Health, Nutrition and Economic Prosperity: A Micro-Economic Perspective

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ABSTRACT

The positive correlation between health and economic prosperity has been widely documented. The extent to which this reflects a causal effect of health on economic outcomes is very controversial. Two classes of evidence are examined. Carefully designed random assignment laboratory and field studies provide compelling evidence that nutrient deficiency -- particularly iron -- reduces work capacity and, in some cases, work output. Confidence in these results is bolstered by a good understanding of the underlying biological mechanisms. Some random assignment studies indicate improved health services yield returns in the labor market. Observational studies suggest that general dimensions of nutritional status, such as height and body mass index, are significant predictors of economic success although their interpretation is confounded because they reflect influences of early childhood investments and family background. Energy intake and possibly diet quality have also been found to be predictive of economic success in observational studies. However, identification of causal pathways in observational studies is difficult and involves statistical assumptions about unobserved heterogeneity that are difficult to test. Illustrations using survey data demonstrate the practical importance of this concern. Furthermore, failure to take into account the dynamic interplay between changes in health and economic status has limited progress in this literature. Broadening random assignment studies to measure effects of an intervention on economic prosperity, investing in population-based longitudinal socio-economic surveys, and exploiting emerging technologies to better measure health in those surveys will yield very high returns in developing a better understanding of how health influence economic prosperity.

KEYWORDS: Economic productivity; wages; nutrition; iron deficiency; random assignment; observational; longitudinal survey; Indonesia.

1. Introduction

Health and economic prosperity go hand in hand. In micro and macro data, there is abundant evidence that a wide array of health indicators are positively associated with many different dimensions of economic prosperity. (See *(1)* for an excellent review.) Explanations for this association have been much debated.

A central issue has been isolating the causal pathways linking health and economic outcomes. Causality likely runs in both directions. First, higher income individuals invest more in human capital, including health: as income grows, individuals invest in better diets, improved sanitation and better health care. Second, if a healthier worker is less susceptible to disease, more alert and more energetic, then he or she will probably be more productive and command higher earnings.

This paper focusses on the second pathway and examines the scientific evidence regarding the effect of health on economic prosperity in low income settings from a micro-economic perspective. While establishing this link is not straightforward, the weight of the evidence points to nutrition, and possibly other dimensions of health, as significant determinants of economic productivity.

We first discuss experimental and quasi-experimental studies which randomize subjects into treatment and control groups and examine the impact of an intervention. These studies provide direct evidence on the causal effect of health on the outcomes studied. We then turn to observational studies which are typically based on survey data and estimated in conjunction with a model of behavior that seeks to provide a plausible argument for interpreting the evidence in a causal framework. We conclude that exploiting the advantages associated with each of these complementary approaches will likely yield important insights into understanding the pathways through which health affects economic prosperity.

2. Experimental and quasi-experimental studies of health and labor outcomes

The link between nutrition and productivity arguably provides the best documented evidence on inter-relationships between health and economic prosperity. Moreover, evidence suggests that, along with genotype and environmental influences, diet plays a role in the etiology of many chronic diseases. We focus first, therefore, on nutrition.

Substantial strides have been made in our understanding of the links between nutrition and health in low income settings. Attention has shifted from focusing primarily on inadequate energy or protein intake to incorporating the influence of micro-nutrients such as iron, iodine, zinc, calcium and several key vitamins. This literature suggests that labor outcomes are probably influenced by both macro- and micro-nutrients.

Experimental designs are well-suited to isolate the impact of specific nutrients on labor outcomes. Several studies have demonstrated there is a causal effect of iron deficiency on reduced work capacity. *(2)* provides an excellent review.

Iron plays an essential role in oxidative energy production. Iron deficient anemia (IDA, low levels of hemoglobin in combination with low iron stores) is associated with, *inter alia,* greater susceptibility to disease, fatigue and reduced cognitive development. IDA affects physical activity through two main

pathways. As hemoglobin levels decline, the maximum amount of oxygen the body can use (aerobic capacity) declines. As iron stores are depleted, the amount of oxygen available to muscles declines, reducing endurance and causing the heart to work harder for the same activity.

Animal and human studies demonstrate a causal relationship between iron deficiency and reduced maximum aerobic capacity (VO_2max) which changes by about 25-30% as subjects are made anemic or receive adequate iron supplementation *(3, 4)*. IDA is also associated with reduced endurance at below maximal work rates *(5, 2)*.

Demonstrating iron deficiency impedes maximal capacity and endurance does not reveal the economic consequences of iron deficiency in daily life. Those consequences may be more closely aligned with energy efficiency (the amount of physiological energy required to perform a given task) *(6)*. In a randomized treatment-control study, Chinese female cotton mill workers who received iron supplementation for 12 weeks had a 5% increase in gross and net energetic efficiencies relative to the controls who received a placebo. Treatments had significantly reduced heart rates and a 17% increase in production efficiency but no increase in work output, perhaps because output was constrained by the (conveyor belt) technology of the mill (and depended on output of co-workers). Treated women did, however, spend more time and expend more energy on non-work activities *(4)*. Similarly, Sri Lankan female tea plantation workers receiving iron supplementation did not increase their output but did increase their voluntary activity *(7)*.

A longitudinal study of male rubber workers in Indonesia provides the strongest evidence that iron status causally affects economic productivity *(8)*. At baseline, 45% of the study population was anemic (hemoglobin$\leq$13g/dl). Among the anemic, baseline productivity (latex collected) was about 20% lower than that of non-anemic workers. Workers were randomly assigned to iron supplementation or placebo. After 60 days, blood hemoglobin, aerobic capacity and work output of those who were initially anemic, and received the treatment, increased to nearly the levels of the non-anemic workers (whose biological indicators did not change). Among anemic controls, productivity and blood hemoglobin levels also rose, although the increase was substantially smaller than among treatments (probably reflecting the effect of incentive payments made to subjects). These results suggest that iron supplementation can raise the output of workers who are IDA by around 20%. This is a very large effect. A potentially serious issue not addressed in the study is the possibility of selective attrition: 156 workers were included in the study but the final analytical sample included only 77 workers. If those who did not benefit from supplementation were more likely to attrit from the study, then the estimated effect of supplementation will be biased upwards.

In sum, clinical and field studies demonstrate iron deficiency affects aerobic capacity, endurance, energy efficiency and output. Studies of children indicate important impacts on cognition *(9)*. These mechanisms suggest a sizeable impact on economic success although there is controversy about the magnitude of that effect with large impacts having been found in only a few studies. Important questions about whether workers change their behavior in response to iron supplementation remain. Results from the Chinese and Sri Lankan studies are important because they suggest iron deficiency had little impact on productivity but did affect how individuals allocate their time. If iron supplementation improves the health and well-being of individuals, we expect they will not only be more productive at work but in other

domains of their lives. Also, they may respond to these changes in many ways such as changing the nature of their work and time spent on work. The full array of these responses are important to understand but difficult to capture in experiments which, by design, isolate specific inputs and outputs in a controlled fashion. We return to this issue below.

Relative to results for iron, studies of less specific food supplementation interventions are not as clear. Sugar cane cutters in Guatemala who received calorie supplements were no more productive than controls (10, 11) although, because randomization was at the village level, changes in productivity between villages during the study may confound the estimates. In contrast, calorie supplementation had a small but significant positive impact on the amount of road dug by construction workers in Kenya where the 47 study subjects were randomized at the individual level (12).

Experiments and quasi-experiments indicate that several domains of health other than nutrition have a causal impact on economic prosperity. A recent experiment in Britain randomly assigned men with back pain to an exercise program (the treatment) or usual primary care management (the control). After a year, the treatments reported less back pain and fewer days of missed work relative to the controls (13).

Changes in the price of health care have served as useful tools for assessing the impact of health on labor outcomes. The RAND Health Insurance Experiment (HIE) randomly assigned subjects to different combinations of deductibles and co-payments. Those who received free care used more health care; health benefits were limited to the poorest and sickest (14). However, females who received free care increased their labor force participation rate relative to other females; a similar finding emerged for males who had not completed high school.

A similar experiment in Indonesia involved changes in the prices of health services. User fees at public health centers were raised in randomly selected "treatment" districts while prices were held constant (in real terms) in neighboring "control" districts. Two years after the intervention, relative to control areas, health care utilization and labor force participation had declined in treatment areas (where prices increased). Reductions in employment were particularly large (and significant) for men and women at the bottom of the education distribution, those whom we would expect to be the most vulnerable. The most plausible interpretation of both the HIE and Indonesian results is that the average treatment effects on labor supply indicate a causal role of improved health on the allocation of time to the labor market (15).

Results from Canada support this conclusion. During the 1960s and early 1970s, Canada introduced national health insurance. Exploiting the fact that the introduction of the system was phased across provinces and occupations, Gruber and Hanratty (16) find that employment and wages increased as workers were covered by national health insurance. The authors conclude that labor demand rose because workers were more productive, either because of increased job mobility and therefore better matching of skills or because their health improved as a result of being covered by health insurance.

The introduction of national health insurance was not designed as an experiment, but this study takes advantage of the fact that some people were covered by the system earlier than others. The plausibility of the results rests crucially on the extent to which this "natural experiment" approximates random assignment. (The authors provide a compelling argument in favor of this interpretation.) It is

feasible to design health interventions to provide a similar "natural experimental" in order to evaluate the effect of the intervention -- on health status and on other outcomes including economic prosperity. It is unfortunate that there have been relatively few such designs.

Experiments and quasi-experiments have many advantages but potential pitfalls as well. First, if treatments benefit from the intervention and controls do not, attrition is likely to be selective. Failure to take that into account can undermine the results and unravel the key advantages of an experimental evaluation. Second, most interventions in this literature have targeted specific individuals. If individuals share the benefits of the intervention with other family members, then the effects of the intervention on the subjects may be under-estimated. For example, workers who receive a calorie supplement may eat less food at home and, therefore, other family members share in the "treatment." This raises the more general issue noted above of complex behavioral responses to interventions. Third, the effects of intervening may be difficult to detect in some institutional settings. Chinese cotton mill workers provide an example: the technology of production limits the scope for increases in output of treatments. Immediate effects of supplementation on work output among these workers are muted but workers who receive supplementation may ultimately reap the benefits of elevated productivity by moving to other tasks, other factories or other jobs. These impacts will be missed in studies that do not follow subjects long enough. The Chinese study also suggests that focussing on productivity misses an important link between health and prosperity. In addition to changes in work, healthier workers may allocate more time to leisure and home production which may result in increased levels of well-being. Enhanced productivity of parents at home may also benefit their children.

3. Observational studies of nutrition and economic prosperity

Many early studies of health and productivity focused on calorie intakes. The first generation of studies demonstrated calories and economic output are positively correlated. Subsequent studies highlighted the importance of unobserved heterogeneity and showed that, when controlled, these positive associations disappear *(20, 21)*. However, treating calories as a choice, studies have found that farm output and wages of males rise with calorie intake *(17, 18* respectively). Moreover, *per capita* calorie and protein intakes have a significant impact on hourly earnings of both the self-employed and employees and earnings increase with improvements in diet quality (fraction of calories consumed from protein) *(19)*. Arguing that piece-rates are better indicators of productivity than wages, *(22, 23)* report piece-rate output is affected by calorie intake even after controlling individual-specific fixed effects.

A positive impact of calorie intake on productivity is consistent with results from the INCAP study of school children in Guatemala in which treatments were given a high calorie supplement while controls were not. The treatments were healthier, performed better in school and had greater work capacity (V0$_2$max) in early adulthood *(24)*. However, interpretation of even these results have been questioned since the supplement was rich in several key micro-nutrients *(25)*.

Because nutrient intakes are difficult to measure in household surveys, researchers have turned to anthropometry. Hands down, the best documented fact in observational studies is that there is a significant

return to height in the labor market. Seminal work by Fogel *(26)* documented secular increases in height which parallel economic growth in the historical literature. Similar patterns have been documented for many of today's low income countries. The upper panel of Figure 1 displays the relationship between year of birth and attained height of male and female adults who were measured in the 1997 wave of the Indonesia Family Life Survey (IFLS). There was substantial growth in attained adult height during the generation prior to the 1955 birth cohort -- an average of about 1.5 cms in each decade. Subsequent cohorts have not fared as well. The figure in the lower panel overlays real GNP *per capita* in the year of birth for the period after 1947. Bearing in mind that adult stature is largely determined during the first few years of life, including the fetal period, the effects of economic downturns during those years in a person's life will plausibly be reflected in attained height of an adult. Apparently the link between downturns in the macro-economy and individual stature is extremely complex and suggests that the scope for households to shift resources across time and among members is considerable. See *(27)* for more detail.

At the micro level, many studies have demonstrated a positive impact of height on hourly earnings. (See *(28)* for a review.) Figure 2 displays the association for adult males in IFLS2: a 1% increase in height is associated with a 5% increase in earnings. While this empirical result is very robust, its interpretation is complex. Taller people are probably stronger -- an attribute that is probably more highly rewarded in lower-income settings. But, height proxies more than just strength. Part of height is genotype and reflects family background. Height is largely determined in early childhood and reflects a broad array of health and human capital investments made by parents. This suggests the correlation between height and wages will diminish as models control other dimensions of human capital. That intuition is true in the Indonesian data: controlling age and education, the elasticity of wages with respect to height is cut in half to 2.6%.

In contrast with height, body mass index (BMI which is weight/height^2 in kg/m^2) depends on net energy intake and so varies through the life course. It captures both longer and shorter run dimensions of nutrition. BMI is related to VO$_2$max and, thus, aerobic capacity and endurance (independent of energy intake) *(29, 30, 31)*. Whether this pathway is one through which health importantly influences productivity is not obvious since many jobs do not require sustained physical effort. Treadmill tests suggest that excess (fat) weight affects the efficiency at which energy is transferred to work output *(32)*.

In developed countries obesity is a central concern; in most low income countries, attention has focused on low levels of BMI (although concerns with obesity are emerging). Using data on workers in the rural Philippines, *(21)* finds that BMI has no effect on earnings. However, using the same sample, *(22, 23)* report that BMI affects the wage of time-rate workers but not piece-rate workers. They argue that health is difficult to observe and employers use BMI as a marker for health. In urban Brazil, BMI affects the hourly earnings of both employees and the self-employed, suggesting BMI is more than just a health marker *(19)*. The authors argue BMI is probably correlated with strength since its effect is largest among the least educated who are more likely to do manual labor. See also *(33)* and *(34)*. While there is little empirical evidence relating BMI to labor supply, it has been shown to affect the proportion of working time that is spent on very physically demanding activities by men *(35, 36, 37)*.

Links between BMI and productivity have not been examined in a dynamic context. This is complicated because BMI has both stock and flow dimensions and thus reflects prior investments in health as well as contemporaneous changes in prices and incomes. In addition, there may be complex lags in how changes in BMI are translated into changes in aerobic capacity and endurance. The fact that weight can be drawn down and converted to energy in times of need further complicates the dynamics.

More generally, the dynamic links between health and economic prosperity have been little studied. This is an important gap in the scientific literature for several reasons. Health is a stock that evolves over time, and prior health behaviors -- and health shocks -- likely influence current economic status. Virtually nothing is known about the speed with which the effects of health transitions at the individual level are transmitted to the labor market in low income settings. Does a period of poor health (or a negative health shock) put a worker on a permanently lower wage trajectory or do the negative consequences of ill-health dissipate as health subsequently improves? The extent of catch up likely depends on the nature of the health problem, the structure of the labor market and characteristics of the worker including age, education and the extent to which the individual has a buffer of resources on which to draw in bad times. Another important advantage of examining the dynamic inter-play between health and economic prosperity is that it is likely to help pin down some of the mechanisms through which the two are correlated. Apart from the econometric advantages associated with analyses based on repeated observations of the same person over time, "natural experiments" arising from unanticipated variation in a respondent's life is likely to be a powerful resource in this literature. *(38)* provides a clever example.

Drawing on IFLS, Table 1 presents empirical results that help illustrate the importance of thinking about dynamic issues. We focus on wages of males age 18 through 68. The first column uses data from the 1997 wave of IFLS and indicates the elasticity of wages with respect to BMI is 2.0; this correlation is displayed in Figure 3. Results in the second column control height, age, education and location of residence: the elasticity is reduced to 1.0 indicating that current weight does reflect, in substantial part, human capital and background characteristics. Prior BMI might serve as a control for these characteristics and so, exploiting the repeat-observation dimension of IFLS, BMI measured in 1993 is added in column 3. It does predict current wages, and soaks up some of the correlation with current BMI. Controlling 1993 BMI, 1997 BMI has the interpretation of weight gain since 1993: its effect is also positive. However, the interpretation of that correlation is not straightforward. It is possible that increased wages were spent on more energy intake (or less energy output) or that changes in both wages and weight arise because of some other unobserved factor.

To explore the interpretation of this result, we turn to wages measured in 1993. Column 4 essentially replicates the 1997 results reported in column 2. Wages in 1993 are related to BMI in 1993 and BMI in 1997 in column 5. BMI in 1993 remains significant. However, weight gained between 1993 and 1997 is a significant predictor of wages in 1993. This is compelling evidence that BMI and wages are jointly determined (or influenced by other unobserved factors) and that the regressions in Table 1 cannot be given a causal interpretation. Modelling the dynamics underlying the evolution of health and economic prosperity is clearly an important scientific endeavor.

The last two columns of the table suggest one direction of enquiry. Males who have not completed primary schooling are included in column 6; subsequent weight gain is a powerful predictor of wages in 1993. The final column indicates that for males with at least primary school, future BMI does not predict current wages. This suggests that the ability to transfer resources across time (credit markets) may play an important role in mediating the effects of variation in health status and economic prosperity. See *(39)* for more details.

4. Summary

The weight of the evidence indicates nutritional status affects labor outcomes, particularly productivity. While the exact mechanisms underlying these relationships are not entirely clear, the literature is distinguished by the co-existence of carefully conducted experimental studies and observational studies that have documented sizeable effects of nutrition on productivity indicators. Explanations that are based on the underlying biological mechanisms that link nutrients with cell functioning have proved to be a powerful force in support of these conclusions, particularly with regard to the importance of iron.

A plausible argument can be -- and has been -- made that other dimensions of health likely affect economic prosperity. Relative to the impact of nutrition on productivity, these links have not been as well established in the scientific literature. Remarkably little is known about the dynamics linking innovations in health and innovations in economic prosperity and the kinds of behavioral responses that accompany health innovations.

These are critical gaps in our knowledge. Filling them calls for integrating the advantages of experimental designs with those of broad-purpose social surveys. Longitudinal surveys with repeated observations on the same individual will be necessary to understand dynamic aspects of the links between health and productivity. Although this is a standard tool in experimental studies, there is a paucity of longitudinal social surveys in low income countries. Moreover, few social surveys have attempted to measure health with the same care as experimental studies. Rapidly emerging technologies for health measurement in the field have dramatically reduced the cost and many assessments can be completed in the household with portable equipment. Bio-markers such as saliva, blood from a finger prick (dried on filter paper) and hair can all be collected, stored and transported at minimal cost. The collection of a wide array of health indicators in population-based longitudinal social surveys is not only feasible, it is highly desirable. At the same time, broadening health surveys to collect good socio-economic data including detailed work outcomes will substantially enhance the potential contributions of those studies. When these sorts of data are placed in the public domain, scientists will be far better equipped to understand how health affects economic success.

Longitudinal surveys, in combination with the changes that will occur in the global economy, will provide an extraordinarily rich laboratory for pinning down some of the causal mechanisms linking health and economic success. It is likely, however, that relying on these "natural experiments" alone will not be enough. There are good reasons to expand the horizon of experimental studies. Specifically, measuring broader socio-economic outcomes than is typically the case, examining behavioral responses to the treatment

and following subjects for an extended period will substantially increase the contributions of these studies. For example, an intervention that seeks to eradicate malaria in an area might not only measure its incidence before and after the intervention, but also track changes in economic productivity as well as behavioral responses to the intervention (such as changes in migration and investments). Since economic and social changes will likely take some time to emerge, subjects will need to be tracked beyond the intervention period. Taking account of the medium and longer term impacts on both health and economic outcomes will provide a more comprehensive assessment of the intervention.

Finally, by co-ordinating longitudinal social surveys with interventions, it will be possible to combine the evidence from these complementary approaches and draw conclusions about the effects of health on economic prosperity with greater confidence that is possible today. To be sure, none of this is easy. However, the challenges provide an extraordinary opportunity for health scientists, social scientists and practitioners to collaborate in order to yield new knowledge that may have a lasting impact on populations throughout the world.

References

1.   **Ruger, J P, Jamison DT, Bloom, DE**. Health and the economy. In Merson MH, Black RE, Mills AJ eds. *International Public Health*, 2001, Gaithersburg, Aspen, pp. 617-666.

2.   **Haas JE, Brownlie IV T**. Iron deficiency and reduced work capacity: A critical review of the research to determine a causal relationship. *Journal of Nutrition*, 2001, **131**: 676S-690S.

3.   **Celsing F, *et al.*** Effects of iron deficiency on endurance and muscle enzyme activity in man. *Med. Sci. Sports Exerc.*, 1986, **18**: 156-161.

4.   **Li R, *et al*.** Functional consequences of iron supplementation in iron-deficient female cotton workers in Beijing, China. *American Journal of Clinical Nutrition*, 1994, **59**: 908-913.

5.   **Scrimshaw N**. Iron deficiency. *Scientific American*, October 1991, 46-51.

6.   **Zhu YI, Haas JD.** Altered metabolic response of iron-depleted nonanemic women during a 15-km time trial. *Journal of Applied Physiology*, 1998, **84**: 1768-1775.

7.   **Edgerton V, *et al.*** Iron-deficiency anemia and its effect on worker productivity and activity patterns. *British Medical Journal*, 1979, **2**: 1546-1549.

8.   **Basta S, Soekirman K, Scrimshaw N**. Iron deficiency anemia and productivity of adult males in Indonesia. *American Journal of Clinical Nutrition*, 1979, **32**: 916-925.

9.   **Pollitt E.** The developmental and probabilistic nature of the functional consequences of iron-deficiency anemia in children. *Journal of Nutrition*, 2001, **131**: 669S-675S.

10.   **Imminck M, Viteri F**. Energy intake and productivity of Guatemalan sugarcane cutters: An empirical test of the Efficiency Wage Hypothesis--Part 1. *Journal of Development Economics*, 1981a, **9**(2): 251-271.

11.   **Imminck M, Viteri F**. Energy intake and productivity of Guatemalan sugarcane cutters: An empirical test of the Efficiency Wage Hypothesis--Part 2. *Journal of Development Economics*, 1981b, **9**(2): 273-287.

12.   **Wolgemuth J et al**. Worker productivity and the nutritional status of Kenyan Road construction laborers. *American Journal of Clinical Nutrition*, 1982, **36**(7): 68-78.

13.   **Moffett JK, *et al*.** Randomised controlled trial of exercise for low back pain: Clinical outcomes, costs, and preferences. *British Medical Journal,* July 31, 1999, **319**: 279-283.

14.   **Newhouse J**. *Free for all? Lessons from the RAND Health Insurance Experiment*. Cambridge, Harvard University Press, 1993.

15.   **Dow W, *et al*.** Health Care Prices, Health and Labor Outcomes: Experimental Evidence. Labor and Population Program Working Paper Series 97-01, 2001, RAND, Santa Monica.

16.   **Gruber J, Hanratty M**. The labor-market effects of introducing National Health Insurance: Evidence from Canada. *Journal of Business and Economic Statistics*, 1995, **13**(2): 163-173.

17.   **Strauss J**. Does better nutrition raise farm productivity? *Journal of Political Economy*, 1986, **94**: 297-320.

18.   **Sahn D, Alderman H**. The effect of human capital on wages and the determinants of labor supply in a developing country. *Journal of Development Economics*, 1988, **29**(2): 157-83.

19.   **Thomas D, Strauss J**. Health and wages: Evidence on men and women in urban Brazil. *Journal of Econometrics*, 1997, **77**: 159-185.

20.   **Deolalikar A**. Nutrition and labor productivity in agriculture: estimates for rural south India. *Review of Economics and Statistics*, 1988, **70**: 406-413.

21. **Haddad L, Bouis H**. The impact of nutritional status on agricultural productivity: wage evidence from the Philippines. *Oxford Bulletin of Economics and Statistics*, 1991, **53**: 45-68.

22. **Foster A, Rosenzweig M**. Information flows and discrimination in labor markets in rural areas in developing countries. In Summers L, Shah S eds. *Proceedings of the World Bank Annual Conference on Development Economics, 1992: Supplement to The World Bank Economic Review and The World Bank Research Observer*. Washington DC, World Bank, 1993, pp. 173-203.

23. **Foster A, Rosenzweig M**. A test for moral hazard in the labor market: Contractual arrangements, effort, and health. *Review of Economics and Statistics*, 1994, **76**(2): 213-227.

24. **Fuentes J A, Hernandez J, Pascual M**. The effects of early nutritional intervention on human capital formation, Monograph, INCAP Guatemala, 2001.

25. **Pollitt E**. Iron deficiency and educational deficiency. *Nutritional Reviews*, 1997, **55**(4): 133-140.

26. **Fogel R**. Economic growth, population theory and physiology: The bearing of long-term processes on the making of economic policy. *American Economic Review*, 1994, **84**(3): 369-395.

27. **Thomas D, Yau J**. Stature and growth. Mimeo, 2001.

28. **Strauss J, Thomas D**. Health, nutrition and economic development. *Journal of Economic Literature*, 1998, **36**: 766-817.

29. **Spurr GB.** Nutritional status and physical work capacity. *Yearbook of Physical Anthropology*, 1983, **26**: 1-35.

30. **Spurr GB.** Body size, physical work capacity and productivity in hard work: Is bigger better? In J. C. Waterlow JC ed. *Linear Growth Retardation in Less Developed Countries*, Nestle Nutrition Workshop Series Vol. 14, New York, Raven Press, 1988, pp. 215-44.

31. **Martorell R, Arroyave G**. Malnutrition, work output and energy needs. In K. Collins K, Roberts F eds.. *Capacity for Work in the Tropics*. Cambridge, Cambridge University Press, 1988.

32. **Cureton K**. Effects of experimental alterations in excess weight on physiological response to exercise and physical performance. In *Body composition and physical performance: Applications for the Military Services*. National Academy of Science Press, 1992.

33. **Glick P, Sahn DE.** Health and productivity in a heterogeneous urban labour market. *Applied Economics*, 1998, **30**(2): 203-216.

34. **Croppenstedt A, Muller C.** The impact of farmers' health and nutritional status on their productivity and efficiency: Evidence from Ethiopia. *Economic Development and Cultural Change*, 2000, **48**(3): 475-502.

35. **Pitt M, Rosenzweig M, Hassan MN.** Productivity, health, and inequality in the intrahousehold distribution of food in low-income countries. *American Economic Review*, 1990, **80**: 1139-1156.

36. **Bhargava A**. Modeling the health of Filipino children. *Journal of the Royal Statistical Society*, *Series A*, 1994, **157**: 417-432.

37. **Fafchamps M, Quisumbing A**. Human capital, productivity and labor allocation in rural Pakistan. *Journal of Human Resources*, 1999, **34**(2): 369-406.

38. **Smith JP.** Healthy bodies and thick wallets: The dual relation between health and economic status. *Journal of Economic Perspectives*, 1999, **13**(2):145-166.

39. **Frankenberg E, Thomas D**. Dynamics of health and work outcomes. Mimeo, 2001.
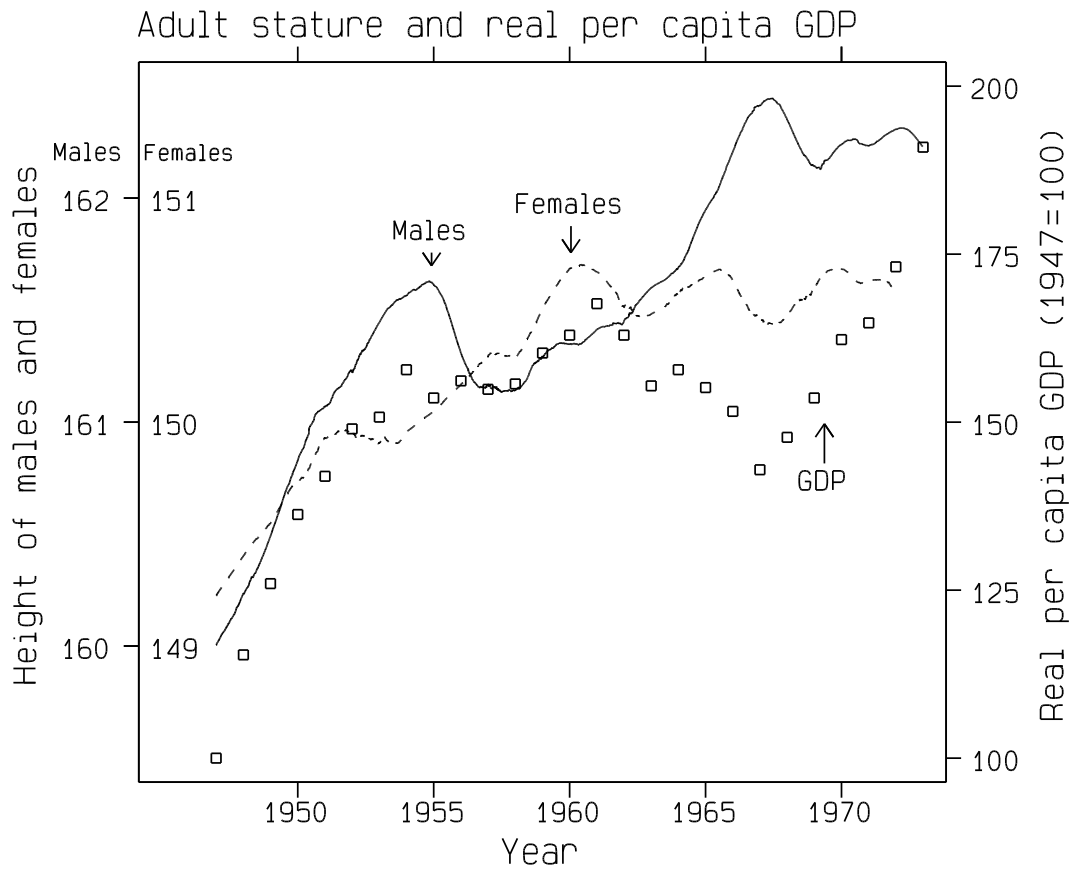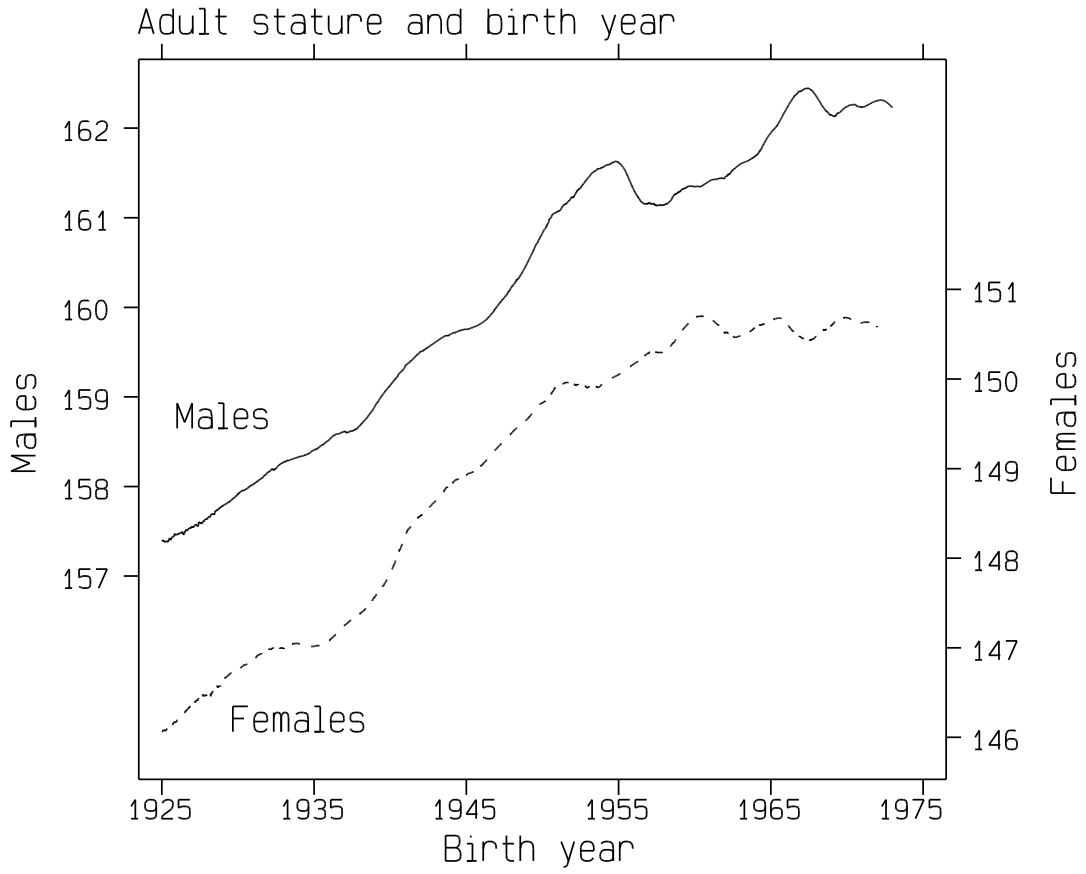
Figure 1

Adult stature and birth year

Adult stature and real per capita GDP

Figure 2

ln(Wage) and ln(Height)
Adult Indonesian males

Source: IFLS2

Figure 3
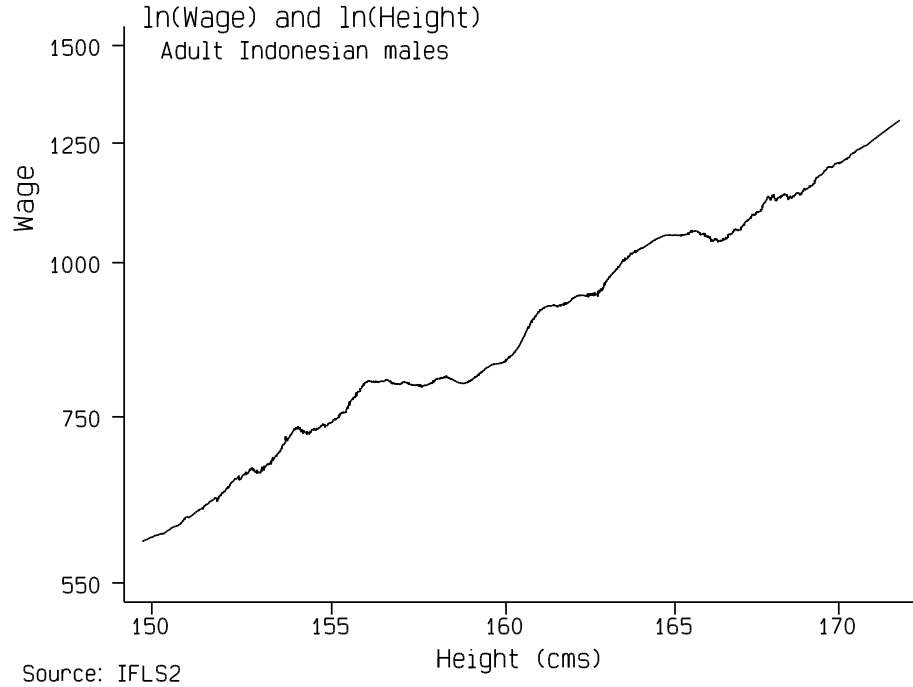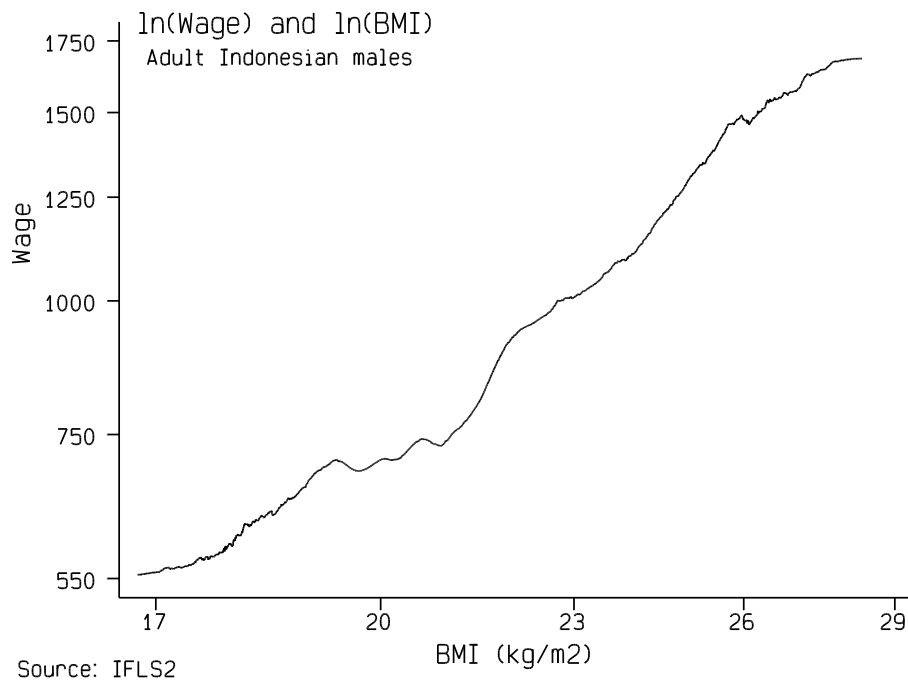
ln(Wage) and ln(BMI)
Adult Indonesian males

Source: IFLS2

Table 1: Dynamic relationship between body mass index and hourly earnings of adult males
Indonesia Family Life Survey, 1993 and 1997.

Covariates:	ℓn(hourly earnings) in 1997				ℓn(hourly earnings) in 1993		
						BMI97 and BMI93	
	BMI97 only	Add height & education	BMI97 & BMI93	BMI93	BMI97 & BMI93	<Primary School	≥Primary School
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ℓn(BMI) in 1997	2.03	1.03	0.82	.	0.35	0.82	0.03
	(0.12)	(0.10)	(0.16)		(0.17)	(0.31)	(0.21)
ℓn(BMI) in 1993	.	.	0.34	0.96	0.78	0.75	0.85
			(0.17)	(0.14)	(0.18)	(0.33)	(0.21)
ℓn(height)	.	2.36	2.40	2.27	2.52	3.39	2.00
		(0.34)	(0.44)	(0.40)	(0.44)	(0.82)	(0.54)
Years of education (spline)							
0-5	.	0.05	0.04	0.05	0.05	0.03	0.00
		(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.00)
6-11	.	0.09	0.10	0.09	0.10	0.00	0.10
		(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.01)
>11	.	0.11	0.10	0.14	0.14	0.00	0.14
		(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.01)
Age & location controls	No	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.06	0.29	0.30	0.30	0.30	0.14	0.28

Notes: Sample includes adult males age 18 through 68 earning income at time of survey. Standard errors in parentheses robust to arbitrary forms of heteroskedasticity and take into account correlations due to survey clustering. Age is specified as spline; location includes control for each province and urban.