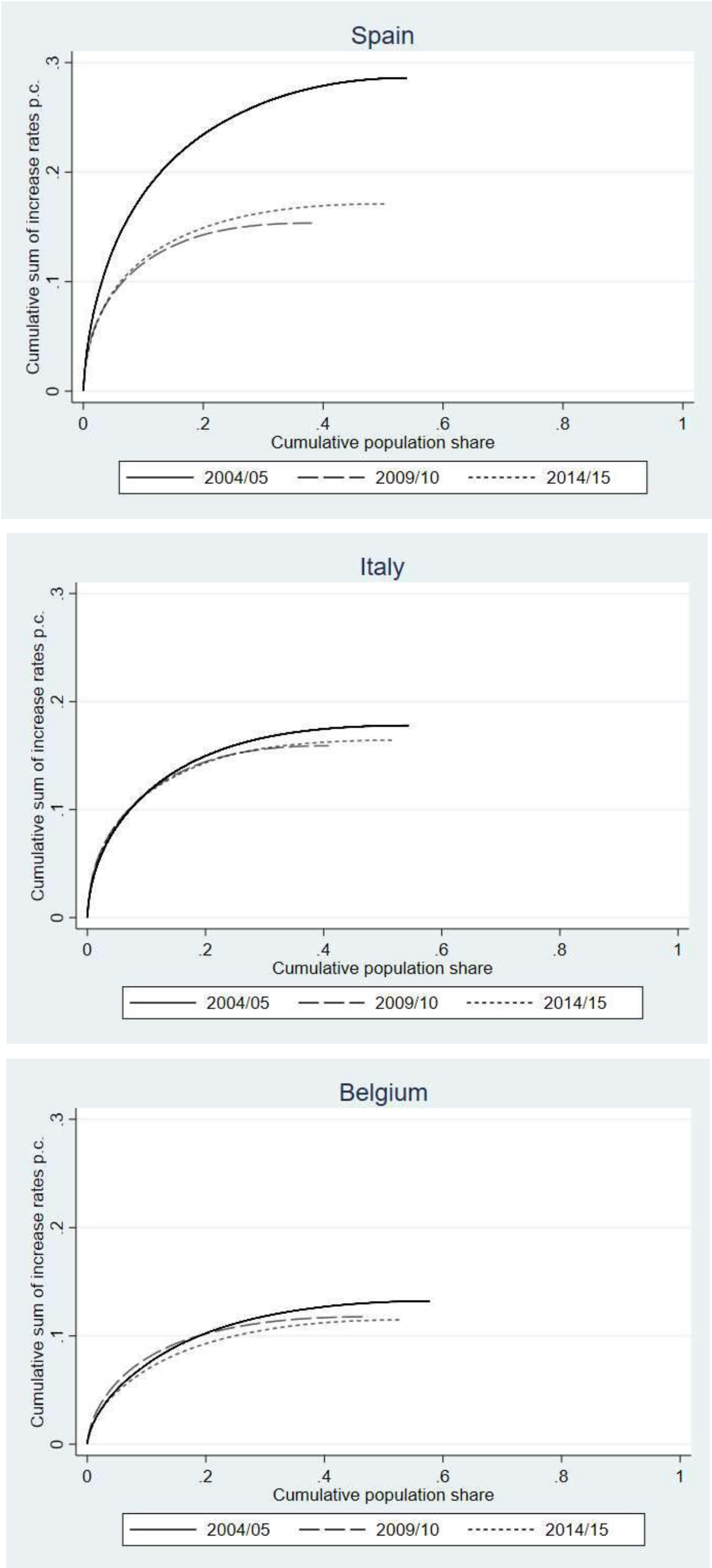
Source: EU-SILC Longitudinal Data, 2004-2015.

Figure 3A. Comparing downward mobility using Three I's of Downward Mobility curves (TIDM) for Spain, Belgium and Italy for three years: 2004-2005, 2009-2010, 2014-2015.



Source: EU-SILC Longitudinal Data, 2004-2015.

Figure 4A. Comparing upward mobility using Three I's of Upward Mobility curves (TIDM) for Spain, Belgium and Italy for three years: 2004-2005, 2009-2010, 2014-2015.



Source: EU-SILC Longitudinal Data, 2004-2015.