The Impact of Body Mass Index on Growth, Schooling, Productivity, and Savings: A Cross-Country Study

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Abstract

We examine the relationship between wealth and health through prominent growth indicators and cognitive ability. Cognitive ability is represented by nutritional status. The proxy variable for nutritional status is BMI. We use the reduced form equation in the cubic specification of time preference rate, strongly related to cognitive ability, to estimate this relationship. The growth indicators utilized are GDP per capita, schooling, overall and manufacturing productivities, and savings. We estimate our models using the FE, GMM estimators, and long difference OLS and IV estimation through balanced panel data for the 1980-2009 period. We conclude that the relationship between all prominent growth indicators and BMI is inverse U-shaped. In other words, cognitive ability has a significant potential to progress growth and economic development only in a healthy status.

Keywords: Cognitive ability, time preference rate, BMI, productivity, health, schooling, growth, economic development

JEL Classification: E21, I15, I25, J24, O11, Q18.

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1. Introduction

Neo-liberal and globalization economic policy implications prevailed during the 1980-2009 period. We investigate the relationship between the engines of growth and Body Mass Index (BMI) for this period. Even if there is evidence that the relationship between GDP per capita, overall and manufacturing productivities, and BMI could be cubic, we take the results of the long-difference quadratic specification into account and conclude that the association between all engines of growth and BMI is non-monotonic and inverse U-shaped.

In this study, first, we theoretically show the effects of the time preference rate on savings and other growth indicators. We use BMI as a health proxy variable by utilizing its relationship with the time preference rate. Then, we use BMI as a substitute for the time preference rate in our reduced form equations. This health proxy variable is chosen because it is age-dependent, embedded in life expectancy, and has a strong relationship with cognitive ability. At this point, we assume that the time preference rate is a result of cognitive ability. Therefore, this proxy preference for health variable can enable us to exchange information with other wealth-health related studies which use life expectancy as a health representative variable. The economic development proxy variables are selected from among indicators according to their strong association with economic growth. The growth indicators that we take into consideration are GDP per capita, schooling, overall and manufacturing productivities, and savings.

We display the effects of BMI (by using FE, and GMM estimators) on these growth indicators. We find certain thresholds for the relationship between growth indicators and BMI. We have used the dynamic panel data models of Arellano and Bond (1991), and also the IV method in estimation. In the long difference IV estimation, BMI is instrumented by survival probabilities. Balanced panel data are used for 47 countries[1] in the estimations for the 1980-2009 period. These 47 countries were also used in the studies by Acemoglu and Johnson (2007), Cervellati and Sunde (2009), and Desbordes (2011).

In this paper, BMI is considered to be a particular dimension of health. This aspect of health has been considered at macro level before by Komlos et al. (2004), who compared the graphs of net domestic saving rates (used as proxy for time preference) and the obesity rates of ten developed countries for the 1989-1996 period. They also noted the reverse causality between impatience rate and health, which is explained in Becker and Mulligan (1997).

Our view of reasoning based on the results of our study is as follows: Growth is determined by time preference rate. In turn, time preference rate is closely related to BMI. As a result, we can conclude that health determines growth. There are other lines of connection between health and growth. We know that health determines productivity and consequently growth. Similarly, education also determines growth.

Thus, we consider that, not necessarily in the causality order, nutrient intake provides energy to activate an individual's cognitive ability. Then, cognitive ability interacts with knowledge and tacit knowledge via education at school. This interaction turns into a skill which is necessary to work and which could also be acquired on-the-job-training. The skill is then transformed into productivity, income and then into savings, investment, and innovation as a future-oriented behavior derived from the patience of cognitive ability. Consequently, all these activities contribute to economic progress as a healthy body and cognitive ability within the healthy body continue to exist. A break in this chain for any individual may create deformation in economic progress through the accumulation of the inabilities of individuals in the economy and society.

We may observe these deformations in estimations of our study as a nonlinear relationship between growth indicators and BMI roughly out of the healthy BMI thresholds. Thus, we believe that

[1] See Appendix for the country list.

macro and micro economic activities suffer from these ability breaks of individuals and accumulated deformations of these breaks in the economic ecosystem since we assume that the economic ecosystem should cover everyone in a country. To be sustainable, social infrastructure and the economic ecosystem should fix the breaks of each individual within the cognitive ability-skill-development cycle and the accumulated deformations of these breaks. Macro and micro level regulations may be applied in the economic ecosystem and social infrastructure in accordance with Hall and Jones (1999) and Bigsten and Levin (2004) to fix these breaks.

From this point of view, the structure and the results of this paper might establish an individual cognitive ability-based connection between macro and micro aspects of economics. Hence, in this study, cognitive ability is represented by nutritional status, which is BMI. We utilize the reduced form equation in the cubic specification of time preference rate to estimate the relationship between the previously mentioned prominent growth indicators and cognitive ability as we assume that the time preference rate is one of the outputs of cognitive ability. With its structure and results, this study might be differentiated from other studies conducted so far.

This paper is organized as follows. Section 2 provides the research questions. A brief review of the literature is presented in Section 3. Section 4 gives the theoretical background. Data and the empirical specifications used are described in Section 5. Section 6 presents the estimation results. The conclusions are presented in Section 7.

2. Research Questions

What is the effect of health on economic development and growth? This is our core question in this study. We use Azomahou et al.’s (2009) study as a guide to address this question. According to the assumptions of Azomahou et al. (2009), people at different ages will have alternative active planning and use different saving options. These saving preferences determine the direction of the association between life expectancy and GDP per capita growth. This association should be tested using different health proxy variables to understand the various dimensions of the relationship. Then, we base our assumption on the medical literature which argues that there is a strong association between aging and BMI. Thus, people at the same ages may have remarkably close BMI measurements. These close BMI measurements in the same age groups create a possibility for the BMI to be utilized in place of life expectancy in the health-related studies.

At this point, the strong relationship between nutritional status and cognitive ability brings in a new aspect for BMI as a health proxy variable in this study. Accordingly, the questions related with nutritional status and economic development are addressed in this paper. Another core question of the study is “What is the impact of BMI on economic growth?” Other questions regarding growth engines and nutritional status association are posed to examine this core question. The first question is related with human capital and nutritional status: What is the effect of BMI on schooling? The second sub-question is associated with productivity and nutritional status: What is the association between (overall and manufacturing) productivity and BMI? The final question is linked to savings and nutritional status: What is the association between gross domestic savings and BMI?

3. Literature Review

The growth models of Harrod (1939), Domar (1946), and Solow (1956) and the studies of Giovannini (1985), Carroll and Summers (1991), Jappelli and Pagano (1994), and Hooi Lean and Song (2009) demonstrate that savings motivate economic growth. Endogenous growth models of Romer (1986, 1990), Lucas (1988) and Barro (1990) explain that long term economic growth depends on savings, and physical and human capital are its engines. Further, health as a new form of human capital has a significant impact on economic development in the first-generation endogenous growth models (Barro, 1996; Barro & Sala-i-Martin, 2004; Grossman, 1972; Mankiw et al., 1992) as well as in the second-generation endogenous growth models (Aghion & Howitt, 1998; Howitt, 2000, 2005; Howitt & Mayer-Foulkes, 2005).

Bloom et al. (2014), Bloom, Kuhn and Prettner (2018), and Bloom, Canning, Kotschy, et al. (2018) explain the impacts of health on economic development. Bloom et al. (2014) show that non-communicable diseases have an adverse effect on labor market and savings. In another empirical study, Bloom, Canning, Kotschy, et al. (2018) use survival probability (from age 15 to 60) as a health proxy variable in their model. They find that an increase in survival probability increases worker productivity. This result explains the income per labor differences between the panel of 116 states for the 1960-2010 period. They also find that macro-, and micro-based approaches are compatible with each other to examine the impacts of health on economic development. According to Weil (2007), better health indirectly increases income by enhancing human and physical capital accumulation, and this indirect effect is as substantial as its direct positive effect.

Leibenstein (1957) provides evidence that the nutritional status has a significant effect on economic growth. Arcand (2001) investigates the association between GDP per capita growth and dietary energy supply per capita. He finds an inverse U-shaped association between economic growth and nutritional status as dietary energy supply. Wang and Taniguchi (2003) observe a negative short-run effect of nutritional status on economic growth for 129 countries. They conclude that if population growth can be controlled, nutritional status can make a positive contribution to economic growth both in the short- and long-term.

Deolalikar (1988) measures nutritional status using both weight-for-height and the daily energy intake data in India. He reveals that nutrition has positive effects on agricultural labor productivity and market wages. He finds high elasticity of farm output and market wages with respect to weight-for-height but not for the daily energy intake. Thus, weight-for-height is a better proxy for nutritional status than daily energy intake. Erdil and Kalyoncu (2010) use per capita dietary energy supply to estimate the labor effort level. They utilize years of schooling to define human capital in their model for 36 countries for the 1990-2000 period. They find a positive relationship between the ratio of physical to human capital and economic growth.

Schultz (1997) examines the association between productivity/wages and BMI. He considers the effect of diminishing scale of BMI on this association based on the Norvegian study by Waaler (1984). He suggests that public and private sectors should collaborate to enable individuals to effectively use recent technologies to secure health and nutrition, raise productivity and accelerate economic growth. Strauss and Thomas (1998) stress the non-linear association between labor productivity and health. They point to the higher mortality risk in low and high values of BMI. They also show that in Brazil, the relationship between wage and BMI is convex and concave-shaped, while it is inverse U-shaped in USA (Strauss & Thomas, 1998, p. 774). Croppenstedt and Muller (2000) offer empirical evidence that nutritional status affects agricultural productivity, and BMI influences market wage rate in Ethiopia. Strikingly, they find that nutrition and BMI strongly affect wage equation and labor productivity. They show that investment in nutrition dramatically improves productivity.

The efficiency wage theory (Bliss & Stern, 1978; Mazumdar, 1959; Mirrlees, 1976; Pitt et al., 1990; Stiglitz, 1976) analyzes the association between labor productivity, wage rate, and nutritional status. The wage determination theory (Shapiro & Stiglitz, 1984; Weiss, 1990), on the other hand, explains the involuntary unemployment and nutrition-productivity nexus. Ayalew (2003) finds that nutrition intake has a positive impact on labor earnings and productivity in Ethiopia. He further suggests that the positive effect of nutritional status is larger than the positive impact of chemical fertilizers on farm productivity. Gregory and Ruhm (2009) examine the relationship between wage and BMI considering whether the value representing the relationship is below and over the clinical threshold of being “obese” or “overweight.” They reveal that if BMI is below the clinical threshold of being “obese” or “overweight”, then wage increases; whereas, if the BMI is above the clinical threshold of being “obese” or “overweight”, then wage decreases for both genders in the US. Kedir (2009) provides evidence that BMI has a significantly positive effect on wage levels in Ethiopia. The study shows a possible inverse U-shaped association between wage and BMI for the 1994-2000 period. According to Kedir (2009), giving priority for the food-related regulations, such as food price subsidies, in policy implications will benefit wage distribution in the market. Kropfhäußer and Sunder's (2015) study in Germany, and Dou et al.'s (2020) study in China find an inverse U-shaped association between wages and BMI.

There are also studies on the relationship between schooling and nutritional status. Devaux et al. (2011) explain that there is a need for new studies to prove the causality between education and obesity in four OECD countries[2]. Brunello et al. (2013) find that education has a different impact on BMI of sexes, such as having significant negative impact on female BMI and no significant impact on male BMI in thirteen European countries[3]. Based on the data on the Italian twins in Italy, Della Bella and Lucchini (2015) show that the relationship between education and BMI can be attributed to common genetic factors by 30%. This finding suggests that genetic heritage should be taken into consideration in studies investigating the education and BMI relationship. Benson et al. (2018) show that there is an increase in average BMI through aging for both sexes; however, based on the survey conducted with people between the ages of 18 and 48 in the US, it can be stated that the mean BMI level difference in the female group between education levels (which are depicted as less than high school graduate, high school graduate and bachelor graduate) is higher in range than male's one. Finn et al. (2018) reveal that higher BMI is related with lower school attainment and achievement in the US.

Correspondingly, it has also been shown that the health status of an individual is related to the rate of time preference as it is well known that the rates of impatience determine tendencies of individuals for savings or consumptions (Rae, 1834/1905; Ramsey, 1928; Rothbard, 2000). Further, the

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[2] These countries are Australia, Canada, England, and Korea.
[3] The countries are Austria, Belgium, Denmark, Finland, France, Germany, Greece, Italy, Ireland, Portugal, Spain, Sweden, and the United Kingdom.

health status of individuals may be improved through health induced interventions, innovations, and investments. It is expected that improvements in the health status of the individuals will have a positive effect on saving preferences. Subsequently, these improvements may motivate engines of growth via their positive impacts on patience of individuals.

The discounting behavior of individuals, namely, their rate of time preference, is also studied in relation to their tendency for savings in the US. Some authors relate the savings in their retirement accounts of individuals to their impatience rate. Bernheim et al. (2001) show a convex-concave shape relationship between wealth and age profiles of low- and high-time-preference households Also, they depict a similar convex-concave shaped relationship between wealth and age profiles of households and individuals with and without a bequest motive. They conclude that there is little evidence for differences in time preference which can explain the relationship between wealth and consumption profile. They suggest that their findings may fit into mental accounting and wealth accumulation in the hyperbolic discounting theories. Pence (2002) finds that retirement saving enhancing program participants have a different demographic background such as having more income and education compared to other workers and inheriting saving motives for their retirement. Hurst (2003) suggests that households who cannot follow the permanent income consumption rules for spending and savings in their working life have low wealth in their retirement. Ameriks et al. (2003) show that the differences in talents and attitudes of households for financial planning can explain the differences in their wealth significantly. Lusardi (2003) finds that the lack of retirement planning is a significant factor for households with low wealth accumulation. Finke and Huston (2013) show that there is a significant relationship between time preference and taking precautionary health behaviours such as exercise and healthy eating into consideration.

The conditions for the rate of time preference are introduced in different studies. Krusell et al. (2002) find that free market policy provides higher welfare if there are time-inconsistent preferences in the economy. Choi and Han (2018) show that time preference can explain the savings behavior of people significantly in Korea. Proper policy tools such as tax incentives for savings can affect time preference of citizens and increase savings.

In addition, there are several studies that relate the time preference to socioeconomic indicators such as socioeconomic status, level and choice of education, fertility decision, health, productivity of labor, and earnings of life span. Schmidt et al. (1978) show that there are gender differences in future orientation domain between men and women. Men are concerned about public events such as economy and politics, while women consider private issues such as family, and occupation in the future in Germany. Fuchs (1982) suggests that time preference is associated with education and health investment and status in the US. Grossman (2006) shows that education has an effect on future orientation such as time preference in the US. Guthrie et al. (2009) show that future orientation scale is related with socioeconomic variables such as education and occupation. The future orientation scale is higher in middle aged adults among three age groups and nearly the same in younger and older aged adults in the US. Golsteyn et al. (2014) show that high time preference is related with less schooling and primary and secondary school achievement in Sweden. Further, higher time preference at younger ages generates lower income at middle ages, increases the possibility for obesity, and leads to longer unemployment duration in the future.

The relationship between rate of time preference and BMI has also been examined in several studies. These studies use health outcomes such as BMI levels, body fatness, waist circumference, being overweight, obesity, and severe obesity as dependent variables. Impatience behaviours are used as explanatory factors. These explanatory factors include savings, measures of financial attitudes, discount factor or time preference questions, questions for healthy diet-related behaviors, and the rate of discounting in monetary and health-related questions. Komlos et al. (2004) show that the ratio of household debt to disposable income and obesity has increased with a similar trend from 1971 to 2000, and also, the ratio of personal real savings to disposable income and obesity has followed an opposite direction during the same period in the US. Further, ten developed countries[4] with lower obesity rate have higher domestic savings rates between 1989 and 1996.

Smith et al. (2005) find that there is a significant positive link between time preference and BMI among different ethnicities, but not among white people in the US in 1989. Borghans and Golsteyn (2006) reveal that individual differences in time preference rates are associated with individual differences in BMI levels in the Netherlands. Adams and Nettle (2009) find that there is a relationship between time preference rate, which is measured by the Consideration of Future Consequences Scale, and the BMI level information based on self-report in the US. Guthrie et al. (2013) find that recreational exercise and smoking are related with time preference, which are measured by the Zimbardo Time Perspective Inventory in the US. Courtemanche et al. (2014) show that long-term discount factor which is measured by survey questions is negatively related with BMI as the dependent variable. This means that long-run time preference rate is positively related with BMI in the US.

Cavaliere et al. (2014), on the other hand, find that BMI, as the dependent variable, is positively related with the time preference rate which is measured by the question related with dietary patterns, such as paying attention to health or taste, in Italy. Based on internet survey in Japan, Kang and Ikeda (2016) reveal that impatience is positively related with unhealthy behaviors of individuals such as having obesity. Brown and Biosca (2016) show that there is a significant negative relationship between fatness and saving behavior in the United Kingdom.

On the other hand, the reverse causality between time preference and health status is suggested by Becker and Mulligan (1997). According to the researchers, health differences determine the differences in time preference. Falk et al. (2019) explain that their findings support Becker and

[4] These countries are Belgium, Denmark, Finland, France, Germany, Italy, Spain, Sweden, Switzerland, and the US.

Mulligan's (1997) hypothesis about the existence of reverse causality between longevity and patience by using cross-sectional dataset including 76 countries.

4. Theoretical Background

Bigsten and Levin (2004) state that pioneering economic growth approaches are generally examined along the axis of the neoclassical growth model in which Solow (1956) and others set the framework. Although countries differ from each other in many respects, this approach assumes that countries are equal except for the initial capital-labor ratio. Also, the neoclassical model proposes that capital will converge to the steady-state level with diminishing returns.

In the neoclassical model, per capita income in the steady-state level is considered depending on the propensity to save and the state of the production function according to Bigsten and Levin (2004). In addition, according to the model, the level of income in the steady state will gradually increase if technical progress is in question. As specified by Barro (1997), the steady state is also determined by government policies, such as policies for public spending and intellectual property rights. Further, the steady state depends on domestic and international market imperfections.

In parallel to Bigsten and Levin (2004), the capital approach can be expanded as human capital, experience and health in the standard model. The endogenous growth literature begins with the work of Romer (1986) and Lucas (1988). According to this approach, growth can be continuous as it is stated that the return on human capital does not have to decrease. It is accepted that the external effects of human capital and the spillovers among producers will enable the economy to avoid diminishing returns on capital. However, Lucas (1988) claims that without having similar rise in human capital, accumulation of physical capital is limited to confront keen diminishing returns. Productivity growth will not be supported with enhanced abilities and knowledge acquired through education if they are not integrated with physical capital, as specified by Hayami and Godo (2004, pp. 176-181).

Long-term per capita income will depend on the level of human and physical capital and the productivity involved in the aggregate production function, as stated in Bigsten and Levin (2004). Then, it is necessary to reveal what determines human and physical capital investments and productivity growth.

In this regard, Hall and Jones (1999) find that per capita income is indirectly determined by social infrastructure. It has been demonstrated that social infrastructure consists of the institutions and government policies that determine the economic ecosystem. The economic ecosystem shapes which individuals will gain skill and which companies will accumulate capital and produce. Therefore, it is important that the economic ecosystem supports productive activities, capital accumulation and individuals' skill acquisition and advanced technology transfer.

According to Bigsten and Moene (1996), rent-seeking affects economic growth negatively. Therefore, Hall and Jones (1999) argue that governments should protect the social infrastructure from rent-seeking type of deviations. In this way, [any] enterprise (private, public, or the mixture of them) does not have to allocate resources to avoid deviations. Thus, the resources allocated for production may increase and companies can get the full return of their investments from their production.

It can be concluded that economic growth requires physical and human capital accumulation, efficiency in resource allocation and the acquisition and employment of new technology in accordance with Bigsten and Levin (2004). The critical question should be how an economic ecosystem and a social infrastructure should be designed to achieve the accumulation and effective distribution of production factors and the innovation of advanced technologies according to Bigsten and Levin (2004).

In our opinion, cognitive ability is the key factor to design the mentioned economic ecosystem within the social infrastructure. It can be assumed that everything in the economic ecosystem is a transformed form of cognitive ability. Therefore, if we can understand the effects of cognitive ability on factors of production, we can have the opportunity to make useful policy implications for the efficient design of an economic ecosystem.

First, we need to understand what the cognitive capability is and its relationship and connection channels with the factors of production. Based on the definition of VandenBos's (2007) APA Dictionary of Psychology, cognitive ability is "the skills involved in performing the tasks associated with perception, learning, memory, understanding, awareness, reasoning, judgment, intuition, and language."

As stated by Batey and Hughes (2017, p. 188), cognitive ability can also be described using Gottfredson's (1997) definition of intelligence as a "mental capability that … involves the ability to reason, plan, solve problems, think abstractly, comprehend complex ideas, learn quickly and learn from experience" (p. 13).

In our view, cognitive ability continues to exist within the shell called the human body. Health status of human body may determine the limits of interaction between cognitive ability and the factors of production. These limits may have an effect on the endogenous growth theory, which expands capital through human capital, experience, and health. In accordance with these explanations, Rossi (2020, pp. 236-238) shows the positive effect of nutrition, health, and accumulated cognitive skills on economic growth. The footprints of these capital concepts can be observed in the definitions of cognitive ability given above and in the interaction of cognitive ability with the human body.

As claimed by Dohmen et al. (2010), having patience is related with cognitive ability. Ackert et al. (2020) demonstrate that cognitive ability has a strong relationship with time preference. Rae (1834/1905, p. 58) also points to the expansion of power of the cognitive ability and its contemplation in the minds of the citizens for the motive of accumulation. As stated in Gómez-Pinilla (2008), nutrition has a strong relationship with cognitive ability. Therefore, it is not surprising to find a significant relationship between BMI and cognitive ability (Dahl et al., 2010; Dahl & Hassing, 2013; Steenbergen & Colzato, 2017) and time preference (Barlow et al., 2016).

As also stated by Oschwald et al. (2020), while there is a need for longitudinal studies, healthy aging for cognitive ability can be achieved through the compensating capacity of the brain for deviated small changes that occurred in its structure. Accordingly, Tosato et al. (2007) maintain that aging can be consistently slowed via healthy diet while keeping required nutrients intake for human body. The Okinawan population is given as an example for that kind of nutrition-based increased lifespan in Tosato et al. (2007). This population has a decreased morbidity and mortality and world's highest percentage of centenarians.

Hence, by slowing aging via decreasing intrinsic mortality rate, we can create an option to delay reaching the highest point for time preference rate through cognitive ability and human body-based health intervention for older adults. Also, this type of intervention may decrease the time preference rate of young adults through the spillover effect. Falk et al. (2019) suggest that increased longevity obtained by health intervention has a positive effect on patience and future-oriented preferences.

According to Sozou and Seymour (2003), old adults have high time preference rate depending on their increased deformation of physiological state, and young adults have high time preference rate, which depends on an assumption they may not have tomorrow. This assumption stems from the incomplete knowledge of young adults about environmental hazard rate. At the same time, middle-aged adults have low time preference rate due to their slow physiological deformation according to Sozou and Seymour (2003). Also, Chao et al. (2009) demonstrate that there is a U-shaped relationship between survival probability and the subjective discount rate (SDR), which points to high values in younger ages, low values in middle ages, and high values in old ages. In Chao et al.'s (2009) study, the SDR plays a similar role with the time preference rate as in Sozou and Seymour (2003).

By slowing aging and deformation in cognitive ability via essential nutrient intake intervention and its spillover effect, the time preference rate for age groups (young, middle-aged, and old adults) may decrease for a longer period of time. Then, saving rate and investment increase. Thus, in the following period, a new higher steady state is converged after the capital stock increases. These steps may provide unbounded optimal growth path in the competitive economy according to the framework proposed by de la Croix and Michel (2002, pp. 112-127).

The new higher steady-state level is reached via the increased capital per effective labor and output per effective labor in the duration of time after savings are increased. Finally, the growth rate transforms into the sum of the population growth rate and the technological growth rate in the long-run as stated in Blanchard (2003, pp. 250-251). Therefore, growth may continue indefinitely. These specifications support the endogenous growth theory within the consistent cognition ability via the thresholds of healthy nutritional status point of view. This health intervention should be combined with the increase in human and physical capital as Lucas (1988) argues.

Due to its strong relationship with cognitive ability, nutritional status may give us an opportunity to examine the effects of cognitive ability on education, productivity, and growth in the long run via the time preference rate function which is developed from the equation in Azomahou et al. (2009). By using BMI as an indicator of nutritional status in place of cognitive ability and time preference, we can reflect the interaction between cognitive ability and human body in health status point of view to the estimations in our study since Dasgupta (1997) explains that "in adults of either sex, BMI has been found to be an index of both the principal stores of energy (i.e., fats) and the active tissue mass" (p. 13). Further, there is almost a convex-concave relationship between the probability of someone not having a health problem and BMI as in function according to Dasgupta (1997, pp. 13-15). The probability of someone not having a health problem is zero until the BMI value of 12 increases slowly to 15, and then rises quickly to 18.5, and remains steady between 18.5 and 25, and then decreases after it is 25 because beyond the BMI value of 25, obesity begins.

Therefore, there is a nearly convex-concave shaped relationship that can be observed in the capacity curve, which demonstrates the relationship between work capacity and nutrition (or income) in

Ray's (1998) study. The capacity curve explains that income which turns into nutrition determines an individual's capacity to perform productive work. At low levels of income, individuals get low levels of nutritional energy, and productivity at work decreases due to little nutritional energy left for work after the metabolic energy consumption of human body. This part of the capacity curve is convex-shaped. Then, by increasing income above a certain limit, individuals can afford more foods that provide enough energy for metabolism to consume and to work productively. The curve after a certain point probably turns downward, but it is neglected by Ray (1998). This probably neglected downward point of the curve explains the concave shape of the capacity curve.

To conclude, we summarize the possible roots of the nonlinear relationship between growth and health status (BMI showing the nutritional status, which has a strong relationship with cognitive ability). Then, we show theoretical considerations for the nonlinear relationship between economic indicators and health.

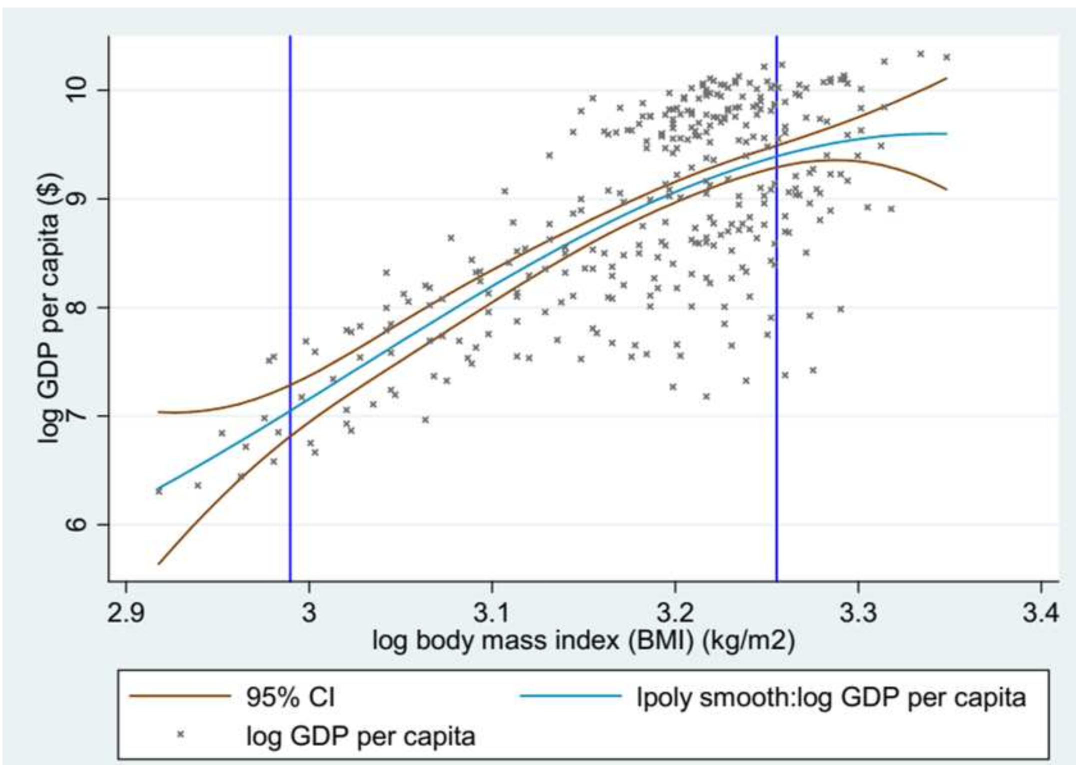
4.1. Non-linearity Issue in Graphical and Theoretical Considerations

The purpose of this section is to graphically show the nonlinear relation between GDP per capita and BMI. Figure 1 demonstrates the local cubic polynomial smooth plots with confidence intervals of GDP per capita and BMI of 47 countries for the 1980-2009 period. The estimation is performed with GMM (Arellona-Bond). There is a convex-concave-shaped relationship between GDP per capita and BMI. The turning points (TPs) are estimated as 19.88-25.93 kg/m^2 (kilogram/square meter) and are shown with blue vertical lines in the figure. According to the Table for Nutritional Status (World Health Organization [WHO], n.d.a), the BMI range for normal weight is 18.5-24.9 kg/m^2.

Figure 1 suggests that the convex-concave-shaped relationship between GDP per capita and BMI is similar to the graphs for the relationship between GDP per capita growth and life expectancy in Azomahou et al.'s (2009, pp. 208-209) study. The only difference is the scale of the turning points which are in BMI units in our study. However, this result is not surprising because BMI has a close relationship with age-dependent survival probabilities according to the weak identification test results in our empirical estimations. Moreover, we observe roughly similar non-parametric estimation graphs with our results in Gregory and Ruhm (2009), Kedir (2009), and Kropfhäußer and Sunder (2015), which depict a nonlinear relationship between wages and BMI. To conclude, we show the nonlinear relationship between GDP per capita and BMI graphically. Then, in the next section, we present the equations for the nonlinear relationships between economic indicators and BMI.

Figure 1

Local Cubic Polynomial Smooth Plots of GDP per Capita and BMI



Source. Prepared by the Authors

4.2. Developing Reduced Form Equations

We follow the theoretical model of Azomahou et al. (2009) closely, and we use the same notation. According to Azomahou et al. (2009, p. 243), M determines the sign of $\frac{\partial^2 g(A_{max})}{\partial A_{max}^2}$, the second-order partial derivative of g [which is the growth rate of GDP per capita] with respect to A_{max} [which is the maximum age]) as it is known that $\lim_{\alpha \to 1} A_{max} = 0$, and either g, L (which is the labor factor) or r (which is the interest rate) falls to 0. At the end of the process, they obtain:

$$M = (2\beta + \rho)(\rho^2 + \beta\rho) > 0. \tag{1}$$

We expand the terms, ρ (which is the intertemporal discount rate of the utility), and β (which is an indicator of survival for old persons) on the right-hand side to obtain:

$$= 2\beta\rho^2 + \rho^3 + 2\beta^2\rho + \beta\rho^2 > 0.$$

Rearranging the terms, we obtain:

$$= 2\beta^2\rho + 3\beta\rho^2 + \rho^3 > 0. \tag{2}$$

In Proposition 7 (Azomahou et al., 2009, p. 225), β is assumed as close to 0. In addition, in Proposition 7 (Azomahou et al., 2009, p. 239), there is a condition for $\rho > | \beta |$. By using the absolute value condition for β, we can assume that close-to-zero value is the absolute value of β. Then, we may take the magnitude of this number into consideration without considering its sign. Accordingly, we assume that close-to-zero value of β may be | –0.00001 | to satisfy Proposition 7. Thus, we can multiply this exceedingly small value of β with coefficient terms as 2 and 3. Consequently, we may ignore these exceedingly small values (multiplication results of β with these coefficient terms as 2 and 3) to leave ρ alone. Hence, we obtain:

$$M \cong \rho + \rho^2 + \rho^3 > 0. \tag{3}$$

Since any non-negative number very close-to-zero, such as 0.00001, may satisfy the condition of being greater than or equal to zero described for $\frac{\partial^2 g(A_{max})}{\partial A_{max}^2}$ (Azomahou et al., 2009, p. 243), we may ignore the magnitude of $\frac{\partial^2 g(A_{max})}{\partial A_{max}^2}$, and we may assume that $\frac{\partial^2 g(A_{max})}{\partial A_{max}^2}$ is restricted to determining the sign. As M determines the sign of $\frac{\partial^2 g(A_{max})}{\partial A_{max}^2}$ in this solution (Azomahou et al., 2009, p. 243), we may ignore the other parts of the solution for $\frac{\partial^2 g(A_{max})}{\partial A_{max}^2}$. Thus, we may define $\frac{\partial^2 g(A_{max})}{\partial A_{max}^2}$ to be M. Then:

$$\frac{\partial^2 \mathrm{g}(A_{max})}{\partial A_{max}^2} \stackrel{\text{def}}{=} M \cong \rho + \rho^2 + \rho^3 > 0. \quad (4)$$

Hence, (4) is consistent with the conclusion in Azomahou et al. (2009: 243) as $\frac{\partial^2 \mathrm{g}(A_{max})}{\partial A_{max}^2} \geq 0$.

We assume that the time preference rate (rate of impatience), ρ, can be represented by any appropriate substitute. For example, ρ increases with life expectancy (Azomahou et al., 2009, pp. 225-229). Thus, life expectancy may be a substitute for ρ in (4). Therefore, life expectancy in cubic specification may determine the sign of $\frac{\partial^2 \mathrm{g}(A_{max})}{\partial A_{max}^2}$. Then, (4) turns into:

$$\frac{\partial^2 \mathrm{g}(A_{max})}{\partial A_{max}^2} \stackrel{\text{def}}{=} M \cong \text{life expectancy} + \text{life expectancy}^2 + \text{life expectancy}^3 > 0. \quad (5)$$

Further, we assume that BMI is embedded in life expectancy due to its age dependency specification. Thus, BMI can be a substitute for life expectancy for cubic specifications in (5). Therefore, BMI may determine the sign of $\frac{\partial^2 \mathrm{g}(A_{max})}{\partial A_{max}^2}$. Then, (5) turns into:

$$\frac{\partial^2 \mathrm{g}(A_{max})}{\partial A_{max}^2} \stackrel{\text{def}}{=} M \cong \mathrm{BMI} + \mathrm{BMI}^2 + \mathrm{BMI}^3 > 0. \quad (6)$$

Thus, we may use BMI for cubic specification estimations in (6) as the substitute for the time preference rate, ρ.

The sign of $\frac{\partial^2 \mathrm{g}(A_{max})}{\partial A_{max}^2}$ is closely related with the indicators of growth. We use GDP per capita, years of schooling (human capital), overall productivity, manufacturing productivity and gross domestic savings. Then, we may utilize these indicators of growth for cubic specification estimations from (6) in the place of $\frac{\partial^2 \mathrm{g}(A_{max})}{\partial A_{max}^2}$. Then, (6) turns into:

$$\text{GDP per capita} \stackrel{\text{def}}{=} M \cong \mathrm{BMI} + \mathrm{BMI}^2 + \mathrm{BMI}^3 > 0. \quad (7)$$

We use the other indicators of growth similarly on the left-hand side. This is the basis of our cubic specification in our estimations.

4.3. Econometric Methodology

Following Desbordes (2011), we use OLS and IV estimation (Baum et al., 2007; Wooldridge, 2002, 2012) by using crude survival probability and age 75-79 crude survival probabilities as instrumental variables. Next, following Hansen (2012), we use fixed effect (FE) estimation (Wooldridge, 2002, 2012) and the Arellano-Bond estimation of the Generalized Method of Moments (GMM) (Arellano & Bond, 1991; Roodman, 2009).

We use long-difference estimation to get full impacts of BMI on economic indicators. In addition, long-difference estimation provides easy evaluation of these impacts measured between only two dates for BMI and economic indicators. The long-difference estimation is used in Acemoglu and Johnson's (2007, pp. 933-934) study for similar reasons. Therefore, we directly observe the full effect of change in BMI on the change in proxy variables of economic growth in the long-difference estimation in a panel containing only the same two dates of economic growth proxy variables and BMI.

5. Data and Empirical Specifications

5.1. Data

Implications of neo-liberal and globalization economic policies are dominant for the 1980-2009 period. Therefore, we arrange the balanced panel data for 47 countries to estimate models for the 1980-2009 period as an appropriate representative period of these economic policy implications to investigate the relationship between economic development and health status by excluding the ripple effects of the 2007-2009 financial crisis. We use BMI as a proxy variable for health status. We prefer to use 47 countries which were also used in the studies by Acemoglu and Johnson (2007), Cervellati and Sunde (2009) and Desbordes (2011) considering data availability for all these 47 countries for the 1980-2009 period. Descriptive statistics for the variables are given in Table 1. Information[5][6][7] regarding each

[5] Gross domestic product (GDP) per capita data for five countries are explained as follows: The values for the year 2008 are utilized for countries El Salvador, Honduras, Nicaragua, Panama, and Paraguay due to the missing values for the year 2009 for these countries.

[6] Manufacturing and value added (percent of GDP) data for five countries are explained as follows: The year 2007 value for Canada in World Bank (n.d.a) is used for the missing the year 2005 value. The year 2001 value for Guatemala in World Bank (n.d.a) is used for the missing the

variable is also provided in this table. Each age-specific death rate represents the mean of age-based death rates for males and females.

Table 1

Variables, Data and Descriptive Statistics for the 1980-2009 Period

Variable	Description / Formula	Data Source	N	Mean	Std. Dev.	Minimum	Maximum
log mean body mass index (BMI) 18+ years	= ln ((male mean body mass index + female mean body mass index) / 2) * (The unit is kg/m² and age-standardized estimate)	Data from 1980 to 2009 are utilized from Non-Communicable Disease (NCD) Risk Factor Collaboration (2016).	329	3.188368	0.0825268	2.917771	3.348148
log years of schooling	The average years of total schooling, aged 15-64, is exactly utilized from Lee and Lee (2016).	Data from 1980 to 2010 are utilized from Lee and Lee (2016).	329	2.042956	0.382604	0.7419373	2.583242
log gross domestic product (GDP) per capita	This variable is exactly used from Maddison Project Database, Version 2013.	Data from 1980 to 2009 are used from Maddison Project Database, Version 2013 by Bolt and van Zanden (2014).	329	8.87584	0.9548445	6.307299	10.33662
log GDP per person engaged	= ln (real GDP at constant national prices (in millions 2011 US $)) / (number of persons engaged (in millions))	Data from 1980 to 2009 are utilized from Feenstra et al. (2015).	329	10.33784	0.9133531	7.320517	11.98606
log manufacturing productivity	= ln ((manufacturing, value added (percent of GDP) × real GDP at constant national prices (in millions 2011 US $)) / (number of persons engaged (in millions))	Data from 1980 to 2009 are used from Feenstra et al. (2015), World Bank (1982, 1983, 1987, 1996, 1997, 1999, 2001, n.d.a), and United Nations (UN) (n.d.).	329	8.655354	0.9570671	4.794788	10.155
gross domestic savings (percent of GDP)	Gross domestic savings are estimated as GDP minus total consumption by World Bank (n.d.b).	Data from 1980 to 2009 are utilized from World Bank (1987, 1992, 1996, n.d.b), and Asian Development Bank (1987, 1992, 1997, 2017).	329	22.44033	8.743491	−2.439481	50.65072
log crude survival probability	= ln (1 − (crude death rate / 1000))	Data for 1980 and 2009 are used from World Bank (n.d.c). Data is used in long-difference estimation only.	94	−0.0082234	0.0022935	−0.0143282	−0.0045332
log age 75-79 survival probability	= ln (1 − (age 75-79 death rate / 1000))	Data for 1980 are utilized from UN (1977, 1987, 1999). Data for 2009 are utilized from WHO (n.d.b). Data is used in long-difference estimation only.	94	−0.0625243	0.0248765	−0.1687146	−0.0314907

5.2. Empirical Specifications

Developing Equation (7) and following the quadratic and cubic empirical specifications in Desbordes (2011), Hansen (2012), and Husain et al. (2014), we specify the following relationship between GDP and BMI in reduced form:

$$\log Y_{it} = \alpha_0 + \alpha_1 \log BMI_{it} + \alpha_2 (\log BMI_{it})^2 + \alpha_3 (\log BMI_{it})^3 + \lambda_i + \eta_t + \omega_{it} , \quad (8)$$

year 2000 value. The year 2010 value for Indonesia in World Bank (n.d.a) is used for the missing the year 2009 value. The year 1993 value for Paraguay in World Bank (n.d.a) is used for the missing the year 1995 value. The year 1981 value for Spain in World Bank (1983) is used for the missing the year 1980 value.

[7] Age 75-79 death rate data for thirteen countries are explained as follows: Bangladesh the year 1981 value, Colombia the year 1985 value, Costa Rica the year 1984 value, El Salvador the year 1984 value, Honduras the year 1981 value, India the year 1961 value, Indonesia the year 1964 value, Nicaragua the year 1965 value, Spain the year 1981 value, and Uruguay the year 1985 value in UN (1999) are used for the missing the year 1980 values for these countries. Hong Kong the year 1980 value in the UN (1999) is used for the missing the year 1980 value for China. Myanmar the year 1962 value in UN (1977) is used for the missing the year 1980 value. Pakistan the year 1976 value in UN (1987) is used for the missing the year 1980 value.

where log indicates the natural logarithm, Y is replaced in turn by GDP per capita, years of schooling (human capital), overall productivity, manufacturing productivity, and gross domestic savings, respectively. Overall productivity is measured by GDP per person engaged. Manufacturing productivity is measured by the manufacturing value added per person engaged. BMI has the unit of kg/m^2, λ and η are the country and time specific effects, and ω is the disturbance term.

Following Hansen (2012), the Model (8) is estimated by including one or two period lagged values of "log GDP" on the right-hand side as an additional regressor. This formulation allows for dynamic effects as well as endogeneity. We estimate this relationship by GMM as it is proposed by Arellano and Bond (1991) and performed by Hansen (2012). Time and country dummies are included to account for the relevant fixed effects.

6. Estimation Results

6.1. Estimation Results for Economic Growth

6.1.1. Diagnostic Tests

Table 2 shows linear and quadratic estimations. Cubic specifications are shown in Table 3. We show long-difference estimation results for linear and quadratic specifications in Table 4 and cubic estimations in Table 5. For GMM estimations in Columns (5) and (6) of Table 2, and in Column (3) of Table 3, we reject the null hypothesis of Arellano-Bond AR (1) at 5% or better significance level, whereas we do not reject the null hypothesis of AR (2). These results satisfy Arellano-Bond estimation assumption[8] in Arellano and Bond (1991), which increases the consistency of estimation. In addition, Hansen tests indicate that over-identification fails to be rejected at 10% or better significance level. This hints that the instrument set is valid.

As seen in Table 4 and 5, the RESET test indicates that the null hypothesis fails to be rejected at 5% or better significance level. This indicates that there is no functional form mis-specification.

[8] The GMM estimator is based on the main assumption that there is no serial correlation between the transformed errors (Arellano & Bond, 1991).

Table 2

The Linear and Quadratic Association between GDP per capita and BMI, 1980-2009

	log GDP per capita			
	(1)	(2)	(3)	(4)
	FE (within)	FE (within)	GMM (Arellano-Bond)	GMM (Arellano-Bond)
lagged log GDP per capita	0.73***	0.68***	0.55***	0.43***
	(0.05)	(0.05)	(0.07)	(0.07)
log mean body mass index 18+ years	1.91***	30.73**	2.33***	49.71***
	(0.65)	(11.41)	(0.84)	(16.27)
(log mean body mass index 18+ years)²	-	−4.58**	-	−7.56***
		(1.75)	-	(2.55)
Number of observations	282	282	235	235
Number of countries	47	47	47	47
R-squared	0.89	0.90	-	-
F test *p*-value	0.00	0.00	0.00	0.00
Arellano-Bond test for AR (1) *p*-value	-	-	0.01	0.02
Arellano-Bond test for AR (2) *p*-value	-	-	0.82	0.81
Hansen test *p*-value	-	-	0.22	0.29
Country dummies	yes	yes	-	-
Time dummies	yes	yes	yes	yes
Turning points	-	28.61	-	26.82

Notes. Robust standard errors (SE)s are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All panels are balanced panels with one observation per five years and per country. The dependent variable is the log GDP per capita. Column (3) and (4) are difference GMM estimations. Turning point is estimated for coefficients at 10% or better significance level in a Column. Mean turning point of the estimations in Columns (2), and (4) is 27.71.

The instrumental variables are crude survival and age 75-79 survival probabilities. These instruments and their squared and cubed values are valid instruments according to the weak identification test statistics[9] when Columns (3) and (5) in Table 4 and Columns (2) and (3) in Table 5 are exempted. Columns (3) in Table 4 and in Table 5 satisfy the rule of thumb[10] that F statistics of the first stage should be at least ten or over (Staiger & Stock, 1997, p. 557; Baum et al., 2007, p. 490).

[9] Kleibergen-Paap Wald rk F statistic is reported as the weak identification test in estimations. Further, Stock-Yogo critical values for the Cragg-Donald i.i.d. case are reported for the critical values of the Kleibergen-Paap statistic (Baum et al., 2007, p. 490).

[10] According to Baum et al. (2007, p. 490), the test of weak identification with rk statistic, one can utilize the critical values arranged by Stock and Yogo (2005) for the i.i.d. case with caution, or one can refer to the older "rule of thumb" of Staiger and Stock (1997). This older rule of thump explains that the F statistic should be at least 10 for weak identification tests. In both cases, there cannot be considered a problem for instrumental variables.

Table 3

The Cubic Association between GDP per capita and BMI, 1980-2009

	log GDP	
	(1)	(2)
	FE (within)	GMM (Arellano-Bond)
first lagged log GDP	0.67***	-
	(0.05)	
second lagged log GDP	-	0.19
		(0.13)
log mean body mass index 18+ years	264.91	−4175.95**
	(310.13)	(1595.02)
(log mean body mass index 18+ years)^2	−78.99	1339.79**
	(98.20)	(507.66)
(log mean body mass index 18+ years)^3	7.87	−143.02**
	(10.36)	(53.93)
Number of observations	282	188
Number of countries	47	47
R-squared	0.90	-
F test *p*-value	0.00	0.00
Arellano-Bond test for AR (1) *p*-value	-	0.02
Arellano-Bond test for AR (2) *p*-value	-	0.27
Hansen test *p*-value	-	0.16
Country dummies	yes	-
Time dummies	yes	yes
Turning points (1)	-	19.88
(2)	-	25.93

Notes. Robust standard errors (SE)s are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All panels are balanced panels with one observation per five years and per country. The dependent variable is the log GDP per capita. Column (2) is difference GMM estimation. Turning point is estimated for coefficients at 10% or better significance level in a Column.

Hansen J tests indicate that over-identification restrictions cannot be rejected at 10% or better significance level. This shows that instruments are appropriate at the given significance level. The null hypotheses of the endogeneity test of BMI fail to be rejected according to Tables 4 and 5 at 10% or better significance level. Thus, the OLS gives the consistent and relatively more efficient estimates.

6.1.2. Estimation Results

In linear specification for the 1980-2009 period, Columns (1) and (3) in Table 2, and Columns (1), (3), and (5) in Table 4 report the estimation results of Model (8). In the linear specification of Model (8), the α_2 and α_3 are restricted to be zero. The coefficient of ln BMI was found to be positive at 5% or better significance level in Columns (1) and (3) in Table 2, and Columns (1), (3), and (5) in Table 4.

Table 4

Long-Difference Estimations for the Linear and Quadratic Association Between GDP per capita and BMI, 1980-2009

	log GDP per capita					
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	OLS	IV (crude survival probability)	IV (crude survival probability)	IV (crude survival probability, and age 75-79 survival probability)	IV (crude survival probability, and age 75-79 survival probability)
lagged log GDP per capita	1.05***	0.99***	1.05***	0.99***	1.05***	0.96***
	(0.04)	(0.04)	(0.05)	(0.04)	(0.05)	(0.05)
log mean body mass index 18+ years	0.90***	22.65***	2.04**	22.53**	2.31**	29.99***
	(0.32)	(5.06)	(1.00)	(9.02)	(1.01)	(7.38)
(log mean body mass index 18+ years)^2	-	−3.49***	-	−3.52**	-	−4.68***
		(0.80)		(1.44)		(1.20)
Number of observations	47	47	47	47	47	47
Number of countries	47	47	47	47	47	47
R-squared	0.96	0.97	0.95	0.97	0.95	0.97
F test *p*-value	0.00	0.00	0.00	0.00	0.00	0.00
Weak identification test statistic	-	-	14.15	9.90	8.09	12.36
Endogeneity test *p*-value	-	-	0.19	0.71	0.14	0.13
Hansen J statistic	-	-	e.e.i.	e.e.i.	0.40	0.47
C (2nd polynomial) RESET test *p*-value	0.07	0.06	0.27	0.07	0.38	0.16
C (3rd polynomial) RESET test *p*-value	0.10	0.16	0.52	0.15	0.65	0.35
Turning points	-	25.66	-	24.53	-	24.51

Notes. Robust standard errors (SE)s are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All Columns are long-difference estimations with two observations per country for the years 1980 and 2009. The dependent variable is the log GDP per capita. Lagged log GDP per capita includes two observations per country for the years 1980 and 2005. In Column (3) log crude survival probability, and in Column (4) log crude survival probability, and its squared value are used as the instrumental variables. In Column (5) log crude survival probability, and log age 75-79 survival probability, and in Column (6) log crude survival probability, and log age 75-79 survival probability, and their squared values are used as instrumental variables. In Hansen J statistic, "equation exactly identified" term is represented by the term as "e.e.i." *C* (GMM-distance) RESET test uses Pesaran-Smith optimal forecast values. In (3), Stock-Yogo weak ID test critical value is 16.38. In (4), Stock-Yogo weak ID test critical value is 7.03. In (5), Stock-Yogo weak ID test critical value is 19.93. In (6), Stock-Yogo weak ID test critical value is 11.04. Turning point is estimated for coefficients at 10% or better significance level in a Column. Mean turning point of the estimations in Columns (2), (4) and (6) is 24.90.

In quadratic specification for the 1980-2009 period, Columns (2) and (4) in Table 2, and Columns (2), (4), and (6) in Table 4 report the estimation results of Model (8). In the quadratic specification of Model (8), the α_3 is restricted to be zero. The coefficients of the linear and the quadratic terms are both significantly different from zero at 5% or better significance level, and they are positive and negative, respectively. The estimated turning points[11] are within the range of 24.51-28.61 kg/m^2 as can be seen in Columns (2) and (4) of Table 2, and Columns (2), (4), and (6) of Table 4. Thus, the quadratic functional

[11] Quadratic specification turning point (*TP*) is estimated by following formula: $TP = \exp\left(\left|\frac{\hat{\beta}_1}{2\hat{\beta}_2}\right|\right)$.

specification estimation results of the present study suggest that there is a non-monotonic and inverse U-shaped relationship between GDP per capita and BMI for the 1980-2009 period.

Table 5

Long-Difference Estimations for the Cubic Association between GDP per capita and BMI, 1980-2009

	log GDP per capita		
	(1)	(2)	(3)
	OLS	IV (crude survival probability)	IV (crude survival probability, and age 75-79 survival probability)
lagged log GDP	0.99***	0.98***	0.94***
	(0.04)	(0.08)	(0.06)
log mean body mass index 18+ years	56.20	−94.79	−822.23
	(165.92)	(1102.98)	(620.11)
(log mean body mass index 18+ years)^2	−14.19	34.27	268.75
	(52.57)	(355.89)	(199.50)
(log mean body mass index 18+ years)^3	1.14	−4.06	−29.23
	(5.55)	(38.26)	(21.39)
Number of observations	47	47	47
Number of countries	47	47	47
R-squared	0.97	0.97	0.95
F test *p*-value	0.00	0.00	0.00
Weak identification test statistic	-	0.10	0.75
Endogeneity test *p*-value	-	0.82	0.46
Hansen J statistic	-	e.e.i.	0.51
C (3rd polynomial) RESET test *p*-value	0.12	0.84	0.42
C (4rd polynomial) RESET test *p*-value	0.05	0.93	0.61
Turning points (1)	-	-	-
(2)	-	-	-

Notes. Robust standard errors (SE)s are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All Columns are long-difference estimations with two observations per country for the years 1980 and 2009. The dependent variable is the log GDP per capita. Lagged log GDP includes two observations per country for the years 1980 and 2005. In Column (2) log crude survival probability, its squared, and cubed values are used as the instrumental variables. In Column (3) log crude survival probability, and log age 75-79 survival probability, and their squared, and cubed values are used as instrumental variables. In Hansen J statistic, "equation exactly identified" term is represented by the term as "e.e.i." *C* (GMM-distance) RESET test uses Pesaran-Smith optimal forecast values. In (2), Stock-Yogo weak ID test critical value is not available. In (3), Stock-Yogo weak ID test critical value is 12.20. Turning point is not estimated for coefficients less than 10% significance level in a Column.

Cubic specifications are reported in Table 3 and Table 5. Accordingly, the coefficients of the linear, the quadratic, and the cubic terms are significantly different from zero at 5% significance level, and as can be seen in Column (2) of Table 3, they are negative, positive, and negative, respectively. The estimated turning point-1[12] is 19.88 kg/m^2, and turning point-2 is 25.93 kg/m^2 in this column.

Also, Column (1) in Table 3, and Columns (1), (2), and (3) in Table 5 demonstrate that the coefficients of the linear, quadratic, and cubic terms are insignificant.

[12] Cubic specification turning points (*TPs*) are estimated by using general mathematical formula: $\frac{d}{dx}\left(\hat{\beta}_3 x^3 + \hat{\beta}_2 x^2 + \hat{\beta}_1 x + \text{constant}\right)$, then, $TPs\,(1,2) = \exp\left((-(2\hat{\beta}_2) \pm \sqrt{(2\hat{\beta}_2)^2 - 4(3\hat{\beta}_3\hat{\beta}_1)})\ /\ (2(3\hat{\beta}_3))\right)$

Hence, the cubic functional specification estimation results suggest that first there is a convex, and then a concave-shaped relationship between GDP per capita and BMI for the 1980-2009 period.

The linear and quadratic relationships are reported in Table 2, while the cubic relationships are given in Table 3. In the linear and quadratic specifications in both FE and GMM estimations, all coefficient estimates are statistically significant. In the cubic specifications in the FE estimation, the coefficient estimates are not statistically significant, whereas in the GMM estimation, they are all statistically significant.

We present the results of the long-difference estimations in Tables 4 and 5. These tables include IV estimations with crude survival probability as instrument. Further, we also use crude survival probability and age 75-79 survival probability jointly as instruments. In all cases, the coefficient estimates are statistically significant at 5 % level of significance or better. However, the coefficient estimates are not statistically significant in the cubic specification. Therefore, we conclude that the relationship between GDP per capita and BMI is inverse U-shaped.

6.2. Estimation Results for Schooling

6.2.1. Diagnostic tests

We display linear and quadratic estimations in Table 6 and cubic specification in Table 7. We provide long-difference estimation results for linear and quadratic specifications in Table 8 and cubic estimations in Table 9. As for GMM estimations shown in Columns (3) and (4) of Table 6, and in Column (2) of Table 7, we reject the null hypothesis of Arellano-Bond AR (1) at 5% or better significance level, whereas we do not reject the null hypothesis of AR (2). These results satisfy the Arellano-Bond estimation assumption summarized in Arellano and Bond (1991).

In Table 8 and Table 9, the RESET test indicates that the null hypothesis fails to be rejected at 5% or better significance level. In other words, there is no functional form mis-specification.

Table 6

The Linear and Quadratic Association between Years of Schooling and BMI, 1980-2009

	log years of schooling			
	(1)	(2)	(3)	(4)
	FE (within)	FE (within)	GMM (Arellano-Bond)	GMM (Arellano-Bond)
first lagged log years of schooling	0.81***	0.75***	-	-
	(0.04)	(0.04)		
second lagged log years of schooling	-	-	0.59***	0.06
			(0.13)	(0.17)
log mean body mass index 18+ years	−0.12	12.66*	2.82**	76.78**
	(0.33)	(6.30)	(1.29)	(37.05)
(log mean body mass index 18+ years)^2	-	−2.02**	-	−11.31*
		(0.98)		(5.98)
Number of observations	282	282	188	188
Number of countries	47	47	47	47
R-squared	0.93	0.93	-	-
F test *p*-value	0.00	0.00	0.00	0.00
Arellano-Bond test for AR (1) *p*-value	-	-	0.04	0.01
Arellano-Bond test for AR (2) *p*-value	-	-	0.16	0.31
Hansen test *p*-value	-	-	0.11	0.36
Country dummies	yes	yes	-	-
Time dummies	yes	yes	yes	yes
Turning points	-	23.13	-	29.77

Notes. Robust standard errors (SE)s are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All panels are balanced panels with one observation per five years and per country. The dependent variable is the log years of schooling. Column (3) and (4) are difference GMM estimations. Turning point is estimated for coefficients at 10% or better significance level in a Column. Mean turning point of the estimations in Columns (2), and (4) is 26.45.

The instrumental variables are crude survival probabilities and age 75-79 survival probabilities. In weak identification tests, all these instruments and their squared and cubed values are not over the critical values[13] (Stock & Yogo, 2005). These test results show that the instruments are not valid (except for Column (4) in Table 8). Column (4) in Table 8 satisfies the rule of thumb that F statistics of the first stage should be at least ten or over (Staiger & Stock, 1997, p. 557; Baum et al., 2007, p. 490). As can be seen in Table 8 and Table 9, the endogeneity test of BMI fails to be rejected at 10% or better significance level. Therefore, OLS estimation with quadratic specification is an efficient and valid estimation (Column

[13] The available critical values are 5% maximal IV relative bias or 10% maximal IV size in Baum et al. (2007).

(2) of Table 8). Thus, we conclude that the relationship between years of schooling and BMI is inverse U-shaped.

Table 7

The Cubic Association between Years of Schooling and BMI, 1980-2009

	log years of schooling	
	(1)	(2)
	FE (within)	GMM (Arellano-Bond)
first lagged log years of schooling	0.75***	-
	(0.04)	
second lagged log years of schooling	-	0.03
		(0.21)
log mean body mass index 18+ years	172.47	509.76
	(105.20)	(1792.38)
(log mean body mass index 18+ years)^2	−52.81	−148.49
	(33.71)	(572.17)
(log mean body mass index 18+ years)^3	5.38	14.47
	(3.60)	(60.91)
Number of observations	282	188
Number of countries	47	47
R-squared	0.94	-
F test *p*-value	0.00	0.00
Arellano-Bond test for AR (1) *p*-value	-	0.03
Arellano-Bond test for AR (2) *p*-value	-	0.35
Hansen test *p*-value	-	0.32
Country dummies	yes	-
Time dummies	yes	yes
Turning points (1)	-	-
(2)	-	-

Notes. Robust standard errors (SE)s are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All panels are balanced panels with one observation per five years and per country. The dependent variable is the log years of schooling. Column (2) is difference GMM estimation. Turning point is not estimated for coefficients less than 10% significance level in a Column.

Hansen J tests indicate that over-identification restrictions fail to be rejected at 10% or better significance level. This shows that the set of instruments is valid at the given significance level.

6.2.2. Estimation Results

As for the linear specification pertaining to the period of 1980-2009, Columns (1) and (3) in Table 6, and Columns (1), (3), and (5) in Table 8 report the estimation results of Model (8). Here, α_2 and α_3 are restricted to be zero. The coefficient of ln BMI was found positive at 5% significance level (Column

3 Table 6). In addition, the coefficient of ln BMI was found insignificant as can be seen in Columns (1) in Table 6, and in Columns (1), (3), and (5) in Table 8.

Table 8

Long-Difference Estimations for the Linear and Quadratic Association between Years of Schooling and BMI, 1980-2009

	log years of schooling					
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	OLS	IV (crude survival probability)	IV (crude survival probability)	IV (crude survival probability, and age 75-79 survival probability)	IV (crude survival probability, and age 75-79 survival probability)
lagged log years of schooling	1.08***	1.03***	1.04***	0.97***	1.03***	1.02***
	(0.04)	(0.05)	(0.07)	(0.13)	(0.07)	(0.05)
log mean body mass index 18+ years	0.04	7.79*	0.91	13.20	0.99	5.93*
	(0.23)	(4.13)	(0.92)	(13.02)	(0.81)	(3.38)
(log mean body mass index 18+ years)^2	-	−1.23*	-	−1.98	-	−0.86
		(0.65)		(1.95)		(0.55)
Number of observations	47	47	47	47	47	47
Number of countries	47	47	47	47	47	47
R-squared	0.95	0.95	0.94	0.94	0.93	0.95
F test *p*-value	0.00	0.00	0.00	0.00	0.00	0.00
Weak identification test statistic	-	-	5.99	1.40	4.16	6.72
Endogeneity test *p*-value	-	-	0.34	0.48	0.20	0.65
Hansen J statistic	-	-	e.e.i.	e.e.i.	0.81	0.56
C (2nd polynomial) RESET test *p*-value	0.995	0.90	0.98	0.82	0.92	0.65
C (3rd polynomial) RESET test *p*-value	0.23	0.27	0.64	0.50	0.64	0.19
Turning points	-	23.78	-	-	-	-

Notes. Robust standard errors (SE)s are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All Columns are long-difference estimations with two observations per country for the years 1980 and 2009. The dependent variable is the log years of schooling. Lagged log years of schooling includes two observations per country for the years 1980 and 2005. In Column (3) log crude survival probability, and in Column (4) log crude survival probability, and its squared value are used as the instrumental variables. In Column (5) log crude survival probability, and log age 75-79 survival probability, and in Column (6) log crude survival probability, and log age 75-79 survival probability, and their squared values are used as instrumental variables. In Hansen J statistic, "equation exactly identified" term is represented by the term as "e.e.i." *C* (GMM-distance) RESET test uses Pesaran-Smith optimal forecast values. In (3), Stock-Yogo weak ID test critical value is 16.38. In (4), Stock-Yogo weak ID test critical value is 7.03. In (5), Stock-Yogo weak ID test critical value is 19.93. In (6), Stock-Yogo weak ID test critical value is 11.04. Turning point is estimated for coefficients at 10% or better significance level in a Column.

The estimations for the quadratic specification according to Model (8) for the 1980-2009 period are shown in Columns (2) and (4) in Table 6, and Columns (2), (4), and (6) in Table 8, where α_3 is restricted to be zero. The coefficients of the linear and the quadratic terms were both found to be significantly different from zero at 10% or better significance level, and they are positive and negative in Columns (2) and (4) in Table 6, and Column (2) in Table 8, respectively. The estimated turning points are within the range of 23.13-29.77 kg/m^2 as seen in these columns.

Table 9

Long-Difference Estimations for the Cubic Association between Years of Schooling and BMI, 1980-2009

	log years of schooling		
	(1)	(2)	(3)
	OLS	IV (crude survival probability)	IV (crude survival probability, and age 75-79 survival probability)
lagged log years of schooling	1.03***	0.98***	1.04***
	(0.05)	(0.08)	(0.05)
log mean body mass index 18+ years	−36.86	(omitted)	174.90
	(106.27)		(263.79)
(log mean body mass index 18+ years)^2	13.01	1.93	−55.11
	(33.82)	(1.22)	(84.94)
(log mean body mass index 18+ years)^3	−1.51	−0.39	5.80
	(3.59)	(0.25)	(9.11)
Number of observations	47	47	47
Number of countries	47	47	47
R-squared	0.95	0.95	0.95
F test *p*-value	0.00	0.00	0.00
Weak identification test statistic	-	0.00	1.59
Endogeneity test *p*-value	-	0.63	0.37
Hansen J statistic	-	e.e.i.	0.57
C (3rd polynomial) RESET test *p*-value	0.29	0.80	0.03
C (4rd polynomial) RESET test *p*-value	0.46	0.68	0.05
Turning points (1)	-	-	-
(2)	-	-	-

Notes. Robust standard errors (SE)s are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All Columns are long-difference estimations with two observations per country for the years 1980 and 2009. The dependent variable is the log years of schooling. Lagged log years of schooling includes two observations per country for the years 1980 and 2005. In in Column (2) log crude survival probability, its squared, and cubed values are used as the instrumental variables. In Column (3) log crude survival probability, and log age 75-79 survival probability, and their squared, and cubed values are used as instrumental variables. In Hansen J statistic, "equation exactly identified" term is represented by the term as "e.e.i." *C* (GMM-distance) RESET test uses Pesaran-Smith optimal forecast values. In (2), Stock-Yogo weak ID test critical value is not available. In (3), Stock-Yogo weak ID test critical value is 12.20. Turning point is not estimated for coefficients less than 10% significance level in a Column.

The coefficients of the linear and the quadratic terms, however, are insignificant as shown in Column (4) and (with the exception of the linear term) Column (6) in Table 8. Thus, our quadratic functional specification estimation suggests that there is a non-monotonic and inverse U-shaped relationship between years of schooling and BMI for the 1980-2009 period.

The estimations for cubic specifications by Model (8) for the 1980-2009 period are presented in Columns (1) and (2) in Table 7, and Columns (1), (2), and (3) in Table 9. They all show that the coefficients of the linear, quadratic, and cubic terms are insignificant.

The linear, quadratic, and cubic estimation results are reported in Tables 6, 7, 8, and 9. We observe that the coefficient estimates are statistically significant in the cases of quadratic specifications with FE and GMM estimations in Columns (2) and (4) in Table 6. In the GMM estimation, we do not reject AR (1), but we reject AR (2) providing consistent estimates. At the same time, the OLS estimation with quadratic specification is an efficient and valid estimation with statistically significant coefficient estimates, as seen in Column (2) of Table 8 and as explained in diagnostic tests. Therefore, we conclude that the relationship between years of schooling and BMI is a quadratic one with an inverse U-shape.

6.3. Estimation Results for Overall Productivity

6.3.1. Diagnostic tests

We give linear and quadratic estimations in Table 10 and cubic specification in Table 11. We present the long-difference estimation results for linear and quadratic specifications in Table 12 and cubic estimations in Table 13. As for GMM estimations, Columns (3) and (4) of Table 10, and Column (2) of Table 11 show that we reject the null hypothesis of Arellano-Bond AR (1) at 10% significance level, whereas we do not reject the null hypothesis of AR (2). These results satisfy the Arellano-Bond estimation assumption discussed in Arellano and Bond (1991), which increases the consistency of the estimation.

As seen in Table 12 and Table 13, the RESET test indicates that the null hypothesis fails to be rejected at 5% significance level, pointing to no functional form mis-specification.

The instrumental variables are crude survival and age 75-79 survival probabilities. All these instruments and their squared and cubed values are valid instruments according to the weak identification test statistics. Column (3) in Table 12 and in Table 13 is exempted, which satisfies the rule of thumb that F statistics of the first stage should be at least ten or over according to Staiger and Stock (1997, p. 557) and Baum et al., (2007, p. 490). However, the weak identification test results in Column (5) in Table 12 and Column (2) in Table 13 are not over the critical values[14] according to Stock and Yogo (2005). These test results show that the instruments are not valid in these columns. Therefore, OLS estimation with quadratic specification is an efficient and valid estimation (Column (2) of Table 12). Thus, we conclude that the relationship between overall productivity and BMI is inverse U-shaped.

[14] Available critical values are 5% maximal IV relative bias or 10% maximal IV size in Baum et al. (2007).

Table 10

The Linear and Quadratic Association between Overall Productivity and BMI, 1980-2009

	log GDP per person engaged			
	(1)	(2)	(3)	(4)
	FE (within)	FE (within)	GMM (Arellano-Bond)	GMM (Arellano-Bond)
lagged log GDP per person engaged	0.75***	0.69***	0.58***	0.43***
	(0.06)	(0.05)	(0.07)	(0.07)
log mean body mass index 18+ years	1.80**	32.35***	2.00**	50.68***
	(0.72)	(11.87)	(0.88)	(14.83)
(log mean body mass index 18+ years)²	-	−4.87**	-	−7.76***
	-	(1.82)	-	(2.31)
Number of observations	282	282	235	235
Number of countries	47	47	47	47
R-squared	0.84	0.86	-	-
F test *p*-value	0.00	0.00	0.00	0.00
Arellano-Bond test for AR (1) *p*-value	-	-	0.00	0.00
Arellano-Bond test for AR (2) *p*-value	-	-	0.27	0.32
Hansen test *p*-value	-	-	0.19	0.21
Country dummies	yes	yes	-	-
Time dummies	yes	yes	yes	yes
Turning points	-	27.69	-	26.17

Notes. Robust standard errors (SE)s are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All panels are balanced panels with one observation per five years and per country. The dependent variable is the log GDP per person engaged. Column (3) and (4) are difference GMM estimations. Turning point is estimated for coefficients at 10% or better significance level in a Column. Mean turning point of the estimations in Columns (2), and (4) is 26.93.

Hansen J tests indicate that over-identification restrictions fail to be rejected at 10% significance level, showing that the set of instruments is appropriate at the given significance level. The endogeneity test of BMI fails to be rejected in Table 12 and in Table 13 at 10% significance level. Thus, the OLS gives consistent and relatively more efficient estimates.

6.3.2. Estimation Results

The estimations of linear specification based on Model (8) for the 1980-2009 period are presented in Columns (1) and (3) in Table 10 and Columns (1), (3), and (5) in Table 12. Here, α_2 and α_3 are restricted to be zero. The coefficient of ln BMI was found to be positive at 5% significance level in Columns (1) and (3) in Table 10 and Column (1) in Table 12. Also, the coefficient of ln BMI turned out to be insignificant as shown in Columns (3) and (5) in Table 12.

Table 11

The Cubic Association between Overall Productivity and BMI, 1980-2009

	log GDP per person engaged	
	(1)	(2)
	FE (within)	GMM (Arellano-Bond)
lagged log GDP per person engaged	0.69***	0.84***
	(0.05)	(0.25)
log mean body mass index 18+ years	305.88	−2256.71*
	(361.01)	(1138.20)
(log mean body mass index 18+ years)^2	−91.79	727.98*
	(114.02)	(365.25)
(log mean body mass index 18+ years)^3	9.20	−78.19*
	(12.00)	(39.11)
Number of observations	282	235
Number of countries	47	47
R-squared	0.86	-
F test *p*-value	0.00	0.00
Arellano-Bond test for AR (1) *p*-value	-	0.06
Arellano-Bond test for AR (2) *p*-value	-	0.13
Hansen test *p*-value	-	0.30
Country dummies	yes	-
Time dummies	yes	yes
Turning points (1)	-	20.03
(2)	-	24.78

Notes. Robust standard errors (SE)s are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All panels are balanced panels with one observation per five years and per country. The dependent variable is the log GDP per person engaged. Column (2) is difference GMM estimation. Turning point is not estimated for coefficients less than 10% significance level in a Column.

The estimation results of Model (8) pertaining to the quadratic specification for 1980-2009 are presented in Columns (2) and (4) in Table 10, and Columns (2), (4), and (6) in Table 12. It should be noted that α_3 is restricted to be zero. The coefficients of the linear and the quadratic terms are significantly different from zero at 5% or better significance level, and they are positive and negative in Columns (2) and (4) in Table 10, and in Columns (2), and (6) in Table 12, respectively.

The estimated turning points are within the range of 24.62-27.69 kg/m^2. In addition, the coefficients of the linear and the quadratic terms are insignificant as can be seen in Column (4) in Table 12. Thus, the quadratic functional specification estimation results suggest that there is a non-monotonic and inverse U-shaped relationship between overall productivity and BMI for the 1980-2009 period.

Table 12

Long-Difference Estimations for the Linear and Quadratic Association between Overall Productivity and BMI, 1980-2009

	log GDP per person engaged					
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	OLS	IV (crude survival probability)	IV (crude survival probability)	IV (crude survival probability, and age 75-79 survival probability)	IV (crude survival probability, and age 75-79 survival probability)
lagged log GDP per person engaged	1.07***	1.01***	1.07***	1.01***	1.07***	1.00***
	(0.05)	(0.04)	(0.05)	(0.05)	(0.05)	(0.04)
log mean body mass index 18+ years	0.91**	20.67***	1.90	19.47	2.16	25.94***
	(0.34)	(5.51)	(1.18)	(12.81)	(1.31)	(8.61)
(log mean body mass index 18+ years)²	-	−3.18***	-	−3.04	-	−4.05***
	-	(0.86)		(2.06)		(1.40)
Number of observations	47	47	47	47	47	47
Number of countries	47	47	47	47	47	47
R-squared	0.96	0.97	0.95	0.97	0.95	0.97
F test *p*-value	0.00	0.00	0.00	0.00	0.00	0.00
Weak identification test statistic	-	-	14.45	7.51	8.50	11.43
Endogeneity test *p*-value	-	-	0.33	0.54	0.38	0.33
Hansen J statistic	-	-	e.e.i.	e.e.i.	0.47	0.60
C (2nd polynomial) RESET test *p*-value	0.06	0.08	0.29	0.08	0.32	0.14
C (3rd polynomial) RESET test *p*-value	0.14	0.21	0.58	0.21	0.59	0.31
Turning points	-	25.79	-	-	-	24.62

Notes. Robust standard errors (SE)s are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All Columns are long-difference estimations with two observations per country for the years 1980 and 2009. The dependent variable is the log GDP per person engaged. Lagged log GDP per person engaged includes two observations per country for the years 1980 and 2005. In Column (3) log crude survival probability, and in Column (4) log crude survival probability, and its squared value are used as the instrumental variables. In Column (5) log crude survival probability, and log age 75-79 survival probability, and in Column (6) log crude survival probability, and log age 75-79 survival probability, and their squared values are used as instrumental variables. In Hansen J statistic, "equation exactly identified" term is represented by the term as "e.e.i." *C* (GMM-distance) RESET test uses Pesaran-Smith optimal forecast values. In (3), Stock-Yogo weak ID test critical value is 16.38. In (4), Stock-Yogo weak ID test critical value is 7.03. In (5), Stock-Yogo weak ID test critical value is 19.93. In (6), Stock-Yogo weak ID test critical value is 11.04. Turning point is estimated for coefficients at 10% or better significance level in a Column. Mean turning point of the estimations in Columns (2), and (6) is 25.20.

The estimations of cubic specification by Model (8) for the 1980-2009 period are shown in Columns (1) and (2) in Table 11, and Columns (1), (2), and (3) in Table 13. The coefficients of the linear, quadratic, and cubic terms are significantly different from zero at 10% significance level, and they are negative, positive, and negative, respectively, as can be seen in Column (2) in Table 11. The estimated turning point-1 is 20.03 kg/m^2 and turning point-2 is 24.78 kg/m^2 in this column. Also, the coefficients of the linear, quadratic, and cubic terms are insignificant in Column (1) in Table 11, and in Columns (1), (2), and (3) in Table 13.

The linear, quadratic, and cubic estimation results are reported in Tables 10, 11, 12, and 13. We observe that the coefficient estimates are statistically significant in the cases of quadratic specifications with FE and GMM estimations, as seen in Columns (2) and (4) in Table 10. In the GMM estimation, we do not reject AR (1), but we reject AR (2) providing consistent estimates. At the same time, the OLS estimation with quadratic specification is an efficient and valid estimation with statistically significant coefficient estimates, as seen in Column (2) of Table 12 and as explained in diagnostic tests. Therefore, we conclude that the relationship between overall productivity and BMI is a quadratic one with an inverse U-shape.

Table 13

Long-Difference Estimations for the Cubic Association between Overall Productivity and BMI, 1980-2009

	log GDP per person engaged		
	(1)	(2)	(3)
	OLS	IV (crude survival probability)	IV (crude survival probability, and age 75-79 survival probability)
lagged log GDP per person engaged	1.01***	1.01***	0.96***
	(0.04)	(0.13)	(0.06)
log mean body mass index 18+ years	200.30	−81.43	−844.10
	(222.96)	(1583.19)	(593.86)
(log mean body mass index 18+ years)^2	−60.47	29.48	275.22
	(70.54)	(511.48)	(190.78)
(log mean body mass index 18+ years)^3	6.09	−3.49	−29.87
	(7.43)	(55.07)	(20.43)
Number of observations	47	47	47
Number of countries	47	47	47
R-squared	0.97	0.97	0.94
F test *p*-value	0.00	0.00	0.00
Weak identification test statistic	-	0.06	0.73
Endogeneity test *p*-value	-	0.61	0.52
Hansen J statistic	-	e.e.i.	0.39
C (3rd polynomial) RESET test *p*-value	0.10	0.94	0.66
C (4rd polynomial) RESET test *p*-value	0.03	0.96	0.84
Turning points (1)	-	-	-
(2)	-	-	-

Notes. Robust standard errors (SE)s are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All Columns are long-difference estimations with two observations per country for the years 1980 and 2009. The dependent variable is the log GDP per person engaged. Lagged log GDP per person engaged includes two observations per country for the years 1980 and 2005. In Column (2) log crude survival probability, its squared, and cubed values are used as the instrumental variables. In Column (3) log crude survival probability, and log age 75-79 survival probability, and their squared, and cubed values are used as instrumental variables. In Hansen J statistic, "equation exactly identified" term is represented by the term as "e.e.i." *C* (GMM-distance) RESET test uses Pesaran-Smith optimal forecast values. In (2), Stock-Yogo weak ID test critical value is not available. In (3), Stock-Yogo weak ID test critical value is 12.20. Turning point is not estimated for coefficients less than 10% significance level in a Column.

6.4. Estimation Results for Manufacturing Productivity

6.4.1. Diagnostic tests

We demonstrate the linear and quadratic estimations in Table 14 and cubic specifications in Table 15. We display the long-difference estimation results for linear and quadratic specifications in Table 16 and cubic estimations in Table 17. For GMM estimations presented in Columns (3) and (4) of Table 14, and in Column (2) of Table 15, we reject the null hypothesis of Arellano-Bond AR (1) at 5%

significance level, whereas we do not reject the null hypothesis of AR (2). These results satisfy the Arellano-Bond estimation assumption stated in Arellano and Bond (1991), which increases the consistency of the estimation.

Table 14

The Linear and Quadratic Association between Manufacturing Productivity and BMI, 1980-2009

	log manufacturing productivity			
	(1)	(2)	(3)	(4)
	FE (within)	FE (within)	GMM (Arellano-Bond)	GMM (Arellano-Bond)
lagged log manufacturing productivity	0.74***	0.60***	0.52***	0.66***
	(0.06)	(0.05)	(0.08)	(0.14)
log mean body mass index 18+ years	2.64*	97.28***	4.26**	90.90**
	(1.37)	(23.81)	(1.97)	(41.06)
(log mean body mass index 18+ years)^2	-	−14.94***	-	−13.51**
		(3.66)		(6.12)
Number of observations	282	282	235	235
Number of countries	47	47	47	47
R-squared	0.60	0.66	-	-
F test *p*-value	0.00	0.00	0.00	0.00
Arellano-Bond test for AR (1) *p*-value	-	-	0.00	0.02
Arellano-Bond test for AR (2) *p*-value	-	-	0.11	0.17
Hansen test *p*-value	-	-	0.20	0.28
Country dummies	yes	yes	-	-
Time dummies	yes	yes	yes	yes
Turning points	-	25.96	-	28.90

Notes. Robust standard errors (SE)s are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All panels are balanced panels with one observation per five years and per country. The dependent variable is the log manufacturing productivity. Column (3) and (4) are difference GMM estimations. Turning point is estimated for coefficients at 10% or better significance level in a Column. Mean turning point of the estimations in Columns (2), and (4) is 27.43.

As seen in Table 16 and Table 17, the RESET test indicates that the null hypothesis fails to be rejected at 5% or better significance level; therefore, there is no functional form mis-specification.

The instrumental variables are crude survival and age 75-79 survival probabilities. All these instruments, and their squared and cubed values are valid instruments according to the weak identification test statistics (except for Columns (3) and (4) in Table 16, and Columns (2) and (3) in Table 17). Columns (3) and (4) in Table 16, and Columns (2) and (3) in Table 17 satisfy the rule of thumb that F statistics of the first stage should be at least ten or over (Staiger & Stock, 1997, p. 557; Baum et al., 2007, p. 490). However, the weak identification test results in Column (5) in Table 16 are not over the critical value[15] according to Stock and Yogo (2005). This test result shows that the instruments are not valid in this column. Therefore, OLS estimation with quadratic specification is an efficient and valid estimation (Column (2) of Table 16). Thus, we conclude that the relationship between manufacturing productivity and BMI is inverse U-shaped.

Table 15

The Cubic Association between Manufacturing Productivity and BMI, 1980-2009

	log manufacturing productivity	
	(1)	(2)
	FE (within)	GMM (Arellano-Bond)
lagged log manufacturing productivity	0.60***	−0.45
	(0.05)	(0.39)
log mean body mass index 18+ years	561.15	−13772.01**
	(611.99)	(6629.30)
(log mean body mass index 18+ years)^2	−162.48	4463.42**
	(193.31)	(2124.92)
(log mean body mass index 18+ years)^3	15.63	−482.04**
	(20.35)	(226.91)
Number of observations	282	235
Number of countries	47	47
R-squared	0.66	-
F test *p*-value	0.00	0.00
Arellano-Bond test for AR (1) *p*-value	-	0.04
Arellano-Bond test for AR (2) *p*-value	-	0.10
Hansen test *p*-value	-	0.49
Country dummies	yes	-
Time dummies	yes	yes
Turning points (1)	-	20.75
(2)	-	23.11

Notes. Robust standard errors (SE)s are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All panels are balanced panels with one observation per five years and per country. The dependent variable is the log manufacturing productivity. Column (2) is difference GMM estimation. Turning point is estimated for coefficients at 10% or better significance level in a Column.

Hansen J tests indicate that over-identification restrictions fail to be rejected at 10% significance level. This indicates that the set of instruments is appropriate at the given significance level. The

[15] The available critical value is 10% maximal IV size in Baum et al. (2007).

endogeneity test of BMI fails to be rejected (Table 16; Table 17) at 10% significance level. Thus, the OLS gives consistent and relatively more efficient estimates.

Table 16

Long-Difference Estimations for the Linear and Quadratic Association between Manufacturing Productivity and BMI, 1980-2009

	log manufacturing productivity					
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	OLS	IV (crude survival probability)	IV (crude survival probability)	IV (crude survival probability, and age 75-79 survival probability)	IV (crude survival probability, and age 75-79 survival probability)
lagged log manufacturing productivity	1.09***	0.98***	1.05***	0.96***	1.06***	0.96***
	(0.05)	(0.04)	(0.05)	(0.07)	(0.05)	(0.05)
log mean body mass index 18+ years	1.14*	40.99***	3.94	49.02*	3.29	50.90***
	(0.66)	(12.43)	(2.46)	(29.25)	(2.30)	(14.38)
(log mean body mass index 18+ years)²	-	−6.31***	-	−7.56	-	−7.89***
		(1.94)		(4.65)		(2.33)
Number of observations	47	47	47	47	47	47
Number of countries	47	47	47	47	47	47
R-squared	0.94	0.95	0.92	0.95	0.93	0.95
F test *p*-value	0.00	0.00	0.00	0.00	0.00	0.00
Weak identification test statistic	-	-	14.22	4.48	8.86	14.14
Endogeneity test *p*-value	-	-	0.16	0.86	0.25	0.16
Hansen J statistic	-	-	e.e.i.	e.e.i.	0.35	0.61
C (2nd polynomial) RESET test *p*-value	0.02	0.03	0.22	0.10	0.16	0.06
C (3rd polynomial) RESET test *p*-value	0.05	0.07	0.44	0.20	0.36	0.18
Turning points	-	25.70	-	-	-	25.19

Notes. Robust standard errors (SE)s are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All Columns are long-difference estimations with two observations per country for the years 1980 and 2009. The dependent variable is the log manufacturing productivity. Lagged log manufacturing productivity includes two observations per country for the years 1980 and 2005. In Column (3) log crude survival probability, and in Column (4) log crude survival probability, and its squared value are used as the instrumental variables. In Column (5) log crude survival probability, and log age 75-79 survival probability, and in Column (6) log crude survival probability, and log age 75-79 survival probability, and their squared values are used as instrumental variables. In Hansen J statistic, "equation exactly identified" term is represented by the term as "e.e.i." *C* (GMM-distance) RESET test uses Pesaran-Smith optimal forecast values. In (3), Stock-Yogo weak ID test critical value is 16.38. In (4), Stock-Yogo weak ID test critical value is 7.03. In (5), Stock-Yogo weak ID test critical value is 19.93. In (6), Stock-Yogo weak ID test critical value is 11.04. Turning point is estimated for coefficients at 10% or better significance level in a Column. Mean turning point of the estimations in Columns (2), and (6) is 25.45.

6.4.2. Estimation Results

Model (8) estimation results for linear specifications for the 1980-2009 period are demonstrated in Columns (1) and (3) in Table 14, and Columns (1), (3), and (5) in Table 16. It should be noted that α_2 and α_3 are restricted to zero. The coefficient of ln BMI is positive at 10% or better significance level as can be seen in Columns (1) and (3) in Table 14 and Column (1) in Table 16. Also, the coefficient of ln BMI is insignificant in Columns (3) and (5) in Table 16.

Columns (2) and (4) in Table 14, and Columns (2), (4), and (6) in Table 16 report the estimation results of Model (8) pertaining to the quadratic specifications for the 1980-2009 period. Here, α_3 is restricted to zero. The coefficients of the linear and quadratic terms are both significantly different from zero at 5% or better significance level, and they are positive and negative, respectively as can be seen in Columns (2) and (4) in Table 14, and Columns (2), and (6) in Table 16. The estimated turning points are within the range of 25.19-28.90 kg/m^2.

Table 17

Long-difference Estimations for the Cubic Association between Manufacturing Productivity and BMI, 1980-2009

	log manufacturing productivity		
	(1)	(2)	(3)
	OLS	IV (crude survival probability)	IV (crude survival probability, and age 75-79 survival probability)
lagged log manufacturing productivity	0.99***	0.96***	0.90***
	(0.04)	(0.06)	(0.09)
log mean body mass index 18+ years	466.03	(omitted)	−949.87
	(347.79)		(1137.84)
(log mean body mass index 18+ years)^2	−142.02	8.17**	314.32
	(110.60)	(3.21)	(365.85)
(log mean body mass index 18+ years)^3	14.43	−1.68**	−34.55
	(11.72)	(0.69)	(39.21)
Number of observations	47	47	47
Number of countries	47	47	47
R-squared	0.95	0.95	0.93
F test *p*-value	0.00	0.00	0.00
Weak identification test statistic	-	0.00	0.61
Endogeneity test *p*-value	-	0.96	0.28
Hansen J statistic	-	e.e.i.	0.42
C (3rd polynomial) RESET test *p*-value	0.05	0.50	0.57
C (4rd polynomial) RESET test *p*-value	0.05	0.39	0.27
Turning points (1)	-	25.46	-
(2)	-	-	-

Notes. Robust standard errors (SE)s are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All Columns are long-difference estimations with two observations per country for the years 1980 and 2009. The dependent variable is the log manufacturing productivity. Lagged log manufacturing productivity includes two observations per country for the years 1980 and 2005. In in Column (2) log crude survival probability, its squared, and cubed values are used as the instrumental variables. In Column (3) log crude survival probability, and log age 75-79 survival probability, and their squared, and cubed values are used as instrumental variables. In Hansen J statistic, "equation exactly identified" term is represented by the term as "e.e.i." *C* (GMM-distance) RESET test uses Pesaran-Smith optimal forecast values. In (2), Stock-Yogo weak ID test critical value is not available. In (3), Stock-Yogo weak ID test critical value is 12.20. Turning point is estimated for coefficients at 10% or better significance level in a Column.

In addition, Column (4) in Table 16 shows that the coefficient of the quadratic term is insignificant. Thus, the quadratic functional specification estimation results suggest that there is a non-monotonic and inverse U-shaped association between manufacturing productivity and BMI for the 1980-2009 period.

The estimation results of cubic specifications by Model (8) for the 1980-2009 period are reported in Columns (1) and (2) in Table 15, and Columns (1), (2), and (3) in Table 17. The coefficients of the linear, quadratic, and cubic terms were found to be significantly different from zero at 5% or better significance level, and they are negative, positive, and negative, respectively as shown in Column (2) in Table 15. The estimated turning point-1 is 20.75 kg/m^2 and turning point-2 is 23.11 kg/m^2 in Column (2) of Table 15.

At the same time, we find that the coefficient of the linear term is omitted, and the coefficients of the quadratic and the cubic terms are significantly different from zero at 5% or better significance level, and they are positive and negative, respectively as in Column (2) in Table 17.

In addition, the coefficients of the linear, quadratic, and cubic terms are significantly different from zero at 1% significance level, and they are positive, negative, and positive respectively as shown in Column (1) in Table 15. Also, the coefficients of the linear, quadratic, and cubic terms are insignificant as can be seen in Column (2) in Table 15, and in Columns (1) and (3) in Table 17.

The linear, quadratic, and cubic estimation results are reported in Tables 14, 15, 16, and 17. We observe that the coefficient estimates are statistically significant in the cases of quadratic specifications with FE and GMM estimations as seen in Columns (2) and (4) in Table 14. In the GMM estimation, we do not reject AR (1), but we reject AR (2) providing consistent estimates. At the same time, the OLS estimation with quadratic specification is an efficient and valid estimation with statistically significant coefficient estimates, as seen in Column (2) of Table 16 and as explained in diagnostic tests. Therefore, we conclude that the relationship between manufacturing productivity and BMI is a quadratic one with an inverse U-shape.

6.5. Estimation Results for Gross Domestic Savings

6.5.1. Diagnostic tests

We present the linear and quadratic estimations in Table 18 and cubic specifications in Table 19. We display the long-difference estimation results for linear and quadratic specifications in Table 20 and cubic estimations in Table 21. As regards GMM estimations presented in Columns (3) and (4) of Table 18, and in Column (2) of Table 19, we reject the null hypothesis of Arellano-Bond AR (1) at 5% or better significance level, whereas we do not reject the null hypothesis of AR (2). These results satisfy the Arellano-Bond estimation assumption stated in Arellano and Bond (1991), which increases the consistency of the estimation.

Table 18

The Linear and Quadratic Association between Gross Domestic Savings and BMI, 1980-2009

	Gross domestic savings			
	(1)	(2)	(3)	(4)
	FE (within)	FE (within)	GMM (Arellano-Bond)	GMM (Arellano-Bond)
lagged gross domestic savings	0.32***	0.29***	0.51*	0.45***
	(0.09)	(0.10)	(0.26)	(0.16)
log mean body mass index 18+ years	26.14	790.88**	23.92	623.62**
	(29.00)	(315.34)	(54.19)	(233.61)
(log mean body mass index 18+ years)^2	-	−121.53**	-	−95.52**
		(51.48)		(37.97)
Number of observations	282	282	235	235
Number of countries	47	47	47	47
R-squared	0.17	0.19	-	-
F test *p*-value	0.01	0.00	0.01	0.00
Arellano-Bond test for AR (1) *p*-value	-	-	0.02	0.01
Arellano-Bond test for AR (2) *p*-value	-	-	0.48	0.41
Hansen test *p*-value	-	-	0.43	0.48
Country dummies	yes	yes	-	-
Time dummies	yes	yes	yes	yes
Turning points	-	25.89	-	26.16

Notes. Robust standard errors (SE)s are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All panels are balanced panels with one observation per five years and per country. The dependent variable is the gross domestic savings (percent of GDP). Column (3) and (4) are difference GMM estimations. Turning point is estimated for coefficients at 10% or better significance level in a Column. Mean turning point of the estimations in Columns (2), and (4) is 26.02.

As can be seen in Table 20 and Table 21, the RESET test indicates that the null hypothesis fails to be rejected at 5% or better significance level. This indicates that there is no functional form mis-specification.

Table 19

The Cubic Association between Gross Domestic Savings and BMI, 1980-2009

	Gross domestic savings	
	(1)	(2)
	FE (within)	GMM (Arellano-Bond)
first lagged gross domestic savings	0.28***	-
	(0.10)	
second lagged gross domestic savings	-	−0.19**
		(0.09)
log mean body mass index 18+ years	10704.21	27026.11
	(11881.24)	(24659.41)
(log mean body mass index 18+ years)^2	−3271.67	−8397.85
	(3783.89)	(7796.13)
(log mean body mass index 18+ years)^3	333.41	870.01
	(401.00)	(820.64)
Number of observations	282	188
Number of countries	47	47
R-squared	0.19	-
F test *p*-value	0.00	0.03
Arellano-Bond test for AR (1) *p*-value	-	0.04
Arellano-Bond test for AR (2) *p*-value	-	0.71
Hansen test *p*-value	-	0.32
Country dummies	yes	-
Time dummies	yes	yes
Turning points (1)	-	-
(2)	-	-

Notes. Robust standard errors (SE)s are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All panels are balanced panels with one observation per five years and per country. The dependent variable is the gross domestic savings (percent of GDP). Column (2) is difference GMM estimation. Turning point is not estimated for coefficients less than10% significance level in a Column.

The instrumental variables are the crude survival and age 75-79 survival probabilities and their squared and cubed values in Tables 20 and 21. The weak identification test statistics is not satisfied in any of the IV estimations, except in the quadratic specification with crude survival probability IV as seen in Column (4) of Table 20. The weak identification test statistics is over the critical value[16] (Stock & Yogo,

[16] The available critical value is 10% maximal IV size in Baum et al. (2007).

2005). Further, in this case, the endogeneity test indicates that exogeneity is not rejected. Therefore, OLS estimation with quadratic specification is an efficient and valid estimation (Column (2) of Table 20). Thus, we conclude that the association between savings and BMI is inverse U-shaped.

Hansen J tests indicate that over-identification restrictions fail to be rejected at 10% or better significance level, providing evidence that the set of instruments is appropriate at the given significance level.

Table 20

Long-Difference Estimations for the Linear and Quadratic Association between Gross Domestic Savings and BMI, 1980-2009

	Gross domestic savings					
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	OLS	IV (crude survival probability)	IV (crude survival probability)	IV (crude survival probability, and age 75-79 survival probability)	IV (crude survival probability, and age 75-79 survival probability)
lagged gross domestic savings	0.85***	0.80***	0.85***	0.81***	0.85***	0.82***
	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.06)
log mean body mass index 18+ years	15.70	546.00***	41.97	532.60	37.79	386.45*
	(16.77)	(191.00)	(44.94)	(337.63)	(37.73)	(199.68)
(log mean body mass index 18+ years)^2	-	−85.12***	-	−82.88	-	−60.49*
		(30.40)		(52.70)		(33.44)
Number of observations	47	47	47	47	47	47
Number of countries	47	47	47	47	47	47
R-squared	0.77	0.79	0.76	0.79	0.76	0.79
F test *p*-value	0.00	0.00	0.00	0.00	0.00	0.00
Weak identification test statistic	-	-	14.11	8.13	8.29	7.63
Endogeneity test *p*-value	-	-	0.48	0.997	0.48	0.58
Hansen J statistic	-	-	e.e.i.	e.e.i.	0.81	0.91
C (2nd polynomial) RESET test *p*-value	0.23	0.43	0.18	0.50	0.18	0.53
C (3rd polynomial) RESET test *p*-value	0.31	0.26	0.31	0.35	0.30	0.29
Turning points	-	24.71	-	-	-	24.39

Notes. Robust standard errors (SE)s are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All Columns are long-difference estimations with two observations per country for the years 1980 and 2009. The dependent variable is the gross domestic savings (percent of GDP). Lagged gross domestic savings (percent of GDP) includes two observations per country for the years 1980 and 2005. In Column (3) log crude survival probability, and in Column (4) log crude survival probability, and its squared value are used as the instrumental variables. In Column (5) log crude survival probability, and log age 75-79 survival probability, and in Column (6) log crude survival probability, and log age 75-79 survival probability, and their squared values are used as instrumental variables. In Hansen J statistic, "equation exactly identified" term is represented by the term as "e.e.i." *C* (GMM-distance) RESET test uses Pesaran-Smith optimal forecast values. In (3), Stock-Yogo weak ID test critical value is 16.38. In (4), Stock-Yogo weak ID test critical value is 7.03. In (5), Stock-Yogo weak ID test critical value is 19.93. In (6), Stock-Yogo weak ID test critical value is 11.04. Turning point is estimated for coefficients at 10% or better significance level in a Column. Mean turning point of the estimations in Columns (2), and (6) is 24.55.

6.5.2. Estimation Results

The results pertaining to the estimation of linear specification (Model 8) for the 1980-2009 period are given in Columns (1) and (3) in Table 18, and Columns (1), (3), and (5) in Table 20. In linear specification in this model, α_2 and α_3 are restricted to be zero. In Columns (1) and (3) in Table 18 and in Columns (1), (3), and (5) in Table 20, the coefficient of ln BMI was found to be insignificant.

Table 21

Long-Difference Estimations for the Cubic Association between Gross Domestic Savings and BMI, 1980-2009

	Gross domestic savings		
	(1)	(2)	(3)
	OLS	IV (crude survival probability)	IV (crude survival probability, and age 75-79 survival probability)
lagged gross domestic savings	0.80***	0.82***	0.82***
	(0.07)	(0.10)	(0.07)
log mean body mass index 18+ years	4565.95	15092.52	18704.16
	(6763.42)	(72565.06)	(21350.49)
(log mean body mass index 18+ years)^2	−1366.73	−4770.99	−5929.12
	(2167.33)	(23403.75)	(6851.12)
(log mean body mass index 18+ years)^3	136.09	502.84	626.40
	(231.09)	(2513.91)	(732.64)
Number of observations	47	47	47
Number of countries	47	47	47
R-squared	0.79	0.78	0.77
F test *p*-value	0.00	0.00	0.00
Weak identification test statistic	-	0.07	0.98
Endogeneity test *p*-value	-	0.97	0.58
Hansen J statistic	-	e.e.i.	0.84
C (3rd polynomial) RESET test *p*-value	0.21	0.20	0.34
C (4rd polynomial) RESET test *p*-value	0.37	0.36	0.53
Turning points (1)	-	-	-
(2)	-	-	-

Notes. Robust standard errors (SE)s are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All Columns are long-difference estimations with two observations per country for the years 1980 and 2009. The dependent variable is the gross domestic savings (percent of GDP). Lagged gross domestic savings (percent of GDP) includes two observations per country for the years 1980 and 2005. In Column (2) log crude survival probability, its squared, and cubed values are used as the instrumental variables. In Column (3) log crude survival probability, and log age 75-79 survival probability, and their squared, and cubed values are used as instrumental variables. In Hansen J statistic, "equation exactly identified" term is represented by the term as "e.e.i." *C* (GMM-distance) RESET test uses Pesaran-Smith optimal forecast values. In (2), Stock-Yogo weak ID test critical value is not available. In (3), Stock-Yogo weak ID test critical value is 12.20. Turning point is not estimated for coefficients less than 10% significance level in a Column.

The estimations for quadratic specification by Model (8) for the 1980-2009 period are presented in Columns (2) and (4) in Table 18, and Columns (2), (4), and (6) in Table 20. Here α_3 is restricted to be zero. The coefficients of the linear and quadratic terms are both significantly different from zero at 10% or better significance level, and they are positive and negative, respectively, as shown in Columns (2) and (4) in Table 18, and Columns (2) and (6) in Table 20. The estimated turning points are within the range of 24.39-26.16 kg/m^2 in these columns.

In addition, the coefficients of the linear and the quadratic terms are insignificant as seen in Column (4) in Table 20. However, the OLS estimation with quadratic specification is an efficient and valid estimation. Therefore, the quadratic functional specification estimation results suggest a non-monotonic and inverse U-shaped association between gross domestic savings and BMI for the 1980-2009 period.

As far as the cubic specification for the 1980-2009 period is concerned, Columns (1) and (2) in Table 19, and Columns (1), (2), and (3) in Table 21 report the estimation results of Model (8). The coefficients of the linear, quadratic, and cubic terms are insignificant in these columns.

The linear, quadratic, and cubic estimation results are reported in Tables 18, 19, 20, and 21. We observe that the coefficient estimates are statistically significant in the cases of quadratic specifications with FE and GMM estimations in Columns (2) and (4) in Table 18. In the GMM estimation, we do not reject AR (1), but we reject AR (2) providing consistent estimates. At the same time, the OLS estimation with quadratic specification is an efficient and valid estimation with statistically significant coefficient estimates in Column (2) of Table 20 as it is explained in diagnostic tests. Therefore, we conclude that the association between savings and BMI is a quadratic one with inverse U-shape.

7. Conclusions

This study examines the effects of BMI on GDP per capita, years of schooling (human capital), overall productivity, manufacturing productivity, and gross domestic savings for the 1980-2009 period. The empirical results are generally in agreement with the findings related to GDP per capita growth- life expectancy association in Azomahou et al. (2009). There are non-linear and non-monotonic relationships between all dependent variables and BMI. These findings support our assumption concerning the impact of BMI as a human physiological function on life expectancy via aging.

Correspondingly, Tosato et al. (2007) confirms that while protecting appropriate nutrient intake for human functions, aging can be steadily slowed down with a healthy diet. Accordingly, Falk et al. (2019) show that patience and future-oriented preferences can be obtained through health interventions which improve longevity. To conclude, the empirical findings of the present study yield significant evidence that healthy mean population BMI level secures economic development by promoting savings. The following paragraphs present detailed concluding remarks about the effects of BMI on all the dependent variables which we considered and which represent economic development and growth.

For GDP per capita, in linear specification, the coefficient of BMI is positive at 5% or better significance level. In addition, in quadratic specification, the coefficients of the linear and quadratic terms are both significantly different from zero at 5% or better significance level, and they are positive and negative, respectively. The estimated turning points in quadratic specification are within the range of 24.51-28.61 kg/m^2. Also, in cubic specification, the coefficients of the linear, quadratic, and cubic terms are significantly different from zero at 5% or better significance level, and they are negative, positive, and negative, respectively. This relationship is first convex-, and, then concave-shaped. In the latter, the estimated turning point-1 is 19.88 kg/m^2, and the turning point-2 is 25.93 kg/m^2. Although there is evidence that the relationship could be cubic, we take the results of the long-difference quadratic specification into account and conclude that the relationship between GDP per capita and BMI is inverse U-shaped.

According to human capital results, in linear specification, the coefficient of BMI is positive at 5% significance level. In quadratic specification, on the other hand, the coefficients of the linear and quadratic terms are both significantly different from zero at 10% or better significance level, and they are positive and negative, respectively. The estimated turning points in quadratic specification are within the range of 23.13-29.77 kg/m^2. Cubic specification produced insignificant coefficients of the linear, quadratic, and cubic terms for the association between years of schooling and BMI. For this reason, we suggest that there is a non-monotonic and inverse U-shaped association between years of schooling and BMI.

For overall productivity, the coefficient of BMI for the linear specification was observed to be positive at 5% or better significance level. For the quadratic specification, the coefficients of both the linear and quadratic terms are significantly different from zero at 5% or better significance level, and they are positive and negative, respectively. For the quadratic specification, the estimated turning points are within the range of 24.62-27.69 kg/m^2. Also, in cubic specification, the coefficients of the linear, quadratic, and cubic terms are significantly different from zero at 10% or better significance level, and they are negative, positive, and negative, respectively. The association is first convex-, and, then concave-shaped. In the convex-concave-shaped association, the estimated turning point-1 is 20.03 kg/m^2; and turning point-2 is 24.78 kg/m^2. Although there is evidence that the relationship could be cubic, we take the results of the long-difference quadratic specification into account and conclude that the relationship between overall productivity and BMI is inverse U-shaped.

Considering manufacturing productivity, the BMI coefficient in the linear specification was found to be positive at 10% or better significance level. For quadratic specification, the coefficients of both the linear and quadratic terms are significantly different from zero at 5% or better significance level, and they are positive and negative, respectively. For the quadratic specification, the estimated turning points are within the range of 25.19-28.90 kg/m^2. Further, in cubic specification, the coefficients of the linear, the quadratic, and the cubic terms are significantly different from zero at 5% or better significance level, and they are negative, positive, and negative, respectively. The association is first convex-, and then concave- shaped. In the latter, the estimated turning point-1 is 20.75 kg/m^2; and turning point-2 is 23.11 kg/m^2. Although there is evidence that the relationship could be cubic, we take the results of the long-difference quadratic specification into account and conclude that the relationship between manufacturing productivity and BMI is inverse U-shaped.

For gross domestic savings, the coefficient of BMI in the linear specification is found to be negative at 1% significance level. In addition, in quadratic specification, the coefficients of both the linear and quadratic terms are significantly different from zero at 10% or better significance level, and they are positive and negative, respectively. For the quadratic specification, the estimated turning points are within the range of 24.39-26.16 kg/m^2. The cubic specification produced insignificant coefficients of the linear, quadratic, and cubic terms as regards the association between gross domestic savings and BMI. Therefore, we suggest that there is a non-monotonic and inverse U-shaped relationship between gross domestic savings and BMI.

The endogeneity of BMI is taken into account, and the reverse causality between the growth indicators and BMI is responded with using the instrumental variable estimation through the crude survival and age 75-79 survival probabilities as instrumental variables. By introducing reverse causality in their estimations, Husain et al. (2014) suggest that the shape of the wealth-health curve could be inverse U-shaped. This result of Husain et al. (2014) also generally agrees with our findings as mentioned above. Husain et al. (2014) suggest that health affects wealth through several channels such as savings and education.

By using long-difference IV estimations, we have an opportunity to show the causal effect of BMI on growth indicators, including savings and schooling, which are also referred to as channels in Husain et al. (2014). Therefore, in this study, we show that BMI, as the representative of the cognitive ability, may positively affect growth indicators only in healthy BMI thresholds through the channels of schooling, overall and manufacturing productivities, and savings. This finding is also generally in agreement with the function in Dasgupta (1997, pp. 13-15) which demonstrates the relationship between the probability of someone not having a health problem and a BMI that remains steady between 18.5 and 25 kg/m^2.

According to our reasoning, we evaluate that the nonlinear relationship between growth indicators and BMI, which we observed roughly outside the healthy BMI thresholds in the estimations of our study, is due to the accumulated deformations of the breaks in the cognitive ability-skill-development cycle of each individual. Therefore, assuming that the economic ecosystem should include everyone in a country, we may conclude that these ability breaks of individuals and the accumulated deformations of these breaks in the economic ecosystem undermine the sustainability of macro and micro economic activities.

In our view, if the social infrastructure and economic ecosystem fix the breaks in the cognitive ability-skill-development cycle of each individual and the accumulated deformations of these breaks, economic sustainability will be progressed. According to Hall and Jones (1999) and Bigsten and Levin (2004), macro and micro-level adjustments can be applied in the economic ecosystem and social infrastructure to address these disruptions.

An applicable mixture of evolutionary, induced, and path dependence innovation approaches, cited from Dosi (1984) in Ruttan (2001, pp. 100-146), may be utilized to design the compatible economic ecosystem and social infrastructure supporting the cognitive ability-skill-development cycle of each individual. Furthermore, appropriate suggestions in Rae (1834/1905, p. 58), Rayner and Lang (2012), Stiglitz (2012, 2020), and Mazzucato (2021) may be taken into consideration for this process.

Related to these innovation activities, Rae (1834/1905, p. 58) recommends a combination of several issues to enhance the accumulation of the factors of production: firstly, social, altruistic, and future-oriented behaviors in the community; secondly, expansion of the power of the cognitive ability and its reflection in the foresight and in the wisdom of the members of the society; and lastly, the stability of the public interactions via the rule of law and order.

These innovation efforts may promote better public health standards that may help establish BMI-friendly schools, workplaces, and other local environments. Some recent examples of innovative technologies are healthy diet foods (Rayner & Lang, 2012).

Furthermore, connected with all these contexts, there are several suggestions by Stiglitz (2012, 2020) for sustainable economic development and growth. One of them is attaining education easily in the community and then turning education into income, equality provider, and guarantor. Another suggestion is enhancing the saving ability of the society and transforming these savings into resources, full employment creative, and protective investments, and innovations. The next direction is ensuring the easy access of the public to health care and social protection initiatives.

Mazzucato (2021) gives the clear-cut-examples of induced innovation approaches for several challenges, such as “ageing society” and “citizen health and wellbeing”, which may help establish a compatible economic ecosystem and social infrastructure that can support the cognitive ability-skill-development cycle of each individual.

Finally, we believe that an individual's positive contribution to economic activities may not end with only death but also with the loss or disability of cognitive ability before death. Therefore, we may predict that the earlier and widespread loss of or injury in cognitive abilities may also affect this contribution and may make it impossible for each individual to operate the cognitive ability-skill-development cycle.

As a proxy for nutritional status, BMI is one of the channels that may affect the loss of or the injury in the cognitive ability-skill-development-cycle of each individual, depending on its thresholds. Policy implications that focus on preventive measures for the loss of the cognitive ability-skill-development cycle contents and channels and on treatment activities for the injury in the cycle may also help establish the compatible economic ecosystem and social infrastructure supporting sustainable economic development.

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Appendix

The Country List

Countries in balanced panel data are listed as follows: Argentina, Brazil, Chile, Colombia, Ecuador, Paraguay, Peru, Uruguay, and Venezuela in South America; Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama in Central America; Canada, Mexico, and the United States of America in North America; Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom in Europe; Bangladesh, China, India, Indonesia, Malaysia, Myanmar, Pakistan, Philippines, South Korea, Sri Lanka, and Thailand in Asia; Australia; New Zealand in the Southwestern Pacific Ocean.