An Introduction to the Structure of Biomarker Equations

David G. Blanchflower
Dartmouth College, Stirling University, IZA,
and National Bureau of Economic Research, USA
blanchflower@dartmouth.edu

Nicholas A. Christakis
Harvard Medical School
christak@hcp.med.harvard.edu

Andrew J. Oswald
University of Warwick and IZA
andrew.oswald@warwick.ac.uk

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Abstract

Most economists are not familiar with so-called biomarker data. We attempt here to provide an introduction to such data and to describe the econometric structure of simple biomarker equations. We draw upon information on the heart rate, systolic and diastolic blood pressure, fibrinogen, and C-reactive protein levels of 100,000 adults. We show that it is extremely important to control for fruit and vegetable consumption (more so than is conventionally recognized in health economics). Once that is done, there are income gradients only in heart-rate and C-reactive protein equations, and those gradients are small. Education enters remarkably weakly in these biomarker equations.

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Corresponding author: andrew.oswald@warwick.ac.uk.
Address: Department of Economics, University of Warwick, Coventry CV4 7AL, United Kingdom.
Telephone: (+44) 02476 523510.
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"A comprehensive programme of research needs to be carried out before biomarkers can be used … in the clinic, courtroom, classroom and community. The programme … can be accomplished only through interdisciplinary interactions between neuroscience researchers, doctors, social scientists, ethicists, legal scholars, policymakers and those involved in commercializing biomarkers." Nature (Singh and Rose, July 2009)

1. Introduction

Human well-being is shaped by health and a mixture of economic, sociological, and political forces. The relative importance of these influences is not yet fully understood. A president of the European Economic Association recently argued that the future of economics will be one in which a drawing together and understanding of biological and social-scientific forces will be required (Fehr 2009), and joint research by teams of economists and scientists is becoming more common (Fliessbach et al. 2007 and Coates et al. 2009, for example).

One way in which knowledge might be advanced is by the collection of new kinds of data. Social-science surveys have started to incorporate objective biological information (so-called 'biomarkers') and it appears that such surveys will do so still more in the future[1]. This will provide a wide range of researchers, particularly health economists, with an opportunity denied to earlier generations of scholars. In principle, it is becoming possible to distinguish between physiological measures and other influences that undergird happiness and feelings of well being. Because they are cardinal, such measures are intrinsically appealing to economists (among others).

[1] We are aware that this is currently being discussed by scientific funding agencies in both Britain and the USA, for example.

What are biomarker data and how best can they be exploited? In this paper, we discuss that issue, and we attempt to combine biomarkers and conventional social-science methods. Our aim is partly pedagogic and partly substantive. The result is a set of statistical findings -- both descriptive and analytical -- that we hope might be of interest to a variety of kinds of social and medical scientists. We will later have in mind particularly researchers in health economics. The paper's general analysis overlaps with new work on well-being at the borders between economics, psychology, and science (such as Dolan and Kahneman 2008). [2]

Our data set is the Health Surveys of England and was commissioned by the UK's Department of Health. Each HSE is a nationally representative survey of private households in England, which offers an annual cross-section of the population[3]. These data are collected by a combination of face-to-face interviews, self-completion questionnaires, and medical examinations undertaken by a nurse. Blood and saliva samples are taken. For this reason, the HSE is unusual internationally in that it contains detailed information on a range of both self-reported and objectively assessed health indicators, including blood pressure measurements, fibrinogen, and C-reactive protein levels. Various individual and household demographic characteristics are recorded. Information on family household income is also collected.

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[2] Recent contributions from psychologists, economists, and other investigators, include Diener et al. (1993, 2008), Clark and Oswald (1994), Di Tella and MacCulloch (2006), Di Tella et al. (2001, 2003), Theodossiou (1998), Oswald (1997), Frey and Stutzer (2002), Easterlin (1974, 2003), Graham (2005), Helliwell (2003), Blanchflower and Oswald (2004, 2008a, 2008b), Kahneman et al. (2004), Kahneman and Riis (2005), Van Praag and Ferrer-I-Carbonell 2004, Gilbert 2006, Offer (2006), Shields and Wheatley Price (2005), Smith et al. (2005), Dolan et al. (2008), Dolan and Peasgood (2008), Blanchflower (2009), Fowler and Christakis (2009) and Oswald and Powdthavee (2007). But see the interesting conceptual criticisms of Ng (1997), and also the kind of data in Bray and Gunnell (2006).

[3] The HSEs use the Postcode Address File as a sampling frame. The average response rate of households at selected addresses is 75%, within which successful interviews are conducted with 90% of individuals. An annual sample of approximately 16,000 individuals is obtained.

We focus on the issue of how a mixture of biomarker and social-science variables might be used. Specifically, the paper addresses the following questions:

(i) *Are there income and education gradients in biomarker equations?* In the case of income, for three types of biomarker -- systolic pressure, diastolic pressure, fibrinogen level -- we find that the answer is no. The income gradient disappears when factors such as diet, smoking and BMI are held constant. However, in two cases -- heart rate, C-reactive protein -- the answer is yes. We are unable to test whether this is related to resources or to high-rank per se (Pham-Kanter 2009 is an interesting inquiry into this issue, although her biomarker data are on blood pressure, and not variables such as heart rate or C-reactive protein). For education, interestingly, our result is still starker. There is surprisingly little sign of systematic education gradients in any biomarker variable. [4]

(ii) *Is there a biomarker variable that might serve as a cardinal empirical proxy for the economist's notion of utility?* We find a little evidence that human heart-rate data might be able to do so. We appeal to the intuitive idea that raised pulse may act as a marker for underlying mental strain in a human population and, more formally, upon a literature represented by papers such as Troubat et al. (2009).

The social-science literature on links between health and income is now a large one: an electronic search on the combination of those two words in the Social Science Citation Index, for example, returns a count of approximately 14,000 journal articles.

[4] Health economists have done fairly little research on healthy foods. A search on the issues of the Journal of Health Economics, for example, finds only two articles that have in the title, abstract or key words the words "fruit", "vegetables", or "healthy food". One is Capacci and Mazzochi (2011), which is not about the effects of food upon health. The other is interesting work by Belot and James (2011), which looks at the implications of food for children's educational outcomes. There are approximately 15 articles on obesity, but these are not explicitly about the direct health consequences of different kinds of food. Blanchflower, Oswald and Stewart-Brown (2011) discusses diet in the context of the literature on mental health. Griffith and O'Connell (2009) may mark a beginning by economists in new ways to study nutrition.

Nevertheless, objective biomarker data have so far been used rather little in the health-economics literature, and some of our later results attempt to make a contribution to epidemiological and medical knowledge.

2. Background

As Crimmins et al. (2008) point out, the two standard indicators of blood pressure are the most commonly measured biomarkers: systolic blood pressure (SBP) is the maximum pressure in an artery at the moment when the heart is beating and pumping blood; diastolic blood pressure (DBP) is the lowest pressure in an artery in the moments between beats when the heart is resting. Excessive levels of either measurement suggest hypertension. Current guidelines define hypertension as SBP over 140 mm Hg or DBP over 90 mm Hg. We also look at resting pulse rate (i.e. heart rate). Two further measures studied here are fibrinogen and C-reactive protein (CRP). Fibrinogen, also called serum fibrinogen, plasma fibrinogen, and factor I, is a protein produced by the liver. Fibrinogen helps stop bleeding by promoting the formation of blood clots. Fibrinogen has been shown to be strongly predictive of both mortality (Fried et al. 1998) and the onset of cardiovascular disease (Ridker et al. 1997). It is also produced in response to stress, as if to help the body prepare for fighting, injury, and possible bleeding, which might requiring clotting. C-reactive protein (CRP) is an acute phase response protein produced in the liver that indicates general systemic levels of inflammation. CRP is a general marker for inflammation and infection, and it has a number of functions related to immunity and host defence. CRP levels rise as part of the immune response to infection and tissue damage or injury and may be elevated due to the presence of chronic conditions, like diabetes, asthma, rheumatoid arthritis, and heart disease. Crimmins et al. (2008) explain that in an acute response the level of CRP can jump one thousand fold but drops fairly quickly after an infection passes. For that reason, our later equations examine the logarithm of CRP. A blood level above 10 mg/dl is considered a sign of acute illness. CRP levels are also related to hormone levels in women and are elevated with the use of oral contraceptives or postmenopausal hormone replacement therapy. CRP can be used as a rough proxy for heart disease risk since it also rises in response to inflammation in coronary vessels (Koenig et al. 1999). Research has suggested that high levels of CRP, between 3 and 10 mg/dl, are related to the development of cardiovascular disease (Ridker et al. 2000) and cardiac events.

Our work is concerned with the issues discussed in Adler and Ostrove (1999) and Ecob and Davey Smith (1999), and in the broadest sense is in a modern tradition represented by work such as Urry et al. (2004) who look for neural correlates with human happiness. Ryff et al. (2006) in a sample of 135 women demonstrate that there are links between biomarker measures and mental well-being and ill-being. Hamer et al. (2009) finds a small amount of evidence that CRP is associated with depressive symptoms. In a sample of 216 men and women, Steptoe et al. (2005) examine biological correlates with people's happiness over a working day, and show that positive affect is associated with reduced neuroendocrine, inflammatory and cardiovascular activity. Hamer et al. (2008) examine nearly 7000 men, and, using GHQ scores (see, for an explanation of the General Health Questionnaire screening instrument score, Goldberg et al. 1997, and the recent arguments of Hu et al. 2007) and biomarker information, conclude that the links between psychological distress and heart disease risk is almost entirely explained by behavioural choices like smoking. Wright et al. (2009) focus upon 113 supervisors in California, and suggest that psychological well-being is linked to measures of heart rate but not to blood pressure. Steptoe et al. (2007) is a review and meta-study.

In large representative data sets, there has been much less work. Hildrum et al. (2007) is important. Using information on 61,000 Norwegian males and females aged between 20 and 89, the authors find that anxiety and depression are correlated with low systolic blood pressure, though association with diastolic blood pressure is weaker. In a slightly smaller data set, the same kind of result is replicated longitudinally -- namely using baseline anxiety as a prospective factor -- in Hildrum et al. (2008).

Muennig et al. (2007) show, in data from the National Health Examination and Nutrition Survey, an inverse association between CRP and income and education. There is no link with fibrinogen. Albert et al. (2006) detect an inverse income/education gradient with fibrinogen among 23,000 American women. Jousilahti et al. (2003) study 1500 Finnish males and find evidence of lower CRP and fibrinogen among higher socioeconomic status individuals; similar results for fibrinogen were reported early on, in Finnish data, by Wilson et al. (1993) and Myllykangas et al. (1995). Steptoe et al. (2003a,b) in a sample of 221 British civil servants observe an inverse relationship between employment grade with fibrinogen, but not with blood pressure or heart rate.

In Seeman et al. (2008), data from the nationally representative US National Health and Nutrition Examination Survey (NHANES) III cohort were used to examine the hypothesis that socio-economic status is negatively associated with nine biological parameters known to predict health risks (diastolic and systolic blood pressure, pulse, HDL and total cholesterol, glycosylated hemoglobin, c-reactive protein, albumin and waist hip ratio). As hypothesized by the authors, consistent education and income gradients were seen for biological parameters reflecting cardiovascular, metabolic and inflammatory risk. Individuals with lower education and income exhibited a greater prevalence of high-risk values for each of the nine individual biological markers.

There is some evidence that happiness and heart rate are negatively associated among men, and that well-being is correlated with cortisol levels and cardiovascular behaviour (Steptoe et al. 2005). As Ostir et al. (2001) and Joynt et al. (2003) demonstrate, rates of depression and heart disease seem to be connected. A review of related evidence is available in Rutledge and Hogan (2002). Steptoe and Wardle (2005) offer some evidence that blood pressure is inversely related to reported happiness. Their data come from middle-aged men and women, with positive 'affect' (a psychological term for a form of happiness) assessed through repeated ratings over a day. Greater happiness is associated with lower salivary cortisol, reduced fibrinogen stress responses, and lower ambulatory heart rate in men. These patterns are independent of age, socioeconomic status, smoking, body mass and psychological distress. Happiness is found to be inversely related to ambulatory systolic blood pressure. The results suggest that affective states are linked to outcomes. Similarly, Lazaro et al. (1993) shows that borderline hypertension is associated with worse GHQ mental strain scores [5].[6]

[5] Huppert and Whittington (2003) suggest that a GHQ score has positive and negative affect within it. Hu et al. (2006) argue that GHQ scores can be used to detect 'happiness' as well as mental illness.

[6] The work of Jonas and Lando (2000) argues that there is a positive connection between anxiety today and hypertension in the future. A population-based cohort of 3310 initially normotensive and chronic disease-free persons tracked. The association between hypertension and baseline negative affect is analyzed using Cox proportional hazards regression, adjusting for baseline age, sex, race, education, smoking, alcohol use, diastolic and systolic blood pressure, body mass index, and change in body mass index as a time-dependent covariate. Steptoe et al. (2005) paints a complementary picture. It demonstrates that levels of positive affect in middle-aged men and women are associated with reduced neuroendocrine, inflammatory, and cardiovascular activity. Well-being in the study is assessed by aggregating momentary experience samples of happiness over a working day and is found to be inversely related to cortisol output over the day. Once again, happiness is inversely related to heart rate measured using ambulatory monitoring methods. Banks et al. (2006) argues that Americans are less healthy than Europeans; differences in blood pressure form part of the authors' evidence. Stamler et al. (1992) establishes that education is inversely related to

Ellaway and Macintyre (2007) search for but cannot detect correlations between biomarker heart risk factors and social engagement. Gardner and Oswald (2004) uncover little or no effect from high GHQ scores on to subsequent mortality risk. In a different spirit, Kario et al. (2003) suggests that exogenous disasters raise people's blood pressure. Further evidence on the linkages between biomarkers and stress is provided in Der et al. (1999), Martin et al. (2000), and Rasul et al. (2002), and Toivanen and Hemstrom (2006).

The Health Surveys of England have been used rather little to study mental well-being, but there has been some research into biomarker variables within it. Banks et al. (2006) compare with US data; Johnston et al. (2009) argue that an income gradient can be found in objective, but not subjective, measures of hypertension; Currie et al. (2007) examine the same data set from 1997 to 2002, but their focus is the role of income in the determination of child health. Jurges et al. (2009) and Powdthavee (2010) use the raising-of-the-school-leaving-age as a natural experiment.

3. Biomarker Equations

To illustrate the patterns in biomarker data, we describe a set of regression equations in which biomarker variables are in each case the dependent variable. Conventional independent variables -- conventional from the economist's perspective -- are then gradually included.

Table 1 reports a regression equation in which people's resting heart rate -- their measured pulse rate -- is the dependent variable. The mean of this dependent variable is approximately 71 beats per minute, with a standard deviation of 12. More details of the data are in the Appendix. Table 1 uses an ordinary least squares (OLS) method.

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hypertension. Owen et al. (2005) uncovers childhood influences. Colhoun et al. (1998) provides a summary of similar evidence.

Throughout the paper, we use an average of three nurse-taken readings where available (and also for the construction of later blood-pressure variables).

The income variable used in this study is annual equivalized household income. The number of observations is 100,436. Unlogged, the mean of income is £24,104 pounds, with a standard deviation of £22,710. The minimum value in the data set is £153 and the maximum is £262,295.

Resting heart rate slows as people age. Column 1 of Table 1, which controls for a large set of independent variables -- but not yet the level of income, quantity of fruit and vegetables consumed, or social class -- makes clear that this happens in an increasingly gradual way (age and age squared enter with a form that implies the function is convex from below). Men have a pulse that is, on average, 2.7 beats a minute slower than women. Individuals with a higher body mass index (BMI) have a faster heart rate. Every unit point increase in BMI is associated in the cross-section with a faster rate by approximately 0.2 beats per minute.

For reasons that are not understood, there are marked differences in heart rate across England's regions. Yorkshire/Humberside in the north of England tops the league table of heart rate speed, with a pulse rate almost 2 beats a minute faster than the South West, which is the region with the slowest heart rate. Married individuals have a heart rate approximately 0.9 beats a minute slower than unmarried individuals, and divorced and separated people's heart rate is in turn approximately 0.5 beats a minute faster than that of the unmarried. Unemployed people's heart rate is 1.3 beats faster than those in work. The temporarily sick and disabled have markedly higher pulse levels -- by around 3 beats per minute. There are other effects, but no correlation with the number of children in the household. Finally, those individuals who are cigarette smokers -- for each person this is a zero/one dummy -- have on average a heart that beats, ceteris paribus, approximately 3 beats a minute faster than non-smokers.

Strikingly, and against the spirit of some epidemiological research on health, there are here no statistically significant effects from years of schooling. There is a hint of a decline in pulse speed -- going down the ALS age-left-school variables in column 1 of Table 1 -- but the null of zero cannot be rejected on any level of education when compared to the omitted category.

Column 2 of Table 1 moves to a specification in which household income is included as a regressor. It enters significantly and has a coefficient of -0.3371. To explore its robustness, column 3 then adds (eight) social-class dummy variables. Column 4 of Table 1 includes a further variable denoted “# Fruit and Vegetables”, which is the number of daily portions of fruit and vegetables that the individual consumes.

Income enters strongly negatively in each of these pulse-rate equations. Its coefficient, of approximately -0.3, is only marginally affected in size by the addition of the extra variables in columns 3 and 4. On closer inspection (results not reported) income enters in a concave way in the data, so is specified throughout as a logarithm. A number of other notable patterns emerge. Once sufficient control variables are included in Table 1, the variable for unemployment declines in size below unity and it is not longer possible to reject the null of zero at conventional confidence levels.

Even with a full set of controls, there continue to be large differences in heart rate by geographical area. We believe this finding, which is not widely known, warrants further research scrutiny.

What are the general messages from Table 1? One concerns the quantitative implications of the income gradient. At -0.3 on Log Household Income, this implies that the associated change in Pulse = -0.3 Percentage change in income. With a mean of 71 on pulse, that translates into an income elasticity of pulse of approximately -3/710, which is -.004. This can be viewed as small. A large move of one SD from below the mean of income to one SD above is then associated with a drop in pulse by less than 0.5 beats per minute. It should be recalled from Table 1 there is no such associated effect from even large alterations in the level of education.

Another result of note is the comparatively large coefficient on fruit-and-vegetables. It is approximately -0.17. Because, as explained in the descriptive data section in the Appendix, the number of portions of fruit and vegetables consumed has a standard deviation of 2.6, this implies that variation in this variable has far larger substantive consequences -- as a matter of association -- than does variation in income. A one-SD rise in fruit and vegetable portions is associated with a decline of one half beat a minute in heart rate.

Next, consider blood-pressure biomarker equations. In Table 2, systolic blood pressure readings are the dependent variable. [7] The age-squared term is insignificantly different from zero and is therefore omitted. Married people have relatively low blood pressure. There are large differences across geographical areas, even with a full set of controls in the equation. The systolic blood pressure of Londoners, for example, is 4 points lower than that of comparable Northerners.

[7] Our approach, it should perhaps be explained, differs a little from the work of Johnston et al (2009) because they focus on hypertension itself (that is, on the very upper end of blood pressure).

Income initially appears in Table 2 to have a powerful effect in a systolic equation. Even after the inclusion of social class dummies, in column 3 of Table 2, it has a coefficient of -0.436 with a t-statistic of 4.4. However, the log of household income has a negligible role once diet is held constant in column 4 of Table 2. Otherwise the structure of these equations is reminiscent of the form of Table 1's pulse equations. High-education people in column 1 of Table 1 have low levels of blood pressure, with ALS greater than or equal to 19 (i.e. college students) with a coefficient implying that systolic blood-pressure is 1.6 points lower. Yet by the final column this education correlation has almost disappeared. The null of zero can be rejected on the ALS16 category, but this leaves this comparatively poorly educated group with lower blood pressure than college graduates.

In Table 2, smoking and diet are influential. In a mechanical correlational sense, seven pieces of fruit and vegetables a day can essentially 'offset' smoking. But perhaps the most striking thing about Table 2 is that the diet variable destroys any direct statistical role for income. This finding seems to be a new one, and to have potential implications for policy.

We might want to compare this paper's statistical results with still-controversial MONICA findings published fairly recently in the British Medical Journal (at http://www.bmj.com/cgi/content/full/332/7542/629). For example, over the course of ten years, systolic blood pressure in industrialized countries fell about 2.2 mm of mercury in men (and, paradoxically, this fall was not associated with greater use of anti-hypertensive medication per se). Our results in the early columns of Table 2 are consistent with the idea that, on a population level, changes in income have similar small, but notable, effects.

Systolic BP equations are one place where we observe slight education effects. If education alters blood pressure BP but not heart rate HR (and taking the lack of effect of education on HR to be a point estimate of zero, and not just statistically indistinguishable for zero), then it must affect what is known as total peripheral resistance. In physiology, a basic equation is BP=HRxSVxTPR, where HR is heart rate, SV is stroke volume (how much blood the heart pumps at each beat), and TPR is 'total peripheral resistance,' which is a measure of vascular 'tone' (which is generally higher when people are under stress).

Diastolic blood-pressure equations are laid out in Table 3. Perhaps unsurprisingly, they are similar in structure to the systolic equations of Table 2. In this diastolic case, income and education play virtually no role under any of the econometric specifications, and by column 4 of Table 2 there are if anything signs of higher education being positively correlated with blood pressure.

Table 4 gives regression equations in which fibrinogen readings form the dependent variable. The mean of the dependent variable is 2.9 (SD of 0.8). These inflammatory-marker readings are increasing in age, and higher among women, those with high BMI, those with low levels of education, and those who are unmarried. Fibrinogen levels in column 1 of Table 4 are low in the rural region of East Anglia; there is no effect here from unemployment; fibrinogen readings are high among disabled people, and among home workers with large household sizes, and low among those with children; high among smokers; and low among those who eat large numbers of portions of fruit and vegetables.

Interestingly, until the fruit-and-vegetable-portions diet variable is controlled for in Table 4, high income is associated with lower fibrinogen levels. By column 4 of Table 4, however, evidence of an income gradient has disappeared. This result is symmetric, in a sense, to that for the earlier blood-pressure findings.

Equations for CRP (C-reactive protein) are provided in Table 5. The readings are lower among men; higher among those with a large BMI and here, across the columns, some sign of an education gradient; there is no association with marital status, and, by column 4 of Table 5, little correlation with the region that the person lives in; until the final column CRP levels are somewhat higher among the unemployed, and are among the disabled; lower among those with children; and higher among smokers and those who eat few fruit and vegetable portions.

There is a well-determined negative association, in all columns of Table 5, between C-reactive protein readings and the log of the household's income. This may turn out to be important for research. It may eventually help us to understand the biological roots of the famous healthier-wealthier correlation (Pritchett and Summers 1996). A one-SD move up in log income is associated with a 10% decline in a person's level of C-reactive protein, although the latter, as the Appendix reveals, is a skewed and highly dispersed variable.

The interesting and readable physiological study of Troubat et al. (2009) shows that in a group of experienced chess players the heart rate of players increases by approximately 10 beats per minute over the course of play. Because the players are physically immobile, this is sharp example of links between stress and the heart. A further current of evidence is described in papers such as Nilsson et al. (2001), and an early study of young people in examinations in Edmonds (1982).

4. Possible links to well-being

In Table 6, for completeness, we therefore move to a final measure, and one of a different kind, which is that of mental well-being. These regression equations are not for biomarker data but instead take as their dependent variable the answers to the question "Have you been feeling reasonably happy?", where people can answer on a 4-point scale from "much less than normal" to "much more than usual". It can be seen that, with the exception of the aging structure, there are similarities in Table 6's columns with the structure of the heart rate equations of Table 1.

Would it do injustice to these data to hypothesize that, in the spirit of Troubat (2009), high heart rate is akin to mental strain? Approximately, when comparing the structure of Table 1 and Table 6, it would not. It can be seen in Table 6 that:

(i) men have higher happiness and a slower pulse

(ii) people with a higher BMI have a higher pulse and lower happiness

(iii) there is little or no effect from education

(iv) married people have a lower pulse and higher happiness (and divorced/separated equivalently)

(v) the south west of England has high well-being and the slowest pulse

(vi) unemployed people report markedly lower happiness, with some signs of a concomitantly faster pulse

(vii) disabled and sick people are less happy and have a faster pulse

(viii) cigarette smokers are markedly less happy, with a higher pulse rate

(ix) high income people are happier and have a slower pulse

(x) people who eat large numbers of fruit and vegetable portions are happier and have a slower pulse.

Hence, from an economist's perspective, it appears that, as a matter of sheer correlational structure, a heart-rate equation somewhat takes an econometric form like that of a (negative) utility function. We leave the further consideration of this unusual analytical possibility to future work.

5. Conclusions

Biomarker data have the potential to play an influential role in economics, social science, and the understanding of human well-being. Over the course of the next century, as the social sciences and medical science draw together, it is possible that biomarker information will form a central element in empirical inquiry.

This paper has attempted to provide an introduction to heart biomarkers. As an illustration, the paper takes physiological data -- measuring pulse, blood pressure, fibrinogen, and C-reactive protein -- on a random sample of 100,000 English citizens. Apart from any pedagogical contribution, the paper draws three main conclusions. First, there are income gradients only in heart-rate and C-reactive protein equations. Even these are not large. For example, the income elasticity of human pulse is estimated here, admittedly with simple methods, at approximately -0.004. The income elasticity of C-reactive protein is bigger -- it is approximately -0.04 -- but by its nature this dependent variable has a highly dispersed distribution. Second, in this study, education variables have surprisingly little effect within biomarker equations. Third, it is more important to control for the consumption of fruit and vegetables than we had realised -- and arguably than is recognized in the health-economics literature.

The growing interest among funding bodies and scientists to collect biological data as part of large-scale social science surveys, the increasing interest among clinicians and biologists conducting drug trials to collect socioeconomic data and measures of outcomes, the declining price of genotyping individuals over the coming years, the declining price of collecting biomarker data, and the explosion of sensing devices and passive data collection (e.g., by mobile telephony that allow everything from body temperature to miles walked per day to be tracked) -- all of these are likely to lead to a progressive merging of the topics of interest to biomedical scientists and social scientists. These will afford new opportunities to disentangle how biological and social experiences are connected.

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Table 1. Pulse (i.e. Resting Heart Rate) Regression Equations, 1998-2007

	(1)	(2)	(3)	(4)
Log income		-.3371 (4.60)	-.2738 (3.62)	-.2713 (2.97)
# Fruit & vegetables				-.1657 (7.15)
Age	-.0890 (5.16)	-.1030 (5.35)	-.0951 (4.91)	-.1003 (4.28)
Age^2	.0005 (3.14)	.0007 (3.60)	.0006 (3.28)	.0006 (2.66)
Male	-2.6633 (29.04)	-2.6453 (26.35)	-2.6283 (24.40)	-2.7858 (21.63)
BMI	.1972 (21.29)	.2013 (19.93)	.2010 (19.86)	.2097 (17.39)
Black	.8763 (3.38)	.6038 (2.08)	.5675 (1.95)	1.0834 (2.95)
Asian	2.9950 (14.32)	3.0078 (12.60)	2.8532 (11.81)	2.8210 (9.27)
Other race	-.0340 (0.07)	.2084 (0.39)	.2079 (0.39)	-.2598 (0.36)
Still at school	1.0701 (1.85)	.9492 (1.44)	.7928 (1.20)	.5254 (0.63)
AgeLeftSchool≤14	-.0507 (0.17)	-.2751 (0.84)	-.3155 (0.96)	-.6807 (1.69)
ALS 15	-.1007 (0.37)	-.2723 (0.90)	-.2827 (0.93)	-.2534 (0.70)
ALS 16	-.1074 (0.41)	-.1539 (0.53)	-.1043 (0.36)	-.0707 (0.20)
ALS 17	.0358 (0.12)	.0546 (0.17)	.1485 (0.46)	.1883 (0.49)
ALS 18	-.4403 (1.55)	-.3514 (1.12)	-.2171 (0.69)	-.1366 (0.37)
ALS >=19	-.4196 (1.59)	-.2727 (0.93)	-.0651 (0.22)	.1767 (0.50)
Married/living	-.8774 (7.08)	-.7934 (5.74)	-.7529 (5.43)	-.5929 (3.54)
Separated/divorced	.3808 (2.14)	.3753 (1.94)	.3825 (1.97)	.6313 (2.71)
North West	.3146 (1.49)	.3504 (1.54)	.3388 (1.48)	.3514 (1.29)
Yorks/Humber	.8859 (3.98)	1.0094 (4.20)	.9946 (4.13)	.4477 (1.56)
East Midlands	-.1118 (0.50)	.0631 (0.26)	.0635 (0.26)	-.4202 (1.44)
West Midlands	-.6687 (2.97)	-.5323 (2.20)	-.5451 (2.25)	-.7200 (2.50)
East Anglia	-.8390 (3.81)	-.7467 (3.18)	-.7366 (3.13)	-.8165 (2.91)
London	-.5300 (2.37)	-.4981 (2.05)	-.5079 (2.09)	-.6552 (2.22)
South East	-.4359 (2.05)	-.3702 (1.62)	-.3569 (1.56)	-.5653 (2.07)
South West	-.9114 (4.13)	-.7914 (3.34)	-.7812 (3.29)	-1.2908 (4.60)
Employed	.0279 (0.10)	.0138 (0.04)	.2634 (0.82)	.0718 (0.19)
Govt scheme	-.0810 (0.07)	-.8293 (0.62)	-.4875 (0.36)	-.5119 (0.30)
Unpaid work	-.7787 (0.82)	-.7232 (0.67)	-.4406 (0.41)	-.3551 (0.27)
Wait work	.4620 (0.53)	.4188 (0.43)	.7107 (0.73)	.3550 (0.32)
Unemployed	1.2065 (2.95)	.7957 (1.73)	.9387 (2.02)	.7219 (1.27)
Temp sick	2.7377 (3.64)	2.0543 (2.52)	2.2305 (2.73)	1.6013 (1.62)
Disabled	3.4113 (9.48)	3.1678 (7.92)	3.3335 (8.26)	3.1206 (6.46)
Retired	.1504 (0.47)	-.1684 (0.47)	.0770 (0.21)	-.0472 (0.11)
Home worker	1.2658 (4.09)	1.0358 (3.00)	1.1095 (3.19)	.8432 (2.03)
Labor force dk	3.6890 (1.23)	5.1333 (1.58)	8.0924 (2.30)	7.4525 (2.14)
Household size	.2295 (4.35)	.1653 (2.68)	.1487 (2.41)	.0639 (0.85)
# Children	-.0883 (1.25)	-.0808 (1.02)	-.0754 (0.95)	-.0217 (0.22)
Smokes cigarettes	3.4138 (32.03)	3.4104 (29.27)	3.4125 (29.16)	3.1939 (22.23)
Constant	67.7384	71.3670	71.3565	72.9774
Year dummies	9	9	9	5
Social class dummies			8	8
N	76,621	65,297	65,146	43,754
Adjusted R^2	.0524	.0513	.0517	.0556

Source: National Health Surveys of England. OLS equations.

Notes: Years 1998-2007. ALS is age left school. Fruit and vegetable portions available only for 2001-2006. Excluded categories no ft education; single and widowed; controls also included for retired; home worker; going to school or college; doing unpaid work; on a government scheme waiting to take up a job. Income is equivalised household income. The calculation of the equivalised income involves calculating a McClement score for each household (dependent on number, age and relationships of adults and children in the household), and then dividing the total household income by this score to get an equivalised household income. Social class fits individuals into seven classes plus na and not fully described, i.e. i-professional ; ii- managerial technical; iiin-skilled non-manual; iiim-skilled manual; iv-semi-skilled manual; v- unskilled manual and vi- armed forces.

t-statistics in parentheses.

All equations also include 11 month-of-interview dummies and 6 day-of-interview dummies.

Table 2. Systolic Blood-Pressure Regression Equations, 1998-2006

	(1)	(2)	(3)	(4)
Log income		-.5902 (6.15)	-.4360 (4.40)	-.0894 (0.75)
# Fruit & vegetables				-.0992 (3.29)
Age	.4249 (73.85)	.4263 (68.38)	.4289 (68.42)	.4170 (55.31)
Male	5.4704 (44.82)	5.5646 (42.28)	5.7508 (40.77)	6.1893 (36.89)
BMI	.6866 (56.04)	.6870 (52.20)	.6887 (52.26)	.6711 (42.95)
Black	1.0761 (3.12)	.9191 (2.42)	.8979 (2.36)	1.0977 (2.30)
Asian	-.6367 (2.29)	-.7371 (2.35)	-.8466 (2.67)	-.8260 (2.08)
Other race	-1.7936 (2.78)	-1.8751 (2.69)	-1.8172 (2.59)	-1.4853 (1.60)
Still at school	1.4639 (1.91)	.8343 (0.97)	.7390 (0.85)	1.2187 (1.12)
ALS ≤14	.8103 (2.07)	.4762 (1.11)	.3668 (0.85)	.2225 (0.42)
ALS 15	-.8974 (2.49)	-1.1061 (2.81)	-1.1524 (2.92)	-.7697 (1.64)
ALS 16	-.9737 (2.82)	-1.2554 (3.34)	-1.1719 (3.10)	-.9745 (2.18)
ALS 17	-.9057 (2.36)	-1.1434 (2.75)	-.9911 (2.37)	-.6533 (1.32)
ALS 18	-.9059 (2.41)	-.9465 (2.31)	-.6972 (1.69)	-.1436 (0.30)
ALS >=19	-1.6348 (4.68)	-1.6562 (4.33)	-1.2255 (3.15)	-.7157 (1.56)
Married/living	-3.8223 (24.96)	-3.7105 (21.87)	-3.6034 (21.14)	-3.5381 (17.17)
Separated/divorced	-3.1097 (13.46)	-3.1977 (12.95)	-3.1316 (12.67)	-2.6475 (8.90)
North West	-1.6165 (5.73)	-1.6870 (5.64)	-1.6700 (5.58)	-1.3452 (3.79)
Yorks/Humber	-.4623 (1.56)	-.4372 (1.39)	-.4352 (1.38)	-.4571 (1.22)
East Midlands	-1.6581 (5.56)	-1.6455 (5.21)	-1.6230 (5.13)	-1.9590 (5.17)
West Midlands	-1.9877 (6.63)	-1.9643 (6.18)	-1.9380 (6.09)	-1.8648 (4.98)
East Anglia	-2.6109 (8.91)	-2.5728 (8.35)	-2.5378 (8.22)	-2.7257 (7.45)
London	-4.0991 (13.77)	-4.0938 (12.85)	-4.087 (12.81)	-4.3530 (11.29)
South East	-1.9321 (6.81)	-1.9369 (6.46)	-1.9158 (6.38)	-2.3272 (6.52)
South West	-2.3187 (7.89)	-2.2913 (7.37)	-2.2514 (7.22)	-2.5160 (6.88)
Employed	-.5696 (1.55)	-.4376 (1.07)	-.1699 (0.41)	-.5592 (1.13)
Govt scheme	-.3578 (0.22)	-1.1803 (0.67)	-.7648 (0.44)	-1.4422 (0.65)
Unpaid work	-2.4194 (1.92)	-3.2762 (2.31)	-3.0727 (2.16)	-2.0619 (1.18)
Wait work	.0488 (0.04)	-.1555 (0.12)	.1283 (0.10)	-.4078 (0.28)
Unemployed	-.2889 (0.53)	-.6904 (1.15)	-.5342 (0.88)	-.3472 (0.47)
Temp sick	-1.7766 (1.78)	-2.6447 (2.48)	-2.4198 (2.26)	-3.2686 (2.54)
Disabled	-2.2812 (4.81)	-2.6145 (5.05)	-2.4085 (4.60)	-2.5692 (4.13)
Retired	.5894 (1.37)	.3375 (0.71)	.6146 (1.28)	.4939 (0.87)
Home worker	-8.0706 (2.01)	-7.0255 (1.65)	-6.0639 (1.32)	-1.4057 (0.31)
Household size	.2804 (4.00)	.1437 (1.78)	.1181 (1.46)	.1075 (1.10)
# Children	-1.6608 (17.81)	-1.6145 (15.64)	-1.5911 (15.38)	-1.5733 (12.54)
Smokes cigarettes	.9289 (6.55)	.8085 (5.30)	.8079 (5.27)	.8661 (4.63)
	(			
Constant	99.0440	105.1435	104.2566	95.7027
Year dummies	9	9	9	6
Social class dummies			8	8
N	76,621	65,295	65,144	43,754
Adjusted R^2	.2989	.3000	.3003	.2981

Source: National Health Surveys of England, 1998-2006

Table 3. Diastolic Blood-Pressure Regression Equations, 1998-2006

	(1)	(2)	(3)	(4)
Log income		-.0846 (1.14)	-.1005 (1.31)	-.0089 (0.10)
# Fruit & vegetables				-.0911 (3.95)
Age	.8976 (51.33)	.8869 (45.44)	.8927 (45.42)	.8511 (36.54)
Age^2	-.0074 (41.59)	-.0073 (36.32)	-.0073 (36.38)	-.0072 (29.78)
Male	2.6122 (28.09)	2.6830 (26.36)	2.7171 (24.89)	2.1155 (16.52)
BMI	.4431 (47.15)	.4448 (43.45)	.4457 (43.45)	.4886 (40.75)
Black	1.4819 (5.64)	1.5033 (5.11)	1.5177 (5.15)	1.6593 (4.54)
Asian	1.7254 (8.14)	1.7912 (7.40)	1.6984 (6.93)	1.9657 (6.49)
Other race	-.3808 (0.78)	-.4610 (0.86)	-.5056 (0.93)	-.8277 (1.17)
Still at school	.1249 (0.21)	-.3117 (0.47)	-.4414 (0.66)	-.0283 (0.03)
ALS ≤14	-.3016 (1.01)	-.4459 (1.34)	-.3853 (1.15)	-.9315 (2.32)
ALS 15	-.6323 (2.28)	-.7621 (2.48)	-.7027 (2.28)	-.5651 (1.56)
ALS 16	-.4281 (1.62)	-.5617 (1.92)	-.5118 (1.74)	-.4210 (1.23)
ALS 17	-.0085 (0.03)	-.0895 (0.28)	-.0449 (0.14)	.1224 (0.32)
ALS 18	-.0892 (0.31)	-.1167 (0.37)	-.0678 (0.21)	.1456 (0.39)
ALS >=19	.0739 (0.28)	-.0014 (0.01)	.0285 (0.09)	.3257 (0.93)
Married/living	-1.3194 (10.50)	-1.3303 (9.49)	-1.3108 (9.33)	-1.3186 (7.92)
Separated/divorced	-.6370 (3.52)	-.7317 (3.72)	-.7220 (3.67)	-.5549 (2.39)
North West	-1.0967 (5.11)	-1.1354 (4.91)	-1.1350 (4.90)	-.9109 (3.36)
Yorks/Humb	.0944 (0.42)	.0944 (0.39)	.1024 (0.42)	.0327 (0.11)
East Midlands	-1.6090 (7.09)	-1.5648 (6.41)	-1.5373 (6.29)	-1.7489 (6.04)
West Midlands	-1.7312 (7.59)	-1.7725 (7.22)	-1.7622 (7.16)	-1.6096 (5.63)
East Anglia	-1.8936 (8.48)	-1.9519 (8.19)	-1.9247 (8.06)	-1.9229 (6.89)
London	-2.3099 (10.19)	-2.4064 (9.77)	-2.4012 (9.73)	-2.5242 (8.58)
South East	-1.5631 (7.24)	-1.6131 (6.96)	-1.5908 (6.85)	-1.6774 (6.16)
South West	-1.4212 (6.35)	-1.4691 (6.11)	-1.4542 (6.03)	-1.7115 (6.13)
Employed	-.2622 (0.93)	-.1311 (0.41)	.0921 (0.28)	-.1672 (0.44)
Govt scheme	.0064 (0.01)	-.0959 (0.07)	.1408 (0.10)	-.6849 (0.41)
Unpaid work	-2.2386 (2.33)	-2.8235 (2.58)	-2.6070 (2.37)	-2.2884 (1.72)
Wait work	.1185 (0.13)	-.1281 (0.13)	.1232 (0.13)	-.4622 (0.42)
Unemployed	.2051 (0.49)	.1876 (0.40)	.2985 (0.63)	.5303 (0.94)
Temp sick	.1634 (0.21)	-.5318 (0.64)	-.3481 (0.42)	-1.1979 (1.22)
Disabled	-.0057 (0.02)	-.0461 (0.11)	.1027 (0.25)	-.0112 (0.02)
Retired	-1.3980 (4.26)	-1.4744 (4.02)	-1.2780 (3.43)	-1.4067 (3.23)
Home worker	-.6826 (2.17)	-.5303 (1.52)	-.4286 (1.22)	-.2354 (0.57)
Household size	-.1424 2.66)	-.2283 (3.66)	-.2357 (3.76)	-.1847 (2.48)
# Children	-.3181 (4.46)	-.2482 (3.09)	-.2505 (3.11)	-.3429 (3.56)
Smokes cigarettes	.3035 (2.81)	.2883 (2.44)	.3164 (2.67)	.3752 (2.63)
		()		
Constant	41.8321	42.9079	43.3626	42.3783
Year dummies	9	9	9	6
Social class dummies			8	8
N	76621	652997	65146	43755
Adjusted R^2	.1457	.1409	.1409	.1421

Source: National Health Surveys of England, 1998-2006

Table 4. Fibrinogen Regression Equations, 1998-2006

	(1)	(2)	(3)	(4)
Log income		-.0189 (3.00)	-.0154 (2.36)	-.0074 (0.84)
# Fruit & vegetables				-.0096 (4.28)
Age	.0114 (29.69)	.0115 (27.41)	.0116 (27.55)	.0122 (21.07)
Male	-.1885 (23.70)	-.1808 (21.03)	-.1848 (20.03)	-.2000 (15.98)
BMI	.0333 (40.75)	.0324 (36.62)	.0323 (36.56)	.0333 (27.93)
Black	-.0391 (1.89)	-.0479 (2.11)	-.0496 (2.18)	-.0509 (1.58)
Asian	.1184 (7.16)	.1067 (5.78)	.0984 (5.27)	.1109 (4.17)
Other race	.1240 (2.91)	.1147 (2.48)	.1147 (2.48)	.1343 (1.66)
Still at school	.0329 (0.66)	.0958 (1.73)	.0810 (1.45)	.0275 (0.34)
ALS ≤14	.0224 (0.85)	.0236 (0.82)	.0220 (0.76)	.0509 (1.25)
ALS 15	-.0283 (1.15)	-.0243 (0.91)	-.0227 (0.84)	.0005 (0.02)
ALS 16	-.0432 (1.81)	-.0363 (1.40)	-.0311 (1.20)	-.0094 (0.26)
ALS 17	-.0699 (2.68)	-.0534 (1.89)	-.0460 (1.62)	-.0056 (0.15)
ALS 18	-.0659 (2.56)	-.0534 (1.90)	-.0436 (1.55)	-.0378 (0.98)
ALS >=19	-.0877 (3.66)	-.0731 (2.79)	-.0600 (2.25)	-.0257 (0.71)
Married/living	-.0483 (4.78)	-.0441 (3.92)	-.0417 (3.70)	-.0569 (3.64)
Separated/divorced	-.0269 (1.86)	-.0274 (1.76)	-.0266 (1.71)	-.0256 (1.19)
North West	.0031 (0.16)	.0004 (0.02)	.0011 (0.06)	.0032 (0.12)
Yorks/Humb	-.0132 (0.65)	-.0075 (0.35)	-.0070 (0.33)	-.0061 (0.21)
East Midlands	-.0058 (0.29)	-.0054 (0.26)	-.0047 (0.22)	-.0446 (1.50)
West Midlands	-.0129 (0.64)	-.0090 (0.42)	-.0079 (0.37)	.0311 (1.09)
East Anglia	-.0393 (1.97)	-.0344 (1.63)	-.0331 (1.57)	-.0470 (1.63)
London	.0103 (0.52)	.0080 (0.38)	.0079 (0.37)	.0114 (0.39)
South East	-.0053 (0.28)	.0002 (0.01)	.0016 (0.08)	-.0122 (0.44)
South West	-.0123 (0.62)	-.0039 (0.19)	-.0020 (0.09)	.0186 (0.66)
Employed	-.0179 (0.69)	-.0394 (1.35)	-.0236 (0.80)	-.0580 (1.45)
Govt scheme	.0649 (0.53)	.0518 (0.40)	.0741 (0.57)	.2347 (1.26)
Unpaid work	.0190 (0.23)	.0121 (0.13)	.0289 (0.31)	-.1867 (1.44)
Wait work	.0974 (1.20)	.0871 (1.00)	.1055 (1.20)	-.0321 (0.28)
Unemployed	.0316 (0.84)	-.0009 (0.02)	.0129 (0.31)	.0365 (0.61)
Temp sick	.1265 (1.90)	.0864 (1.21)	.1016 (1.42)	.1226 (1.23)
Disabled	.1472 (4.42)	.1092 (2.99)	.1218 (3.31)	.1031 (2.04)
Retired	.1076 (3.63)	.0708 (2.15)	.0857 (2.58)	.0415 (0.92)
Home worker	.0732 (2.55)	.0577 (1.82)	.0600 (1.89)	.0098 (0.23)
Household size	.0101 (2.20)	.0118 (2.21)	.0109 (2.03)	.0178 (2.37)
# Children	-.0222 (3.69)	-.0291 (4.32)	-.0286 (4.24)	-.0323 (3.40)
Smokes cigarettes	.2532 (26.91)	.2475 (24.41)	.2483 (24.38)	.2647 (18.23)
Constant	1.4273	1.6551	1.6764	1.9236
Year dummies	5	5	5	3
Social class dummies			8	8
N	31,212	26,814	26,814	14,760
Adjusted R^2	.2543	.2482	.2488	.2030

Source: National Health Surveys of England, 1998-2006

Notes: Years 1998-2000 and 2003-2006. Switching to a logged dependent variable leaves the results essentially unchanged.

Table 5. Log C-Reactive Protein Regression Equations, 1998-2006

	(1)	(2)	(3)	(4)
Log income		-.0409 (3.92)	-.0359 (3.34)	-.0382 (2.77)
# Fruit & vegetables				-.0271 (7.72)
Age	.0104 (16.32)	.0100 (14.55)	.0102 (14.69)	.0094 (10.31)
Male	-.1624 (12.33)	-.1611 (11.34)	-.1600 (10.50)	-.1586 (8.08)
BMI	.0931 (68.97)	.0926 (63.75)	.0927 (63.75)	.0916 (49.12)
Black	-.1578 (4.75)	-.1747 (4.79)	-.1752 (4.80)	-.1804 (3.61)
Asian	.1831 (6.85)	.1659 (5.57)	.1641 (5.45)	.1990 (4.83)
Other race	.0286 (0.42)	.0333 (0.45)	.0327 (0.44)	.1123 (0.90)
Still at school	.3420 (4.29)	.3318 (3.70)	.3325 (3.69)	.1705 (1.33)
ALS ≤14	.2457 (5.64)	.2238 (4.70)	.2185 (4.58)	.2312 (3.59)
ALS 15	.1266 (3.14)	.1305 (2.98)	.1268 (2.89)	.1536 (2.64)
ALS 16	.0413 (1.06)	.0402 (0.96)	.0397 (0.94)	.0726 (1.30)
ALS 17	.0326 (0.77)	.0428 (0.93)	.0434 (0.94)	.0986 (1.63)
ALS 18	.0680 (1.62)	.0831 (1.83)	.0880 (1.92)	.0909 (1.52)
ALS >=19	-.0117 (0.30)	.0064 (0.15)	.0231 (0.54)	.0859 (1.53)
Married/living	-.0239 (1.42)	-.0220 (1.18)	-.0213 (1.14)	-.0396 (1.61)
Separated/divorced	-.0517(2.16)	-.0659 (2.57)	-.0653 (2.54)	-.0340 (1.02)
North West	-.0419 (1.31)	-.0403 (1.19)	-.0398 (1.17)	-.0143 (0.33)
Yorks/Humber	-.0546 (1.61)	-.0558 (1.55)	-.0561 (1.55)	-.0647 (1.39)
East Midlands	-.0424 (1.27)	-.0468 (1.32)	-.0468 (1.31)	-.0659 (1.40)
West Midlands	-.0397 (1.18)	-.0529 (1.49)	-.0523 (1.47)	-.0392 (0.87)
East Anglia	-.0610 (1.83)	-.0715 (2.03)	-.0721 (2.05)	-.0426 (0.94)
London	-.0675 (2.05)	-.0693 (1.96)	-.0715 (2.02)	-.0727 (1.57)
South East	-.0488 (1.52)	-.0509 (1.49)	-.0513 (1.50)	-.0397 (0.89)
South West	-.0884 (2.65)	-.0940 (2.65)	-.0933 (2.63)	-.0834 (1.86)
Employed	.0605 (1.45)	.0631 (1.36)	.0659 (1.39)	.0657 (1.07)
Govt scheme	-.1285 (0.67)	-.1920 (0.93)	-.1875 (0.91)	.0001 (0.00)
Unpaid work	.0638 (0.47)	.1489 (1.00)	.1480 (0.99)	.1252 (0.64)
Wait work	.2215 (1.71)	.2754 (1.97)	.2784 (1.99)	.2552 (1.47)
Unemployed	.1619 (2.68)	.1481 (2.21)	.1518 (2.25)	.1220 (1.33)
Temp sick	.2268 (2.14)	.2367 (2.08)	.2415 (2.11)	.1814 (1.17)
Disabled	.3878 (7.26)	.3629 (6.21)	.3663 (6.21)	.3772 (4.87)
Retired	.2515 (5.24)	.2288 (4.31)	.2320 (4.32)	.1979 (2.86)
Home worker	.2000 (4.34)	.1854 (3.64)	.1848 (3.63)	.1537 (2.30)
Household size	.0214 (2.91)	.0221 (2.55)	.0219 (2.52)	.0351 (3.01)
# Children	-.0411 (4.23)	-.0522 (4.80)	-.0512 (4.70)	-.0634 (4.29)
Smokes cigarettes	.3002 (19.52)	.2927 (17.70)	.2925 (17.61)	.2836 (12.60)
Constant	-2.7031	-2.2609	-2.3052	-2.0907
Year dummies	4	4	4	2
Social class dummies			8	8
N	30,522	26,306	26,306	14,756
Adjusted R^2	.2198	.2147	.2149	.2157

Source: National Health Surveys of England, 1998-2006

Notes: Years 1998, 1999, 2003, 2004 and 2006.

Table 6. Ordered Logit 'Been Feeling Reasonably Happy' Equations, 1998-2006

	(1)	(2)	(3)	(4)
Log income		.0571 (4.33)	.0693 (5.10)	.0644 (3.82)
# Fruit & vegetables				.0299 (6.95)
Age	-.0283 (9.12)	-.0313 (9.10)	-.0312 (9.02)	-.0351 (8.07)
Age^2	.0002 (8.08)	.0002 (8.31)	.0002 (8.30)	.0003 (7.14)
Male	.1950 (11.72)	.1990 (10.97)	.1828 (9.41)	.1740 (7.23)
BMI	-.0033 (1.98)	-.0030 (1.66)	-.0032 (1.81)	-.0033 (1.50)
Black	.2171 (4.88)	.2902 (5.91)	.2833 (5.76)	.2956 (4.68)
Asian	.0957 (2.78)	.0951 (2.40)	.0962 (2.40)	.1576 (3.03)
Other race	-.0194 (0.21)	-.0457 (0.45)	-.0453 (0.45)	-.1350 (0.95)
Still at school	.0253 (0.22)	-.1137 (0.87)	-.1132 (0.86)	-.0615 (0.37)
ALS ≤14	-.0197 (0.38)	-.0235 (0.41)	-.0466 (0.81)	.0197 (0.27)
ALS 15	.0803 (1.68)	.0711 (1.35)	.0569 (1.07)	.1107 (1.70)
ALS 16	-.0106 (0.23)	-.0301 (0.60)	-.0307 (0.61)	-.0193 (0.31)
ALS 17	-.0495 (0.97)	-.0842 (1.50)	-.0744 (1.32)	-.0648 (0.94)
ALS 18	-.0190 (0.38)	-.0840 (1.52)	-.0702 (1.27)	-.1179 (1.75)
ALS >=19	.0468 (1.01)	-.0076 (0.15)	.0135 (0.26)	.0338 (0.53)
Married/living	.1020 (4.57)	.0980 (3.96)	.1001 (4.04)	.1033 (3.34)
Separated/divorced	-.1566 (4.79)	-.1329 (3.76)	-.1329 (3.76)	-.0734 (1.66)
North West	.0075 (0.19)	.0139 (0.34)	.0160 (0.39)	.0054 (0.10)
Yorks/Humber	.0028 (0.07)	.0059 (0.14)	.0057 (0.13)	.0462 (0.85
East Midlands	.0372 (0.91)	.0513 (1.17)	.0502 (1.15)	.0202 (0.37)
West Midlands	.0578 (1.41)	.0699 (1.60)	.0701 (1.60)	.0193 (0.36)
East Anglia	.0733 (1.83)	.0659 (1.55)	.0684 (1.61)	.0461 (0.87)
London	.0643 (1.60)	.0827 (1.90)	.0875 (2.01)	.0393 (0.72)
South East	.0407 (1.05)	.0486 (1.17)	.0515 (1.24)	.0375 (0.73)
South West	.0906 (2.22)	.1198 (2.74)	.1212 (2.77)	.1227 (2.27)
Employed	.0427 (0.87)	.0293 (0.53)	.0242 (0.43)	.0632 (0.91)
Govt scheme	.2898 (1.42)	.1714 (0.75)	.1837 (0.81)	.2489 (0.81)
Unpaid work	-.0681 (0.38)	.1026 (0.50)	.1055 (0.52)	.4163 (1.64)
Wait work	.1557 (0.97)	.1690 (0.97)	.1634 (0.94)	.4569 (2.25)
Unemployed	-.4967 (6.92)	-.4566 (5.68)	-.4614 (5.72)	-.4666 (4.56)
Temp sick	-1.5082 (12.28)	-1.5057 (11.33)	-1.5162 (11.37)	-1.3811 (8.08)
Disabled	-1.3518 (21.69)	-1.3380 (19.40)	-1.3480 (19.38)	-1.3624 (15.87)
Retired	-.0200 (0.35)	-.0268 (0.42)	-.0255 (0.39)	-.0478 (0.59)
Home worker	-.0866 (1.57)	-.1043 (1.70)	-.1108 (1.80)	-.1285 (1.69)
Household size	.0199 (2.11)	.0266 (2.43)	.0259 (2.36)	.0284 (2.05)
# Children	-.0637 (5.00)	-.0609 (4.27)	-.0607 (4.25)	-.0708 (3.91)
Smokes cigarettes	-.1831 (9.56)	-.1804 (8.66)	-.1884 (9.01)	-.2085 (7.83)
Cut 1	-4.7844	-4.3002	-4.2032	-4.3198
Cut 2	-2.8107	-2.3178	-2.2205	-2.2849
Cut 3	1.6038	2.1057	2.2047	2.1633
Year dummies	8	8	8	5
Social class dummies			8	8
N	98,066	82185	82,185	53,195
Pseudo R^2	.0170	.0181	.0184	.0203

Source: National Health Surveys of England, 1998-2006

Appendix 1. Table of Means and Standard Deviations

	N	Mean	Standard deviation
Pulse in beats per minute	83739	70.9746	12.4291
Diastolic b.p.	83737	74.2962	13.2000
Systolic b.p.	83737	132.3305	19.5979
Fibrinogen score	34318	2.9306	.7877
C-reactive protein score	32857	3.3677	6.6877
Age	124659	47.7830	19.5097
Male	124659	.4440	.4968
BMI	108366	26.7014	4.9535
1998	124659	.1276	.3336
1999	124659	.1174	.3219
2000	124659	.0840	.2775
2001	124659	.1255	.3313
2002	124659	.0828	.2756
2003	124659	.1190	.3238
2004	124659	.1084	.3109
2005	124659	.0826	.2753
2006	124659	.1134	.3171
2007	124659	.0388	.1933
Still at school	122926	.0088	.0937
AgeLeftSchool <=14	122926	.1231	.3286
ALS 15	122926	.1820	.3859
ALS 16	122926	.2529	.4346
ALS 17	122926	.0790	.2698
ALS 18	122926	.0886	.2842
ALS >=19	122926	.1907	.3929
Married/living together	122124	.6047	.4888
Separated/widowed/divorced	122124	.0904	.2868
Student	121413	.0639	.2446
Employed	121413	.5264	.4993
Govt scheme	121413	.0016	.0401
Unpaid work	121413	.0020	.0456
Wait work	121413	.0026	.0514
Unemployed	121413	.0219	.1466
Temp sick	121413	.0039	.0624
Disabled	121413	.0407	.1977
Retired	121413	.2238	.4168
Home worker	121413	.1125	.3160
Labor force dk	121413	.0001	.0118
Household size	122166	2.8165	1.4594
# Children	122166	.5332	.9479
Smoker	124577	.2382	.4259
Log household income	100436	9.7588	.8315
Sclass n/a	124421	3.0360	1.7662
Sclass i	124421	.0437	.2045
Sclass ii	124421	.2539	.4352
Sclass iiin	124421	.2260	.4182
Sclass iiim	124421	.1710	.3765

Sclass iv	124421	.1678	.3737
Sclass v	124421	.0539	.2259
Sclass armed forces	124421	.0017	.0415
Sclass dk	124421	.0031	.0563
#Fruit & vegetable portions per day	80941	3.6219	2.6247

Distribution of well-being dependent variable

Been feeling reasonably happy	
Much less than usual	1,784
Less so than usual	9,348
About same as usual	86,945
More so than usual	12,445
Total	110,522