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Report on impact of early-life policies and interventions based on dynamic microsimulation models

Do specific fiscal policies reduce preterm births and childhood obesity? A study based on microsimulations and scenario evaluations

LifeCycle report D10.2

Authors:

Costanza Pizzi (UNITO)

Davide Rasella (UNITO)

Mark Hanson (UOS)

Lorenzo Richiardi (UNITO)

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LIFECYCLE Project
Coordination and leadership:
Erasmus MC
Generation R (Na-2918)
PO box 2040
3000 CA Rotterdam
The Netherlands
Phone: +31 (0)10 704 3405
Email: lifecycle@erasmusmc.nl
Web: lifecycle-project.eu

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LIFECYCLE Project
Coordination and leadership:
Erasmus MC
Generation R (Na-2918)
PO box 2040
3000 CA Rotterdam
The Netherlands
Phone: +31 (0)10 704 3405
Email: lifecycle@erasmusmc.nl
Web: lifecycle-project.eu

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List of Abbreviations

ALSPAC: Avon Longitudinal Study of Parents and Children;
BI: Basic Income;
BIB: Born in Bradford;
BMI: Body Mass Index;
BS: Baseline Scenario;
BW: birth weight;
CB: Child Benefit;
CEDAP: Certificato di Assistenza al Parto;
CHO: child health outcomes;
EHII: Equivalised Household Income Indicator;
EUSILC: European Union Statistics on Income and Living Conditions;
GA: gestational age;
IOTF: International Obesity Task Force;
INMA: Infancia y Medio Ambiente;
M1: Module 1;
M2: Module 2;
M3: Module 3;
MICH: Microsimulation for Income and Child Health;
NB: New-born Benefit;
NFBC86: Northern Finland Birth Cohorts;
NINFEA: Nascita e Infanzia: gli Effetti dell'Ambiente;
PR: Poverty Reduction;
SSE: sum of squared errors;
WT: weight

LIFECYCLE Project
Coordination and leadership:

Erasmus MC
Generation R (Na-2918)
PO box 2040
3000 CA Rotterdam
The Netherlands

Phone: +31 (0)10 704 3405
Email: lifecycle@erasmusmc.nl
Web: lifecycle-project.eu

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Executive Summary

Task 10.2 aimed at implementing dynamic microsimulation models for scenario analyses on policy and intervention strategies focused on optimizing early-life stressors. In particular we decided to develop a microsimulation model for investigating the prospective effects of poverty alleviation fiscal policies on child health outcomes, simulating the effects of alternative fiscal policies on household income and forecast the impact of these income increases at the time of childbirth on child health. The microsimulation model, named Microsimulation for Income and Child Health (MICH), has been develop using Italy as the setting of interest and using childhood overweight and obesity as the outcome of interest. MICH model is composed of three integrated modules. Firstly, module 1 (M1) simulates the effects of fiscal policies on disposable household income using the tax-benefit microsimulation program EUROMOD fed with the country-specific EU-SILC data (for this study Italy EUSILC 2010 data). We considered four different fiscal policies to be compared with the baseline scenario (actual fiscal system of the country analysed): Basic Income, Poverty Reduction, New-born Benefit and Child Benefit. Secondly, module 2 (M2) exploits EU Child Cohort Network data and runs a series of concatenated regressions in order to estimate the prospective effects of income on child body mass index (BMI) at different ages (for this study we used the data of the Italian NINFEA birth cohort). Finally, module 3 (M3) uses dynamic microsimulation techniques that combine the population structure and incomes obtained by M1, with regression model specifications and estimated effect sizes provided by M2, projecting BMI distributions according to the simulated policy scenarios. Our results show that fiscal policies, especially the focalised interventions, can have a strong impact on childhood health conditions. The MICH model, exploiting the cross-country comparative nature of EUROMOD and the comparability of birth cohort data member of the EU Child Cohort Network, can be applied to different settings both in term of populations and of the outcome of interest. The MICH model constitutes a useful tool to provide evidence of how fiscal policies could affect health outcomes in the population and thus could be used in fiscal and health policy-making.

LIFECYCLE Project
Coordination and leadership:
Erasmus MC
Generation R (Na-2918)
PO box 2040
3000 CA Rotterdam
The Netherlands
Phone: +31 (0)10 704 3405
Email: lifecycle@erasmusmc.nl
Web: lifecycle-project.eu

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1. Introduction

1.1 Background

The role of parental socioeconomic position in determining child health outcomes is widely recognised. Household income is one of the strongest socioeconomic determinants of health; increasing household income, especially among the most vulnerable families, could prevent several health outcomes (1,2).

Fiscal policies, including fiscal benefits and tax reductions, are interventions that can quickly and effectively change the income of poor households (3). However, little is known of the health effects of tax and benefit systems, which in most countries are responsible for a vast redistribution of resources and provide significant income support, in the form of targeted benefits, fiscal incentives and tax reductions, to a large number of individuals and households. Fiscal systems are not designed with health outcomes – and in particular child health outcomes – in mind; however, health outcomes are potentially large side effects of fiscal policies, and their consideration might change the way we think and prioritise about them. Hence, both from the point of view of the design of fiscal systems and from the point of view of public health interventions, analysing the health impact of tax and benefit systems is of high interest.

Several steps separate fiscal policies from child health outcomes, making the analysis non-trivial. First, there is interaction between policies, insofar income support received under a specific scheme might have an effect on eligibility to other schemes. Second, the targeting of fiscal policies (for instance, unemployed individuals in case of unemployment benefits), is typically different from the population of interest (children with more disadvantaged background) – said differently, the outcome (child health) is defined on a different population from the intervention (fiscal policies). There are also data availability issues, as tax and benefit models are not typically applied to data containing detailed health information for all family members.

Dynamic microsimulation modelling involves the generation of simulated data on individual units and is particularly suited for policy evaluations and scenario analyses. It is a multi-process simulation model, in which each process is estimated at an individual level and feeds back into the other processes.

1.2 Objectives

To develop a flexible three-part integrated microsimulation model as a useful policy design tool for investigating the prospective effects of poverty alleviation fiscal policies on child health outcomes, simulating the effects of alternative

LIFECYCLE Project
Coordination and leadership:
Erasmus MC
Generation R (Na-2918)
PO box 2040
3000 CA Rotterdam
The Netherlands
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fiscal policies on household income and forecast the impact of these income increases at the time of childbirth on child health.

2. Methods

The microsimulation model has been developed using Italy as the pilot setting with the population distributions obtained from Italian national surveys and associational estimates from the NINFEA birth cohort and using childhood overweight and obesity as the outcome of interest. The microsimulation model exploits two unique assets, namely (i) EUROMOD, the EU-28 tax-benefit microsimulation model that we will use to analyse the effects of different policy measures on equivalised household disposable income (4), and (ii) the availability of harmonized birth cohort data ensured by EU Child Cohort Network. With respect to the latter, we specifically make use of the standardized Equivalised Household Income Indicator (EHII) that was developed within the LifeCycle project (task 3.1.1) and build upon a systematic review of the effect of income-related interventions also carried out within the LifeCycle project (task 9.2). We then use an integrated design of analyses of cohort data and microsimulation models to evaluate the effects of fiscal policies on childhood overweight and obesity.

In brief, the modelling strategy involves two phases and three integrated modules. The first phase comprises two modules. Firstly, we simulate the prospective effects of different fiscal policies on the EHII using EUROMOD (module 1 (M1)). Secondly, we run a series of concatenated regressions to estimate the distribution, correlations and associations between the EHII and the childhood Body Mass Index (BMI) analysed using NINFEA data for Italy (module 2 (M2)).

In the second phase, the estimated parameters obtained from M2 are applied to the simulated population obtained from M1 in order to get a simulated BMI distribution (module 3 (M3)).

The overall structure of our Microsimulation for Income and Child Health (MICH) model and flow of inputs and outputs for each stage are shown in **Figure 1**, where the example of the Italian case-study is presented. A description of the data sources and a more detailed description of each module will be provided below in the following sections.

LIFECYCLE Project
Coordination and leadership:
Erasmus MC
Generation R (Na-2918)
PO box 2040
3000 CA Rotterdam
The Netherlands
Phone: +31 (0)10 704 3405
Email: lifecycle@erasmusmc.nl
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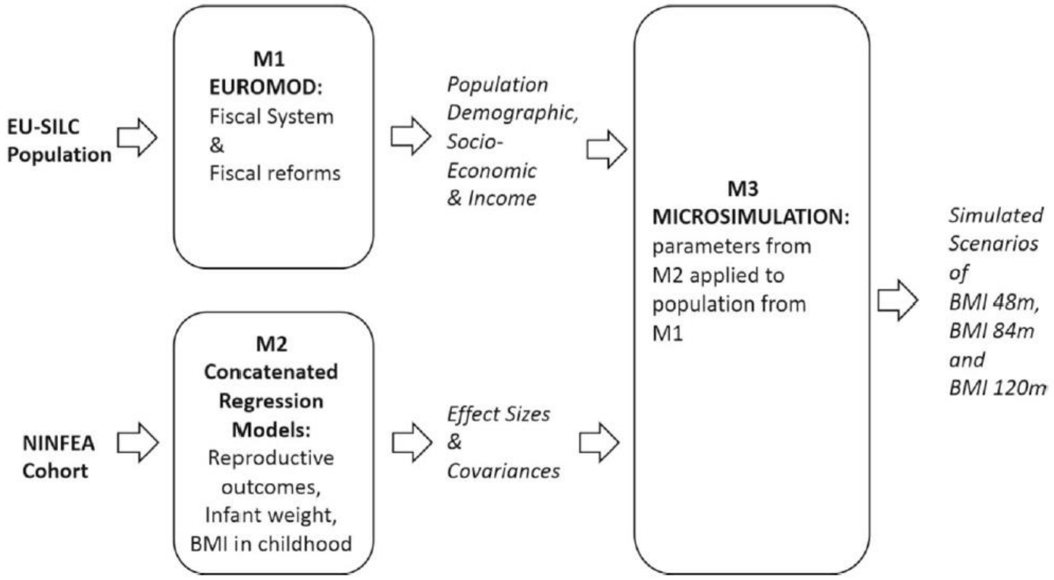

Figure 1. Design of the MICH model and its components. Example of the Italian case-study

2.1 Data sources

2.1.1 EUROMOD

EUROMOD is a tax-benefit microsimulation model for the European Union and the United Kingdom that enables researchers to compute the effects of taxes and benefits on household incomes for the population of each country and for the EU as a whole. It is the only multi-country model and one of the most consolidated microsimulation models in EU and its focus is on economic and fiscal studies. EUROMOD is updated to recent policy systems using data from the European Union Statistics on Income and Living Conditions (EUSILC) as the input database. EUSILC is a survey that collects from 2005 and onwards comparable annual microdata at both individual (basic demographic data, education information, limited health data, labour force data, income data) and household level (housing conditions, basic demographic data, material deprivation and aggregated income data) in samples of persons aged at least 16 years in 28 European Union States - as well as Iceland, Norway and Switzerland (~500,000 European residents annually). Several income variables are collected through this survey including the total disposable household income, which is the one we used to derive the EHII in LifeCycle task 3.1.1. We use the Italian EUSILC 2010 data as the input population for EUROMOD, in order to be consistent with EHII, which was estimated using the 2011 ESUILC data for NINFEA given that Italian

LIFECYCLE Project
Coordination and leadership:
Erasmus MC
Generation R (Na-2918)
PO box 2040
3000 CA Rotterdam
The Netherlands
Phone: +31 (0)10 704 3405
Email: lifecycle@erasmusmc.nl
Web: lifecycle-project.eu

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EUSILC 2011 data for EUROMOD was not available. The baseline scenario is based on the tax-benefit system corresponding to June 2018, given that this was the most recent system when this study was carried out.

2.1.2 NINFEA

The Nascita e Infanzia: gli Effetti dell'Ambiente (NINFEA) project is an Italian birth cohort study included in the EU Child Cohort Network. For these analyses the database version 02.2019, consisting of 6625 mothers and 7423 pregnancies, was used. As stated above, within task 3.1.1. of the LifeCycle project, using internal data of the cohort and external data from the EUSILC 2011 survey, the EHII - an indicator of the equivalised total disposable household income at baseline - was derived for the NINFEA participants as well for most of the other LifeCycle cohorts. Children's birth weight, gestational age at birth and weight at 6 months of age were collected using the 6-month questionnaire, and weight at 18 months of age was obtained from the 18-month questionnaire. From the corresponding follow-up questionnaires at 4, 7 and 10 years of age, the NINFEA dataset includes 4232, 2152 and 973 measurements of children's weight and height, respectively. These two measurements were used to calculate each children's BMI at each follow-up, as the ratio between weight (in kilograms) and squared height (in metres). Overweight and obesity for each age were defined according to the official International Obesity Task Force (IOTF) cut-offs.

2.2 The MICH model

2.2.1 M1 - EUROMOD

The M1 module uses EUROMOD to simulate the effect of different fiscal policies on the total disposable equivalised household income. EUROMOD produces an output dataset that contains a population that is the same as the Italian EUSILC 2010 sample, but with added information on disposable income for each individual, based on the specific, actual or hypothetical policy system considered. This is then transformed in the equivalised household income using the same formula used for the EHII developed in task 3.1.1.

2.2.1.1 Simulated fiscal policies

The Baseline Scenario (BS) is simulated applying the actual 2018 Italian fiscal system on the Italian EUSILC 2010 data. Other four alternative fiscal interventions are then simulated: Basic Income (BI), Poverty Reduction (PR), New-born Benefit (NB) and Child Benefit (CB). Each of these four simulated policies was implemented with two different levels of intensity regarding the

LIFECYCLE Project
Coordination and leadership:
Erasmus MC
Generation R (Na-2918)
PO box 2040
3000 CA Rotterdam
The Netherlands
Phone: +31 (0)10 704 3405
Email: lifecycle@erasmusmc.nl
Web: lifecycle-project.eu

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benefit amounts, but keeping the same rules for eligibility and recipients among them, with the aim to evaluate the potential dose-response effects.

- Basic income scenarios, BI1 and BI2, consist of benefit amounts of €100 per year or per month, respectively, to all citizens without eligibility requirements.
- Poverty reduction scenarios, PR1 and PR2, simulate poverty-relief interventions of €100 per year or per month, respectively, for each member of a household with a per capita disposable income of less than €500 per month.
- New-borns benefit scenarios, NB1 and NB2, simulate more targeted fiscal interventions of €500 per year or per month, respectively, for each child less than 1 year old in households with an equivalised disposable income of less than €500 per month.
- Child benefit scenarios, CB1 and CB2, simulate the new-borns benefits scenarios but with the only difference being that the eligibility rule regarding the age threshold for recipients is raised from less than 1 year of age to 5 years of age.

2.2.2 M2 – The concatenated regression models

The aim of this module is to estimate the regression parameters of interest and the corresponding variance-covariance matrix that are required later in the third module M3.

Using the NINFEA data concatenated multivariable regression models are fitted to estimate the relationship between the EHII and child health outcomes, adjusted for confounders. In general, the dependent variables considered are: gestational age at birth, birth weight, infant weight and BMI at different ages during childhood (depending on data availability). The structure of the concatenated regressions models fitted on the NINFEA data is described in the following equations:

$$GA = \alpha_{ga} + \delta_{ga}EHII + \Sigma\ \beta_{ga}X_s + \varepsilon \quad (1)$$

$$BW = \alpha_{bw} + \beta_{bw}GA + \delta_{bw}EHII + \Sigma\ \beta_{bw\_s}X_s + \varepsilon \quad (2)$$

$$WT_{6m} = \alpha_{wt6} + \beta_{wt6\_1}GA + \beta_{wt6\_2}BW + \delta_{wt6}EHII + \Sigma\ \beta_{wt6\_s}X_s + \varepsilon \quad (3)$$

$$WT_{18m} = \alpha_{wt18} + \beta_{wt18\_1}WT_{6m} + \beta_{wt18\_2}GA + \delta_{wt18}EHII + \Sigma\ \beta_{wt18\_s}X_s + \varepsilon \quad (4)$$

$$BMI_{48m} = \alpha_{bmi48} + \beta_{bmi48\_1}WT_{18m} + \beta_{bmi48\_2}WT_{6m} + \delta_{bmi48}EHII + \Sigma\ \beta_{bmi48\_s}X_s + \varepsilon \quad (5)$$

$$BMI_{84m} = \alpha_{bmi84} + \beta_{bmi84\_1}BMI_{48m} + \beta_{bmi84\_2}WT_{18m} + \delta_{bmi84}EHII + \Sigma\ \beta_{bmi84\_s}X_s + \varepsilon \quad (6)$$

$$BMI_{120m} = \alpha_{bmi120} + \beta_{bmi120\_1}BMI_{84m} + \beta_{bmi120\_2}BMI_{48m} + \delta_{bmi84}EHII + \Sigma\ \beta_{bmi120\_s}X_s + \varepsilon \quad (7)$$

LIFECYCLE Project
Coordination and leadership:
Erasmus MC
Generation R (Na-2918)
PO box 2040
3000 CA Rotterdam
The Netherlands
Phone: +31 (0)10 704 3405
Email: lifecycle@erasmusmc.nl
Web: lifecycle-project.eu

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where GA and BW stand for gestational age and birth weight; WT_{6m} and WT_{18m} stand for weight at 6 and 18 months of age respectively; BMI_{48m}, BMI_{84m} and BMI_{120m} stand for BMI at 4, 7 and 10 years of age respectively. In all equations, EHII is the income indicator (log-transformed), with δ being the estimated coefficient of interest for the income indicator. Moreover, α is the intercept—different for each regression, Σ βs Xs is the sum of sex of child, maternal country of birth and age at delivery and ε is the error component. The underlying assumption is that all outcomes analysed are influenced by the two previous ones and by the other factors cited above.

In general, while the M1 models can be represented by the formula EHII= g(TB,…), M2 will use M1 outputs as independent variables according to CHO=f(EHII,,…), where TB is the tax-benefit system and CHO child health outcomes.

For each independent variable, these models provide estimated effect sizes, confidence intervals, and the corresponding variance-covariance matrix required by M3.

2.2.3 M3 – Microsimulation scenarios

The last module of the MICH model applies effect sizes from M2 to the population obtained from M1. M3 is developed in two steps: first we create a synthetic cohort of live-born infants based on the NINFEA data and on the EU-SILC demographic and socioeconomic structure. In particular from M1 output, we select the population of children less than 5 years old and expand it using the Italian EUSILC survey sample weights. In the second step using the same set of concatenated multivariable linear regressions shown above, with the outputs from M1 and M2 used as inputs, the integrated model estimates the distribution of gestational age for the population of children under 1 year old using regression equation (1). The obtained distribution of gestational age is successively introduced in regression equation (2) together with the same set of demographic and socioeconomic variables, including the equivalised household disposable income from M1. The same principle is applied for the other regression equations creating a flow of outputs used as inputs for the next regression model and allowing us to simulate the final BMI distributions at 18, 48 and 84 months, in a sequential order. In this way, we estimate the effects of changes in the household disposable income on individual families, and we evaluate the individual, subpopulation and overall effect of alternative fiscal policies simulated in M1, including their effects on health inequalities, using childhood overweight and obesity as outcomes. For each outcome and each policy, 1000 simulations are performed using the Monte Carlo sampling method.

LIFECYCLE Project
Coordination and leadership:
Erasmus MC
Generation R (Na-2918)
PO box 2040
3000 CA Rotterdam
The Netherlands
Phone: +31 (0)10 704 3405
Email: lifecycle@erasmusmc.nl
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This allows the main parameter values, in our case the estimated alphas and betas of the regression equations, to vary in each simulation cycle according to their assumed underlying distributions and their variance-covariance matrix. Because the intercepts were obtained from the regression models applied to the NINFEA cohort of the country of interest, which is not representative of the Italian population, we need to calibrate their values. The calibration was achieved varying the alpha of the first regression model, in order to obtain the lower sum of squared errors (SSE) in comparison with the Italian national prevalence of premature births, and for regression model (2) with the average birth weight, both from the “Certificato di Assistenza al Parto” (CEDAP) of the year 2011.

2.2.4 Outcomes

All scenarios were compared in terms of prevalence ratios, using the selected scenario as the numerator and the real fiscal scenario as the denominator. EUROMOD also provides the overall cost for the public budget and, therefore, after comparison with the baseline, the cost of the changes implemented in the counterfactual scenarios, which can be used to calculate the marginal benefit (health outcome gain compared with the policy cost) of the reforms. Marginal benefits - a normalised measure of the effectiveness of the different policy instruments - were obtained by dividing the cost of the fiscal intervention, provided by EUROMOD in M1, by the prevalence difference between scenarios. These characterisation of the health effects of fiscal policies enables a better understanding of the relative advantages of different schemes, and can inform the discussion about interventions aimed at potentiating current national schemes found to be of high health efficacy, and designing new “health-friendly” policies.

3. Results

The results of the application of the MICH method to the case study of childhood overweight and obesity in Italy are extensively described in the methodological paper entitled “Developing an integrated microsimulation model for the impact of fiscal policies on child health in Europe: the example of childhood obesity in Italy”, recently published in BMC Medicine (5).

The main results are reported in **Figure 2**, that shows the estimated coefficients for each regression model in the series of concatenated regression (equations (1)-(7)) included in M2, **Figure 3**, where the prevalence ratios of overweight and obesity at the different time occasions between the baseline scenario and the

LIFECYCLE Project
Coordination and leadership:
Erasmus MC
Generation R (Na-2918)
PO box 2040
3000 CA Rotterdam
The Netherlands
Phone: +31 (0)10 704 3405
Email: lifecycle@erasmusmc.nl
Web: lifecycle-project.eu

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alternative fiscal interventions are reported, and in **Figure 4**, that shows the estimated cost of 1% prevalence reduction in the outcome.

In brief, we observed an inverse relationship between the EHII and BMI in all the periods analysed, with the effect increasing with time (**Figure 2**). Both universal benefits, such as universal basic income (BI), and targeted interventions, such as child benefit (CB) for poorer households, have a significant effect on childhood overweight, with a prevalence ratio (PR) in 10-year-old children—in comparison with the baseline fiscal system—of 0.88 (95%CI 0.82–0.93) and 0.89 (95%CI 0.83–0.94), respectively. The impact of the fiscal reforms was even larger for child obesity, reaching a PR of 0.67 (95%CI 0·50–0.83) for the simulated BI and 0.64 (95%CI 0.44–0.84) for CB at the same age. While both types of policies show similar effects, the estimated costs for a 1% prevalence reduction in overweight and obesity with respect to the baseline scenario is much lower with a more focalised benefit policy than with universal ones.

Variables	(1) Gestational age at birth (weeks)	(2) Birth weight (kg)	(3) Weight at 6 months (kg)	(4) Weight at 18 months (kg)	(5) BMI at 48 months	(6) BMI at 84 months	(7) BMI at 120 months
EHII	0.31 [0.11 to 0.51]	– 0.55 [– 0.99 to – 0.10]	– 0.60 [– 1.58 to 0.39]	1.36 [0.07 to 2.65]	– 0.31 [– 0.57 to – 0.05]	– 0.52 [– 0.93 to – 0.10]	– 0.85 [– 1.58 to – 0.12]
Mother's age	– 0.05 [– 0.06 to – 0.04]	0.03 [0.01 to 0.06]	– 0.05 [– 0.11 to – 0.00]	– 0.02 [– 0.09 to 0.05]	– 0.00 [– 0.02 to 0.01]	0.00 [– 0.02 to 0.03]	– 0.01 [– 0.05 to 0.03]
Mother's country of birth	0.02 [– 0.19 to 0.22]	0.65 [0.11 to 1.19]	1.88 [0.66 to 3.09]	– 1.30 [– 2.82 to 0.23]	– 0.20 [– 0.54 to 0.14]	– 0.01 [– 0.62 to 0.61]	0.17 [– 0.87 to 1.22]
Sex	– 0.05 [– 0.13 to 0.04]	– 1.39 [– 1.58 to – 1.19]	– 4.46 [– 4.90 to – 4.02]	– 1.47 [– 2.07 to – 0.86]	0.29 [0.18 to 0.41]	0.16* [– 0.01 to 0.34]	– 0.12 [– 0.40 to 0.17]
Gestational age at birth (weeks)		1.70 [1.63 to 1.76]	– 0.46 [– 0.62 to – 0.29]				
Birth weight (kg)			0.89 [0.83 to 0.94]	0.23 [0.16 to 0.30]			
Weight at 6 months (kg)				0.83 [0.79 to 0.87]	0.01 [0.00 to 0.02]		
Weight at 18 months (kg)					0.05 [0.05 to 0.06]	0.02 [0.01 to 0.03]	
Body mass index at 48 months						0.55 [0.48 to 0.63]	0.27 [0.15 to 0.39]
Body mass index at 84 months							0.77 [0.67 to 0.88]
Constant	38.83 [37.39 to 40.27]	– 31.01 [– 34.98 to – 27.03]	73.19 [64.52 to 81.86]	32.69 [22.92 to 42.47]	10.70 [8.75 to 12.66]	8.73 [5.55 to 11.92]	7.62 [2.03 to 13.22]
Observations	6387	6202	5173	4141	2923	1621	658
R^2	0.01	0.37	0.28	0.46	0.20	0.26	0.49

Note: 95% confidence intervals in brackets. *EHII* Equivalised Household Income Indicator. Sex (0 = male; 1 = female). Mother's country of birth (0 = Italy; 1 = others)

Figure 2. Estimated coefficients of the concatenated multivariable regressions from M2

LIFECYCLE Project
Coordination and leadership:
Erasmus MC
Generation R (Na-2918)
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3000 CA Rotterdam
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	Basic income		Poverty reduction		New-borns benefit		Child benefit	
	BI1	BI2	PR1	PR2	NB1	NB2	CB1	CB2
48 months								
Children overweight	0.994 [0.987–1.000]	0.946 [0.895–0.998]	0.996 [0.991–1.000]	0.967 [0.934–1.001]	0.999 [0.998–1.000]	0.993 [0.985–1.000]	0.993 [0.985–1.001]	0.952 [0.904–1.000]
Children obesity	0.986 [0.966–1.005]	0.907 [0.809–1.004]	0.988 [0.971–1.006]	0.936 [0.861–1.012]	0.998 [0.994–1.002]	0.987 [0.971–1.004]	0.982 [0.957–1.008]	0.912 [0.813–1.011]
84 months								
Children overweight	0.991 [0.985–0.996]	0.913 [0.858–0.968]	0.994 [0.99–0.998]	0.946 [0.911–0.982]	0.999 [0.997–1.000]	0.988 [0.979–0.996]	0.989 [0.982–0.996]	0.921 [0.869–0.974]
Children obesity	0.968 [0.94–0.995]	0.807 [0.67–0.945]	0.972 [0.947–0.997]	0.854 [0.734–0.974]	0.996 [0.991–1.002]	0.973 [0.949–0.997]	0.957 [0.918–0.995]	0.805 [0.654–0.957]
120 months								
Children overweight	0.988 [0.982–0.993]	0.876 [0.819–0.933]	0.992 [0.988–0.996]	0.925 [0.888–0.961]	0.998 [0.997–0.999]	0.982 [0.972–0.992]	0.986 [0.98–0.993]	0.887 [0.831–0.943]
Children obesity	0.946 [0.918–0.975]	0.666 [0.501–0.83]	0.951 [0.924–0.979]	0.721 [0.562–0.881]	0.993 [0.985–1.001]	0.950 [0.917–0.982]	0.920 [0.875–0.965]	0.639 [0.439–0.838]

Note: 95% confidence intervals in brackets. Ratios and prediction intervals according to the different fiscal reform scenarios in comparison with the baseline

Figure 3. Prevalence ratio and predicted intervals for children overweight and obesity at 48, 84 and 120 months

	Basic income		Poverty reduction		New-borns benefit		Child benefit	
	BI1	BI2	PR1	PR2	NB1	NB2	CB1	CB2
48 months								
Overweight	79.8	109.9	20.6	32.5	6.4	8.7	4.7	8.4
Obesity	272.1	505.0	60.7	133.2	27.6	40.5	15.0	36.4
84 months								
Overweight	33.7	43.1	9.0	12.7	2.4	3.3	2.0	3.3
Obesity	109.0	217.1	22.7	51.5	10.7	17.0	5.5	14.6
120 months								
Overweight	19.7	23.3	5.6	7.0	1.4	1.8	1.2	1.8
Obesity	59.3	110.2	11.9	23.8	4.6	7.9	2.7	6.9

Note: Prevalence reduction with respect to the baseline scenario. Figures in billions of euros

Figure 4. Estimated cost for 1% prevalence reduction in overweight and obesity

4. Application to other settings

As stated above, the MICH model has been developed using the case of childhood overweight and obesity in Italy. Cross-country comparison is of particular relevance in this framework, as differences in health effects between countries might arise from (i) differences in the population/household structure, (ii) differences in the tax and benefit systems, and (iii) differences in the role of stressors in determining the health outcomes of interest. However, comparability of the results between countries requires that both the tax and

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benefit components and the health components have a comparative perspective.
One of the main advantages of our method is that it can be applied to different settings both in term of populations but also in term of the outcome of interest. This is because the MICH model exploit the cross-country comparative nature of EUROMOD and the comparability of birth cohort data member of the EU Child Cohort Network, that ensures the availability of several harmonized exposures and outcomes variables.

4.1 Childhood overweight and obesity in several European countries

The analyses to evaluate the effects of different fiscal policies on childhood overweight and obesity using the MICH approach are currently been extended to other European countries, namely Spain, UK and Finland, using data from the INMA, ALSPAC/BIB and NFBC86 cohorts (all members of the EU Child Cohort Network) respectively and national surveys of the corresponding countries to obtain the association estimates and the population distributions.
In this application the structure of the concatenated regression model has been slightly changed to account for the different study design of the cohorts involved, in particular the fact that in some of the study the anthropometric measurements during infancy are available only for a limited number of subjects or are available at very different time occasions. The structure used for these analyses is the following:

$$GA = \alpha_{ga} + \delta_{ga}EHII + \Sigma\ \beta_{ga}X_s + \varepsilon \quad (8)$$

$$BW = \alpha_{bw} + \beta_{bw}GA + \delta_{bw}EHII + \Sigma\ \beta_{bw\_s}X_s + \varepsilon \quad (9)$$

$$BMI_{t1} = \alpha_{bmit1} + \beta_{bmit1\_1}BW + \beta_{bmit1\_2}GA + \delta_{bmit1}EHII + \Sigma\ \beta_{bmit1\_s}X_s + \varepsilon \quad (10)$$

$$BMI_{t2} = \alpha_{bmit2} + \beta_{bmit2\_1}BMI_{t1} + \beta_{bmit2\_2}BW + \delta_{bmit2}EHII + \Sigma\ \beta_{bmit2\_s}X_s + \varepsilon \quad (11)$$

$$BMI_{t3} = \alpha_{bmit3} + \beta_{bmit3\_1}BMI_{t2} + \beta_{bmit3\_2}BMI_{t1} + \delta_{bmit3}EHII + \Sigma\ \beta_{bmit3\_s}X_s + \varepsilon \quad (12)$$

where BMI_{t1} is the BMI during the pre-school age period, BMI_{t2} during the school-age period and BMI_{t3} during the pre-adolescence period. Preliminary results of these analyses are shown in the next sections.

4.1.1 Results of the M2 module

Figures 5-8 show the estimated coefficients for each regression model (equations (8)-(12)) obtained from the INMA, ASLPAC, BIB and NFBC86 data respectively (M2 module). In each figure the effect of the EHII (log-euro) on the different outcomes are displayed in the first line, with the models for the BMI at the different time occasions shown in the last three columns.

LIFECYCLE Project
Coordination and leadership:
Erasmus MC
Generation R (Na-2918)
PO box 2040
3000 CA Rotterdam
The Netherlands
Phone: +31 (0)10 704 3405
Email: lifecycle@erasmusmc.nl
Web: lifecycle-project.eu

This project received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 733206 (LifeCycle).

INMA - SPAIN (started: 2005)	Gestational age (days)	Birth weight (grams)	Mean BMI at 48-60 months	Mean BMI at 66-78 months	Mean BMI at 126-138 months
Log Equivalised Income (EU-SILC)	0.8209	17.1942	-0.1937	-0.5690	-0.9521
	(-0.7474; 2.3892)	(-45.1844; 79.5727)	(-0.4689; 0.0816)	(-0.8428; -0.2953)	(-1.8166; -0.0876)
Mother's Age at Birth (years)	-0.2277	11.1677	-0.0129	-0.0082	-0.0010
	(-0.3397; -0.1157)	(6.6865; 15.6490)	(-0.0335; 0.0077)	(-0.0286; 0.0123)	(-0.0646; 0.0626)
Mother born in EU country (outside cohort country) = 1	-0.1751	77.2615	-0.3926	-0.3239	1.4303
	(-3.5006; 3.1505)	(-54.5569; 209.0798)	(-1.0922; 0.3071)	(-1.0763; 0.4285)	(-0.9744; 3.8350)
Mother born in other country = 2	-0.5665	162.1581	0.2322	-0.4364	-0.8771
	(-2.4350; 1.3021)	(88.0612; 236.2550)	(-0.1352; 0.5997)	(-0.8364; -0.0365)	(-2.0866; 0.3324)
Female = 1	0.6565	-130.5086	0.0721	-0.0005	-0.1763
	(-0.2598; 1.5729)	(-166.9569; -94.0602)	(-0.0914; 0.2356)	(-0.1611; 0.1601)	(-0.7047; 0.3521)
Gestational Age (days)	-	21.1096	-0.0176	-	-
	-	(19.2905; 22.9287)	(-0.0268; -0.0084)	-	-
Birth weight (grams)	-	-	0.0008	-0.0000	-
	-	-	(0.0006; 0.0010)	(-0.0002; 0.0002)	-
Mean BMI at 48-60 months	-	-	-	1.0895	-0.0929
	-	-	-	(1.0395; 1.1394)	(-0.3783; 0.1926)
Mean BMI at 66-78 months	-	-	-	-	1.4320
	-	-	-	-	(1.2212; 1.6429)
(Intercept)	280.4913	-3058.2938	20.1126	3.2379	4.3344
	(269.5427; 291.4398)	(-3729.1925; -2387.3951)	(17.0695; 23.1557)	(1.0558; 5.4201)	(-2.6715; 11.3404)
N valid observations per model	1834	1823	1468	791	328
Mean of dependent variable	278.9205	3257.5377	16.2165	16.4340	19.5893

Figure 5. Estimated coefficients of the concatenated multivariable regressions – INMA study

ALSPAC - UK (started: 1991)	Gestational age (days)	Birth weight (grams)	Mean BMI at 69 months	Mean BMI at 92 months	Mean BMI at 127 months
Log Equivalised Income (EU-SILC)	0.2702	-76.7082	0.0716	-0.1967	-0.0892
	(-0.8731; 1.4135)	(-117.9775; -35.4388)	(-0.2215; 0.3647)	(-0.4499; 0.0565)	(-0.3452; 0.1668)
Mother's Age at Birth (years)	-0.0647	9.2387	-0.0044	-0.0146	-0.0027
	(-0.1236; -0.0057)	(7.1092; 11.3682)	(-0.0196; 0.0108)	(-0.0277; -0.0015)	(-0.0161; 0.0107)
Mother born in EU country (outside cohort country) = 1	-0.0843	68.8517	-0.0535	-0.3549	0.1147
	(-2.1488; 1.9802)	(-6.5727; 144.2761)	(-0.5762; 0.4692)	(-0.8224; 0.1127)	(-0.3648; 0.5941)
Mother born in other country = 2	-0.7182	-19.4245	0.0523	-0.0729	0.1742
	(-2.2962; 0.8599)	(-76.5208; 37.6717)	(-0.3335; 0.4381)	(-0.4016; 0.2557)	(-0.1641; 0.5126)
Female = 1	1.3436	-137.1276	0.0220	0.4053	0.0025
	(0.8236; 1.8635)	(-155.9263; -118.3289)	(-0.1089; 0.1529)	(0.2952; 0.5155)	(-0.1086; 0.1136)
Gestational Age (days)	-	24.0106	-0.0114	-	-
	-	(23.2554; 24.7659)	(-0.0179; -0.0050)	-	-
Birth weight (grams)	-	-	0.0007	0.0003	-
	-	-	(0.0005; 0.0008)	(0.0002; 0.0004)	-
Mean BMI at 69 months	-	-	-	0.6713	-0.0059
	-	-	-	(0.6415; 0.7012)	(-0.0432; 0.0313)
Mean BMI at 92 months	-	-	-	-	1.3441
	-	-	-	-	(1.3088; 1.3795)
(Intercept)	278.8786	-2937.0069	16.1655	6.2902	-2.7519
	(271.0471; 286.7101)	(-3289.6904; -2584.3233)	(13.5863; 18.7447)	(4.4203; 8.1601)	(-4.6300; -0.8738)
N valid observations per model	8813	8710	3684	3017	2686
Mean of dependent variable	271.9193	3381.2279	15.6954	16.2635	18.2552

Figure 6. Estimated coefficients of the concatenated multivariable regressions – ALSPAC study

LIFECYCLE Project
Coordination and leadership:
Erasmus MC
Generation R (Na-2918)
PO box 2040
3000 CA Rotterdam
The Netherlands
Phone: +31 (0)10 704 3405
Email: lifecycle@erasmusmc.nl
Web: lifecycle-project.eu

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BIB - UK (started: 2008)	Gestational age (days)	Birth weight (grams)	Mean BMI at 48-60 months	Mean BMI at 92-104 months	Mean BMI at 120-132 months
Log Equivalised Income (EU-SILC)	2.3203	7.3823	-0.2952	-0.1530	-0.0626
	(1.3088; 3.3318)	(-26.3531; 41.1177)	(-0.4552; -0.1352)	(-0.3860; 0.0799)	(-0.9597; 0.8344)
Mother's Age at Birth (years)	-0.1832	9.4880	-0.0042	0.0131	0.0038
	(-0.2314; -0.1350)	(7.8772; 11.0987)	(-0.0118; 0.0034)	(0.0024; 0.0238)	(-0.0405; 0.0481)
Mother born in other country = 0	-0.1513	-103.9843	-0.2329	0.1662	0.0732
	(-0.6975; 0.3949)	(-122.1859; -85.7826)	(-0.3179; -0.1480)	(0.0470; 0.2854)	(-0.3535; 0.4999)
Female = 1	0.3475	-130.6381	0.1678	0.1920	-0.0644
	(-0.1550; 0.8500)	(-147.3833; -113.8930)	(0.0880; 0.2475)	(0.0796; 0.3043)	(-0.4770; 0.3482)
Gestational Age (days)	-	26.9527	-0.0153	-	-
	-	(26.3167; 27.5888)	(-0.0193; -0.0114)	-	-
Birth weight (grams)	-	-	0.0010	-0.0002	-
	-	-	(0.0009; 0.0011)	(-0.0003; -0.0001)	-
Mean BMI at 48-60 months	-	-	-	1.3817	0.0697
	-	-	-	(1.3476; 1.4158)	(-0.1462; 0.2856)
Mean BMI at 92-104 months	-	-	-	-	1.0664
	-	-	-	-	(0.9468; 1.1861)
(Intercept)	265.1595	-4441.8371	19.3324	-4.3414	-0.4612
	(258.4967; 271.8224)	(-4720.7316; -4162.9426)	(17.9209; 20.7440)	(-6.0023; -2.6804)	(-7.0829; 6.1606)
N valid observations per model	10584	10582	6881	4172	206
Mean of dependent variable	275.9751	3205.4579	16.0600	16.7791	18.6146

Figure 7. Estimated coefficients of the concatenated multivariable regressions – BIB study.

NFBC86 - FINLAND (started: 1985)	Gestational age (days)	Birth weight (grams)	Mean BMI at 42-54 months	Mean BMI at 78-90 months	Mean BMI at 126-138 months
Log Equivalised Income (EU-SILC)	0.1702	14.7290	0.0702	0.1314	-0.6438
	(-1.0642; 1.4047)	(-31.3763; 60.8343)	(-0.1143; 0.2548)	(-0.0701; 0.3328)	(-0.9306; -0.3569)
Mother's Age at Birth (years)	-0.1736	10.8711	-0.0079	0.0021	0.0185
	(-0.2214; -0.1259)	(9.0814; 12.6608)	(-0.0153; -0.0006)	(-0.0059; 0.0100)	(0.0073; 0.0298)
Female = 1	0.6734	-144.2444	-0.0306	0.0732	-0.0838
	(0.1523; 1.1945)	(-163.7138; -124.7749)	(-0.1089; 0.0478)	(-0.0116; 0.1580)	(-0.2047; 0.0370)
Gestational Age (days)	-	26.8673	-0.0098	-	-
	-	(26.0554; 27.6792)	(-0.0140; -0.0056)	-	-
Birth weight (grams)	-	-	0.0007	0.0000	-
	-	-	(0.0006; 0.0008)	(-0.0001; 0.0001)	-
Mean BMI at 42-54 months	-	-	-	1.1193	0.0071
	-	-	-	(1.0868; 1.1519)	(-0.0609; 0.0751)
Mean BMI at 78-90 months	-	-	-	-	1.2716
	-	-	-	-	(1.2275; 1.3157)
(Intercept)	281.6569	-4265.6653	15.9212	-2.6236	1.9621
	(272.4601; 290.8537)	(-4678.3116; -3853.0190)	(14.1741; 17.6682)	(-4.2154; -1.0317)	(-0.2871; 4.2113)
N valid observations per model	8132	8132	4291	3977	3034
Mean of dependent variable	278.1175	3542.0442	15.8346	16.2283	18.2751

Figure 8. Estimated coefficients of the concatenated multivariable regressions – NFBC86 study

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In brief, when analysing the INMA data we observed very similar estimates to those obtained in the NINFEA study; in the UK cohorts a less strong inverse relationship between EHII and BMI is observed in the first periods only but not at approximately 10 years of age on the contrary of the results obtained in NFBC86, where a relevant negative effect is observed at 10 years of age only.
These results will be used to inform the MICH M3 phase for all the countries.

5. Conclusion

The MICH model constitutes a useful tool to provide evidence of how fiscal policies could affect health outcomes in the population and thus could be used in fiscal and health policy-making. The results of the study carried out in the Italian setting using childhood overweight and obesity as the outcome of interest show that fiscal policies, especially the focalised interventions, can have a strong impact on childhood overweight and obesity especially for the most vulnerable families. The MICH model, exploiting the cross-country comparative nature of EUROMOD and the comparability of birth cohort data member of the EU Child Cohort Network, can be applied to different settings both in term of populations and of the outcome of interest.

6. Contribution of partners

- **UNITO**: has led this task
- **UOS:** has contributed to the design of the case-study to develop the microsimulation model, to the discussion of the results and the draft of the methodological paper describing the MICH method.
- **ISGLOBAL**: has contributed to the project with the INMA data for the application of the MICH model to the case of childhood overweight and obesity in Spain, and contributed to the definition of the M2 model for Spain.
- **UNIVBRIS**: has contributed to the project with the ALSPAC data for the application of the MICH model to the case of childhood overweight and obesity in UK, and contributed to the definition of the M2 model for UK.
- **BTHFT***:* has contributed to the project with the BIB data for the application of the MICH model to the case of childhood overweight and obesity in UK, and contributed to the definition of the M2 model for UK.
- **UOULU***:* has contributed to the project with the NFBC86 data for the application of the MICH model to the case of childhood overweight and obesity in Finland, and contributed to the definition of the M2 model for Finland.

LIFECYCLE Project
Coordination and leadership:
Erasmus MC
Generation R (Na-2918)
PO box 2040
3000 CA Rotterdam
The Netherlands
Phone: +31 (0)10 704 3405
Email: lifecycle@erasmusmc.nl
Web: lifecycle-project.eu

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7. Deviations from original plan

This deliverable has been fulfilled fully in line with the original plan as stated in the grant agreement.

8. Dissemination activities

As stated previously in the report, to reach the scientific community outside of LifeCycle a manuscript describing the method and showing its application to the case of childhood obesity in Italy was published in a scientific journal. We plan to present our results also in conference presentations.

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LIFECYCLE Project
Coordination and leadership:
Erasmus MC
Generation R (Na-2918)
PO box 2040
3000 CA Rotterdam
The Netherlands
Phone: +31 (0)10 704 3405
Email: lifecycle@erasmusmc.nl
Web: lifecycle-project.eu

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