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Human Height, Milk, and GDP per capita: An Instrumental Variable Analysis from Global Panel Data

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Abstract

This study examines the relationship between milk consumption and human height using panel data for 108 countries from 1990 to 2016. GDP per capita is used as an instrumental variable for milk consumption, while accounting for dietary composition and socioeconomic conditions. The results show a positive relationship between milk consumption and average height, with larger estimates when potential endogeneity is addressed. The findings suggest that milk consumption is an important dietary factor associated with population-level differences in human height.

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1. Introduction

Human height has long been viewed as a reflection of long-run health, nutrition, and quality of life (Baten & Komlos, 1998; Huffman & Orazem, 2007). Cross-country evidence consistently shows that populations in richer economies tend to be taller on average, reflecting improvements in nutrition, disease environments, and access to health-enhancing resources as incomes grow (Bogin, Scheffler, & Hermanussen, 2017; Grasgruber et al., 2016; Grasgruber & Hrazdira, 2020). Despite this well-established relationship, the specific dietary channels through which rising incomes translate into improvements in human stature remain less clearly understood. One potentially important pathway is the role of milk consumption.

Milk is nutrient-dense and rich in high-quality proteins, fats, and bioavailable micronutrients that are associated with human growth (Stulp & Barrett, 2016). Micro-level studies provide evidence linking milk consumption to greater height among children and adolescents in a variety of contexts, including the United States (Wiley, 2009), Sweden (Almon et al., 2011), and China (Guo et al., 2020). At the macro level, milk availability correlates with national height patterns and broader indicators of human development (Grasgruber et al., 2016). Historical evidence also suggests that increased dairy consumption has contributed to reductions in child stunting in some regions (Haile & Headey, 2023). However, much of the existing evidence remains correlational, leaving open questions about the relationship between income-driven dietary change and physical development across countries.

Understanding this relationship is important for several reasons. First, milk consumption tends to rise with income as higher earnings relax household budget constraints and increase access to nutrient-rich animal-source foods (Baltzer & Baten, 2008). Second, identifying whether milk consumption is associated with improvements in human stature can help clarify the mechanisms linking economic development to biological well-being. Third, examining this relationship across a large global sample contributes to the broader debate regarding the roles of nutrition, environment, and genetics in shaping cross-country differences in human height (Stulp & Barrett, 2016).

This paper contributes to the literature by examining the relationship between milk consumption and human height using a global panel dataset covering 108 countries from 1990 to 2016. We focus on the average height of 18-year-old males and explore the association between national dairy consumption and physical development. To address the strong correlation between dietary patterns and economic development, we use GDP per capita as an instrument for milk consumption, and include regional fixed effects to account for unobserved regional heterogeneity across groups of countries. This approach allows us to examine the relationship between milk consumption and human height using income-related variation in dairy consumption. It provides additional evidence on the association between milk intake and long-run human physical development.

The results show a consistent positive association between milk consumption and height across specifications. Instrumental-variable estimates indicate that increases in milk consumption associated with higher income levels are linked to greater average adult height. More broadly, the findings highlight how structural changes in food consumption accompanying economic

development may influence population-level biological outcomes. The remainder of the paper is organized as follows. Section 2 describes the data. Section 3 outlines the empirical methodology. Section 4 presents the results. Section 5 concludes.

2. Data

The analysis combines annual data for 108 countries over 27 years from several international statistical sources. The dependent variable is average male height at age 18, derived from the global pooled analysis by Rodriguez-Martinez et al. (2020) in *The Lancet*. Their dataset synthesizes more than 2,000 population-based studies and 65 million participants to generate harmonized height estimates across countries. The height of 18-year-old boys is used as a proxy for adult stature and long-run nutritional status.

The key explanatory variable is per capita milk consumption (excluding butter), obtained from World Bank food balance data and measured in kilograms per year. To capture broader dietary patterns, the dataset also includes national per capita consumption of poultry, beef, sheep and goat meat, and pig meat, based on standardized food availability classifications. Additionally, we include the percentage of milk consumption relative to overall dietary consumption. This measure is calculated as milk consumption as a share of the daily per capita supply of calories and is obtained from the Food and Agriculture Organization (FAO). This variable captures the relative importance of milk in the overall diet, rather than only its absolute per capita consumption.

To instrument for dietary change, GDP per capita (PPP, constant 2021 international dollars) is taken from the World Bank's World Development Indicators. Additional controls include the urban population share, mean years of schooling among adults aged 25 and older, and the prevalence of overweight adults ($BMI \geq 25$), sourced from the World Bank and the WHO. These variables account for demographic, educational, and epidemiological factors correlated with both economic development and nutritional outcomes.

Appendix Table III reports summary statistics. Average height is 170.61 cm, and milk consumption varies widely across countries (mean 103.89 kg, SD 95.58). GDP per capita ranges from low- to high-income contexts, with a mean of \$17,705.64. Other dietary and socioeconomic variables also display substantial cross-country heterogeneity, providing the variation necessary for the empirical analysis.

3. Methodology

We estimate a series of panel-data regressions to analyze how milk consumption influences average male height across countries. Cross-country regressions are useful for identifying broad empirical relationships across countries, though their estimates may reflect underlying structural differences rather than causal effects (Pritchett, 2023). The baseline specification is a random-effects GLS model of the form:

$$Height_{it} = \beta_0 + \beta_1 Milk_{it} + X_{it}\beta + \epsilon_{it} \quad (1)$$

where i denotes the country and t the year. The dependent variable is the average height of 18-year-old males, taken from Rodriguez-Martinez et al. (2020). The main explanatory variable of interest, *Milk*, measures per-capita milk consumption excluding butter. The vector X_{it} includes the share of milk consumption within the broader diet, measured as daily calories of milk consumption per capita relative to the daily per capita supply of total calories, as well as, urbanization, schooling, overweight prevalence, and per-capita consumption of poultry, beef, sheep and goat meat, and pig meat.

Because the error structure may exhibit heteroskedasticity and contemporaneous correlation across countries, we also estimate feasible GLS (FGLS) versions of Equation (1). However, milk consumption may be endogenous due to its strong correlation with income and broader patterns of economic development. To address this concern, we employ instrumental variables (IV) estimation using GDP per capita (PPP) as an instrument. The IV framework takes the standard two-stage form:

$$Milk_{it} = \alpha_0 + \alpha_1 GDPPC_{it} + Z_{it}\alpha + u_{it} \quad (2)$$

$$Height_{it} = \gamma_0 + \gamma_1 \widehat{Milk}_{it} + X_{it}\gamma + e_{it} \quad (3)$$

GDP per capita provides income-driven variation in dairy availability and dietary structure and thus serves as a plausible instrument for milk consumption. Comparing GLS, FGLS, and IV estimates allows us to distinguish correlations arising from observable covariates from the effect of income-related changes in milk consumption on population height.

We extend the IV specification by incorporating regional fixed effects based on the World Bank's geographic classification (e.g., Europe and Central Asia, East Asia and Pacific, Sub-Saharan Africa, Middle East and North Africa, etc.). These regional fixed effects capture persistent differences across broad geographic areas that reflect genetic, cultural, and dietary characteristics, including variation in lactose tolerance and traditional dairy consumption patterns. In particular, this specification helps account for the higher prevalence of lactose tolerance historically observed in European populations relative to many other regions (Itan et al., 2010). By controlling for these regional characteristics, the revised IV estimates reduce potential bias arising from cross-regional heterogeneity in dairy consumption traditions and genetic traits associated with lactose digestion.

4. Results

Figures 1 and 2 provide descriptive evidence of the relationships examined in the analysis. Figure 1 shows a positive association between average height and milk consumption per capita across the 108 countries during 1990–2016. Figure 2 illustrates a positive relationship between GDP per capita and milk consumption per capita, consistent with the instrumental-variable strategy used in the paper.

Table I reports the baseline GLS and FGLS regression results examining the relationship between milk consumption and average human height across countries. Columns (1) and (2) present random-effects GLS estimates, while Columns (3) and (4) report cross-sectional time-series FGLS estimates. Across all specifications, milk consumption is positively associated with human height.

The GLS estimates indicate that a one-kilogram increase in milk consumption per capita is associated with an increase in height of approximately 0.0005–0.0007 cm, while the FGLS estimates range from 0.0006 to 0.0007 cm. These coefficients are statistically significant across most specifications and indicate a consistent positive relationship between milk consumption and average population height.

Table II presents the instrumental-variable (IV) results using GDP per capita as an instrument for milk consumption. Columns (5), (6) and (7) report the baseline IV estimates, while Columns (8), (9) and (10) include regional fixed effects based on the World Bank's geographic classification (East Asia, Sub-sahara Africa, Europe and Central Asia, etc) to account for unobserved regional heterogeneity across groups of countries. The IV estimates show a larger positive relationship between milk consumption and height compared with the GLS and FGLS estimates. The coefficient on milk consumption ranges from 0.0468 to 0.1142, and all estimates are statistically significant at the 1 percent level. Due to the change of sign in the beef consumption variable across specifications, it provides a caution that there are other omitted variables correlated with income, height, and beef consumption. These larger coefficients suggest that omitted variables correlated with income, nutrition, and health conditions may bias the non-IV estimates downward.

The control variables behave largely as expected. Years of schooling are positively associated with height in several specifications, reflecting the role of socioeconomic development and human capital in improving health outcomes. The coefficients on meat consumption variables vary across specifications, indicating that the relationship between different types of animal-source foods and population height may differ across countries. The inclusion of regional fixed effects does not alter the main conclusion that higher milk consumption is positively associated with average human height.

The first-stage regression results reported in Table II confirm that GDP per capita is strongly correlated with milk consumption. The estimated coefficient on GDP per capita is positive and statistically significant across all specifications. The corresponding first-stage F-statistics range from 59.10 to 934.31, which exceed conventional thresholds of 10 suggested for weak instruments by Staiger and Stock (1997), indicating that GDP per capita provides a strong instrument for milk consumption in this analysis.

5. Conclusion

This paper examines the relationship between milk consumption and human height using a global panel dataset covering 108 countries from 1990 to 2016. Using GDP per capita as an instrument for milk consumption, we estimate a positive association between dairy consumption and average adult height across countries. The results remain robust across GLS, FGLS, and instrumental-variable specifications, including models incorporating regional fixed effects.

These findings suggest that increases in milk consumption associated with rising incomes are linked to improvements in population-level physical development. More broadly, the results highlight the importance of dietary composition as a potential channel through which economic

development influences long-run biological well-being. While the analysis focuses on cross-country relationships, future research could further explore the roles of food prices, dietary composition, and genetic heterogeneity in shaping the relationship between nutrition and human growth.

Table I: Estimation results on the relationship between height and milk; 27 years (1990-2016), 108 countries.

Variable	Dependent variable: Height			
	(1)	(2)	(3)	(4)
	Random-effects GLS regression	Random-effects GLS regression	Cross-sectional time-series FGLS regression	Cross-sectional time-series FGLS regression
Milk cons. per cap.	0.0007*** (0.0003)	0.0005* (0.0003)	0.0007*** (0.0002)	0.0006*** (0.0002)
Urbanization (%)	0.0335*** (0.0038)	0.0127*** (0.0047)	0.0846*** (0.0038)	0.0530*** (0.0044)
Years of schooling	0.3303*** (0.0158)	0.1213*** (0.0244)	0.3774*** (0.0201)	0.2350*** (0.0221)
Overweight		0.0461*** (0.0066)		0.0708*** (0.0058)
Poultry cons. per cap.		0.0184*** (0.0028)		0.0009 (0.0017)
Beef cons. per cap.		-0.0104*** (0.0032)		0.0027* (0.0016)
Sheep goat cons. per cap.		0.0329*** (0.0081)		0.0074* (0.0038)
Pig cons. per cap.		0.0181*** (0.0033)		0.0126*** (0.0018)
Constant	166.2038*** (0.3124)	166.6491*** (0.3096)	163.2600*** (0.1883)	162.9787*** (0.1842)
Observations	2913	2913	2913	2913
No. of countries	108	108	108	108
Wald χ^2	72.88***	121.17***	2047.90***	2411.46***
R-squared	0.5546	0.5918	-	-

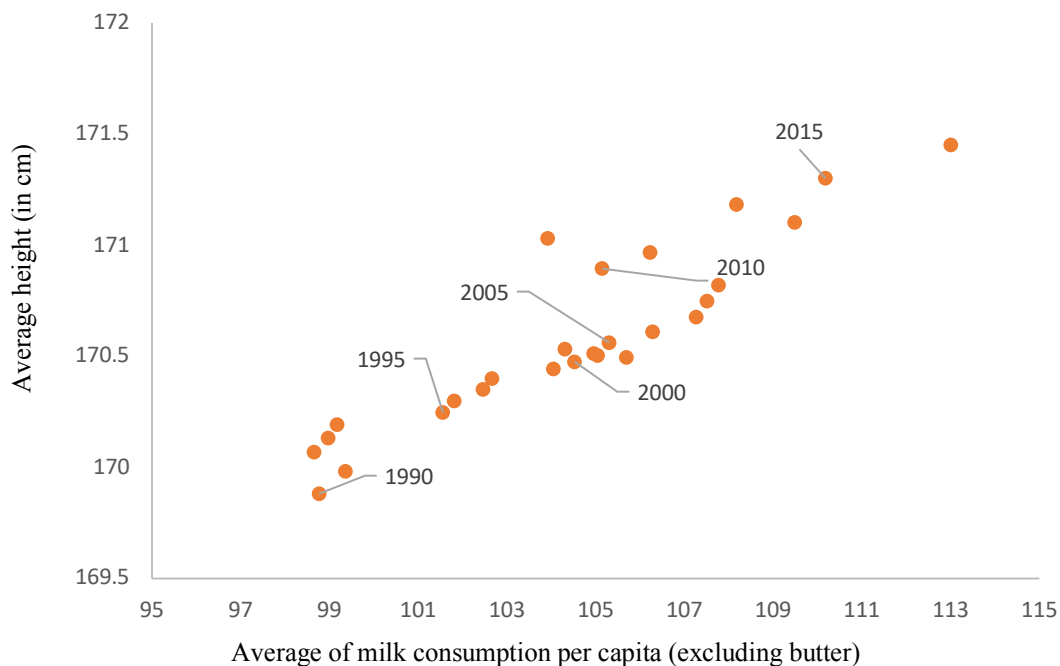
Note: $p^* < 0.1$, $p^{**} < 0.05$, $p^{***} < 0.01$, standard errors in parentheses. Data sources: Rodriguez-Martinez et al. (2020) for height; World Bank for milk consumption and other variables.

Table II: IV (GDP per capita) estimation results on the relationship among height, milk consumption and; 27 years (1990-2016), 108 countries.

Variable	(5)	(6)	(7)	(8)	(9)	(10)
Panel A: Second-stage IV results (Dependent variable: Height)						
Milk cons. per cap.	0.0468*** (0.0018)	0.0493*** (0.0025)	0.0916*** (0.0075)	0.0623*** (0.0051)	0.0773*** (0.0086)	0.1142*** (0.0162)
% Milk over diet			-106.8533*** (11.6764)			-122.1041*** (20.2678)
Urbanization (%)	0.0061 (0.0045)	0.0080 (0.0050)	-0.0064 (0.0069)	-0.0214*** (0.0069)	-0.0149** (0.0073)	-0.0238** (0.0096)
Years of schooling	0.1726*** (0.0364)	0.0064 (0.0389)	-0.0505 (0.0527)	0.2863*** (0.0441)	0.0527 (0.0569)	-0.0023 (0.0729)
Overweight		0.0162** (0.0070)	0.0404*** (0.0089)		0.0568*** (0.0113)	0.0723*** (0.0148)
Poultry cons. per cap.		0.0351*** (0.0065)	0.0205** (0.0083)		-0.0017 (0.0116)	-0.0021 (0.0139)
Beef cons. per cap.		-0.0641*** (0.0092)	-0.0499*** (0.0114)		-0.1462*** (0.0258)	-0.0937*** (0.0236)
Sheep goat cons. per cap.		0.0587*** (0.0116)	0.1632*** (0.0179)		0.0562*** (0.0150)	0.1716*** (0.0239)
Pig cons. per cap.		0.0137* (0.0076)	0.0000 (0.0107)		0.0929*** (0.0121)	0.0423*** (0.0121)
Constant	163.9088*** (0.2045)	164.1978*** (0.2187)	165.9903*** (0.3935)	160.1364*** (0.3711)	160.0528*** (0.4465)	162.8807*** (0.6263)
Observations	2913	2913	2913	2913	2913	2913
No. of countries	108	108	108	108	108	108
Wald χ^2	3905.52***	4148.32***	2522.67***	775.82***	752.73***	546.71***
R-squared	0.5104	0.5015	0.1612	0.3773	0.5015	0.1259
Anderson LM test	708.149***	476.804***	181.134***	175.392***	476.804***	58.214***
Endogeneity test	353.068***	345.152***	335.876***	225.669***	345.152***	214.642***
Regional FE	No	No	No	Yes	Yes	Yes
Panel B: First-stage regression (Endogenous variable: Milk cons. per cap.)						
GDP per capita	0.0033*** (0.0001)	0.0029*** (0.0001)	0.0013*** (0.0001)	0.0017*** (0.0001)	0.0012*** (0.0001)	0.0008*** (0.0001)
% Milk over diet			1387.5294*** (27.4798)			1204.3500*** (30.3658)
Urbanization (%)	0.4999*** (0.0753)	-0.1509* (0.0863)	0.1191* (0.0632)	0.6033*** (0.0755)	0.1940** (0.0789)	0.2103*** (0.0636)
Years of schooling	1.7831*** (0.6241)	-1.1345* (0.6838)	0.2286 (0.4998)	1.0960* (0.5975)	1.0485* (0.6248)	1.2097** (0.5031)
Overweight		1.1890*** (0.1170)	0.2213** (0.0875)		-0.2539** (0.1251)	-0.3143*** (0.1007)
Poultry cons. per cap.		-0.4220*** (0.1091)	-0.0007 (0.0800)		0.6881*** (0.1048)	0.4420*** (0.0846)
Beef cons. per cap.		1.3738*** (0.1385)	0.4352*** (0.1028)		2.4236*** (0.1297)	1.0249*** (0.1103)
Sheep goat cons. per cap.		0.7243*** (0.1972)	-1.0308*** (0.1481)		0.3596** (0.1751)	-0.9091*** (0.1446)
Pig cons. per cap.		0.7277*** (0.1117)	0.5056*** (0.0816)		-0.9761*** (0.1194)	-0.1217 (0.0985)
Constant	4.4729 (3.7968)	0.2800 (3.7413)	-23.1497*** (2.7695)	13.0799** (5.5298)	19.9302*** (5.2253)	-15.2067*** (-3.5366)
F-Stats	934.31***	568.36***	192.48***	186.05***	95.76***	59.10***

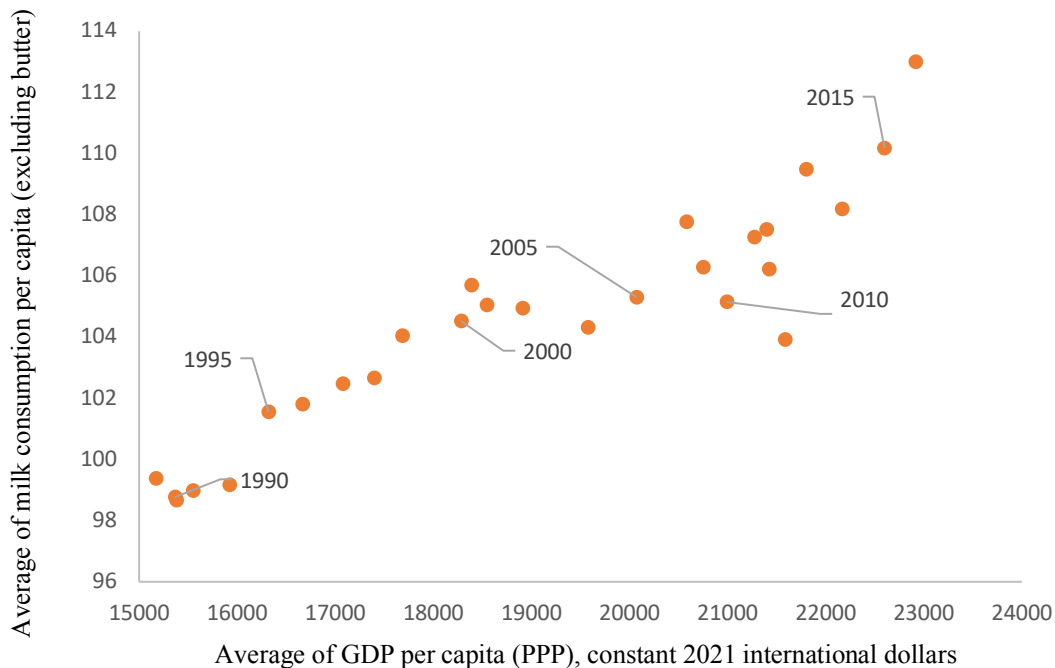
Note: $p^* < 0.1$, $p^{**} < 0.05$, $p^{***} < 0.01$, standard errors in parentheses. Regional fixed effects are based on the World Bank geographic classification. Data sources: Rodriguez-Martinez et al. (2020) and World Bank.

Figure 1: Average height of all 108 countries and the average of milk consumption per capita (excluding butter) of all 108 countries for years 1990 – 2016.



Note: Figure illustrates the reduced-form relationship between GDP per capita and height. Data source: Rodriguez-Martinez et al. (2020) for height, and World Bank for milk.

Figure 2: Average of milk consumption per capita (excluding butter) of all 108 countries and the average GDP per capita of all 108 countries for years 1990 – 2016.



Note: Figure presents the first-stage relationship between GDP per capita and milk consumption. Data source: World Bank.

References

- Almon, R., Nilsson, T., Sjöström, M., & Engfeldt, P. (2011). Lactase persistence and milk consumption are associated with body height in Swedish preadolescents and adolescents. *Food & Nutrition Research*, 55(1), 7253.
- Baltzer, M., & Baten, J. (2008). Height, trade, and inequality in the Latin American periphery, 1950–2000. *Economics & Human Biology*, 6(2), 191–203.
- Baten, J., & Komlos, J. (1998). Height and the standard of living. *The Journal of Economic History*, 58(3), 866–870.
- Bogin, B., Scheffler, C., & Hermanussen, M. (2017). Global effects of income and income inequality on adult height and sexual dimorphism in height. *American Journal of Human Biology*, 29(2), e22980.
- Grasgruber, P., & Hrazdíra, E. (2020). Nutritional and socio-economic predictors of adult height in 152 world populations. *Economics & Human Biology*, 37, 100848.
- Grasgruber, P., Sebera, M., Hrazdíra, E., Cacek, J., & Kalina, T. (2016). Major correlates of male height: A study of 105 countries. *Economics & Human Biology*, 21, 172–195.
- Guo, Q., Wang, B., Cao, S., Jia, C., Yu, X., Zhao, L., ... Duan, X. (2020). Association between milk intake and childhood growth: Results from a nationwide cross-sectional survey. *International Journal of Obesity*, 44(11), 2194–2202.
- Haile, B., & Headey, D. (2023). Growth in milk consumption and reductions in child stunting: Historical evidence from cross-country panel data. *Food Policy*, 118, 102485.
- Huffman, W. E., & Orazem, P. F. (2007). Agriculture and human capital in economic growth: Farmers, schooling and nutrition. In R. Evenson & P. Pingali (Eds.), *Handbook of Agricultural Economics* (Vol. 3, pp. 2281–2341). Elsevier.
- Pritchett, L. (2024). “Rely (only) on the rigorous evidence” is bad advice. *Review of Development Economics*, 28(4), 2034–2058.
- Rodriguez-Martinez, A., Zhou, B., Sophiea, M. K., Bentham, J., Paciorek, C. J., Iurilli, M. L. C., Carrillo-Larco, R. M., *et al.* (2020). Height and body-mass index trajectories of school-aged children and adolescents from 1985 to 2019 in 200 countries and territories: A pooled analysis of 2181 population-based studies with 65 million participants. *The Lancet*, 396(10261), 1511–1524.
- Staiger, D., & Stock, J. H. (1997). Instrumental variables regression with weak instruments. *Econometrica*, 65(3), 557–586.

Stulp, G., & Barrett, L. (2016). Evolutionary perspectives on human height variation. *Biological Reviews*, 91(1), 206–234.

Wiley, A. S. (2009). Consumption of milk, but not other dairy products, is associated with height among U.S. preschool children in NHANES 1999–2002. *Annals of Human Biology*, 36(2), 125–138.

Appendices

Appendix Table III. Variable Statistics, 108 countries, Year 1990 – 2016

Variable Name	Variable Description	Mean	Std. Dev.
<i><u>Dependent variable</u></i>			
Height	Average human height	170.61	4.89
<i><u>Instrumental variable</u></i>			
GDP per capita	GDP per capita, PPP (constant 2021 international \$)	17705.64	17930.23
<i><u>Explanatory variables</u></i>			
Milk consumption	Milk consumption, excluding Butter (per capita per year, in kg)	103.89	95.58
% Milk over diet	Dairy calories of milk consumption per capita relative to the daily per capita supply of total calories (in percentage)	0.056	0.042
Urbanization	Urban population (% of total population)	54.64	22.02
Year of schooling	Average years of schooling is the average number of years of formal education completed	7.22	3.19
Overweight	Prevalence of overweight among adult, BMI ≥ 25	39.76	16.24
Poultry consumption	Poultry consumption (per capita, in kg)	15.31	13.75
Beef consumption	Beef consumption (per capita, in kg)	11.60	10.35
Sheep consumption	Sheep and goat consumption (per capita, in kg)	3.42	6.13
Pig consumption	Pig consumption (per capita, in kg)	12.24	15.19

Appendix Table IV. List of the 108 Countries Used in This Study

Albania	Algeria	Jordan	New Zealand
Argentina	Ecuador	Japan	Pakistan
Australia	Egypt	Kenya	Panama
Austria	Spain	Cambodia	Peru
Benin	Finland	South Korea	Philippines
Bangladesh	Fiji	Liberia	Poland
Bulgaria	France	Saint Lucia	Portugal
Bahamas	Gabon	Sri Lanka	Paraguay
Belize	United Kingdom	Lesotho	Romania
Bolivia	Ghana	Morocco	Rwanda
Brazil	Guinea	Maldives	Senegal
Barbados	Gambia	Mexico	Sierra Leone
Botswana	Greece	Mali	El Salvador
Central African Rep.	Guatemala	Malta	Sao Tome
Canada	Guyana	Myanmar	Sweden
Switzerland	Honduras	Mongolia	Togo
Chile	Haiti	Mozambique	Thailand
China	Hungary	Mauritania	Trinidad and Tobago
Cote d'Ivoire	Indonesia	Mauritius	Tunisia
Cameroon	India	Malawi	Turkey
Congo	Ireland	Malaysia	Tanzania
Colombia	Iran	Namibia	Uganda
Costa Rica	Iraq	Niger	Uruguay
Cyprus	Iceland	Nicaragua	Samoa
Germany	Israel	Netherlands	South Africa
Denmark	Italy	Norway	Zambia
Dominican Republic	Jamaica	Nepal	Zimbabwe