Inequality in Body Mass Indices across Countries: Evidence from Convergence Tests

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October 8, 2018

Abstract

This study examines the long-term inequality in body mass index (BMI) based on convergence tests applied to a database of 172 countries recently published by the NCD Risk Factor Collaboration. First, we find that countries converge in clubs, which indicates that country disparities in BMIs will persist over time. Second, there are three and six convergence clubs in BMIs for female and male individuals, respectively. That is, we would not observe a single convergence pattern in body weights as the nutrition transition theory and the dietary convergence hypothesis seem to suggest. Females have only one healthy club ($18.5 \leq \text{BMI} < 25$) and two overweight clubs ($\text{BMI} \geq 25$). Males have three healthy clubs and three overweight clubs. Third, the analysis of club convergence indicates that BMI inequality has increased due to the BMI growth observed in club 1 (the one with the highest average BMI and led by the US) in each gender group. Finally, potential determinants of BMI such as globalization, human capital, income, and urbanization are relevant to understand differences across clubs. We interpret the club convergence as the result of a heterogeneous integration of countries into the global economy, which is probably related to strong domestic preferences, policies designed to manage the impacts of globalization, and shifts in productive structures.

JEL Codes: D91, I12, I31, O47.
Keywords: obesity, dietary convergence, health inequality, globalization, nutrition transition, sex differences.

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1 Introduction

When scholars and policymakers started to consider that defeating underweight and undernutrition in the poorest areas of the world was an achievable goal, overweight and obesity—perhaps surprisingly—began to constitute serious problems in advanced and developing nations. The potential dietary convergence, as part of the nutrition transition (Popkin, 1993, 2006; FAO, 2004), and the phenomenon of increasing body weights worldwide raise several questions. One is whether low- and middle-income economies will become more similar in the level or growth of their average body mass index (BMI, kg/m^2) compared with their high-income counterparts in an increasingly globalized world. For example, consider the case of females in the United Kingdom (UK) and Bolivia. According to data from the NCD Risk Factor Collaboration (2016), Bolivian females showed an average BMI of 22.8 in 1975, which was 0.7 below their British peers in the same year (23.5). By 2014, the average BMI of Bolivian females rose to 27.3, which is 0.2 above that of British females. Alas, such 2014 BMI levels, in both cases, are in the range of values classified as overweight by international organizations (WHO, 2000).

We investigate global inequality in average BMIs and its evolution over time. A state of the world with countries that show minor differences in BMI should not be alarming per se. On the one hand, it would be a concern in terms of global welfare if inequality in BMI widens over time such that a group of countries move toward unhealthy levels ($BMI > 25$). On the other hand, finding a constant gap between healthy and unhealthy nations would raise questions about the conditions behind the differences in countries' health statuses. The concept of convergence—understood as the tendency of differences among countries to vanish over time (Durlauf and Johnson, 2008)—allows us to determine if the BMI inequality that is currently observed among countries is transitory or not. Furthermore, we also evaluate if the variables that the literature identifies as covariates of obesity (i.e., globalization, income, education, and urbanization) can explain persistent inequality among groups of countries.

We analyze inequality in BMIs through the lens of the most recent convergence tests proposed in the literature. We use the relative convergence test formulated by Phillips and Sul (2007a, PS henceforth) and the σ-convergence test by Kong, Phillips, and Sul (2017, KPS henceforth). Under relative convergence, two or more nations may approach each other in the long term in either the levels or growth rates of BMIs. Under σ-convergence, the cross-sectional dispersion of BMIs shows a tendency to decline over time, as should be expected if two or more time series converge. One of the advantages of PS is that the authors propose an algorithm to detect club convergence, that is, convergence in a subset of countries if the hypothesis of relative convergence is rejected in the full sample (Phillips and Sul, 2007b).[1] If clubs of convergence in BMI are found, we can characterize them and assess what potential covariates proposed in the literature are associated with the BMIs in each cluster. For this purpose, we use a

[1]Another reason to use PS is that most of the BMI series exhibit an upward trend and the time span of the available data is relatively small to observe trend shifts that indicate that convergence could be achieved in the long run. That poses an additional obstacle for traditional convergence tests looking for evidence of long-term comovement between variables that might have a low convergence rate (Phillips and Sul, 2007a).

dynamic panel data model and a bias-corrected fixed effects estimator. The database recently published by the NCD Risk Factor Collaboration (2016; NCD-RisC, henceforth), with long-run BMI trend estimates per gender across countries between 1975 and 2014, constitutes a unique input for our objectives.

The concept of convergence in body weights can be understood from various theoretical perspectives. From the viewpoint of public health, convergence in BMIs might be the result of convergence in diets—from traditional diets to the Western diet—and physical activity across nations (Popkin and Gordon-Larsen, 2004), which might be driven by the globalization process (Popkin, 2006; Pingali, 2007). From an economic viewpoint, the rational eating model (Levy, 2002, 2009; Philipson and Posner, 2003; Dragone, 2009) predicts that individuals will eventually converge in body weights (Duncan and Toledo, 2018). Intuitively, if two representative individuals start with different body weights at some initial period, all else being equal, the one with initial low weight tends to gain weight faster than the one with higher weight. This is the so-called β-convergence. However, this definition of convergence involves the strong assumption of homogeneity in preferences and constraints, making it difficult to find empirically across countries. In this paper, we study less restrictive concepts of convergence that allow the sort of heterogeneity aforementioned.[2]

In line with Duncan and Toledo (2018), we confirm that the world does not converge in BMIs using different tests. Our main results indicate the following. First, we find that countries converge in clubs. Club convergence cannot be rejected in terms of the BMI growth rates, implying that country disparities in average body weights will persist over time.[3] Second, we find three convergence clubs in BMIs for female individuals and six for male individuals. According to the average BMI in 2014, females show one healthy club ($18.5 \leq \text{BMI} < 25$) and two overweight clubs ($\text{BMI} \geq 25$). Males show three healthy clubs and three overweight clubs. The United States (US)—probably one of the most representative countries of the Western dietary pattern—is the only advanced economy in the female club with the highest BMI. We identify a set of low- and middle-income economies that are part of the overweight clubs with the highest BMIs. Third, the increasing inequality in BMIs across nations is mainly driven by club 1 (led by the US in each gender group). Fourth, we also find significant σ-convergence (convergence in dispersion of BMIs) within clubs, entailing that cross-sectional dependence of BMIs within each club will increase over time. Fifth, we find that globalization, human capital, urbanization, and income are relevant to understand differences among clubs. The effect of a globalization measure on BMIs is mostly positive, statistically significant, and heterogeneous across clubs and gender. We interpret this result as a consequence of a heterogeneous integration of countries into the global economy where factors such as strong

[2]To the best of our knowledge, ours is the first work to test for relative and σ-convergence in body mass indices worldwide. Li and Wang (2016) evaluate β-convergence in prevalence rates across US states. Duncan and Toledo (2018) test for β-convergence in BMIs and their analysis is mainly focused on European countries.

[3]Duncan and Toledo (2018) also provide evidence that the world does not converge in BMIs but assuming homogeneous parameters in the theoretical model and split the full sample exogenously into world regions in the empirical analysis. They find that only Europe converges in levels of BMI. In our current paper, we aim to detect convergence not only in levels but also in growth rates, capture heterogeneities among countries and in their transitions to the long-run equilibrium, and find convergence clubs in BMIs.

domestic preferences, local policies designed to manage globalization (Jacoby and Meunier, 2010), and shifts in the productive structure of an economy could explain different trends among clubs. Higher human capital is associated with lower BMI indicating that formal education can be used as an active policy to counteract the effects of globalization, especially in those clubs that might still have to intensify their economic integration with the rest of the world. We also find a positive association of migration from rural areas to metropolitan areas with BMI in healthy clubs. Finally, in some clubs, we find a counteracting income effect. That is, a higher GDP per person is associated with lower BMI.

Our study relates to the literature of the nutrition transition and the dietary convergence (Popkin and Gordon-Larsen, 2004; FAO, 2004; Hawkes, 2006; Pingali, 2007; FAO, WFP and IFAD, 2012; Brunelle *et al.*, 2014). In the nutrition transition, we should observe increasing similarity in diets (dietary convergence) and physical activity worldwide (Popkin and Gordon-Larsen, 2004). Our paper contributes to the understanding of one implication of this hypothesis. If diets and physical activity converge across economies, all else being equal, we should expect convergence in BMIs as well. We do not obtain convergence at the global level, but we find convergence in clubs of economies. In particular, we identify those economies (30 countries in the females' club 1 and 17 in the males' club 1) whose average BMIs are converging to the average US BMI (28.8 for females and 29 for males in 2014).

Our work is also related to studies that explore convergence in nutritional outcomes (Ingram, 1992; Hobijn and Franses, 2001; Mazumdar, 2003; Neumayer, 2003; Kenny, 2005; Weil, 2014) and convergence in food consumption (Regmi and Unnevehr, 2006; Regmi *et al.*, 2008). Some of these studies find convergence in daily calorie or protein supplies (Ingram, 1992; Kenny, 2005), whereas others conclude that either divergence exists or convergence is observed but only in certain subsamples (Hobijn and Franses, 2001; Mazumdar, 2003; Regmi and Unnevehr, 2006; Regmi *et al.*, 2008). Our results suggest that convergence in nutritional outcomes and food consumption could be found for certain economies that form convergence clubs.

We also complement the literature that analyzes the link between obesity-related indicators and their determinants across countries (Fumagalli *et al.*, 2013; De Vogli *et al.*, 2014; Goryakin *et al.*, 2015, Miljkovic *et al.*, 2015; Costa-Font and Mas, 2016; Goryakin *et al.*, 2017; Oberlander *et al.*, 2017). In contrast to other works, we pay attention to long-run dynamics, gender heterogeneities, and convergence clusters of nations (see Appendix Table A1 for a comparison of such studies and ours). We find that members of a club share a similar long-run trend that can be related to traditional covariates associated with BMI: globalization, income, education, and the urbanization rate. More importantly, these effects vary among clubs and gender. Another difference with respect to prior cross-country studies is that education shows a statistically significant and negative relationship with BMI.[4]

The latter findings have relevant policy implications. Those economies that converge to their high-obesity counterparts within unhealthy clubs should be more concerned about the adverse

[4]The studies listed in Appendix Table A1 either omit measures of education or find mixed results for the education-obesity link.

effects on average body weights, especially if they are developing countries where educational attainment does not improve at the same pace as its integration with the rest of the world. The empirical evidence points out that globalization and human capital accumulation do not go hand in hand (e.g., Blanchard and Olney, 2017). Without the protective effect of education in an increasingly globalized world, individuals will be worse off in terms of BMI. We think that monitoring obesity should be a component of any agenda of development, especially in those countries where globalization has not been accompanied with a proper development of urban areas or improvements in human capital. In this context, we may view our analysis on convergence in clubs as a tool similar to an early-warning indicator.

The paper is organized as follows. Section 2 provides the theoretical background, a rational eating model with heterogeneity, to motivate the use of the empirical test of relative convergence. Additionally, we discuss the σ-convergence test and the data features. Section 3 presents the results. We characterize the convergence clubs using panel data techniques and discuss transitional divergence. Section 4 provides an interpretation of our main results and their implications. We discuss the formation of clusters in BMI, gender heterogeneities, the role of genetics, the dietary convergence hypothesis, and the limitations of our data and methods. Section 5 concludes with a summary and policy implications.

2 Methods

2.1 Theoretical Background

Consider a rational eating model along the lines of Levy (2002), Lakdawalla and Philipson (2009), Dragone and Savorelli (2012), and Duncan and Toledo (2018), but with heterogenous representative agents.[5] In each economy i, a representative individual chooses food consumption (c_{it}) and (height-adjusted) body weight (w_{it+1}) to maximize the lifetime utility function

$$U_i = E_0 \sum_{t=0}^{\infty} {\beta_i}^t \left[c_{it} \left(\overline{c}_i - \frac{c_{it}}{2} \right) - \frac{\gamma_i}{2} (w_{it} - {w_i}^I)^2 \right] \tag{1}$$

subject to a law of motion of weight given by

$$w_{it+1} = (1 - \delta_i) w_{it} + \phi_i c_{it} - \psi_i s_{it} + \epsilon_{it+1} \tag{2}$$

an initial weight ($w_{i0} > 0$), non-negativity constraints ($c_{it} \geq 0$, $w_{it} \geq 0$), and the corresponding transversality condition. Omitting country subscripts, the parameter β denotes

[5] The empirical method to be introduced in the next subsection is flexible enough to encompass other model specifications. These alternative specifications can consider either extensions of the rational eating model (e.g., including leisure-work time decisions and energy spending) or, more importantly, deviations from rationality (e.g., myopic decision making as in Burke and Heiland, 2007). We use this version of the rational eating model for simplicity.

the discount factor, $\bar{c}$ stands for the satiation level of food consumption, γ is the parameter related to the disutility of having a weight different from the ideal weight (w^I), δ is the rate at which calories are burned and the individual loses weight (basal metabolic rate; BMR), ϕ measures the effect on weight of an additional unit of consumption, s_t represents the strenuousness of home or market production activities,[6] and ϵ_t is an error term. We normalize each individual's height and set it equal to one, such that weight and height-adjusted weight (BMI) are equivalent.[7]

The solution to this standard linear-quadratic problem[8] has the form

$$w_{it} = \eta_i + \rho_i w_{it-1} + \epsilon_{it} \tag{3}$$

where η_i and ρ_i are reduced-form parameters that depend on the structural parameters of the rational eating model, and the stochastic error term might include time effects $(\tau_t) : \epsilon_{it} = \tau_t + \nu_{it}$.

2.2 Empirical Model and Tests

Although equation (3) could be used to test for the traditional concept of β-convergence,[9] such a test would fail to find convergence because of two related reasons. First, the observed BMI series contain increasing trend components that differ among countries. Second, these trend components could be temporary, but the number of periods is insufficient to predict that this heterogeneity is transitory, as required by the traditional β-convergence tests. For these reasons, we use the PS test with a more general specification for the BMI pattern that also allows for temporary deviations from the long-run BMI pattern. In addition, the PS method includes an algorithm to detect convergence clubs in the absence of convergence in the full sample. Thus, we reformulate equation (3) as:

$$w_{it} = \theta_{it}\mu_t \tag{4}$$

where $\theta_{it} = (\eta_i + \rho_i w_{t-1} + \tau_t + \nu_{it})/\mu_t$, sometimes called factor loading coefficients, is the proportional deviation of country i's from the common component (i.e., a systematic idiosyncratic element that evolves over time), and μ_t is the common trend component. PS derive the following regression model to test for relative convergence:[10]

$$log\frac{H_1}{H_t} - 2log(log(t)) = a + blog(t) + u_t \tag{5}$$

[6]We assume that s_t is exogenous as in Lakdawalla and Philipson (2009). The inclusion of s_t as a choice variable that enters in the utility function in quadratic form does not alter the linear solution represented by equation (3).

[7]As in Dragone and Savorelli (2012), we can interpret $\bar{c}$ as the solution of a standard static problem in which the individual chooses amounts of food and a non-food good to maximize utility subject to a budget constraint. If food is a normal good, $\bar{c}$ increases with income and decreases with the price of food.

[8]For a similar derivation see Duncan and Toledo (2018).

[9]For instance, under parameter homogeneity ($\eta_i = \eta$ and $\rho_i = \rho$), the model predicts convergence to a unique non-stochastic steady-state equilibrium if $0 < \rho < 1$.

[10]For additional details about the test, see Appendix B.1.

for $t = T_0, \ldots, T$, where $H_t = N^{-1} \sum_{i=1}^{N} (h_{it} - 1)^2$ is the mean square transition differential, $h_{it} = w_{it} / (N^{-1} \sum_{i=1}^{N} w_i)$ denotes the relative transition coefficient for country i during period t, $-2log(log(t))$ is a penalty component to improve the test performance, T_0 is the initial observation,[11] and u_t is an error term. The null hypothesis (convergence for all i) and the alternative hypothesis (no convergence for some i) can be expressed in equation (5) as $H_0 : b \geq 0,\ H_A : b < 0$. The null hypothesis is tested using a one-sided t-test constructed with a heteroskedasticity and autocorrelation consistent (HAC) estimate. More intuitively, when t tends to infinity (long run), the mean square transition differential (H_t) tends to zero, the relative transition coefficient (h_{it}) tends to one, and hence the country's BMI (w_{it}) converges to the average BMI. Every country's BMI converges to the average BMI of the sample, which entails that every country's BMI converges in the long term. In the case that the null hypothesis of relative convergence is rejected for the full sample, PS propose an algorithm to find convergence clubs (see Appendix B.2).

Finally, since relative convergence does not imply σ-convergence nor vice versa, we also test for σ-convergence using the KPS test. We test for σ-convergence with the heteroskedasticity autocorrelation robust (HAR) covariance matrix estimator proposed by KPS. To this end, we estimate:

$$K_{Nt} = \mu + \phi t + \nu_t \tag{6}$$

for $t = 1, \ldots, T$, where $K_{Nt} = N^{-1} \sum_{i=1}^{N} \left[w_{it} - \frac{1}{N} \sum_{i=1}^{N} w_{it} \right]^2$ is the cross-sectional variance of BMIs, and ν_t is an error term. The null and the alternative hypotheses are $H_0 : \phi \geq 0$ (no σ-convergence), $H_A : \phi < 0$. If we reject the null hypothesis, then we can conclude that the evidence points to lower disparities in BMIs across countries. For further technical comments, see Appendix B.3.

2.3 Data

We apply our econometric tests to the NCD-RisC panel of average BMI estimates across nations. The data collection considers 1,698 population-based data sources, with more than 19.2 million adult participants (9.9 million men and 9.3 million women) in 200 countries and territories between 1975 and 2014. For the analysis that follows, we consider only those economies with GDP data available, which gives us a sample of 172 economies. Our aim is to focus on a set of countries with relatively high quality information.

Two important features of the database are that the BMI series are age-standardized and height and weight are measured by the interviewer. The latter is useful because self-reports of height and weight tend to be biased. In addition, we use only unadjusted BMI series. These are estimated without using covariates (e.g., GDP per person, urban population rate,

[11] This is usually set as $T_0 = [rT]$, i.e., the integer part of rT where $0 < r < 1$. As PS suggest, we discard the first 30% ($r = 0.3$) of the sample to implement the test.

and schooling years). The idea here is to avoid the potentially artificial influence of those covariates in our tests.[12]

Broadly speaking, the statistical model used by NCD-RisC to estimate mean BMI per country has a hierarchical structure (country, region, super-region, and world). In simple words, a country with complete data will use its own surveys to calculate the mean estimate, whereas countries with missing data could use information from the same country and different years or, ultimately, from other countries that belong to the same region (see Appendix Table 1 in NCD-RisC, 2016). We address this point again in Subsection 4.5.

For the characterization of clubs in Subsections 3.2 and 3.3, we use covariates described in Appendix Table C1. This appendix provides details about the sample, definitions, and data sources as well as descriptive statistics.

3 Results

3.1 Relative Convergence, σ-Convergence, and Robustness Checks

Table 1 lists the results of the convergence tests. We reject the null hypothesis of relative convergence for the world for both female and male individuals [column (3)]. However, we observe club convergence and substantial heterogeneity. We find three convergence clubs for females (with 31, 101, and 40 countries, respectively) and six clubs for males (with 18, 66, 29, 28, 27, and 2 countries), as well as a non-convergent male group with only two members (Bangladesh and Ethiopia). Figures 1 and 2 illustrate the convergence clubs in world maps and Appendix D reports the complete list of countries in each club.

[Table 1 about here.]

[Figure 1 about here.]

[Figure 2 about here.]

Column (2) in Table 1 presents the distribution of countries per world region. Among females, club 1 is led by the US (the only advanced economy in this cluster) and followed by 18 Latin American and Caribbean countries. In club 2, Europe has the most important participation (38) followed by African nations (31). In the third club, Asian economies are more numerous

[12]That said, NCD-RisC does not find important statistical differences between adjusted and unadjusted data.

(17), of which East Asian countries have the largest participation, and they are followed by African countries (16).

As in the case of females, the males' club 1 also includes the US. However, this club has fewer countries and Asia and Europe have more relative importance. Once again, the most important world region in club 2 is Europe (32), followed by Latin America and the Caribbean (21). Club 3 is composed of Asian countries (10), whereas Africa predominates in clubs 4 and 5.[13]

Perhaps the most worrisome result is that several developing countries, like Bolivia, El Salvador, Nicaragua, and Suriname, among others, share the same growth path of BMI with the US in the females' club 1. The US has a high average BMI (28.8 in 2014 according to NCD-RisC). Similarly, in club 1 among males, emerging and developing economies, such as Belize, Jordan, Kuwait, and Qatar, among others, tend to grow at the same rate as advanced economies like Ireland, the UK, and the US (with 2014 mean BMIs of 27.9, 27.4, and 29, respectively).

Column (3) in Table 1 provides the slope estimate and t-statistic of equation (5) for each club or group. We reject the null hypothesis of relative convergence for the full samples of females and males and for the no-convergence group. All the clubs show relative convergence, as expected. As a robustness check, we also tested for relative convergence grouping adjacent clubs and we rejected the null hypothesis in all the cases (results are available on request). Put differently, there is no possibility to obtain global convergence or fewer clubs in our sample, all else unchanged.

Given the magnitudes of the estimates, we observe convergence in growth rates. As it seems implausible to foresee an unbounded trajectory of a BMI in the long run, one possible interpretation of this result is the following. We would expect that average BMIs of the members from the same club will grow at a similar (non-zero) growth rate for a long period; then, they will all stabilize and grow at a small, probably close to zero, growth rate.[14]

Column (4) in Table 1 shows the results for the σ-convergence test. In the full samples, we reject the null hypothesis of no σ-convergence for females but not for males. In other words, we confirm that the reduction in the dispersion of BMIs across countries is statistically significant for female individuals. It is important to recall that σ-convergence does not imply necessarily relative convergence or vice versa. In turn, the remainder of the test results tend to confirm the presence of σ-convergence within clubs in women and men. The exception is

[13]In light of the findings reported in Duncan and Toledo (2018), the important presence of Europe in club 2 in both samples is not surprising. That study finds that Europe converges in BMIs and constitutes a convergence club. In Table 2 we can see that the great majority of European countries –84% in the females sample and 71% in the males sample– are (endogenously) classified in a single club (club 2) by the PS test. The discrepancies might be due to the different concepts of convergence (relative and β-convergence) and the methodologies to impose or find clubs in each study.

[14]The estimation of such growth rates at which BMIs would stabilize in the future constitutes a forecasting exercise beyond the scope of the present work.

the males' club 6, but this result is driven by the small number of countries in that club. The group of non-relative convergence does not show σ-convergence either.

Figure 3 shows the evolution of the cross-sectional variance of BMIs (K_{Nt}, as defined in Subsection 2.2) for the female and male samples. After a few years of a steady decline, the males' variance has increased since the late 1980s, confirming the lack of σ-convergence in males' BMI and, consequently, a rise in BMI inequality. Females' variance also shows a U-pattern with the critical difference that the trough is reached by the early 2000s. Afterward, the females' variance shows a sustained increase. Although σ-convergence is not rejected in the females' sample, we interpret this result with caution because we did not find relative convergence, and the BMI series tend to trend upward. In other words, we expect that females' BMI series will continue growing slowly along their heterogeneous long-run trends and, therefore, show a higher variance—at least in the near future.

[Figure 3 about here.]

As described in Appendix B, before performing the club convergence tests, the BMI series for all the countries are sorted according to the last observation in the panel. Now, we analyze the sensitivity of our results to an ordering based on the 2009-2014 average (last 15% of the sample). The results are reported in Appendix Table E1. We observe minor changes in the clubs' formation. Approximately, 11% and 9% of the countries changed to an adjacent club or group among females and males respectively. Among females, several countries migrate from baseline clubs 2 and 3 to the (new) clubs 1 and 2 respectively.[15] Among males, we observe the movement of some countries toward clubs of lower average BMI. Moreover, we obtain a seventh club, but composed only of two countries (Rwanda and Uganda).[16] That said, our main conclusions remain unchanged. As in our baseline results, under the alternative ordering there is also no convergence in the world, club convergence and significant heterogeneity, the US leads club 1 and Europe is the most important world region in club 2 in both genders, and a number of developing nations in the first clubs tend to exhibit a growth in BMI similar to that of the US.[17]

3.2 Characterization of the Convergence Clubs

Table 2 displays the indicators that characterize the convergence clubs. Aside from the mean BMI in 2014, we include a set of variables usually suggested in recent studies that seek to explain BMIs. This set is composed of PPP-adjusted GDP per capita, a human capital index,

[15] Ecuador, New Zealand, Trinidad and Tobago, and Turkey, for example, move from club 2 to club 1.

[16] Belgium, Denmark, Finland, and Slovenia migrate from club 2 to club 3.

[17] To avoid the risk of providing misleading conclusions, we do not perform estimations for different values of r, the fraction of the sample we need to discard to implement the convergence test. The choice of $r = 0.3$ is suggested by the authors when the sample size, T, is moderate or small (e.g., $T < 50$). A smaller value of r (e.g., 0.2) jointly with a small T affects the size of the test, whereas a larger value could affect its power.

the urbanization rate, and a globalization index (see Appendix C for further details). We report the mean of each indicator (the median for GDP per capita) for every club and group over the 1975-2014 period.

[Table 2 about here.]

Following Gygli *et al.* (2018), we understand globalization as "the process of creating networks of connections among actors at intra- or multi-continental distances, mediated through a variety of flows including people, information and ideas, capital, and goods. Globalization is a process that erodes national boundaries, integrates national economies, cultures, technologies and governance, and produces complex relations of mutual interdependence."

In Table 2, the ordering of the convergence clubs of females and males follows the value of their corresponding average BMI. Based on the average BMI in 2014, we can classify the convergence clubs in two categories: healthy clubs $(18.5 \leq BMI < 25)$ and overweight clubs $(BMI \geq 25)$.[18] In the category of healthy clubs, we have the females' club 3 and the males' clubs 4, 5, and 6. Probably, the most concerning fact is that of club 1 in the female and male samples. Club 1 shows the highest average BMI in 2014, which implies overweight.

For the males' clubs, we observe that, on average, BMI correlates positively with the covariates (GDP per capita, human capital, urbanization rate, and globalization). Notably, the mean (median) of these covariates are above the worldwide mean (median) for the males' overweight clubs (i.e., clubs 1 and 2).

Interestingly, the previous characterization does not hold completely for the female clubs. The female club with the highest average BMI (club 1) does not have the highest level of globalization, GDP per capita, or human capital. In contrast, club 2 is the one that shows average indicators above the worldwide means or medians. In other words, as the average covariate of a club increases (e.g., globalization or GDP per capita), the average BMI increases as well. However, above a certain level, the association turns negative, and the mean BMI decreases while the other indicators increase —except the urbanization rate (Table 2). That is, higher average levels of globalization, human capital, or GDP per capita are not associated with a higher average BMI. In the next subsection, we explore these relationships in depth.

3.3 Assessing the Effects of Covariates on BMI across Convergence Clubs

The previous characterization of convergence clubs suggests that different levels of the covariates of BMI could explain the formation of clubs in males. However, the non-linear relationship observed for females suggests that it is not only the level of these indicators that

[18] Other categories, such as underweight $(BMI < 18.5)$ or obese $(BMI > 30)$ are not observed for the clubs in our analysis.

could differ across clubs, but also the magnitude of their effects. In order to evaluate this hypothesis, we estimate the following specification:

$$\begin{aligned} BMI_{it} = \varphi_i + \rho BMI_{it-1} + \sum_{j=1}^{N_C-1} \left(\alpha_j Glob_{it} + \beta_j HCI_{it} + \delta_j UR_{it} + \gamma_j GDP_{it}^{pc}\right) D_{ij} \\ + \left(\alpha_{N_C} Glob_{it} + \beta_{N_C} HCI_{it} + \delta_{N_C} UR_{it} + \gamma_{N_C} GDP_{it}^{pc}\right) + \omega_{it} \end{aligned} \tag{7}$$

where φ_i represents country fixed effects, $Glob$ denotes the globalization index, HCI is the human capital index, UR stands for the urbanization rate, GDP^{pc} is the real GDP per capita, D_{ij} is a dummy variable that takes the value of 1 if country i belongs to club j and 0 otherwise, N_C is the total number of clubs per gender sample, and ω_{it} is an error term. The parameters of interest are the semi-elasticities α_j, β_j, δ_j, and γ_j, for $j = 1, ..., N_C$. As we show in Table 2, average BMIs tend to increase from the last club to the first club. To measure the effects of covariates on BMI, we use the club with the lowest average BMI (indexed by N_C) as the reference club. For instance, α_1 measures the difference of the globalization effect on BMIs between club 1 and club N_C. Thus, the total effect of globalization on BMI in club 1 is given by $\alpha_1 + \alpha_{N_C}$. For that reason, the parameters α_{N_C}, β_{N_C}, δ_{N_C}, and γ_{N_C} can be also interpreted as the common effects of the covariates across clubs. A similar interpretation should be given to the parameters associated with the other regressors.

Because the dependent variable is the average BMI of a country, we expect that covariates have small effects (i.e., coefficients of low magnitude). That said, these effects might reflect significant distributional effects of BMIs at an individual level. We expect positive coefficients for the globalization index. In particular, positive values for $\alpha_1, .., \alpha_{N_C-1}$ indicate that the impact of globalization on BMIs in those clubs is larger than that in the reference club. The expected effects of income, human capital, and urbanization on human body weights are, in principle, ambiguous (for a brief discussion, see Appendix F).

We employ a bias-corrected fixed effects estimator (LSDVC) for the estimation of this dynamic panel data model (Kiviet, 1995). The LSDVC tends to show a lower root mean squared error compared to IV and GMM estimators (Bruno, 2005). Recent simulation studies (Flannery and Hankins, 2013; Dang *et al.*, 2015) concur that the LSDVC is a more accurate and robust estimator than GMM estimators such as Arellano and Bond (1991).[19]

Table 3 displays the estimated coefficients of the covariates from equation (7) for each club, bootstrapped standard errors, and p-values for the null hypothesis that the difference between coefficients of club i and club j is equal to zero, for $i \neq j$ and $i, j = 1, ..., N_{C-1}$.[20] We do not include the sixth club in the male's sample because of the small number of observations (only two economies).

[19] It is worth mentioning that the LSDVC assumes exogeneity in the regressors, except for the lagged dependent variable.

[20] To save space in the table, we focus on the differences between coefficients of adjacent clubs (except for the reference clubs).

Mostly, the effect of globalization on BMIs is positive, statistically significant, and heterogeneous across clubs. In the females' sample (Table 3, Panel A), the parameter estimates of globalization and GDP per person for clubs 1 and 2 are significantly larger than that for club 3 (the one with the lowest current average BMI). For the latter club, globalization does not exhibit a significant association with the BMI, whereas the estimate of globalization in club 1 is the largest one and statistically different from that of club 2. Similarly, in the males' sample, the effect of globalization on BMI tend to increase from club 5 to club 1 (from right to left in Panel B of Table 3). The exception is the estimate of club 1, which is not significantly different from that of club 2.

The parameters of the globalization index and GDP per person are different in the females' clubs 1 and 2. In club 2, higher GDP per person is associated with a lower BMI (counteracting effect), whereas such a relationship is positive in club 1 and reinforces the adverse effect of globalization on BMI. This reinforcing effect is also found in males' clubs 1 and 2, where the positive effect of GDP per person on BMI is not significantly different from the reference club (club 5). In contrast, clubs 3 and 4 show the counteracting effect. That is, regardless of the adverse effect that a higher level of globalization has on BMI, an increase in GDP leads to lower BMI.

Regarding the other regressors, the parameter estimates of urbanization are somewhat heterogeneous across clubs. Their signs range from negative in the clubs that have relatively higher globalization or GDP to positive in those clubs with lower globalization or GDP. Overall, the estimate of human capital is homogeneous across clubs. The parameter estimate is negative and not significantly different from that of the reference club, except for the males' club 3, which has a larger negative estimate.[21]

Overall, Table 3 shows that club formation is not only driven by different levels of the covariates associated with overweight or obesity, but also by the different effects of these covariates, especially globalization, income per person, and human capital.

[Table 3 about here.]

To analyze the quantitative size of the estimated effects, we calculate the long-run elasticities of BMI with respect to its covariates in Table 4.[22] To illustrate the size of the effects, consider a one-standard-deviation change in the globalization indicator. In the female club 2, this shift is comparable to a rise in the ranking position of the 2014 globalization index from Haiti to Argentina. Using the corresponding elasticity, the long-run effect is an increase in 5.2% in BMI, which is equivalent to 45% of the change in club 2's BMI over the last four decades.

[21]The corresponding estimate for the female's club 2 has a small but positive effect. Even though this result seems hard to understand, it could be driven by a human capital proxy that is not an accurate measure of females' education, especially in those countries where most male individuals are highly educated.

[22]We transform the short-run semi-elasticities (slope coefficients) into long-run elasticities. The long-run elasticity of BMI with respect to a covariate in each (non-reference) club is the ratio of the covariate's slope coefficient plus the slope coefficient of the reference club (females' club 3 and males' club 5, as reported in Table 3) divided by (1 minus the coefficient of the lagged BMI) times the clubs' average BMI. For example, the long-run elasticity of globalization in club i is $(\alpha_i + \alpha_{NC})/[(1-\rho)\overline{BMI}]$ for $i = 1, ..., N_C - 1$.

[Table 4 about here.]

Similarly, in the male club 3, a one-standard-deviation change in the globalization index is analogous to a shift in ranking position from Uzbekistan to Armenia. The effect is an increase in BMI approximately of 12%, a rate higher than the one observed in our sample period (8.1%).

Three conclusions emerge from Table 4. First, we obtain inelastic long-term relationships between BMI and its covariates. Second, in spite of that, we observe medium size effects on BMIs in some cases depending on the club, gender, and covariate. Globalization elasticities tend to be relatively high for unhealthy clubs, especially for men, whereas income elasticities are, in general, not significant except for the statistically significant and negative estimates in females' clubs 2 and 3. Education elasticities are consistently negative and urbanization elasticities are positive for some healthy clubs. Third, elasticities in male clubs are less precise in terms of confidence intervals than those in female clubs.

It is worth adding that we took a closer look at the link between BMI and the globalization dimensions. First, we re-estimate our panel model using the economic, social, and political components of the overall index of globalization. Second, we use the short-run semi-elasticities and the 1975-2014 average BMI to compute point estimates of the long-run elasticities for each covariate including the globalization components. We find that the most important long-run elasticities are those related to political globalization for females (especially for clubs 1-2), and economic globalization (clubs 1-3) and social globalization (clubs 3-5) for males. That said, we take these results with caution because the breakdown of the overall index into its components jointly with the club dummies in our panel model generates high collinearity that induces unexpected signs and statistical insignificance. That is, some relevant dimensions of globalization could appear statistically insignificant when they are actually relevant to understand BMI trends. These results are available upon request.

3.4 Relative Transition Curves

An advantage of the methodology proposed by PS is that it allows us to analyze transitional dynamics and identify temporary disparities among countries. Figure 4 displays the relative transition curves across clubs (the average h_{it} of each club for every period t). In these curves, deviations from 1 (the dashed horizontal line) denote dynamics different from the world's average BMI. The two most striking conclusions we draw are the following.

[Figure 4 about here.]

BMIs and convergence clubs tend to show a high degree of persistence over time. The females' club 2—the one with the overweight and more European presence—and males' club 3 evolve over time, maintaining an average similar to the world's. Females' club 3 and males' clubs 2, 4, and 5 show relatively smooth transition curves over the period of analysis. Put differently, inequality in BMIs has not changed among clubs except for club 1.

Club 1—which includes the US in the females' sample, whereas Malta, the US, the UK, and a few other advanced economies are in the males' sample—is the main responsible of the disparities in BMI for both genders globally. As other clubs are maintaining a similar gap with respect to the world's mean (the flatter curves in the graphs), club 1 tends to trend upward. In other words, club 1 in each gender group contributes to the higher inequality in BMIs across the nations. The results in Subsections 3.2 and 3.3 suggest that the reinforcing effect between globalization and GDP is not the only reason behind the deviation of club 1 from the worldwide BMI trend. For males, such a deviation is also explained by the highest levels of the globalization indicator and GDP. In contrast, the highest level of globalization in the females' club 2 is mitigated through a smaller effect than the one observed for club 1.

4 Discussion

4.1 Formation of BMI Clubs and Globalization

We interpret the formation of convergence clubs as different long-run equilibria which are the result, at least in part, of a heterogeneous integration of countries to the global economy. For example, the US—an economy highly integrated with the rest of the world—leads club 1 with innovations that constitute the technological frontier and contribute to gains in body weight through various transmission mechanisms. These include, for example, the relatively low price of unhealthy food products, eating habits like consuming fast food and snacking, home cooking habits (especially those focused on processed food), and a more sedentary lifestyle (e.g., greater screen time). Economic globalization expressed in free trade agreements (lower tariffs and fewer trade barriers) and liberalization of foreign direct investment (e.g., internationalization of fast-food chains), have contributed to the increase in average BMIs among the main US trade partners (Mexico is probably an illustrative example).[23]

The other levels of global integration might be mainly led by European and East Asian countries (e.g., Germany, France, Japan, and South Korea, among others). These are economies with more regulated food markets compared with the US. As a result, traditional farming and local preferences still have a relative importance in their food systems and eating habits. Moreover, even though these economies are also integrated with the rest of the world economy, the degree of integration is lower compared with that of the US because they tend to manage the effects of globalization (Jacoby and Meunier, 2010). In general, these economies rely comparatively more on traditional diets as opposed to diets with more processed food,

[23] Technological advances in transportation and geographical proximity also contribute to lower trade costs and, thus, reduce the relative price of unhealthy food products in countries that trade these goods. For an empirical analysis of free trade and obesity in Mexico, see Giuntella *et al.* (2017).

despite the gradual reversion of this tendency (Pingali, 2007).[24] Another important element that explains a key difference among BMI patterns is the presence of many African and some Southeast Asian countries in the females' club 3 and, especially, males' club 5. These nations have faced external conflicts, civil wars, famines, and infectious diseases that affected their average body weights and caused malnutrition and high underweight prevalence for many years.[25]

Based on our previous discussion and the results from Section 3.2 (Table 2), one could be tempted to hypothesize that the higher the country's degree of development and integration with the rest of the world, the higher its average BMI, and the more likely it is to belong to the unhealthiest clubs. Interestingly, we provide evidence against this—perhaps tragic—conjecture. First, females' club 2 has the highest level of globalization and income, but it shows a smaller effect of globalization on BMI than the one observed in club 1. Second, if human capital increases with globalization, overall, that could have a beneficial effect on individuals' health through lower overweight. Finally, it is possible to observe a counteracting effect of income on BMI in some clubs as Table 3 indicates. If good health and physical appearance are viewed as normal goods, people could spend more time and money on reducing weight as income increases.

There is another channel by which globalization can affect BMI differently across clubs that is related to shifts in the productive structure. The changing composition of the global production of goods and services in recent decades, including the gradual adjustment toward a higher share of services in advanced economies, might imply less strenuous work (e.g., Böckerman *et al.* 2008) in such economies and be partly responsible for the formation of different clubs in BMIs. Countries with higher globalization index have more education as well, on average. In these countries, most of the types of jobs are related to the service sector. In contrast, in those countries with lower educational levels, more globalization is associated with more jobs in the agricultural sector (especially in African and South Asian countries), and less sedentary jobs.[26] Hence, globalization seems to have lower impact on BMI in the latter countries.

Finally, globalization can modify preferences and social norms dissimilarly across nations. For example, globalization plays a role in shaping the preferences for food products of the

[24]Globalization does not only affect the supply of cheap unhealthy foods but also influences the supply of other (non-food) goods such as technological devices and certain luxury goods. In low-income countries, the access to a more diverse supply of cheap unhealthy food could be an important channel to explain the shift to a high-sugar or high-fat diet. But in middle-income countries the desire for those non-food goods makes an inexpensive unhealthy diet more attractive to increase income's purchasing power and be able to afford such non-food goods.

[25]It is important to point out that leaders in each club also interact and influence leaders in other clubs (e.g., the so-called Americanization of Europe), but this effect is probably relatively smaller than the effect on the recipient members in their own clubs.

[26]According to data from the International Labor Organization, on average, 51% of males' jobs in clubs 4 and 5 are in the agricultural sector, whereas 47% of females' jobs in club 3 are in that economic sector in their corresponding countries.

recipient countries and making them similar to those of the leader.[27] On the other hand, the promotion of tolerance for different body shapes might be rapidly accepted in some countries whereas others could be more reluctant to that message. This kind of tolerance can transform the perceptions of a "normal" weight in a society. In the context of the theoretical model formulated in Section 2, this effect might be captured by the ideal weight (w_i^I), which in turn affects the individual's body weight.[28,29]

4.2 Gender Heterogeneities

We find a couple of interesting gender heterogeneities. First, the number of convergence clubs is smaller in the females' sample. Three tentative explanations are the following. On the one hand, home production has persisted over time among females' duties. Even though female participation in post-secondary education and labor markets has been increasing, females are still in charge of 90% of housework (World Bank, 2011). This common use of time and, in turn, common physical activities at home, might be associated with a larger concentration of average body weights in a few clubs. On the other hand, pregnancy could also explain common patterns of weight. According to Goldstein *et al.* (2017), gestational weight gains are increasingly globally (e.g., 47% of pregnant women in developed countries had gestational weight greater that the one recommended by the Institute of Medicine). A third potential factor could be body image among women and its role in homogenizing ideal body weights. In contrast to males, females tend to feel more dissatisfaction with their body weights (Calogero and Thompson, 2010) and their body images are becoming more similar (Swami *et al.*, 2010; Swami, 2015). Altogether, these elements would induce more concentration among females in terms of number of convergence clusters.

The second relevant heterogeneity has to do with the way globalization affects BMIs by gender. The association between the overall globalization index and BMI is weaker in females' clubs than in males' clubs (i.e., on average, smaller elasticities of globalization for females than for males; see Table 4). Given that females share more common factors than males and have a lower participation in the labor markets, globalization might have different impacts in terms of sedentary lifestyles by gender. A related finding is the relatively high long-run elasticity between BMI and political globalization for females commented in Subsection 3.3. Similar to Goryakin *et al.* (2015), we also find a positive link between political globalization

[27] This is sometimes known as Americanization. Hawkes (2006) calls it the Coca-Colonization hypothesis in the process of a dietary convergence.

[28] Burke and Heiland (2007) endogeneize the ideal or reference weight and show that this jointly with a fall in food prices and heterogeneous metabolisms helps explain the recent rise in obesity in the US.

[29] Another channel by which social globalization could affect average BMIs is through international labor mobility. In fact, the social globalization index includes one sub-component of foreign population. However, the weight of this sub-component is around 10% (26% of 38% of the overall index). Even though we acknowledge that migration might be playing a role, we consider this is comparatively small because barriers to labor mobility are more restrictive than those to trade and international capital flows (see, Freeman, 2006). Only 3.4% of the world population (about 258 million individuals) live outside their country of birth (United Nations, 2017).

and females' BMI. We believe this specific finding deserves more attention to understand the channel through which globalization affects body weights.

4.3 Genetics

Genetic factors can play a role in our results of convergence clusters. In our view, however, there is no consensus about the dimension of the effect of genetics on obesity and the transmission mechanisms (interactions with other determinants). For instance, Philipson (2001) argues that even though one possible explanation of obesity is a large genetic component to obesity, the problem with this argument is that although it may explain cross-sectional differences, it cannot explain a change over time for obesity; the change would be much slower than observed if it were transmitted genetically.

There might be different implications for our panel data estimates and convergence tests depending on how the genetics-obesity link works across countries and over time. First, if genetic factors do not change significantly over a few decades, which is the most likely case as Philipson (2001) claims, then the fixed effects in the panel model should capture them without apparent consequences on long-term BMI trends. Second, if genetic factors do not fluctuate over time but interact with the covariates in the model (e.g., education and genetics; see Amin *et al.*, 2017), then they should be captured by fixed effects and partly by the slope coefficients provided that genetic variation across nations in the same cluster is relatively small. In this case, genetics would contribute to explain the formation of clubs. Third, if a measure of genetic factors varies over time without interaction with other drivers, then it could be an omitted relevant variable. This would imply biased estimates in our panel model as long as the omitted proxy is correlated with the included regressors. The sign of the bias seems hard to define, especially for globalization. However, this omission is irrelevant for our convergence tests. Fourth, there is also the possibility that genetic components affect the basic metabolic rate (Burke and Heiland, 2007). Recall that the BMR is included in the law of motion of weight in our theoretical model. In this case, genetics might influence the convergence rate of BMI and the formation of different clubs. Having said that, to the best of our knowledge, there is not clear evidence that obesity genes are distributed geographically forming clusters or they have been changing over time.

4.4 The Dietary Convergence Hypothesis (DCH)

The nutrition transition theory has been developed since the seminal paper by Popkin (1993). In that article, the author outlines the stages or patterns of this world phenomenon. According to Popkin, developing countries are shifting from a pattern of receding famine to another of degenerative diseases. The latter is characterized by a diet often termed the "Western diet". In particular, modern societies seem to be converging to a pattern high in saturated fat, sugar, and refined foods and low in fiber, in an economy with fewer jobs with heavy physical activity due to the growth of a service sector and mechanization. As a result, we observe an increased prevalence of obesity that contributes to degenerative diseases. Later, Popkin (2006) would explicitly add globalization as a crucial driver—among other socio-economic and demographic factors—of this nutrition transition. Mostly, descriptive analyses—including case studies of emerging market economies like China, India, and Mexico—are provided as the empirical support for this theory.

Put differently, the nutrition transition theory predicts an increasing similarity in diets and physical activity in a progressively globalized world. If this prediction holds in practice, then we should observe convergence in body weights across countries. In spite of many years of expanding globalization, the empirical evidence we provide in this study point outs that no single convergence pattern exists in the world. If the observed BMI trends continue, our tests indicate that we should expect the same convergence clubs in the future. Moreover, globalization jointly with other variables like education, urbanization, and income, is statistically related to average BMI in different clusters. As explained in Subsection 4.1, one possibility is that globalization and the accumulation of human capital do not follow a uniform process across countries. Another compatible possibility, addressed in Subsection 4.2, is that genetic factors also contribute to the emergence of convergence clubs in BMI. It is also interesting to note that countries like China and India are not converging in unhealthy clubs with advanced economies with high average BMI such as the US or the UK. In any case, our findings might allow the nutrition transition proponents and other scholars to make more precise conjectures and polish the DCH.[30]

4.5 Limitations

We have discussed some data issues and robustness checks in Subsections 2.3 and 3.1. Some final notes regarding limitations and strengths follow.

4.5.1 Data

In Section 2 we mention that NCD-RisC uses a hierarchical model to estimate mean BMI per country and missing-data imputation could use information ultimately from other countries that belong to the same region. In this sense, one could make a case that estimates for countries with non-existent or weakly informative data—for instance, countries from the

[30] It is fair to mention that the DCH was proposed as part of the nutrition transition model, which is a conceptual model. In contrast to mathematical models like the rational eating model, we understand that the DCH was proposed in the public health literature without the explicit purpose of implementing a specific quantitative test. Thus, we opt to be cautious about the implications of our findings for this hypothesis. We know that even useful models have limitations and they can be improved based on new empirical evidence. We aim to contribute to the DCH literature by providing evidence of heterogeneous convergence in BMIs across nations.

regions of Central Africa or Andean Latin America that did not have data before 1985—might be correlated with other estimates for countries of the same region and, hence, share a long-run trend.[31] Nevertheless, our results indicate that countries from a given region do not necessarily belong to the same club. For example, Bolivia and Peru in the Andean Latin America region or DR Congo and Angola in the Central Africa Region (see Appendix D for the list of club members). Likewise, the region of North Western Europe contains countries with the richest BMI datasets and, similarly to the regions with low quality data, those countries are not classified in the same club per our tests.

It is important to add that the validation tests of the hierarchical model show that the estimates of the mean BMI are unbiased and have median prediction errors that are less than $\pm 0.13\ Kg/m^2$ and slightly larger for females when data of some countries are excluded from the estimation of the model. Errors are also close to zero if a third of the data of all countries are removed from the model estimation. NCD-RisC concludes that the statistical model performs appropriately in terms of prediction of the mean BMI. From that point of view, the margin of error of the mean BMI estimates can be viewed as the usual non-systematic error that are intrinsic to estimated aggregate variables.

Note also that the unit of observation in our study is a nation not the individual. Therefore, heterogeneities within countries might be lost when the data are aggregated and the focus is on the average BMI, the first moment of the BMI distribution. It can be argued that in countries like India and China obesity rates tend to be higher among the high-income individuals and that could be marginally captured by the average BMI. Another possibility is to view such obesity rates as a transitory phenomenon, not as part of a long-run trajectory, to the extent that those high-income individuals have the means to tackle overweight and its related health issues. Recall that the PS method also considers the possibility of transitional divergence in the series as commented in Section 3.4. In any case, we think that future studies that combine aggregate information (including genetic factors) with individual data from demographic health surveys could be valuable to understand different long-term BMI patterns within and across countries and identify transmission channels.

4.5.2 Methods

For a given dataset, the PS test can identify if there is at least convergence in the long-run growth rate for a group of countries. In the specific context of a conceivably bounded indicator like the BMI, the existence of a trend is consistent with a gradual convergence to an upper limit. Those countries in the same group will share a common BMI trend in the long term and, potentially, the same level of BMI. Our results provide evidence of convergence in growth rates within clubs. Overall, the high persistence in the increasing BMI trends does not allow us to determine whether convergence will be also in levels. Since body weights cannot

[31] The Melanesia region is the one with the lowest amount of data but only Fiji is included in our sample. Other regions with lacking data before 1985 are Central Africa, Southern Africa, Central Latin America, and Andean Latin America.

increase boundlessly, we could expect that we will be able to confirm such convergence in levels as more data become available in the future.

It is worth mentioning that our panel data estimations have the purpose of identifying not only the sources of BMI variation for each club but also exploring if the effect of each source differs across clubs. Such sources of variation have been considered in previous research but not in the context of identifying heterogeneous long-term trends across countries. Put differently, we think that the covariates in the panel model contain relevant trend components that are statistically associated with the BMI trend components.

A deeper analysis will be necessary to assess specific transmission mechanisms and verify that the statistical associations we find in the panel analysis reflect causal relationships. In particular, we need to understand how the adverse side effects of globalization work among males. If most of these effects are related to the type of job that males have—e.g., more sedentary jobs—as an economy develops, then global policies oriented to eliminate gender inequalities in the labor market could also have a unhealthy impact on females' weights.

Given the definition and proxy of globalization used in this study, it is possible that covariates such as the globalization proxy or income per person might be caused by or capturing technological advances, which are identified as the usual suspects of the obesity epidemic via the rise in energy consumption and reduction in physical activity. In the future, it would be useful to explore these relationships with more precise measures of globalization and technological progress. The related high collinearity among the set of covariates in the panel model is another challenge.[32] For that reason, we have to be cautious in interpreting statistically insignificant globalization components in our analysis.

5 Concluding Remarks and Policy Implications

We identify a set of empirical findings about convergence in BMIs that deserve careful attention. The lack of worldwide relative convergence indicates that the current observed BMI inequality will persist in the long run. To characterize such an inequality, we search for evidence of clustering convergence in BMIs. If convergence exists within a group of countries, then those countries share a common long-run trend. We observe club convergence in the BMIs globally. This evidence supports the fact that, regardless of the gender, inequality in BMIs has increased and will probably continue increasing worldwide. Furthermore, we find significant σ-convergence within most of the clubs, indicating that cross-sectional dependence of BMIs would increase in the future within each club. We observe different convergence clubs for males and females. The ranking of clubs per the 2014 mean BMI reveals one healthy club of female individuals and three healthy clubs of males, and all are mostly composed of Asian and African countries. Low- and middle-income economies, especially

[32] The collinearity arises from the inclusion not only of the set of regressors but also the club dummy variables. The correlation coefficients of our covariates range from 0.5 to 0.8.

from Latin America and Eastern Europe, pose another challenge. Those countries, jointly with certain high-income members such as the US and the UK, belong to convergence clubs with relatively high BMI levels (overweight clubs). We also conclude that club 1, led by the US in both female and male samples, is the most important cluster of countries behind the global inequality in BMIs. Western and central European countries have not played a crucial role in the increase of this global inequality.

As Phillips (2003) recalls, the more we learn in any scientific discipline the more there is to know. The determination of the factors behind our findings is a challenging task that deserves a deeper analysis. However, in that line, we began to provide certain guidelines. Globalization, human capital, urbanization, and income seem key to starting to understand the main drivers of these phenomena and the transmission mechanisms. First, we find that the effect of globalization on BMIs is mostly positive and statistically significant in the currently unhealthy clubs, whereas the relationship is small or not significantly different from zero in healthy clubs. We interpret this result as a consequence of a heterogeneous integration of countries into the global economy where factors such as strong domestic preferences, local policies designed to manage globalization, and changes in the productive structure of an economy induced by international trade could explain different trends among clubs. Second, higher human capital is associated with lower BMI. Then, formal education can be used as an active policy to counteract the effects of globalization, especially in those clubs that might still have to intensify their economic integration with the rest of the world. Third, our results indicate a positive association between BMI and the migration from rural areas to metropolitan areas in healthy clubs. Finally, in some clubs, we find a counteracting income effect. That is, GDP per person and BMI are inversely related.

In contrast to other cross-country studies that analyze the link between obesity-related indicators and their determinants, we focus on long-run heterogeneous relationships via club convergence tests. Other studies do not pay enough attention, if any, to clusters (clubs) of nations, heterogeneities by gender, and long-run dynamics as we show in the Appendix Table A1. These differences are not only the basis of our main contribution but also have relevant policy implications. To the extent that drivers of BMI, like globalization, affect nations differently, policy recommendations to these nations should be tailored accordingly. Those that converge to high-obesity economies within unhealthy clubs should be more concerned about the adverse effects on average body weights, especially if they are developing countries where educational attainment does not improve at the same pace as its integration with the rest of the world. The empirical evidence seems to indicate that globalization and human capital accumulation do not go hand in hand. As Blanchard and Olney (2017) argue, economic growth based on less skill-intensive exports does not improve educational attainment. Without the protective effect of education in an increasingly globalized world, individuals will be worse off in terms of BMI.

The 2030 Agenda for Sustainable Development signed by the United Nations in 2015 states as one of its goals to reduce by one third premature mortality from non-communicable diseases (NCDs). In accordance with this objective, since obesity is related to NCDs our findings indicate that monitoring obesity should be a component of any agenda of development, especially in those countries where globalization has not been accompanied with a proper development of urban areas or improvement in human capital. In this context, we may view our analysis on convergence in clubs as a tool similar to an early-warning indicator. We do not know if (or when) average BMIs in certain developing economies will slow down and stabilize in the future, but we do know that they converge within an unhealthy club. This piece of information helps as a cautionary advice for that particular set of middle-income and low-income developing countries. The update of this test results with more data could be useful to monitor if such countries continue in the same club or, perhaps due to a structural break or policy change, migrate to a club with lower or higher BMI.

Because globalization brings several, if not many, benefits for an economy,[33] we need to evaluate prudential measures to tackle its unintended effects on individuals weights and, at the same time, minimize the costs of discouraging trade and financial inflows on economic activity. Policies that point to changes in relative prices seem to be adequate candidates to consider. Deficit-neutral proposals that make unhealthy imported food products relatively more expensive than healthy ones—such as moderate tax rates or tariffs whose revenues can be used as subsidies for imported or domestic healthy goods—may be part of the policy discussion. Probably, this issue is even more important in those economies that plan to renegotiate or enter into new trade or foreign investment agreements.

[33]Notably, the most important is economic growth in the developing world (Dreher, 2006; Meissner, 2014).

Appendix

A Cross-country studies on the determinants of overweight

Table A1 summarizes the main features of the cross-country studies on obesity-related indicators and their main covariates.

Table A1: Empirical Studies on the Determinants of Overweight

Study	Fumagalli *et al.*(2013)[a]	De Vogli *et al.*(2014)	Goryakin *et al.*(2015)	Miljkovic *et al.*(2015)	Costa-Font and Mas(2016)	Goryakin *et al.*(2017)	Oberlander *et al.*(2017)	This Study
Dependent variable(s)	Categorical (diff. rates)	BMI	Overweight Dummy	Obesity Rate	Obesity rate, calorie intake	BMI	BMI	BMI
Gender heterogeneity analyzed	No	No	No[b]	No	No	Yes	No	Yes
Included regressors								
Globalization	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Income	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Education	Yes	No	Yes	No	Yes	No	No	Yes
Urbanization	Yes	Yes	No	No	Yes	Yes	No[c]	Yes
Globalization proxy	Imports-to-GDP ratio	KOF index, TrOp, FDI	KOF index	TrOp., FDI, GSI	CSGR Glob., KOF index	...	KOF index	KOF index
Period (years)	1990-2007 (18)	1980-2008 (29)	1991-2009 (19)	1986-2008 (23)	1989-2005 (17)	1980-2008 (29)	1970-2011 (42)	1975-2014 (40)
Long-run dynamics	No	No	No	No	No	No	No	Yes
Countries	47 DC	127 DC, AC	56 DC	79 DC, AC	26 DC, AC	173 DC, AC	70 DC, AC	172 DC, AC
Cluster/club analysis	No	No	No	No	No	No	No[d]	Yes
Micro-Data (type)	Yes (DHS)	Yes (G-Group)	Yes (DHS)	No	No	No	No	No

Notes: The categorical (diff. rates) includes four categories: underweight, normal, overweight, and obesity. The overweight dummy equals 1 if individual has a BMI>25 and 0 otherwise. *TrOp* stands for an indicator of trade openness ([exports+imports]/GDP). *CSGR Glob.* is the globalization index developed by the University of Warwick Globalization Project. Long-run dynamics refers to the inclusion (or not) of the lagged dependent variable as a model regressor or other type of long-run analysis. DC and AC denote developing and advanced countries. DHS is Demographic Health Survey. G-Group denotes the Global Burden of Metabolic Risk Factors of Chronic Diseases Collaborating Group. GSI represents the Globalization Social Index. KOF is the Swiss Economic Institute (KOF) index of globalization. [a]The study mainly focuses on political factors and BMI status. [b]The sample includes only female data. [c]Urbanization is used in a robustness check for nutrition outcomes. [d]Oberlander *et al.*(2017) use a grouped-fixed-effect estimator.

B PS test, algorithm for identifying convergence clubs, and $\sigma-$convergence test

B.1 PS test

Recall the equation

$$w_{it} = \theta_{it}\mu_t$$

In a broad sense, μ_t captures the common trend components of observable and unobservable factors due to, for example, technological change, globalization aspects, demographic transitions, food and health policies, and income levels (e.g., Lakdawalla and Philipson, 2009; Cutler *et al.*, 2003; Philipson and Posner, 2003; Popkin, 2006; Goryakin and Suhrcke, 2014; Goryakin *et al.*, 2015, Costa-Font and Mas, 2016; Goryakin *et al.*, 2017). The factor loading coefficients capture the time-varying cross-country marginal effects of such factors on an individual's weight (e.g., preferences shaped by cultural factors).

The factor loading coefficients, θ_{it}, are modeled in a semiparametric form:

$$\theta_{it} = \theta_i + \sigma_i \xi_{it} L(t)^{-1} t^{-\alpha} \tag{8}$$

where θ_i is fixed, ξ_{it} is $iid(0\ 1)$ across i and weakly dependent over t, and $L(t)$ is a slowly varying function (like $log(t)$). This specification ensures that θ_{it} converges to θ_i for all $\alpha \geq 0$, which constitutes the null hypothesis of interest. Furthermore, the model allows for periods of transitional heterogeneity or even transitional divergence across countries.

PS propose the concept of relative convergence, defined as

$$\lim_{k\to\infty} \frac{w_{it+k}}{w_{jt+k}} = 1,$$

for all i and j. In other words, two countries converge if their ratio of BMIs becomes 1 in the long run, for every pair of countries in the sample. This condition is equivalent to convergence of the coefficients θ_{it}. That is, $\lim_{k\to\infty} \theta_{it} = \theta$. In this case, all the countries would show a BMI proportional to the common trend component in equation (4).

B.2 Algorithm for identifying convergence clubs

Phillips and Sul (2007, p. 1800) propose an algorithm to identify clusters or clubs of convergence that has four steps. In step 1, the series under analysis are ordered for each country according to the last observation in the panel. In step 2, the procedure selects the first k highest values in the panel to form the subgroup G_k for some $N > k \geq 2$, run the log t regression (see equation (5) in Section 2), calculates the convergence test statistic for this subgroup, and chooses the core group size k^* by maximizing the test statistics over k subject to the constraint that the minimum test statistic cannot be less than -1.65. The objective here is to find a core convergence group and then proceed in step 3 to evaluate additional countries for membership of this group. In step 3, the algorithm adds one country at a time to the k^* core members of G_{k^*}, runs the log t test, and includes the country if the new test statistic is higher than a chosen critical value. This procedure is repeated for the remaining countries and the first sub-convergence group is formed. Finally, step 4 forms a subgroup of the countries for which the new test statistic is lower than the chosen critical value from step 3 and run the log test for this subgroup to see if the test statistic is higher than -1.65 and this cluster converges. If so, the conclusion is that there are two convergent subgroups in the panel. If not, the algorithm repeats steps 1-3 on this subgroup to determine whether there is a smaller subgroup of convergent members of the panel. If there is no k in step 2 for which the statistic is higher than -1.65, the conclusion is that the remaining countries diverge.

B.3 Technical notes on the $\sigma-$convergence test

Although the observed BMI series exhibit an increasing trend in our sample, it is reasonable to think that the trend will not continue indefinitely, that is, the BMI trend component is not divergent in the long term. However, if convergence in BMI is slow, we will observe the short-run trend pattern for a long period. Then, the concept of relative convergence in BMI is understood as countries that share a common trend component—the same μ_t in the terminology of equation (6)—that will be constant in the long run.

The σ-convergence test developed by KPS is well suited for series that do not have a divergent trend.[34] However, in the case of slow convergence, the test might not be adequate if the BMI series do not share a common trend, that is, if relative convergence does not hold. In the latter case, the test could incorrectly identify a statistically significant downward trend in the cross-sectional dispersion of the BMI series, if some countries have a relatively low initial BMI exhibiting high growth, whereas other countries with a relatively high initial BMI could grow at a lower rate. Because, as we will observe in Section 3, relative convergence is found for groups of countries, the test should be able to identify if there is σ-convergence within such groups.[35]

C Sample, definitions of series and data sources

With regard to world regions, the sample of 172 economies is distributed as follows: Africa (50 nations), Asia (40), Europe (45), Northern America (3), Latin America and the Caribbean (31), and Oceania (3).

[34]See KPS (page 13) for an example of a series with a divergent trend.

[35]The σ-convergence test requires $N > T$ in order to correctly reject the null hypothesis of no sigma convergence.

- BMI: body mass index, expressed in kilograms per square meters. Source: NCD Risk Factor Collaboration (2016). We do not filter the BMI data for the tests since they are long-run time series that mainly contain trend components. The BMI series are age-standardized and do not use self-reported height and weight. We use unadjusted BMI data; that is, the data constructed by NCD-RisC without using covariates (income per person, urbanization rate, and schooling) in order to minimize the possible artificial influence of such variables on body weight indicators.[36]

- GDP per capita: Expenditure-side real GDP at chained PPPs (in mil. 2011 US$ dollars) divided by population (in mil. of persons). Both series come from Feenstra *et al.*, (2015). The log-transformation of this series enters in the empirical model. Source: Penn World Tables 9.0.

- Human capital index: based on years of schooling and returns to education; see human capital in Feenstra *et al.*, (2015). The log-transformation of this series enters in the empirical model. Source: Penn World Tables 9.0.

- Urbanization rate: percentage of population living in urban areas as defined by national statistical offices. It is calculated using World Bank population estimates and urban ratios from the United Nations World Urbanization Prospects. Source: World Development Indicators (World Bank).

- Globalization index: the Swiss Economic Institute (KOF) index of globalization that measures the economic, social, and political dimensions of globalization and comes from Gygli *et al.* (2018). The weights of the economic, social, and political components in the overall index are approximately 35%, 37%, and 28%. The economic integration component includes the following variables: actual flows (trade, foreign direct investment, portfolio investment, and income payments to foreign nationals, all in percentage of GDP) and restrictions (hidden import barriers, mean tariff rate, taxes on international trade, and capital account restrictions). The social component considers data on personal contact (outgoing telephone traffic, transfers, international tourism, telephone average costs of call to USA, and foreign population), data on information flows (telephone mainlines, internet hosts, cable television, daily newspapers, and radios), and data on cultural proximity (number of McDonalds restaurants). The political engagement component includes embassies in country, membership in international organizations, and participation in UN Security Council missions. For further details about the construction of this index, see Dreher (2006). The log-transformation of this series enters in the empirical model.

[36]NCD-RisC kindly provided us the unadjusted dataset.

Table C1: Descriptive statistics

Variable	No. of observations	Mean	Standard deviation	Minimum	Median	Maximum
Body Mass Index						
Females	6880	24.32	2.31	17.60	24.68	30.57
Males	6880	23.74	2.13	18.37	24.06	29.00
Other variables						
Globalization index	6368	48.02	18.44	12.91	45.20	92.84
Human capital index	5481	2.19	0.71	1.01	2.14	3.73
Urbanization rate (%)	6825	52.05	23.61	3.52	51.59	100.00
GDP per person	6521	12537.2	17209.2	142.4	6423.71	221818.5

Note: The full sample includes 172 countries and territories over the 1975-2014 period. The KOF globalization index comes from Gygli *et al.* (2018). GDP per capita is real GDP at chained PPP (in 2011 US$ dollars). Human capital index is based on years of schooling and returns to education. Real GDP and human capital series are from Penn World Tables 9.0 (Feenstra *et al.*, 2015). Urbanization rate (%) series are from World Bank's World Development Indicators.

D List of countries in each club

Females' clubs. Club 1 = Antigua and Barbuda, Bahamas, Barbados, Belize, Bermuda, Bolivia, Dominica, Dominican Republic, Egypt, El Salvador, Fiji, Grenada, Guatemala, Honduras, Iraq, Jamaica, Jordan, Kuwait, Mexico, Nicaragua, Qatar, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Saudi Arabia, South Africa, Suriname, Swaziland, Syrian Arab Republic, United Arab Emirates, United States of America. Club 2 = Albania, Algeria, Angola, Argentina, Armenia, Australia, Azerbaijan, Bahrain, Belarus, Benin, Bhutan, Bosnia and Herzegovina, Botswana, Brazil, Bulgaria, Cape Verde, Cameroon, Canada, Chad, Chile, Colombia, Comoros, Congo, Costa Rica, Cote d'Ivoire, Cyprus, Czech Republic, Ecuador, Equatorial Guinea, Estonia, Finland, Gabon, Gambia, Georgia, Germany, Ghana, Greece, Guinea Bissau, Haiti, Hungary, Iceland, Indonesia, Iran, Ireland, Israel, Italy, Kazakhstan, Kenya, Kyrgyzstan, Latvia, Lebanon, Lesotho, Liberia, Lithuania, Luxembourg, Macedonia (TFYR), Malaysia, Maldives, Mali, Malta, Mauritania, Mauritius, Moldova, Mongolia, Montenegro, Morocco, Namibia, Netherlands, New Zealand, Norway, Oman, Pakistan, Panama, Paraguay, Peru, Poland, Portugal, Russian Federation, Sao Tome and Principe, Senegal, Serbia, Seychelles, Slovakia, Slovenia, Spain, Sudan, Sweden, Tajikistan, Tanzania, Thailand, Togo, Trinidad and Tobago, Tunisia, Turkey, Turkmenistan, Ukraine, United Kingdom, Uruguay, Uzbekistan, Venezuela, Zimbabwe. Club 3 = Austria, Bangladesh, Belgium, Brunei Darussalam, Burkina Faso, Burundi, Cambodia, Central African Republic, China, China (Hong Kong SAR), Croatia, DR Congo, Denmark, Djibouti, Ethiopia, France, Guinea, India, Japan, Lao PDR, Madagascar, Malawi, Mozambique, Myanmar, Nepal, Niger, Nigeria, Philippines, Romania, Rwanda, Sierra Leone, Singapore, South Korea, Sri Lanka, Switzerland, Taiwan, Uganda, Vietnam, Yemen, and Zambia.

Males' clubs. Club 1 = Belize, Chile, Cyprus, Czech Republic, Ireland, Jordan, Kuwait, Lebanon, Malta, New Zealand, Qatar, Saint Kitts and Nevis, Saint Lucia, Saudi Arabia, Spain, United Arab Emirates, United Kingdom, United States of America. Club 2 = Albania, Antigua and Barbuda, Argentina, Australia, Austria, Bahamas, Barbados, Belarus, Belgium, Bermuda, Bulgaria, Canada, Colombia, Costa Rica, Croatia, Denmark, Ecuador, Egypt, El Salvador, Estonia, Fiji, Finland, Georgia, Germany, Greece, Haiti, Honduras, Hungary, Iceland, Iraq, Israel, Italy, Jamaica, Kazakhstan, Latvia, Lithuania, Luxembourg, Macedonia (TFYR), Malaysia, Mexico, Moldova, Montenegro, Nicaragua, Norway, Oman, Panama, Paraguay, Peru, Poland, Portugal, Saint Vincent and the Grenadines, Serbia, Slovakia, Slovenia, Suriname, Sweden, Switzerland, Syrian Arab Republic, Tajikistan, Trinidad and Tobago, Tunisia, Turkey, Turkmenistan, Ukraine, Uruguay, Venezuela. Club 3 = Algeria, Armenia, Azerbaijan, Bahrain, Bolivia, Bosnia and Herzegovina, Brazil, Cameroon, China, China (Hong Kong SAR), Dominica, Dominican Republic, France, Grenada, Guatemala, Iran, Kyrgyzstan, Maldives, Mauritius, Mongolia, Morocco, Netherlands, Pakistan, Romania, Russian Federation, Seychelles, South Africa, Taiwan, Uzbekistan. Club 4 = Angola, Bhutan, Brunei Darussalam, Cape Verde, Chad, Comoros, Cote d'Ivoire, Gabon, Gambia, Ghana, Guinea Bissau, Indonesia, Japan, Lao PDR, Liberia, Mali, Mauritania, Namibia, Nepal, Philippines, Sao Tome and Principe, Singapore, South Korea, Sri Lanka, Sudan, Swaziland, Thailand, Yemen. Club 5 = Benin, Botswana, Burkina Faso, Burundi, Cambodia, Central African Republic, Congo, DR Congo, Djibouti, Equatorial Guinea, Guinea, Kenya, Lesotho, Madagascar, Malawi, Mozambique, Myanmar, Niger, Nigeria, Senegal, Sierra Leone, Tanzania, Togo, Uganda, Vietnam, Zambia, Zimbabwe. Club 6 = India, Rwanda. No-convergence group: Bangladesh and Ethiopia.

E Additional robustness checks

Table E1: Convergence Clubs Under Different Orderings Used in Algorithm

Sorted by last-year observations	**Sorted by last 6 observations (15% of sample)**
Females	
Club 1 (31): LAC (18), Asia (7), Africa (3), Northern America (2, inc. US), Oceania (1)	Club 1 (35): LAC (20), Asia (7), Africa (3), Europe (1), Northern America (2, inc. US), Oceania (2)
Club 2 (101): Europe (38), Africa (31), Asia (16), LAC (13), Oceania (2) Northern America (1)	Club 2 (112): Europe (40), Africa (37), Asia (22), LAC (11), Oceania (1), Northern America (1)
Club 3 (40): Asia (17), Africa (16), Europe (7)	Club 3 (25): Asia (11), Africa (10), Europe (4)
Males	
Club 1 (18): Asia (6), Europe (6), LAC (4), Northern America (1, US), Oceania (1)	Club 1 (18): Asia (6), Europe (6), LAC (4), Northern America (1, US), Oceania (1)
Club 2 (66): Europe (32), LAC (21), Asia (7), Northern America (2), Oceania (2), Africa (2)	Club 2 (62): Europe (28), LAC (21), Asia (7), Northern America (2), Oceania (2), Africa (2)
Club 3 (29): Asia (10), Europe (7), LAC (6), Africa (6)	Club 3 (35): Asia (11), Europe (11), LAC (6), Africa (7)
Club 4 (28): Africa (16), Asia (12)	Club 4 (25): Africa (14), Asia (11)
Club 5 (27): Africa (23), Asia (4)	Club 5 (25): Africa (21), Asia (4)
Club 6 (2): Africa (1), Asia (1)	Club 6 (2): Africa (2)
No-convergence group (2): Africa (1), Asia (1)	Club 7 (2): Africa (2)
	No-convergence group (3): Africa (1), Asia (2)

Notes: The table displays the number of convergence clubs and non-convergent groups and distribution of club members per world region. For comparison purposes, we replicate our results from columns (1) and (2) of Table 1 in the first column. The number of countries that changed to an adjacent club/group is 0, 4, and 15 among the females' clubs (i.e., 11% of the total number of countries), and 0, 4, 0, 5, 4, 2, and 0 among the males' clubs (9% of the total number of countries).

F On the expected signs of the covariates on BMI

- **Globalization index.** A number of studies mostly find positive effects of proxies of global integration on BMI or obesity-related indicators (De Vogli *et al.*, 2014; Goryakin *et al.*, 2015, Miljkovic *et al.*, 2015; Costa-Font and Mas, 2016; Oberlander *et al.*, 2017).

Goryakin *et al.* (2015), along the lines of Dreher (2006), suggest an ambiguous effect of political globalization: greater political integration at a regional level is likely to intensify regional cooperation (e.g., trade blocks) and eventually protect participating countries from outside economic competition. Therefore, the precise effect of political globalization on overweight is hard to predict.

- **GDP per capita.** Additional income could either increase or decrease BMI. Theoretically, it depends on two opposite effects (Cawley, 2015). If food and sedentary pursuits are normal goods, then more income leads to weight gains. If good health and appearance are normal goods, then more income involves weight losses.

- **Human capital.** In the case of indicators of education and body weight, scholars tend to argue that the link is negative. Even though more educated individuals could be better informed about nutrition and health and choose a healthier lifestyle, more education is usually related to higher income and, therefore, more food consumption. In the microeconomic literature that uses data at individual level, an inverse association is more common in advanced economies and a positive relationship is more frequent in lower-income economies (Cohen *et al.*, 2013). See also Brunello *et al.* (2013), Etilé (2014), and Kim (2016) as well as the references therein. Important reviews of the literature that relates socioeconomic status to obesity are Sobal and (1989) and Dinsa *et al.* (2012). In the literature that uses aggregate data, education is either omitted or ambiguous results are found. Fumagalli *et al.* (2013) report a positive link, whereas Goryakin *et al.* (2015) find mixed results. Costa-Font and Mas (2016) finds statistically insignificant estimates using a female-to-male secondary enrollment indicator.

- **Urbanization rate.** Similarly, the effect of urbanization is also ambiguous (Costa-Font and Mas, 2016). Urban areas might involve more sedentary work time (less physically demanding employments) but they could also offer access to a wider variety of products including healthy foods. For example, Goryakin *et al.* (2017) find a statistically significant and positive association between urbanization and BMI in low and middle income countries but statistically insignificant in high income economies.

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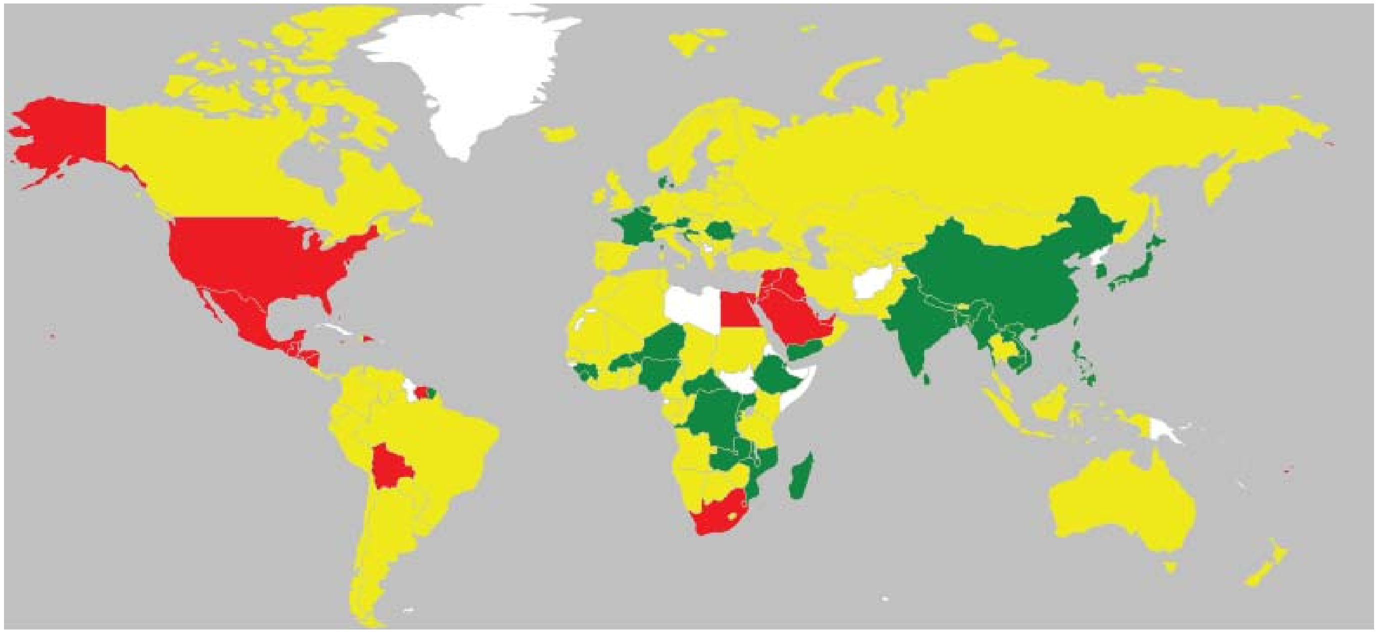


Figure 1: Females' Clubs in BMI in the World.

Notes: Countries or territories colored in red belong to club1; yellow refers to club 2; and green refers to club 3. White areas are not part of the sample.

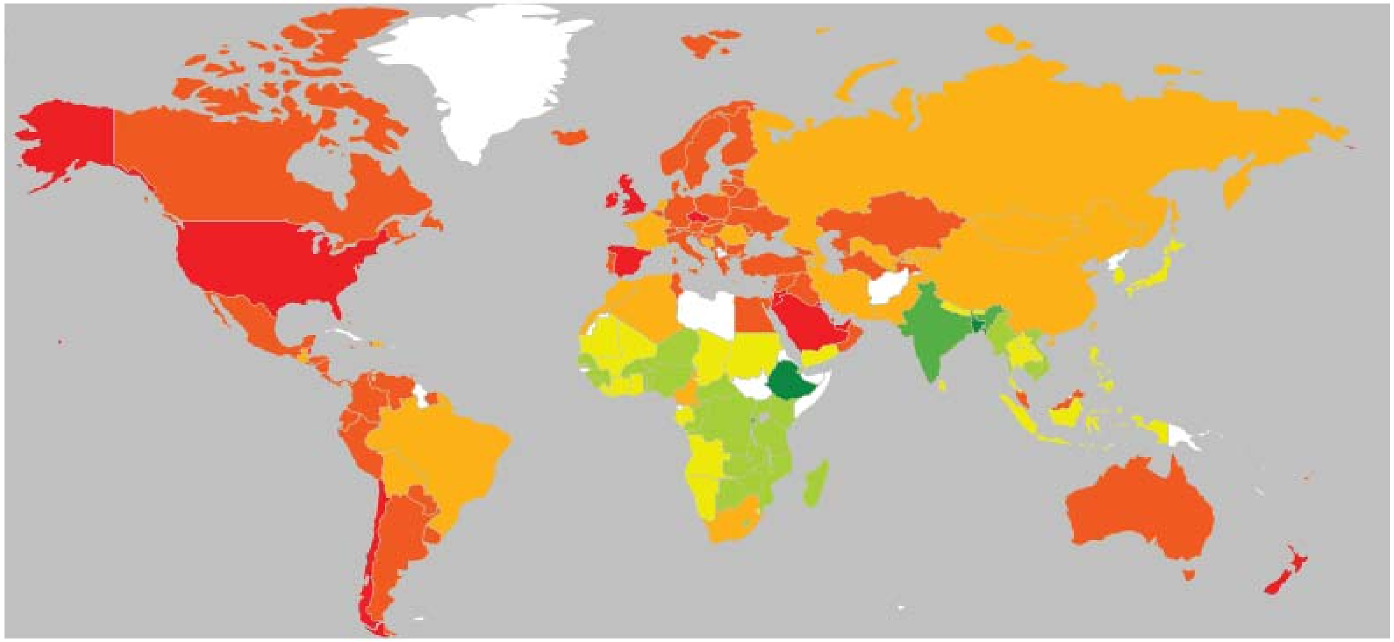


Figure 2: Males' Clubs in BMI in the World.

Notes: Countries or territories colored in red belong to club 1; dark orange refers to club 2; light orange refers to club 3; yellow refers to club 4; green-yellow relates to club 5; light green refers to club 6; dark green refers to the no-convergence group 7. White areas are not part of the sample.

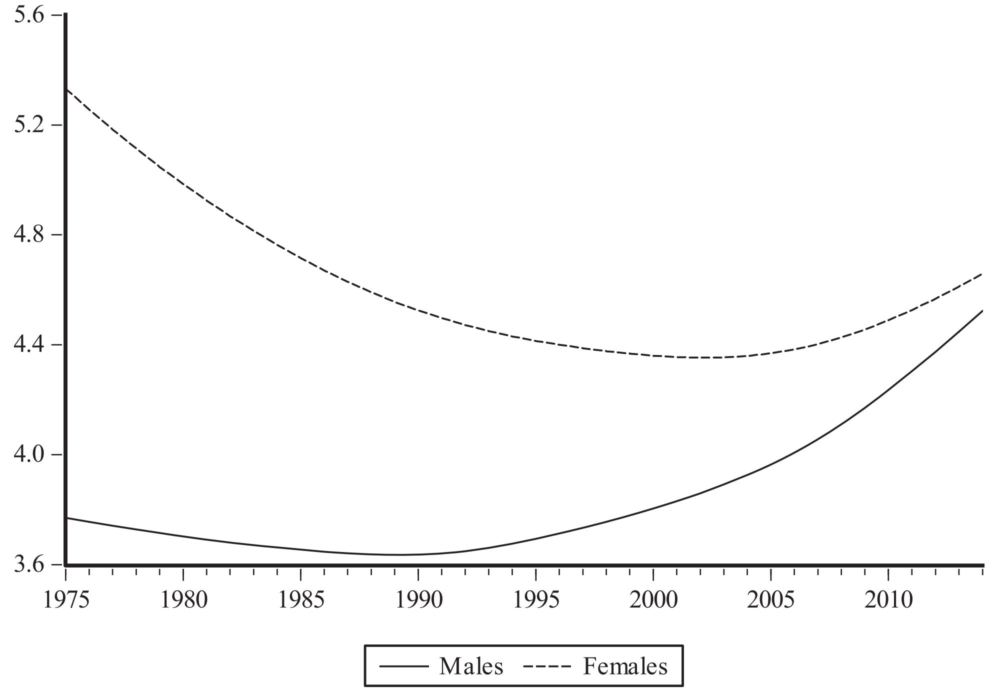
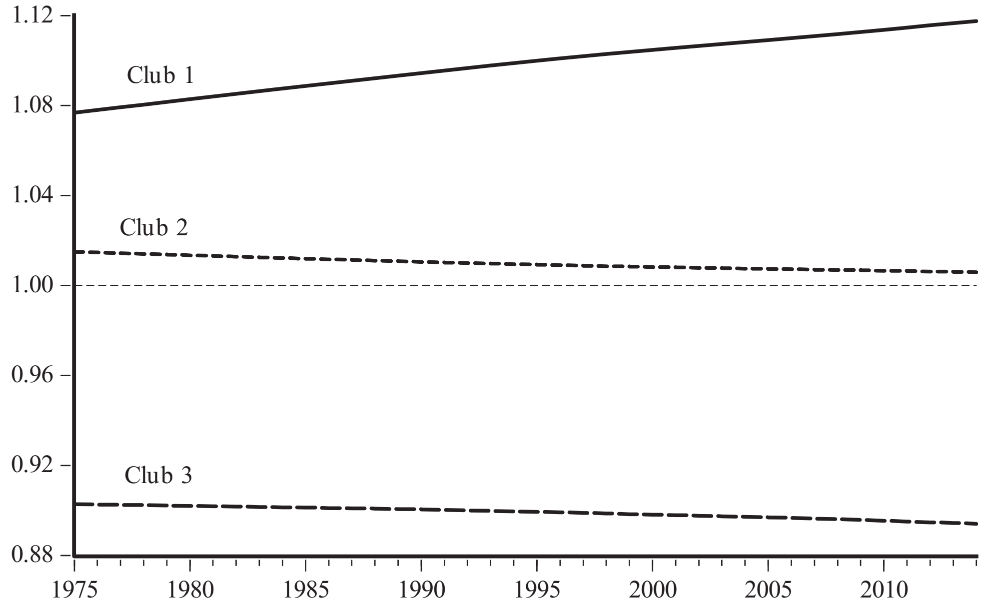
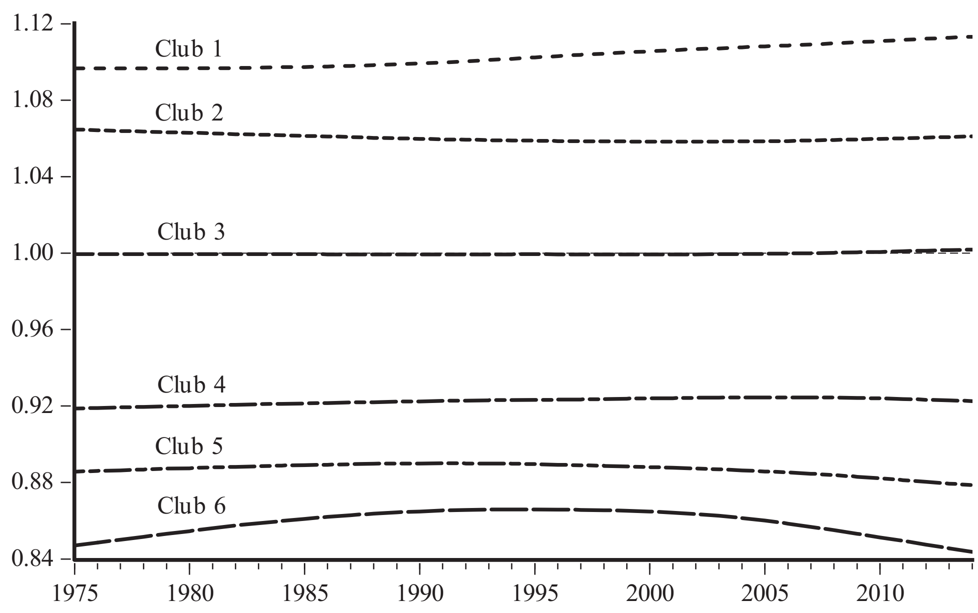


Figure 3: Cross-sectional Variance of BMIs for Females and Males (K_{Nt}; Full Sample: 1975-2014).



Notes: The dashed line at the value of one represents the world average rate. Club 1 = ATG, BHS, BRD, BLZ, BMU, BOL,DMA,DOM,EGT,SVL, FJI,GRD,GTM,HND,IRQ,JAM, JOR, KWT, MEX, NIC, QAT, KNA, LCA, VCT, SAU, ZAF, SUR, SWZ, SYR, ARE, USA. Club 2 =ALB, DZA, AGO, ARG, ARM,AUS, AZE, BHR, BLR, BEN, BTN, BIH, BWA, BRA, BGR, CPV, CMR, CAN, TCD, CHL, COL, COM,COG ,CRI, CIV, CYP, CZE, ECU, GNQ, EST, FIN, GAB, GMB, GEO, DEU, GHA, GRC, GNB, HTI, HUN, ISL, IDN, IRN, IRL, ISR, ITA, KAZ, KEN, KGZ, LVA, LBN, LSO, LBR, LTU, LUX, MKD, MYS, MDV, MLI, MLT, MRT, MUS, MDA, MNG, MNE, MAR, NAM,NLD, NZL, NOR, OMN, PAK, PAN, PRY, PER, POL, PRT, RUS, STP, SEN, SRB, SYC, SVK, SVN, ESP, SDN, SWE, TJK, TZA, THA, TGO, TTO, TUN, TUR, TKM, UKR, GBR, URY, UZB, VEN, ZWE, ETH. Club 3 = AUT, BGD, BEL, BRN, BFA, BDI, KHM, CAF, CHN, HKG, HRV, COD,DNK, DJI, FRA, GIN, IND, JPN, LAO, MDG, MWI, MOZ, MMR, NPL, NER, NGA, PHL, ROU, RWA, SLE, SGP,PRK,LKA, CHE, TWN, UGA, VNM, YEM, ZMB.



Notes: Club 1 = BLZ, CZE, IRL, JOR, KWT, LBN, MLT, NZL, QAT, KNA, LCA, SAU, ESP, ARE, GBR, USA. Club 2 = ALB, ATG, ARG, AUS, AUT, BHS, BRB, BLR, BEL, BMU, BGR, CAN, COL, CRI, HRV, DNK, ECU, EGY, SLV, EST, FJI, FIN, GEO, DEU, GRC, HTI, HND, HUN, ISL, IRQ, ISR, ITA, JAM, KAZ, LVA, LTU, LUX, MKD, MYS, MEX, MDA, MNE, NIC, NOR, OMN, PAN, PRY, PER, POL, PRT, VCT, SRB, SVK, SVN, SUR, SWE, CHE, SYR, TJK, TTO, TUN, TUR, TKM, UKR, URY, VEN. Club 3 = DZA, ARM, AZE, BHR, BOL, BIH, BRA, CMR, CHN, HKG, DMA, DOM, FRA, GRD, GTM, IRN, KGZ, MDV, MUS, MNG, MAR, NLD, PAK, ROU, RUS, SYC, ZAF, TWN, UZB. Club 4 = AGO, BTN, BRN, CPV, TCD, COM, CIV, GAB, GMB, GHA, GNB, IDN, JPN, LAO, LBR, MLI, MRT, NAM, NPL, PHL, STP, SGP,PRK, LKA, SDN, SWZ, THA, YEM. Club 5 = BEN, BWA, BFA, BDI, KHM, CAF,COG,COD, DJI, GNQ, GIN, KEN, LSO, MDG, MWI, MOZ, MMR, NER, NGA, SEN, SLE, TZA, TGO, UGA, VNM, ZMB, ZWE. Club 6= IND, RWA, BGD, ETH.

Figure 4: Relative Transition Curves of Convergence Clubs for Females and Males (h_{it}).

Table 1: Relative Convergence and σ-Convergence in BMIs.

Club/group (No. of members)	**Distribution of Countries per world region**	**Relative convergence b-coefficient [t-statistic]**	**σ-convergence ϕ-coefficient [t-statistic]**
(1)	(2)	(3)	(4)
Females			
Full sample (172)		-0.481** [-127.26]	-0.018*** [-3.45]
Club 1 (31)	LAC (18), Asia (7), Africa (3), Northern America (2), Oceania (1)	0.062 [1.94]	-0.030*** [-19.32]
Club 2 (101)	Europe (38), Africa (31), Asia (16), LAC(13), Oceania (2), Northern America (1)	0.091 [3.31]	-0.060*** [-12.98]
Club 3 (40)	Asia (17), Africa (16), Europe (7)	0.366 [8.13]	-0.079*** [-15.65]
Males			
Full sample (172)		-0.677** [-67.58]	0.017 [3.98]
Club 1 (18)	Asia (6), Europe (6), LAC (4), Northern America (1), Oceania (1)	-0.076 [-0.84]	-0.006*** [-5.98]
Club 2 (66)	Europe (32), LAC (21), Asia (7), Northern America (2), Oceania (2), Africa (2)	0.171 [5.70]	-0.012*** [-39.23]
Club 3 (29)	Asia (10), Europe (7), LAC (6), Africa (6)	0.050 [1.36]	-0.016*** [-25.6]
Club 4 (28)	Africa (16), Asia (12)	0.023 [0.47]	-0.006*** [-7.82]
Club 5 (27)	Africa (23), Asia (4)	-0.038 [-0.83]	-0.003*** [-7.38]
Club 6 (2)	Africa (1), Asia (1)	-2.405 [-1.28]	-0.0004 [-1.96]
No-convergence group (2)	Africa (1), Asia (1)	-1.507** [-41.26]	0.003 [12.15]

Notes: Column (1) reports the number of nations in each club in parentheses. The sample of female individuals has 3 convergence clubs and the sample of male individuals has 6 convergence clubs and one divergent group. The full sample comprises 172 nations distributed as follows: Africa (50), Asia (40), Europe (45), Northern America (3), Latin America and the Caribbean (LAC, 31), and Oceania (3). The number of periods is 40 (1975-2014). Column (2) shows the number of nations per world region in each club or group. Column (3) reports the slope of the log t regression (equation (5) in the main text). ** in column (3) denotes that the null hypothesis of relative convergence is rejected at 5% using the test by Phillips and Sul (2007) a with a critical value of -1.65. The first 12 periods (30%) are discarded before regression. Column (4) reports the slope of the trend in the regression (equation (6)) to test for sigma convergence as in Kong, Phillips and Sul (2017). ***, **, and * in column (4) denote that the null hypothesis of no sigma convergence is rejected at 1%, 5%, and 10%.

Table 2: Characterization of the Convergence Clubs

Club/group	2014 BMI	Globalization Index	Human Capital	Urbanization rate (%)	GDP per person
Females					
Full sample	25.74	48.02	2.19	52.05	6424
Club 1	28.77	46.87	2.13	57.05	7451
Club 2	25.89	50.36	2.31	54.82	7627
Club 3	23.01	43.10	1.98	40.94	2020
Males					
Full sample	25.11	48.02	2.19	52.05	6424
Club 1	27.95	61.77	2.64	72.25	19978
Club 2	26.64	56.25	2.58	62.18	11094
Club 3	25.15	46.48	2.18	54.49	7291
Club 4	23.16	39.12	1.86	40.04	2614
Club 5	22.05	33.40	1.52	28.85	1304
Club 6	21.18	31.44	1.48	19.39	1196
No-convergence group	20.64	28.18	1.35	17.73	1153

Notes: The columns report means of each variable except for GDP per person (median). The full sample comprises 172 nations distributed as follows: Africa (50), Asia (40), Europe (45), Northern America (3), Latin America and the Caribbean (31), and Oceania (3). The number of periods is 40 (1975-2014). The BMI data come from NCD-RisC (2016). The KOF globalization index comes from Gygli *et al.* (2018). GDP per capita is real GDP at chained PPP (in 2011 US$ dollars). Human capital index is based on years of schooling and returns to education. Real GDP and human capital series are from Penn World Tables 9.0 (Feenstra *et al.*, 2015). Urbanization rate (%) series are from World Bank's World Development Indicators.

Table 3: BMI and Covariates: Panel Data Estimations across Clubs

Panel A. Females	**Club 1**	**Club 2**	**Club 3**	**Diff (1-2)**
Globalization index	0.019***	0.011***	0.003	0.026
	(0.0039)	(0.0023)	(0.0019)	
Human capital	-0.012*	0.029***	-0.022***	0.000
	(0.0065)	(0.0055)	(0.0046)	
Urbanization rate	-0.0007***	-0.0002**	0.0002**	0.000
	(0.0001)	(0.0001)	(0.0001)	
GDP per person	0.008***	-0.002**	-0.005***	0.025
	(0.0010)	(0.0001)	(0.0007)	
No. observations	5167			
No. of countries	140			

Panel B. Males	**Club 1**	**Club 2**	**Club 3**	**Club 4**	**Club 5**	**Diff (1-2)**	**Diff (2-3)**	**Diff (3-4)**
Globalization index	0.059***	0.062***	0.049***	0.019***	-0.009**	0.197	0.000	0.000
	(0.0101)	(0.0048)	(0.0061)	(0.0063)	(0.0036)			
Human capital	-0.018	0.005	-0.039***	-0.008	-0.032***	0.001	0.013	0.071
	(0.0148)	(0.0115)	(0.0131)	(0.0128)	(0.0088)			
Urbanization rate	0.0000	0.0004**	0.0019***	0.0015***	-0.0008***	0.000	0.039	0.000
	(0.0003)	(0.0002)	(0.0002)	(0.0002)	(0.0002)			
GDP per person	-0.003	-0.003	-0.007***	-0.009***	0.005***	0.067	0.583	0.000
	(0.0023)	(0.0019)	(0.0027)	(0.0023)	(0.0013)			
No. observations	5011							
No. of countries	140							

Notes: $*p < 0.1$, $**p < 0.05$, $***p < 0.01$, for the null hypothesis that the parameter equals zero. The dependent variable is the level of BMI. Bootstrapped standard errors are reported in parentheses. All the regression models include the lagged of BMI, a log trend, and fixed country effects. We use a bias-corrected fixed effects estimator based on an analytical approach (Kiviet, 1995; Bruno, 2005). P-values and standard errors are calculated using 2000 bootstrap replications. We use a third-level accuracy to approximate the bias and system GMM as the initial consistent estimator. We do not include the sixth male club in the estimation because of the small number of observations (only two economies). Diff$(i-j)$ is the p-value for the null hypothesis that the difference between coefficients of club i and club j is equal to zero, for $i, j = 1, ..., N_c$. The last column (club 3 for females and club 5 for males) reports estimates of the reference club. The BMI data come from NCD-RisC (2016). GDP per person is logged real GDP at chained PPP (in 2011 US$ dollars). Human capital is the logged index based on years of schooling and returns to education. GDP per person and human capital series are from Penn World Tables 9.0 (Feenstra *et al.*, 2015). Urbanization rate series are from World Bank's World Development Indicators. Globalization is the logged overall KOF globalization index from Gygli *et al.* (2018).

Table 4: Long-Run Elasticities of the BMI Covariates

	Females			Males				
Covariate	**Club 1**	**Club 2**	**Club 3**	**Club 1**	**Club 2**	**Club 3**	**Club 4**	**Club 5**
Globalization	0.193	0.131	0.029	0.341	0.378	0.303	0.078	-0.076
	[0.13 0.26]	[0.10 0.16]	[-0.01 0.07]	[0.26 0.99]	[0.35 1.06]	[0.26 0.83]	[-0.02 0.25]	[-0.33 -0.04]
Human capital	-0.306	0.071	-0.238	-0.343	-0.192	-0.539	-0.333	-0.274
	[-0.41 -0.2]	[0.02 0.13]	[-0.36 -0.14]	[-1.18 -0.25]	[-0.73 -0.12]	[-1.65 -0.47]	[-1.05 -0.23]	[-0.93 -0.18]
Urbanization	-0.278	0.001	0.076	-0.360	-0.146	0.468	0.240	-0.185
	[-0.39 -0.19]	[-0.05 0.05]	[0.01 0.13]	[-1.24 -0.13]	[-0.51 -0.08]	[0.37 1.25]	[0.18 0.65]	[-0.53 -0.12]
GDP per person	0.026	-0.072	-0.056	0.016	0.013	-0.019	-0.032	0.042
	[0.01 0.04]	[-0.09 -0.06]	[-0.07 -0.04]	[-0.02 0.06]	[-0.01 0.05]	[-0.11 0.02]	[-0.13 -0.01]	[0.02 0.13]

Notes: The long-run elasticity of BMI with respect to a covariate in each club measures the long-run percent change in BMI when there is a 1% change in the covariate and is constructed as the ratio of the long-run semi-elasticity divided by the BMI mean between 1975 and 2014. The long-run semi-elasticity of BMI with respect to a covariate in each (non-reference) club is the ratio of the covariate's slope coefficient plus the slope coefficient of the reference club (females' club 3 and males' club 5, as reported in Table 3) divided by (1 minus the coefficient of the lagged BMI) times the clubs' average BMI. The exception is long-run elasticity of urbanization, which is multiplied by clubs' average BMI divided by average urbanization rate since this indicator is included in levels (not log-levels) in the model. The number of observations in each sample is 5167 and 5011 (see note in Table 3). The 1975-2014 BMI averages are 26.85, 24.91, and 22.91 for female clubs, and 26.19, 25.01, 23.99, 22.36, and 21.22 for male clubs. 95% confidence intervals are reported in brackets.