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Risk factors associated to the COVID-19: comparisons between France and Luxembourg

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Abstract

This paper proposes a study of risk factors in France and Luxemourg associated to the propagation of the COVID-19. The analysis relies on data from wave 8 of the Survey of Health, Ageing and Retirement in Europe, covering France and Luxembourg. The methodology relies on achievement curves stemming from a multidimensional socio-economic health inequality index (Gini) measured across multiple items reflecting physical and mental health. In Luxembourg, the non respect of the preventive hygiene measures (mask, hydroalcoholic gel and coughs) contributes to increase the level of socio-economic health inequalities in the country. However, in France, the role of the preventive hygiene measures cannot be assessed.

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Special issue “In memory of Professor Michel Terraza”

1. Introduction

The coronavirus disease (COVID-19) epidemic started in the last months of 2019. Since then, a large number of epidemiological decisions and recommendations by governments were implemented all over the world. Among them, we can find a certain number of protective and preventive hygiene measures such as wearing a face mask, keeping distance to others when being outside or washing hands more frequently than usual (see for instance, Khalil et al. 2020, Machida et al. 2020, Ghanemi et al. 2021, and WHO 2021). Even though the situation is different in each country in terms of, among other, daily positive rates, numbers of individuals in hospital, the protective measures implemented in each individual country are similar. Additionally, the vaccination against Coronavirus started being proposed at the end 2020, but still the protective and preventive measures are important to avoid the spread of COVID-19 among the population and to prevent people from getting seriously ill or dying from this disease.

Even though the governments express different recommendations, individuals behave differently when they are confronted to risks that can have an impact on their health. In this paper, we aim to identify which risk factors (among those under an individual control or beyond it) increase the socio-economic inequalities in health in France and Luxembourg. Four different endogenous risks (one protective measure and three preventive hygiene measures) and two exogenous risks (medical appointments and treatments denied or postponed) are analyzed.

To study the relationship between health inequality and risk factors, we use a family of multidimensional socio-economic health Gini inequality indices proposed by Mussard & Pi Alperin (2021a). This family of indices depends on different health items and on one risk factor. It allows to take into account two different but at the same time complementary behaviors of the social planner. The first one represents the behavior of the social planner with respect to the degree of aversion to inequality. The second one embodies the sensibility of the social planner with respect to one exogenous risk factor. Then, this family of indices allows to identify those risk factors that increase socio-economic inequalities in health in a society. This identification is made possible by the employ of achievement curves that plot the repartition of the population with respect to the aggregate health items and one given risk factor.

The analysis relies on data from wave 8 of the Survey of Health, Ageing and Retirement in Europe (SHARE), covering France and Luxembourg. As a health measure, we use a continuous synthetic indicator of health summarizing the health status of individuals across multiple items reflecting their physical and mental health.

The paper is organized as follows: Section 2 briefly describes the multidimensional two-parameter Gini indices of health used in the paper. Section 3 presents the SHARE database and the definitions of health and risk factors considered in the analysis. The results of the comparisons between different achievement curves are presented in Section 4. Section 5 deals with sensitivity check. Section 6 concludes the paper.

2. Methodology

On the basis of Makdissi et al.'s (2013) work, Mussard & Pi Alperin (2021a) define a class of multidimensional two-parameter Gini indices which depends on different health items and on one risk factor. This family of indices has been applied to the identification of health risk factors in Luxembourg [Mussard & Pi Alperin (2020, 2021a)] and in multiple European countries

[Mussard & Pi Alperin (2021b)]. Precisely, it allows socio-economic inequalities of health to be measured accounting simultaneously for two complementary behaviors of the social planner: inequality aversion (redistribution) and risk sensibility. The redistribution is defined, as usual in the literature of social choice, as the willingness of the social planner to perform rich-to-poor income transfers. The redistributive policies are calibrated through the parameter ν whose value increases with the ability of the social planner to perform income transfers towards poorer individuals. The risk sensibility captures the sensibility of the social planner with respect to risk factors and is calibrated with a parameter α. These risk factors may be associated with lifestyle (under the individual's control) such as smoking, drinking, or exogenous risk factors (beyond the individual's control) such as living in an unhealthy environment or childhood circumstances, that directly affect the health status of the individual. In this perspective, the class of two-parameter socio-economic health Gini indices can be employed to analyze inequality of opportunity which considers that health outcomes can be the consequence of circumstances beyond individual's control or autonomous choices (the former having to be compensated).

In practice, the class of multidimensional two-parameter Gini indices provides socio-economic health inequality indices. These indices outline the level of income inequality in a society with respect to different health items (characterizing the mental and the physical dimensions of health) and one risk factor -included as one additional health item- considered in the analysis. The risk factor may be either a Boolean or a continuous variable, which can be modelled as a fuzzy variable, that is considering different degrees of risk. As far as the social planner is sensitive towards the risk factor, this may increase the level of inequality in the society, or by duality, this may decrease the level of welfare in the society. Strictly speaking, the dual of these socio-economic health inequality indices are achievement indices which measure the level of health attainment (achievement) with respect to a given income. Then, the measure of welfare is rather a measure of the ability of the individuals to be healthy, that is, to be above a given threshold below which an individual is considered non-healthy. Accordingly, the multidimensional two-parameter Gini indices enable welfare comparisons to be designed thanks to different risk factors taken into consideration.

In order to test whether a risk factor may imply either an improvement or a decline of overall welfare for the society, it is possible to compare (α,ν)-achievement curves. These curves plot the health achievements with respect to income percentiles, with a given degree of redistribution (ν) and a given degree of risk sensibility borne by the social planner (α). This is one of the main advantage of this family of indices. The comparison of health distributions relies on a simple graphical approach. Then, as depicted in Figure 1, if the achievement curve A (the red one) lies nowhere below curve B (the blue one), then the level of health achievement (welfare) is (at least) higher.

The identification of risk factors that increase socio-economic health inequalities in the society can be done by comparing (α,ν)-achievement curves each one of them associated to a different risk factor. For instance, it is possible, for a given society evaluated over a set of health items, to gauge the impact of adding one risk factor on the overall welfare of the society. Suppose that, in Figure 1, curve A is associated with risk A (e.g. alcohol consumption) and curve B associated with risk B (e.g. smoking). Risk B implies a more important deterioration of welfare in the society compared to risk A. If the (α,ν)-achievement curves cross, however, then no

comparison can be done and no conclusion can be drawn about the ranking of the different risk factors under study.[1]

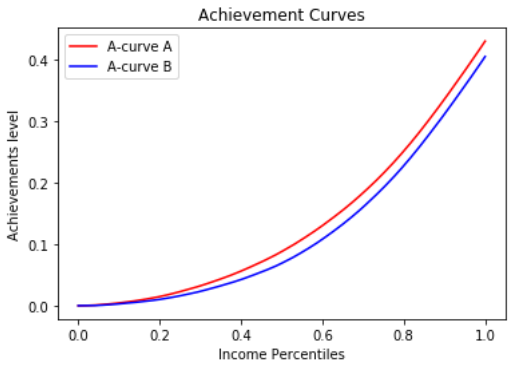

Figure 1. Example of achievement curves

3. Data and other definitions

We use data from the Survey of Health Aging and Retirement in Europe (SHARE).[2] SHARE is a multidisciplinary and international panel survey collecting information allowing to study the effects of health, social, economic and environmental policies over the life-course of European citizens and beyond. In addition to the regular data collection of SHARE, between May and August 2020, a SHARE Corona Survey was conducted by telephone with the objective to estimate the first impact of the Corona outbreak on individuals above 50 years old in Europe.[3]

In particular, our analysis is based on both SHARE Corona Survey and SHARE Regular Wave 8 -Release 1.0.0- conducted between 2019 and early 2020. Only individuals who responded to both questionnaires were considered in the analysis. We focus on individuals living in two neighboring countries: France and Luxembourg. After imputing all the missing values, our estimation samples include 2060 and 932 individuals living respectively in France and Luxembourg.

3.1. Health measurement

The health status of each individual is measured using the methodology proposed by Pi Alperin (2016). This approach, based on the fuzzy set theory, allows to aggregate different items of health in one synthetic indicator. With this methodology, it is possible to account for different degrees of deprivation: for each item of health there are completely healthy individuals, completely non-healthy individuals, and individuals with different intensities of health failure. In practice, the synthetic scores are calculated as a weighted mean of all health items with a weighting scheme proposed by Betti & Verma (1998). In particular, this weighting scheme accounts for the relative frequency of items, from the one hand, and the correlation of items in order to limit the influence of highly correlated health limitations on the synthetic index, from the other hand.[4]

[1] See Mussard & Pi Alperin (2021a) for a detailed description of this methodology.
[2] For a detailed description of SHARE, see Börsch-Supan et al. (2013).
[3] See Scherpenzeel et al. 2020 for a detailed description of the SHARE Wave 8 COVID-19 data.
[4] Note that all the indicators are computed using the MDEPRIV program (see Pi Alperin & Van Kerm, 2020).

In the analysis, different health items are considered reflecting the mental and the physical dimensions of health. In particular, suffering depression, having orientation and cognition problems are the three health items associated with mental health. Chronic illness, various limitation in activities and mobility, eyesight and hearing problems are the health items characterizing the physical dimension of health. A total of nine items are included to measure the global health status of each individual.[5]

3.2. Risk factors

We first concentrate the analysis to a set of endogenous risk factors. In other terms, risk factors under the individual's control. A total of four risk factors are considered to have an impact on the individual health status by increasing their probability of being contaminated with COVID-19. In particular, one risk factor grouping two *protective measures* (protective):

- wearing a face mask when going outside home to a public space;
- and keeping distance to others when they go outside home.

Three risk factors characterize different *preventive hygiene measures*:

- washing hands more frequently than usual (hands);
- using special hand sanitizer or disinfection fluids more frequently than usual (hydro);
- and covering cough and sneeze (coughs).

These well-known protective and preventive barriers (or behavioral risks) are presented in the SHARE Corona Survey. In particular, individuals are asked how often (always, often, sometimes, never) they wear a face mask and keep distance to others when they went outside. Then, the value of the protective risk factor is equal to zero if the individuals always wear a face mask and keep distance, and to one otherwise. The other three endogenous risk factors are binary variables with a value equal to one if individuals do not wash their hands frequently, do not use special hand sanitizer, and do not cover cough, and to zero otherwise.

The analysis is then extended considering two different *exogenous risk factors* or circumstances that are beyond the individual's control but can have an impact on the individual's health. These two risk factors are:

- having a medical appointment scheduled, which the doctor or medical facility decided to postpone due to Corona (postponed);
- and asking for an appointment for a medical treatment since the outbreak of Corona which was denied (denied).

In both cases, the medical treatment concerns a checkup at a general practitioner; at a specialist, including a dentist; a medical treatment, including an operation; physiotherapy, psychotherapy, rehabilitation; and some other types of medical treatment. The value of these variables is equal to one if the medical treatment was denied or postponed, and to zero if the individual had access to all the needed medical treatments.

4. Empirical results

In this Section, we compare the four selected endogenous risk factors and the two exogenous risk factors being associated with the spread of COVID-19 in order to identify the behavioral

[5] See the Appendix for a complete description of the construction of each health item.

risks and circumstances that increase socio-economic health inequalities in Luxembourg and France. The analysis is conducted considering different degrees of risk sensibility of the social planner (from insensibility ($\alpha \to 0$) to extreme sensibility ($\alpha \to \infty$)) with respect to the association between health items and a risk factor, that are combined with different values of the inequality aversion parameter v. In particular, if $v \geq 2$ the index displays health inequality aversion, whereas health inequality loving is obtained whenever $v \in (1,2)$.[6] In other words, more important is the value of parameter ν, more averse to health inequalities is the social planner.

4.1. Endogenous risk factors

Figures 2a-2b present the case where the social planner has risk insensibility ($\alpha \to 0$). In this case, the (absolute) achievement curves remain (almost) invariant with respect to any of the four considered endogenous risk factors. Then, the socio-economic health inequality indexes for both countries remain the same. These Figures further show that, at the order 2, the socio-economic health inequality in the society is the lowest possible because a social planner neutral to risk sensibility considers an individual being non-healthy if he is non-healthy in all health items.

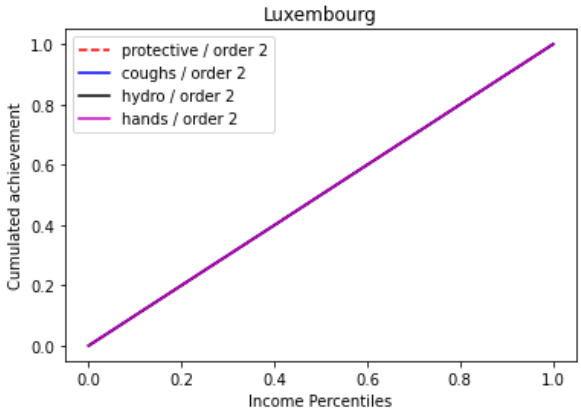

Figure 2.a. $\alpha = 0$; $\nu = 2$

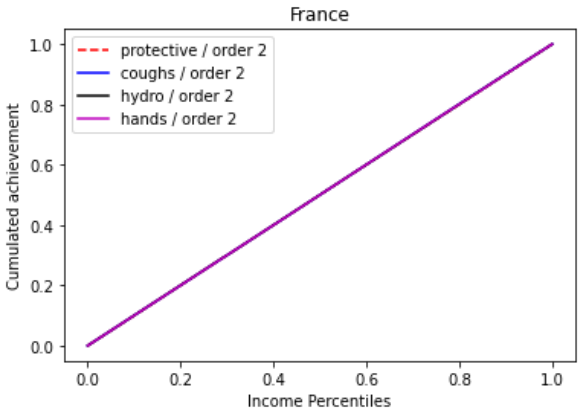

Figure 2.b. $\alpha = 0$; $\nu = 2$

Figures 3a-3b and Figures 4a-4b compare the achievement curves for each endogenous risk factor when the social planner has a moderate risk sensitivity ($\alpha = 50$) and an extreme risk sensitivity ($\alpha \to \infty$), respectively in both countries. The curves move a bit farther from the 45-degree line showing that the more sensitive to risk is the social planner, the more important is the impact of the risk factors on socio-economic health inequalities. In this context, the curves cross and then the social planner cannot proceed to a non-ambiguous ranking of the health achievement curves associated to one risk factor. However, we can see that the achievement curve of protective measures partially lies above the other curves in Luxembourg, and below the other curves in France.

[6] Notice that the value of parameter v denotes the stochastic dominance order. Hence, for example, $v = 2$ represents a two-order stochastic dominance.

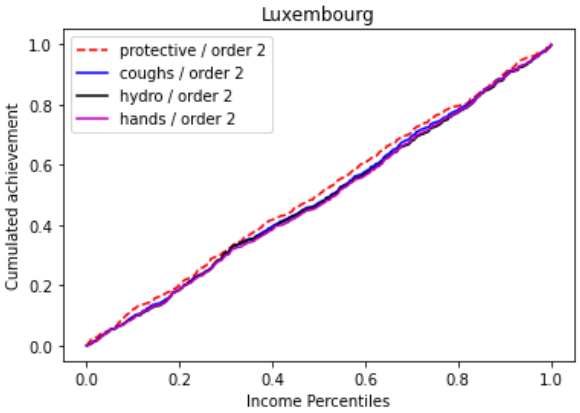

Figure 3.a. $\alpha = 50$; $\nu = 2$

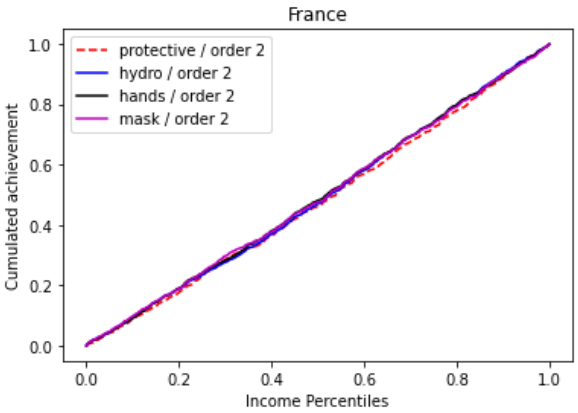

Figure 3.b. $\alpha = 50$; $\nu = 2$

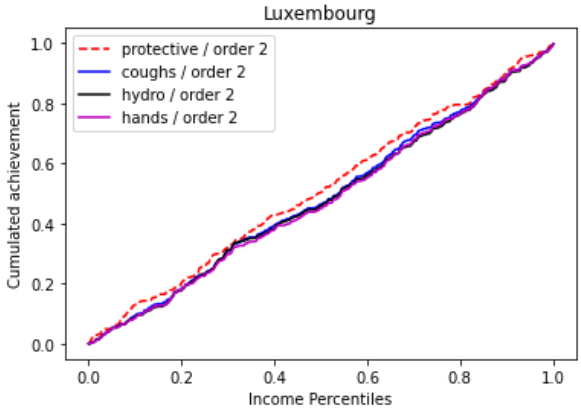

Figure 4.a. $\alpha \to \infty$; $\nu = 2$

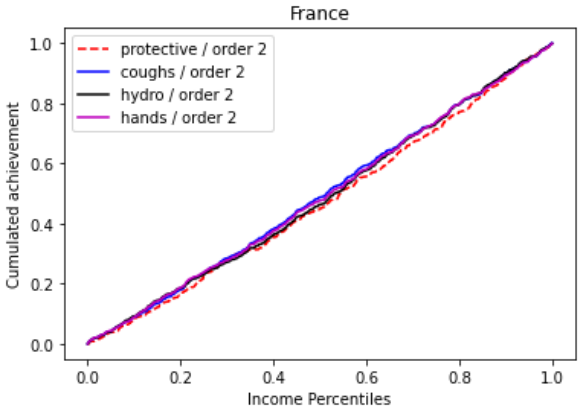

Figure 4.b. $\alpha \to \infty$; $\nu = 2$

Figures 5.a-5.b and Figures 6.a-6.b show two different orders of inequality aversion ($\nu = 3$ and $\nu = 4$, respectively) in the case of extreme risk sensibility ($\alpha \to \infty$). In Luxembourg, an inequality averse social planner ranks, without ambiguity, the distribution with the risk factor protective measures as the less unequal one. The same social planner ranks the distribution with the risk factor protective measures as the most unequal distribution in France. In other words, among all different endogenous risk factors having an impact on the health status of individuals, protective measures (keeping distance and wearing a face mask) constitutes the risk factors that alleviate and aggravate the most the overall level of inequality in Luxembourg and France, respectively.

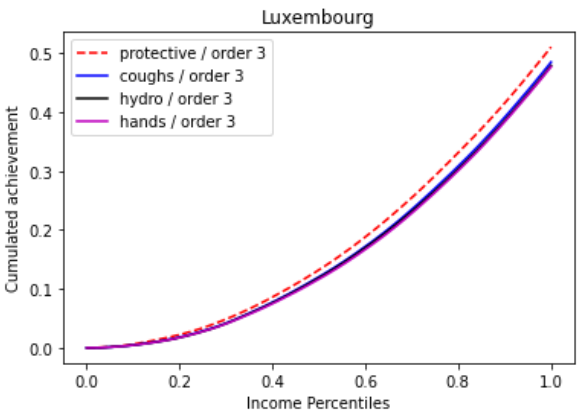

Figure 5.a. $\alpha \to \infty$; $\nu = 3$

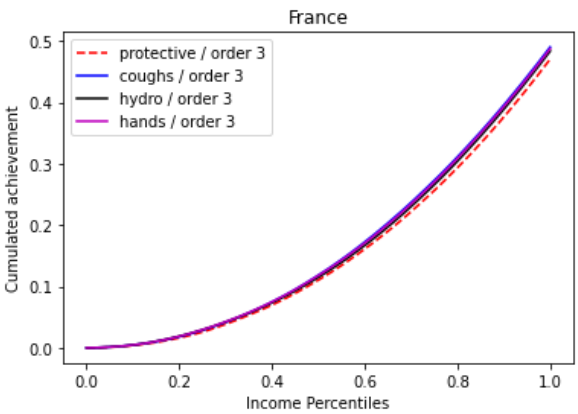

Figure 5.b. $\alpha \to \infty$; $\nu = 3$

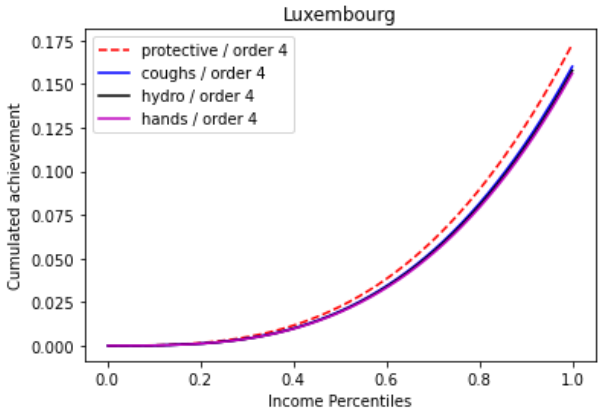

Figure 6.a. $\alpha \to \infty$; $\nu = 4$

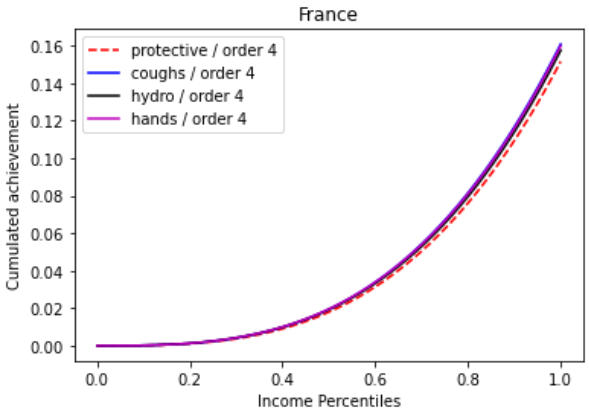

Figure 6.b. $\alpha \to \infty$; $\nu = 4$

4.2. Exogenous risk factors

Another important analysis that can be done is to compare the achievement curves for the protective measures (the risk factor decreasing the most the socio-economic inequalities in health in Luxembourg and increasing socio-economic inequalities in health in France) with those of two exogenous risk factors such as medical treatments and appointments which were postponed and denied during the first wave of the pandemic. Figures 7.a-7.b depict this comparison for Luxembourg and France, respectively. The exogenous risk factors achievement curves cross in both countries. Thus, nothing can be said about what risk factor increases socio-economic inequalities in health. In Luxembourg, however, we can notice that the endogenous risk factor curve lies above the two exogenous ones. We can then say (without significance) that in this country, the protective measures not only generate less inequalities than the other three endogenous risk factors (cough, hands and hydro), but also than the exogenous risks.

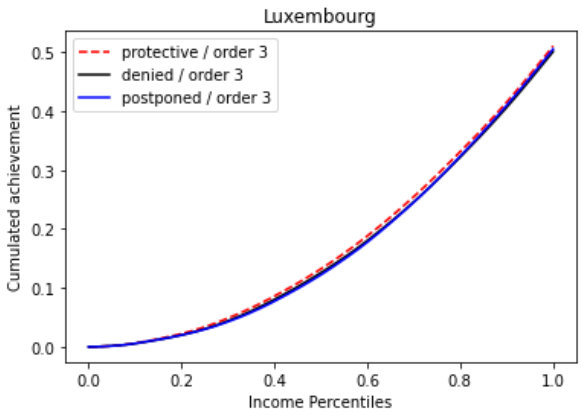

Figure 7.a. $\alpha \to \infty$; $\nu = 3$

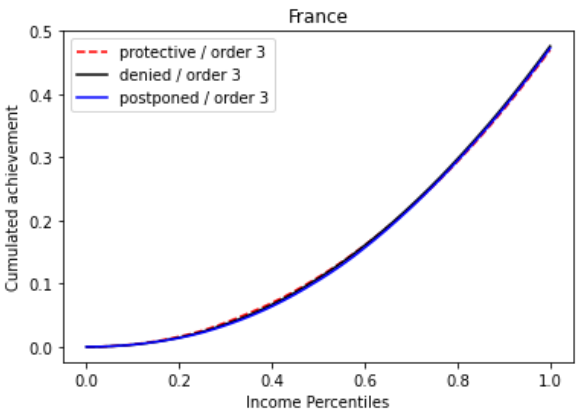

Figure 7.b. $\alpha \to \infty$; $\nu = 3$

4.3. Risk Mixture

In the previous sub-sections, the endogenous risk factor *protective measures* appears as the less unequal factor in Luxembourg. Then, an interesting analysis is to compare this risk factor to a factor representing the average of all endogenous and exogenous risk factors considered in the empirical study (Risk_mix). The exercise is conducted in the case of a social planner with extreme risk sensibility ($\alpha \to \infty$) and averse to inequality ($\nu = 3$), see Figures 8.a-8.b.

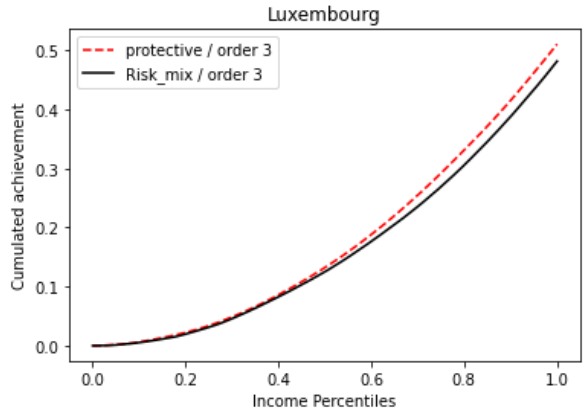

Figure 8.a. $\alpha \to \infty$; $\nu = 3$

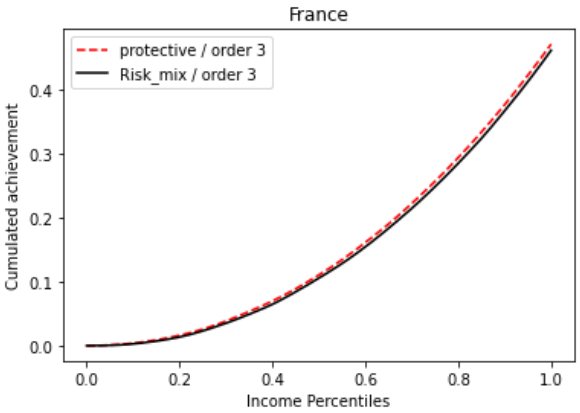

Figure 8.b. $\alpha \to \infty$; $\nu = 3$

In the case of Luxembourg, the result is as expected (Figure 8.a). The protective measures achievement curve lies above the achievement curve of the averaged risk factors. Then, the socio-economic inequalities in health generated by being exposed to all risk factors (Risk_ mix) are more important than the inequalities produced with the protective measures risk factor. The case of France is different. Although both curves are close, we can easily distinguish the protective measure achievement curve lying above the mixture one (Figure 8.b) and being the risk factor generating the less socio-economic inequalities. This is not an expected result, since France displays an achievement curve associated to protective measures being below those of the endogenous risk factors. In contrast, nothing can be said when this curve is compared with the exogenous ones as they all cross.

5. Sensitivity check

The parametrization of the achievement curves relies, among other, on the selection of the weighting scheme used to aggregate the health items and the risk factor. In the main part of the paper, we use the weights proposed by Betti & Verma (1998). In order to test the sensitivity of our findings to this choice, we re-calculated the achievement curves using two alternative weighting schemes: the one proposed by Cerioli & Zani (1990) which only considers the relative frequency of health items, and the equal weight scheme for which each health item has the same weight in the final score.

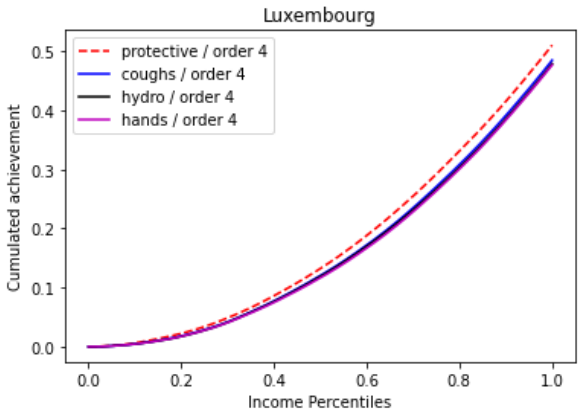

Figure 9.a. $\alpha \to \infty$; $\nu = 3$ (Cerioli & Zani)

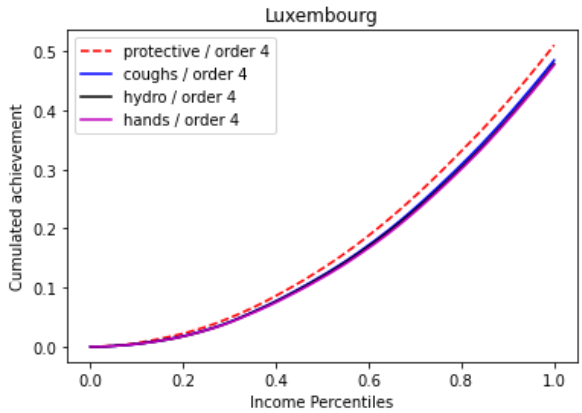

Figure 9.b. $\alpha \to \infty$; $\nu = 3$ (equal weight)

Figures 9.a and 9.b show the endogenous achievement curves for Luxembourg in the case of a social planner with extreme risk sensibility ($\alpha \to \infty$) and averse to inequality ($\nu = 3$), and using respectively Cerioli & Zani's (1990) and equal weighting schemes. It is worth mentioning that the use of different weighting schemes does not affect the empirical findings. For instance, the two alternative weighting schemes does not alter the result for the dominance of the protective measures observed in Luxembourg.

6. Concluding remarks

In this paper, we show that, on the basis of the methodology proposed by Mussard & Pi Alperin (2021a), risk factors associated to the COVID-19 pandemic may be identified. In Luxembourg, the *protective measures* (endogenous risk factor) appears as the factor which alleviates the most the overall level of inequality. In contrary, the non-respect of the *preventive hygiene measures* (washing hands more frequently, using special hand sanitizer and covering cough and sneeze) contribute to increase the level of socio-economic health inequalities in this country. This can be explained by the fact that the protective measures (wearing a face mask and keeping distance to others) are mandatory in public spaces whereas deciding to follow the preventive hygiene measures is a behavioral decision of each individual.

In France, even if the curves are close from each other, we can easily distinguish that the *protective measures* risk factor curve slightly lies below the three other endogenous achievement curves representing the three *preventive hygiene measures*. Thus, among all the endogenous risk factors, the protective measures appear as the risk factor which contributes the most to increase the socio-economic inequalities in health in the country.

Concerning the ranking of the three preventive hygiene measures analyzed in the paper, nothing can be assessed since the achievement curves cross. A similar situation appears with the exogenous risk factors (having a medical treatment denied or postponed), while the achievement curves show that these risk factors generate inequalities in health, they cross and then it is not possible to rank them. This analysis concerns both Luxembourg and France.

Finally, this paper opens the way on future researches about the treatment of many risk factors simultaneously in the analysis rather than a static comparative approach in which factors, being endogenous or exogenous, are treated separately to gauge their impact on the overall level of socio-economic health inequalities.

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Appendix: Construction of each health item

Table A.1: Depression

Depression scale Euro-d*	Degree of membership
Non depressed (0 dimension)	0
Between 1 and 11 dimensions	$1 - (12 - X_i)/12$
Completely depressed (12 dimensions)	1

* Depression, pessimism, suicidal thought, guilty, sleep, interest, irritability, appetite, tiredness, concentration, enjoyment, tearfulness.

Table A.2: Memory

Memory		Degree of membership
Four questions have been asked regarding date, day of the week, month, and year	Knows all	0
	Knows 3 of 4	0.25
	Knows 2 of 4	0.50
	Knows 1 of 4	0.75
	None of them	1

Table A.3: Cognition

Capacity to memorize words		Degree of membership
How many words do you recall?*	I recall more than 15 words	0
	I recall more than 1 and less than 16	$(16 - X_i)/14$
	I recall only 1	1

* This number is the addition between the first trial and the delayed trial.

Table A.4: Chronic illness

Long-term illness		Degree of membership
Do you have any long-term health problems, illness, disability or infirmity?	No	0
	One	0.75
	More than one	1

Table A.5: Limitation activities 1

Health and daily activities		Degree of membership
Because of a health problem, do you have difficulty doing any of the following daily activities?*	No	0
	Somewhat	$1 - (6 - X_i)/6$
	Yes	1

* Dressing, bathing or showering, eating, cutting up the food, walking across a room, getting in or out of bed.

Table A.6: Limitation activities 2

Health and instrumental activities		Degree of membership
Because of a health problem, do you have difficulty doing any of the following instrumental activities?*	No	0
	Somewhat	$1 - (5 - X_i)/5$
	Yes	0

* Telephone calls, taking medications, managing money, shopping for groceries, preparing a hot meal.

Table A.7: Limitation activities 3

Health and general activities		Degree of membership
Because of a health problem, do you have difficulty doing any of the following activities?*	No	0
	Somewhat	$1-(4-X_i)/4$
	Yes	1

* Walking 100 meters, walking across a room, climbing several flights of stairs, climbing one flight of stair

Table A.8: Eyesight

Eyesight distance and reading*	Degree of membership
Both are E or VG	0
One is E or VG, the other is G or F	0.15
One is E or VG, the other is P	0.25
Both are G or F	0.30
One is G or F, the other is P	0.60
Both are P	1

*E: excellent; VG: very good; G: good; F: fair; P: poor

Table A.9: Hearing

Hearing		Degree of membership
Is your hearing*	Excellent or Very good	0
	Good	0.20
	Fair	0.50
	Poor	1

*With or without a hearing aid.