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ABSTRACT

Biomarkers and Long-term Labour Market Outcomes: The Case of Creatine*

Using the Young Finns Study (YFS) combined with the Finnish Linked Employer-Employee Data (FLEED) we show that quantities of creatine measured in 1980 prior to labour market entry affect labour market outcomes over the period 1990-2010. Those with higher levels of creatine (proxied by urine creatinine) prior to labour market entry spend more time in the labour market in the subsequent two decades and earn more. Creatine is not associated with high educational attainment. The associations between creatine and labour market outcomes are robust to controlling for other biomarkers, educational attainment and parental background. Creatine is a naturally occurring nitrogenous organic acid which supplies energy to body cells, including muscles. Our findings are consistent with high energy levels, induced by creatine, leading to productivity-enhancing traits such as a high propensity for effort, perseverance, and high-commitment.

JEL Classification: J24, J31, I12

Keywords: biomarkers, creatine, creatinine, labour market, earnings, employment

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1. Introduction

Standard micro-economic theory assumes that individuals behave according to an economic calculus in which their utility varies with effort and ability. Effort is thus at the heart of labour economics because, together with ability, it can account for a substantial proportion of the variance in individuals' labour productivity and thus their earnings. In the standard model effort is a disutility creating both incentives and monitoring problems for employers eager to raise labour productivity. Individuals' ability and their propensity for effort are usually treated as a "black box" because they are rarely observed, although proxies are observed. Test scores and qualifications are often treated as markers of ability. Effort can be observed at the extensive margin as hours worked, although these are often determined by labour demand factors beyond the worker's control. In the absence of direct measures of effort and ability, it is commonly assumed that worker heterogeneity in ability and effort is fixed over time such that estimates within individuals over time can identify factors influencing the labour market outcome of interest net of differences in effort and ability.[1]

Behavioural economists directly observe effort and ability in laboratory experiments enabling them to draw inferences about which worker types, treatments and social settings are linked to productivity and other work-related outcomes (Charness and Kuhn, 2011). Other economists have begun to explore links between biomarkers and labour market behaviours in an attempt to get inside the "black box".[2] The assumption is that individuals are "wired" differently due to differences in their genetic make-up and physical processes in ways which can help predict their success in acquiring human capital and labour market behaviours. However, knowledge about links between biomarkers and labour market behaviours has been hampered by the paucity of longitudinal data containing biomarkers and labour market outcomes. Most studies have had to rely on cross-sectional data in which labour market status is measured at roughly the same time as the biomedical measurements are taken. There are some exceptions, such as birth cohort studies (e.g. Black et al., 2007), many of which focus on height or weight at an early age and subsequent labour market outcomes. Other studies take biomarker measurements when individuals have already entered the labour market and seek to predict

[1] In the personnel economics literature that concerns the effects of incentive pay on productivity the difference between OLS and individual fixed effects results is often interpreted as the impact of effort (e.g. Pekkarinen and Riddell, 2008).

[2] The term "biomarker", or biological marker, refers to objective indicators of medical state, which can be measured accurately and reproducibly (Strimbu and Tavel, 2010).

future outcomes. The results are often disputed, as are the hypothesised mechanisms linking these biomarkers to labour market outcomes.

We contribute to the literature by examining the association between a biomarker, which is linked to individuals' energy levels, and long-term labour market outcomes. Using the Young Finns Study (YFS) linked to the Finnish Linked Employer-Employee Data (FLEED) we show that quantities of creatine proxied by urine creatinine measured in 1980 prior to labour market entry affect labour market outcomes over the period 1990-2010. Those with higher levels of creatine in 1980 spend more time in the labour market in the subsequent two decades and earn more. Creatine is not associated with educational attainment. The associations between creatine and labour market outcomes are robust to controlling for other biomarkers, educational attainment and parental background. Creatine is a naturally occurring nitrogenous organic acid which supplies energy to body cells, including muscles and brain. Our findings are consistent with high energy levels, induced by creatine, leading to productivity-enhancing traits - such as a high propensity for effort, perseverance, or high-commitment - which results in positive labour market outcomes.

Section Two reviews the existing literature on biomarkers and labour market outcomes, identifying how we contribute to that literature. Section Three outlines the possible mechanisms between creatine and labour market outcomes. Section Four presents the data. Section Five describes the estimation approach and presents the results while Section Six concludes.

2. Theory and empirical evidence

Individuals differ biometrically in ways that may be linked to the acquisition of human capital, labour market behaviour and thus income for a variety of reasons. First, biometric differences may affect individuals' economic preferences, tastes or predispositions. For example, individuals with higher levels of testosterone are known to favour risk-taking, an attribute that can be rewarded in the labour market. For example, Coates et al. (2009) find a biomarker proxying testosterone exposure at birth was linked to the success of financial traders, a high-risk occupation.[3]

[3] Sapienza et al. (2009) find individuals high in testosterone and low in risk aversion were more likely to choose risky careers in finance. Määttänen et al. (2013) report that total testosterone is associated with higher reward dependence which reflects the importance of social rewards to an individual.

Second, individuals differ in their innate abilities which are due, in part, to their genetic make-up. These abilities include mental ability, such as intelligence, and physical aptitudes. These innate abilities may translate into higher productivity and therefore higher earnings or better employment prospects. For example, psychometric intelligence is a good predictor of educational achievement (Deary et al., 2007), occupational level attainment and performance within one's chosen occupation (Schmidt and Hunter, 2004). Some abilities make individuals particularly suited to specific occupations. For instance, manual dexterity is sought after among machinists (Fischer and Sobkow, 1979). Biomarkers may also be predictors of severe diseases which impair individuals' productivity or labour market attachment.

Third, individuals' labour market performance may be partially determined by their subjective well-being and emotional traits. For instance, traits like emotional resilience enable some individuals to persevere in tasks such as job search that others may give up on (Moorhouse and Caltabiano, 2007). There is also evidence that creatine is negatively associated with mental disorders such as depression (Allen, 2012). Conversely, depression lowers employment probabilities, though it seems to have no impact on weekly hours worked nor hourly earnings (Peng et al., 2013). Green (2010) confirms that different aspects of subjective wellbeing have different effects on labour mobility while Hardy et al. (2003) show that job-related depression-enthusiasm is better at predicting absence than job-related anxiety-contentment. This literature leaves open the important question of the extent to which subjective wellbeing simply reflects the underlying physiological well-being captured in biomarkers.[4]

Fourth, the reactions of other labour market actors to an individuals' biometric characteristics may determine labour market outcomes. For instance, physical traits affect the way in which employers respond to job applicants and employees. Audit and correspondence studies indicate traits such as skin colour, facial abnormalities and gender can affect job seekers' probability of receiving a job offer, either because of employers' taste-based preferences or

[4] Kahneman and Krueger (2006, p. 14) suggest that 'personality variables' such as sleep are predictors of life satisfaction and affect. If so the effects of subjective wellbeing on labour market behaviour may be biased: they might even disappear once one introduces biometric data. Alternatively, subjective wellbeing may contain information which is not contained in biomarkers. They may even be orthogonal to one another, in which case their use together may explain more variance in labour market behaviour than the use of one or the other. However, there is no clear evidence linking specific well-being biomarkers to subjective wellbeing in large samples.

statistical discrimination.[5] The wage premium for beauty is consistent with employer taste-based preferences, though this has been challenged. There are certainly other potential reasons for the beauty premium (Hamermesh, 2011).[6] [7] Traits such as beauty may also affect the individual's own self-perception in ways that affect their labour market behaviour. For instance, Mobius and Rosenblat (2006) show that part of the beauty wage premium they identify in a laboratory experiment arises because physically attractive workers are more confident and higher confidence increases wages.

Fifth, individuals' educational attainment and labour market performance, such as earnings, occupational choices and employment, may also be partly determined by their personality (see e.g. Almlund et al., 2011). Recent studies have shown that personality traits may be related to biometric characteristics. For example, double-blind placebo controlled studies showed that subjects with artificially raised testosterone became less trusting (Bos et al., 2010) and less generous (Zak et al., 2008) towards strangers. This implies that biomarkers might be related to labour market performance indirectly via personality.[8]

The main difficulty interpreting results from most of the earlier studies is that the biomarkers appearing as independent variables in analyses of labour market outcomes may, in fact, be simultaneously determined by labour market experiences. This makes interpretation of results tricky. The problem is accentuated in studies using cross-sectional data or where the lag between biometric measurements and labour market outcomes is short. There may also be omitted variables problems which bias the estimates of biometric effects on labour market outcomes. For instance, the positive association between birth weight and subsequent labour market outcomes (e.g. Behrman and Rosenzweig, 2004; Black et al., 2007) may be due to birth weight proxying early life social advantages that carry on through to adulthood. This may also partially explain the wage premium associated with height (LaFave and Thomas,

[5] For a review of recent developments in research into statistical and taste-based discrimination in markets, including labour markets, see Guryan and Charles (2013).
[6] Kanazawa and Kovar (2004) argue that beautiful people are more successful in the labour market because they are more intelligent.
[7] More broadly, individuals may suffer labour market disadvantage by virtue of being treated as different from others, or because society does not accommodate their specific needs, resulting in fewer opportunities for advancement. This is often the case with respect to physical or mental "disabilities" which, if accommodated by employers and society more generally, may no longer prove to be limitations for those with the "disabilities". Such considerations have led to legislative changes requiring employers to make physical adjustments to their workplaces to ensure equal access to potential workers (and customers) with physical limitations.
[8] Mueller and Plug (2006) distinguished three possible mechanisms which might explain the connections between personality and labour market outcomes: 1) Personality contributes to productivity 2) Personality is linked to preferences and therefore e.g. on occupational choices or attitudes towards leisure 3) Labour market discrimination.

2013).[9] Alternatively, these biomarkers may also reflect healthiness, leading to less sickness later in life, and thus a better employment record which is rewarded in the labour market through higher earnings.

Some studies have begun to exploit plausibly exogeneous genetic differences across individuals in an effort to identify the causal relationship between biomarkers and labour market outcomes. For example, when Norton and Han (2008) instrument for obesity with a genetic marker known to predispose individuals to obesity they find no effect of lagged obesity on subsequent employment or wages. In principle, such an approach promises to overcome endogeneity issues provided one can rule out links between the genetic marker and labour market outcomes arising through mechanisms other than obesity. In practice, as von Hinke Kessler Scholder et al. (2010) discuss, genetic markers are not a "silver bullet" in the search for causal identification. In the first place, they are often weak instruments and thus require very large samples to identify robust effects. Second, genetic components operate as a system, rather than in isolation, making it difficult to isolate the impact of a specific genetic marker. Third, specific genetic markers can have multiple pheotypic effects (pleiotropy) leading to uncertain net outcomes.

3. Possible mechanisms for creatine

In this paper we consider the effects of a particular biomarker - creatine - collected prior to labour market entry on labour market outcomes over the subsequent two decades. Although we can not claim to have isolated the causal impact of creatine on labour market outcomes this sequencing helps overcome the simultaneity problem referred to above, while controlling for family background and a range of other biomarkers also collected prior to labour market entry helps overcome omitted variables biases which might arise if we focused on the effects of a single biomarker which might, conceivably, be proxying the effects of other biomarkers.

Creatine is a naturally occurring nitrogenous organic acid which supplies energy to body cells, including muscles and brain. There is a vast literature on the links between creatine and pathology and metabolic capacity (see Wyss and Kaddurah-Daouk, 2000 for a comprehensive review). Two of its effects - one physical, the other mental - seem particularly pertinent to

[9] This is contested by Persico et al. (2004) who pinpoint differences in height in adolescence as an important contributor to the height wage premium.

labour market performance and the acquisition of human capital. Furthermore, creatine may have an indirect effect on labour market outcomes via personality.

The first potential mechanism is creatine's ability to improve work performance, most notably "in a variety of short-term intermittent, supramaximal exercise tests" (Wyss and Kaddurah-Daouk, 2000, p. 1183). For this reason creatine is used by athletes as a performance-enhancing supplement. In their review of creatine supplementation in sports physiology Wyss and Kaddurah-Daouk (2000, p. 1177-1182) state it is a popular supplement for athletes engaged in high-intensity exercise including "bodybuilders, wrestlers, tennis players, cyclists, mountain bikers, rowers, ski-jumpers [and] cross-country skiers as well as among ski, rugby, handball, basketball, football and ice hockey teams" (op. cit.: p. 1177). This performance-enhancing effect of creatine was not known in 1980 when the YFS cohort creatine measurements were taken. Instead we measure the amount of creatine occurring naturally in the body. It seems plausible that, by reducing (increasing) the costs (returns) to effort, the ergogenic effects of creatine may lead to improvements in labour market performance.[10] Greater effort intensity may result in more successful job search,[11] longer periods in employment (for instance, via an increased propensity to supply labour, or reduced absenteeism), and faster earnings growth (as in the case of Lazear's (2000) windshield installers who increase their productivity via effort following the firm's switch to performance pay).[12]

The second mechanism by which creatine may improve labour market performance and educational attainment is via its impact on cognitive ability. Creatine affects brain function and, because creatine is found in large quantities in meat, fish and animal products, researchers have examined the effects of creatine on vegans and vegetarians. One such placebo-controlled double-blind experiment gave small daily doses of creatine to a treatment group for six weeks. Compared with the control group they were able to repeat longer

[10] An additional potential channel for the positive effect of creatine on labour market outcomes in adulthood is that high levels of creatine are related to physical activity when young. Leisure sport activities can in turn be associated with improvements in non-cognitive skills and formation of social capital that are eventually positively rewarded in the labour market (e.g. Lechner 2009).

[11] In the standard search models job search intensity is endogeous with respect to the job offer arrival rate. There are increasing returns to job search intensity, though at a diminishing rate. See, for example, Chirinko (1982).

[12] Indeed, in Lazear's (2000) and Prendergast's (1999) models employers solve the principal-agent problem by eliciting greater effort when linking pay to output, as opposed to paying a fixed wage. In such models effort is costly, so factors such as high levels of creatine which reduce the costliness of effort imply the potential for higher earnings. Effort is multi-dimensional and may show up in a variety of ways in a job context.

sequences of numbers from memory and had higher overall IQ scores (Rae et al., 2003).[13] [14] The results are consistent with creatine increasing the amount of energy available to the brain for computational tasks, thus improving general mental ability. The study did not test for long-term effects but, as the authors note, short-term effects may be sufficient to assist with examination work, for instance, so short-term impacts may nevertheless lead to long-term gains in the labour market and in education.[15] Memory improvements were also found in a similar study, though only for vegetarians, not omnivores, and creatine supplementation had no impact on verbal fluency (Benton and Donohoe, 2011). Also double-blinded placebo-controlled tests for non-vegetarians have found positive connection between creatine supplementation and cognitive performance. Watanabe et al. (2002) report that a dietary supplement of creatine reduced mental fatigue when subjects repeatedly performed a simple mathematical calculation in a stressful time-pressured test. McMorris et al. (2006, 2007a) found that following significant sleep deprivation with mild exercise, creatine supplementation improved mood and performance in cognitive tasks. Creatine supplementation can also increase backward memory span (Hammett et al., 2010) and cognitive performance of elderly people (McMorris et al., 2007b). In addition, studies based on individuals with inborn errors in creatine production and rat experiments confirm that creatine has an important role in normal brain development and cognitive functioning (for a review see Allen, 2012).

The third possible mechanism through which creatine may improve labour market performance is personality. Ryman et al. (2011) found that creatine concentrations in certain parts of brain were associated with individual's Big Five personality traits. The relationship was positive for Conscientiousness and negative for Agreeableness, Extraversion, and Neuroticism. Previous studies have found that higher Conscientiousness, lower Agreeableness and lower Neuroticism are associated with better labour market success in terms of earnings, job performance and employment (see e.g. Almlund et al., 2012; Uysal and Pohlmeier, 2011; Heineck, 2010; Nandi and Nicoletti, 2009). Higher Extraversion, on the other hand, has usually been related to better labour market performance (e.g., Nandi and Nicoletti, 2009;

[13] The experiment showed significant improvements for the treatment group in two tests of what is known as "fluid intelligence", namely the ability to think logically and solve problems in novel settings independently of acquired knowledge. The two tests were the Raven's Progressive Matrices and the backward digit span text from the Wechsler Adult Intelligence Scale.

[14] However, another study found no such effects in young adults (Rawson et al., 2008). It could be that creatine has positive effects on cognitive performance particularly in stressful situations. Positive effects of creatine on cognitive behaviour have been found especially in situations associated with reduced brain creatine, such as sleep deprivation, mild exercise and stressful mathematical tasks (Allen, 2012).

[15] http://news.bbc.co.uk/1/hi/health/3145223.stm

Turban et al., 2009). Therefore, apart from Extraversion, these results suggest that higher levels of creatine might be associated with better performance in the labour market.

Approximately half of an individual's daily creatine requirement is produced naturally by human body in the kidneys, liver, pancreas and possibly in brain cells and the rest is of daily requirement is replenished by dietary intake (Allen, 2012). Because creatine is contained in animal products including meat, dietary products and fish, it may be useful to control for food intake in isolating any relationship between creatine and subsequent labour market outcomes.[16]

We wish to isolate the independent association between creatine levels measured in 1980 and the subsequent educational, labour market and income outcomes for individuals in the following two decades. For reasons noted above we hypothesise that higher levels of creatine prior to labour market entry will result in greater labour market attachment and higher earnings due to the labour market returns to higher effort levels and improved cognitive ability. These, in turn, may result in higher income levels later in life.

4. Data

To examine the relationship between biomarkers and labour market outcomes we link data on biomarkers and parental background drawn from the Cardiovascular Young Finns Study (YFS) to the Finnish Longitudinal Employer-Employee Data (FLEED) of Statistics Finland which records periods of employment and earnings.

The YFS began in 1980 when 4,320 participants in six age cohorts (aged 3, 6, 9, 12, 15 and 18) were randomly chosen from five Finnish university regions using the national population register (Raitakari et al., 2008). A total of 3,596 persons participated in the study in 1980. Seven follow-up studies have been conducted, most recently in 2011/12. The aim of the study is to examine how childhood lifestyle, biological, and psychological factors contribute to the risk of cardiovascular diseases in adulthood. These include factors such as smoking status, alcohol use, diet, physical activity, parental background and chronic diseases. The data contain information on a variety of biomarkers such as height, skinfold measures, pulse (rest

[16] Blanchflower, Christakis and Oswald (2011) find links between income and some biomarkers weaken considerably when controlling for fruit and vegetable intake.

heart rate), blood pressure, cholesterol, triglyceride, insulin, copper and zinc in serum, C-reactive protein, several fatty acids and urine creatinine.

Data is collected using questionnaires, physical measurements and blood tests. All anthropometric measures originate from professional health examinations conducted at local health centres. As family background variables we use parental years of education, parents' health and their income level, which were obtained by a questionnaire in 1980.

Seven biomarkers used in this study were obtained in 1980 when the participants were 3 to 18 year old. Height (in millimeters) was measured by Seca anthropometer. Each skinfold measure is based on the average of three measurements obtained on the non-dominant arm using a Harpenden skinfold caliper (Porkka et al., 1997). We use information on triceps and subscapular skinfolds to measure body fat using the Slaughter equation (Slaughter et al., 1988).[17] YFS data also contain information on BMI (Body mass index).[18] However, BMI blurs the distinction between fat and fat-free mass such as muscle and bone (Yusuf et al., 2005; Burkhauser and Cawley, 2008). Pulse (or the count of arterial pulse per minute) is equivalent to measuring the heart rate at rest. It was measured by listening to the heart beat directly and counting it for a minute. Blood pressure was measured from the brachial artery in sitting position after 5 minutes rest with a standard mercury sphygmomanometer. Readings to the nearest even number of millimeters of mercury were performed 3 times on each subject. For 3-year-olds, blood pressure was measured with an ultrasound device (Juonala et al. 2005, Kivimäki et al. 2006). The mean of three measurements of systolic blood pressure measurement is used in this study.

Serum total cholesterol and triglycerides, were determined based on fasting venous blood samples after 12 hours of fasting. Non-fasting subjects were excluded from the analysis (n = 38). Serum samples were stored frozen at -20C for no more than 6 months until analyzed. All lipid determinations were performed in duplicate in the same season (fall) and as simultaneously as possible and the averages of the two measurements were used to determine the level of serum lipids. Triglycerides were determined by using a fully enzymatic method (Boehringer Mannheim) (Porkka et al., 1997). Serum insulin was measured with a modification of the immunoassay method of Herbert et al. (1965) (Juonala et al., 2005).

[17] For boys the Slaughter equation is 0.783 × (sum of triceps and subscapular skinfold) - 1.7. For girls it is 0.546 × (sum of triceps and subscapular skinfold) + 9.7.
[18] Body mass index is calculated as a person's weight in kilograms divided by height in metres squared.

The YFS also contains information on the amount of creatinine in the urine. Creatinine is a major breakdown product of creatine so that urine creatinine is a good proxy for creatine.[19] Our results using creatinine provide conservative estimates for creatine. Consequently, we obtain the lower bound for the true effect of creatine on long-term labour market outcomes if creatinine is subject to classical measurement error. Creatinine is removed from the body entirely by the kidneys. Creatinine is essentially the waste created from the body's use of creatine. In healthy children with normal kidney function, urine creatinine can be interpreted as an indicator that a child is extensively supplied by creatine. The amount of creatinine was measured using standard urine drug tests, based on the Jaffe method (e.g. Delanghe and Speeckaert, 2011). In analyses triglycerides and creatinine are log-transformed because of their skewed distributions.

The YFS data are linked to Statistic Finland's Finnish Longitudinal Employer-Employee Data (FLEED). We match the YFS and FLEED using unique personal identifiers. This is exact matching and there are no misreported ID codes. We therefore avoid problems created by errors in record linkages (e.g. Ridder and Moffitt, 2007). Thus, every person in the YFS data is identified in FLEED. We use FLEED to measure labour market outcomes. FLEED includes information on individuals' labour market status, and salaries and other income, taken directly from tax and other administrative registers that are collected and/or maintained by Statistics Finland. Thus, our income data do not suffer from underreporting or recall error, nor is it top coded. Short-term, cross-sectional measures of income, such as yearly earnings and hourly wages, contain idiosyncratic components that diminish the precision of the estimates (cf. Dahl et al., 2011). Register-based earnings also have much less measurement error than short-term measures that often originate from surveys. This accuracy increases the efficiency of the estimates, which is particularly important for relatively small samples such as the YFS.

For educational achievement we use an indicator for those who have obtained tertiary education based on the highest obtained degree in 2010. This information originates from the comprehensive register of completed degrees by Statistics Finland. The indicator is easier to interpret than a proxy for education years.

In this paper we use FLEED to construct two income measures for an individual's early life experiences in the labour market. Our income dependent variable in the regression analyses is

[19] If our data contained both creatine and creatinine, then creatinine could be used as an instrument for creatine. From this perspective, our estimation results can be interpreted as reduced-form IV estimates.

the logarithm of the average of annual taxable income over the period of 1990-2010. Taxable income is a broad income measure which includes annual wage and salary earnings and self-employment income. It also includes income transfers and social security benefits, such as unemployment and parental leave benefits, which often are proportional to past wage and salary earnings. Our earnings dependent variable is the logarithm of the average of annual wage and salary earnings over the period of 1990-2010. This is a much narrower measure of income than our first measure. The income measures are deflated using the consumer price index (base year 2000). When we begin to measure labour market outcomes in 1990 the YFS cohort are aged between 13 and 28 years old. Our final labour market outcomes are measured in 2010 when they are aged between 33 and 48 years old.

Data on employment status originate from FLEED that contains information from Employment Statistics. Employment Statistics record the exact labour market status during the last week of each year. This information is based on the state-run pension registers that cover all legal employment contracts.

Table 1 reports descriptive statistics for the variables that are used in the models. Means are presented together with standard errors in parentheses.[20] Table 2 shows the correlation coefficients between biomarkers. All correlations between creatinine and other biomarkers were statistically significant but the correlation coefficient between creatine and height is particularly high at 0.56. This is due to the fact that the level of creatinine steadily increases with age. The correlations between height and creatinine are significantly smaller when calculated within birth cohort.[21] The full set of indicators for birth cohort controls for the age effect in the models.

[INSERT TABLES 1-2]

[20] Descriptive statistics are based on the estimation sample used in Table 3. Because of missing information on some variables the estimation sample is smaller than the original sample of the YFS data. We tested the randomness of this attrition by two-sample test of proportions and two-sample t-test for equality of means. The results based on the available data indicated that the average wage and income were slightly higher in the estimation sample compared to the total sample. Furthermore, the youngest age cohort was slightly under-represented in the estimation sample (with the share of 14.6% in the estimation sample vs. 16.0% in the total sample). A discussion of attrition of the YFS data is provided in Raitakari et al. (2008).

[21] The correlations within cohorts from the youngest to the oldest were as follows: 0.15***; 0.03; 0.09**; 0.13***; 0.13*** and 0.02. "Growth spurt" (i.e. a rapid rise in height) may be related to the positive correlation between creatinine and height for those aged 12 and 15.

5. Results

5.1. Baseline estimates

We first estimate the effect of biomarkers on educational achievement later in life as indicated by completing at least some level of university education. We estimate linear probability models using OLS.[22] The baseline models control for gender, birth cohort and birth month[23] - all clearly predetermined variables. The explanatory variables are jointly statistically significant. However, creatinine is not associated with educational attainment (Table 3, Column 1). The effect of creatinine is not even marginally statistically significant.[24] This result does not imply that creatinine has no impact on cognitive function. It might affect those parts of cognitive function that are not captured in exam tests, or that people develop later in life.

[INSERT TABLE 3]

We argued earlier that creatine can potentially affect labour market outcomes via physical effort and mental endeavour. Both of these are possible due to the way creatine releases energy in the body. If creatine does improve cognitive function it can then have an effect on labour market outcomes either directly via cognitive ability or indirectly through the acquisition of formal educational attainment. Our results in Table 3 (Column 1) discount the possibility that creatine improves labour market outcomes indirectly through the acquisition of educational qualifications leading to access to high wage jobs. This suggests that the positive effect of creatinine manifests itself directly via cognitive ability in jobs in the labour market, or through effort.

But there are other biomarkers that make a difference for obtaining the highest level of formal education. We find that the level of insulin in the body is negatively related with completing at least some university education. The results also show that height has a positive and

[22] The marginal effects from probit models give similar results.
[23] There is evidence that birth month is associated with family background (Buckles and Hungerman, 2013). Also in the YFS data the average family income (in 1979) seemed to be higher among those children who were born at the beginning of the year. We estimated the models also without the indicators for birth month. The creatinine coefficients remained intact.
[24] We have also estimated the models using the imputed years of education as the outcome variable. The imputed measure for the years of formal education is based on the particularly strong assumption that it takes identical amount of time (in years) to complete one's formal education for all individuals given the accomplished level of education. These results show some evidence for the positive effect of creatine on educational attainment for men.

statistically significant effect at the 1% level.[25] The quantitative magnitude of height is non-negligible. An increase in height by one centimetre increases the probability of obtaining at least some university education by ~0.8%. In contrast, our other anthropometric measure i.e. body fat is not a significant determinant of educational attainment later in life, by a wide margin.

Next we estimate the effect of biomarkers on our three labour market outcomes - total income, earnings and employment - over the period 1990-2010 (Table 3, Columns 2-5). As previously, all models include controls for gender, birth cohort and birth month. The most important result is that the quantity of creatinine measured in 1980 prior to labour market entry is positively related to labour market outcomes in the subsequent twenty years. This pattern applies to both income measures and also to the average share of employment years over the observation window. The effect is statistically significant at the 1% level in all models.

The quantitative magnitude of the effect of creatinine is also non-negligible. We find that an increase in creatinine by one percent increases earnings by ~0.15% (Table 3, Column 3). One standard deviation increase from the average level of creatinine is associated with 6.8% increase in earnings. Because the average annual earnings are ~15900 euros over the period 1990-2010, this converts to an increase of ~1080 euros.[26] The effect of creatinine on total income later in life is lower at ~0.1% (Table 3, Column 2). This is in line with the view that total income includes elements of social insurance. For the reasons noted above, these estimates are likely to constitute the lower bound for the true effect of creatine on long-term labour market outcomes.

In contrast, the quantitative magnitude of the effect of creatinine on labour market attachment is much smaller. An increase in the amount of creatinine by one percent increases average employment years only by ~0.0003. The size of the effect is less than one day per year. This implies that creatinine has an influence on labour market outcomes largely on the intensive margin of labour supply. The finding is consistent with the idea that high energy levels, induced by creatinine, lead to productivity-enhancing traits such as a high propensity for

[25] This is an association that has been found previously for Finland (Silventoinen et al., 2000).
[26] The average level of creatinine in 1980 for all cohorts was 8.764 and the standard deviation within cohorts was 3.993. Therefore, a one standard deviation increase from the average level of creatinine is equivalent to 46% change. We found in Table 3 (Column 3) that an increase in creatinine by one percent increases earnings by ~0.15 %. This implies that a 46 %, or one standard deviation, increase in creatinine is associated with ~6.8% increase in annual earnings.

effort, perseverance, and high-commitment. It is also consistent with creatinine increasing cognitive ability and thus earnings potential.

We also find other interesting effects for biomarkers. Height has a significant positive effect on all labour market outcomes later in life. Our results show that height measured in younger ages is *also* related to subsequent labour market outcomes, in contrast to the results in Persico et al. (2004).[27] Body fat has a clear negative effect on earnings[28] but its effect on total income is much smaller and it is also statistically weaker. Body fat is not a significant determinant of labour market attachment. The results also show that triglyceride (a serum lipid) is negatively related to labour market attachment.[29]

5.2. Robustness

To explore the robustness of the baseline estimates, we have estimated several additional specifications that exploit the richness of our data. We briefly discuss each of these results.

First we control for educational attainment when estimating the effect of biomarkers on subsequent labour market outcomes over the period 1990-2010. These results show that the positive effect of creatinine on labour market outcomes remains intact while controlling for education (Table 4). Even the point estimate for creatinine remains almost unchanged. This finding is not surprising since creatinine was not a statistically significant determinant of educational attainment (Table 3, Column 1).

Because we use cross-sectional information on biomarkers, it is important to check the influence of potential outliers on the estimates. For this reason, we have excluded income, earnings and creatinine observations that are outside the 1st and 99th percentiles. This restriction of the estimation sample does not change the effect of creatinine on total income and earnings. Thus, the results are not driven by outliers. This finding is not surprising because we use a logarithmic transformation for both creatinine and our long-term average

[27] Persico et al. (2004) use the National Longitudinal Survey of Youth (NLSY) from 1979 and focus on white men. Their baseline specifications explain wages with height measured at the ages of 7, 11, 16 and 33. Persico et al. (2004, p. 1033) find that, among all recorded heights, only height at age 16 has an economically large and statistically significant effect on adult wages. Böckerman and Vainiomäki (2013) provide earlier evidence on the height premium for Finland.

[28] Wada and Tekin (2010) find similar results for the United States.

[29] Because there is statistically significant positive correlation (0.2442***) between body fat and triglyceride, we have also estimated the model without including body fat among the explanatory variables. Triglyceride obtains in this specification a negative coefficient and it is statistically significant at the 4% level.

measures of labour market outcomes to suppress the influence of potential outliers in the baseline specifications.

[INSERT TABLE 4]

Next we run various subsample estimates to establish how heterogeneous the creatinine effects might be. The analyses of subsamples reduce the sample size that is used in the estimates substantially. Thus, we have to treat these results cautiously. Given occupational differences and the potential for biomarker effects to differ by gender we ran estimates separately by sex. For educational attainment we find that the negative effect of insulin prevails only for men. There is also some evidence that the rest heart rate (i.e. pulse) is positively related to completing at least some university education for men. Most importantly, the non-significant effect of creatinine on educational attainment is apparent for both men and women. Using earnings and total income as the outcome variables we find that the positive effect of creatinine is statistically significant only for men, and this gender difference was significant at the 5% level. The positive effect of creatinine on labour market attachment remains statistically significant for men, but is positive and non-significant for women. Weaker effects for women are plausible, because men are more strongly attached to the labour market and male labour supply decisions are much less affected by family and fertility choices. It is also possible that effort is more highly rewarded in typical male occupations.[30]

We also estimate separate models for two age cohorts i.e. “young” (those who were aged 3-9 in 1980) and “old” (those who were aged 12-18 in 1980). There is some evidence that creatinine is positively related to educational attainment at the 10% level for the younger age cohort. Also, we find that the effect of creatinine on labour market outcomes is notably stronger for the older age cohort. A plausible explanation for this pattern is that we can measure the labour market outcomes for the older age cohort over a longer time horizon than for the younger age cohort, thus reducing measurement error and supporting precision of the estimates.

[30] Reflecting this, work values differ significantly by gender (e.g. Clark 1997). Men rank promotion prospects and pay more highly than do women. To assess the potential differences in the relationship between manual and non-manual work, we have also estimated separate models for those with and without at least some university education. There is some evidence that the effect of creatine is larger for those who do not have university education. However, these estimates are not straightforward to interpret because persons with different levels of education enter the labour market at different ages.

We have estimated several additional specifications that extend the set of covariates. These results have to be treated also with some caution, because some of these new controls (e.g. individuals' own chronic conditions) are not as likely to be predetermined and they may thus capture some of the effects of biomarkers on labour market outcomes later in life.

There is a potential omitted variable bias related to family background. It is possible that biomarkers only reflect parental background while having no independent effect on subsequent labour market outcomes, raising concerns about the causal interpretation of the estimates in Table 3. It is therefore useful that the YFS data contain comprehensive retrospective information on parents' education, their labour market status, health and income level. Importantly, parental background is also predetermined for offspring. We added parents' completed years of education as additional controls to the estimated models. The sample size (N=2828) is somewhat smaller than in the baseline models, because parents' education is not available for all individuals in the YFS data. It is important to control for parents' self-reported labour market status in 1980 (N=2767), because there is a positive intergenerational correlation of labour market outcomes. We also added a health measure that captures parents' chronic conditions to the set of covariates. We incorporate three groups of chronic conditions, namely cardiovascular diseases, lung disorders and other diseases because most of the chronic conditions are rare in the population. Household's total income is self-reported in eight categories in the YFS data. It refers to the year 1979. Household total income is a particularly important additional covariate because it is closely related to the composition of food intake that is a determinant of the amount of creatine in the body. The positive effect of creatinine on labour market outcomes later in life remains intact in all these specifications.[31] The extensive controls for family background narrow the scope for non-causal explanations of the relationship substantially. Therefore, the relationship between creatinine and labour market outcomes does not seem to arise because of omitted variable bias related to childhood advantages in parental investments.

We have also used individuals' own chronic conditions (measured in 1980) as additional controls. They had only minor effect on the results. Thus, the effect of creatinine on labour market outcomes remained intact. Because Blanchflower et al. (2011) stress the importance to control for fruit and vegetable consumption in the analysis of biomarkers, we have added

[31] The correlations between the variables that capture family background and creatinine are small and an order of absolute value of 0.10 at maximum. Interestingly, there is a statistically significant negative correlation between parents' years of education and creatinine.

them as covariates as well.[32] This reduces the sample size substantially (N=1564), because this information is available only for part of the original sample. Despite this, the positive effect of creatinine on labour market outcomes does not change in these models. Thus, we conclude that creatinine is not simply picking up health and diet effects.

We have also checked whether the results are sensitive to the way that creatinine is entered to the model. The amount of creatinine and height are significantly positively correlated at 0.56 (cf. Table 2). For this reason, we have estimated the models excluding height from the set of controls. The baseline models also used the log-transformation of creatinine and triglyceride. Thus, we have estimated the models without using the logarithmic transformation. Furthermore, we have estimated the models excluding all other biomarkers except creatinine from the set of covariates. The earlier conclusions for creatinine remain intact in all these models.

To check the existence of possible non-linear effects of creatinine on educational attainment and subsequent labour market outcomes, we added a quadratic term of creatinine to the specifications but this was not statistically significant.

Finally, we have extended the set of biomarkers, because the YFS data also contain some relevant biomarkers that were not used in the baseline models. These biomarkers are not available for the whole data that were gathered in 1980. Therefore, it is not reasonable to limit the sample size in the baseline models by including these additional biomarkers. The most important finding that stems from these models is that the log-transformation of the amount of C-reactive protein (measured in 1980) is negatively related to educational attainment, earnings and total income later in life (Table 5). This pattern is reasonable, because C-reactive protein is a general marker for inflammation and infection in the body, suggesting these effects may be health-related. The point estimate for earnings is larger than for total income. Interestingly, C-reactive protein is not significantly correlated with labour market attachment. We also tested the use of systolic blood pressure as an explanatory variable. It was not significant in any of the models. Importantly, the creatinine results were robust to the addition of these extra biomarkers. Even the quantitative magnitude of the effect of creatinine remains almost unchanged in Table 5.

[INSERT TABLE 5]

[32] Unfortunately we are unable to control for the intake of meat and fish.

6. Conclusions

Using the Young Finns Study (YFS) linked to the Finnish Linked Employer-Employee Data (FLEED) we show that quantities of creatine measured in 1980 prior to labour market entry affect labour market outcomes over the period 1990-2010. In this way we avoid concerns regarding the simultaneity of creatine measurement and labour market effects. We find that those with higher levels of creatine, which is proxied by urine creatinine measurements taken prior to labour market entry, spend more time in the labour market in the subsequent two decades and earn more. They also have higher total income in adulthood, much of it derived from labour market outcomes at the intensive margin. Both the income and earnings effects are quantitatively substantial, the labour market attachment outcomes less so.

The effect of creatine on labour market outcomes does not arise through the acquisition of formal education as measured by having at least some university education. Nor does it appear to be proxying the effects of other biomarkers, nor parental background. Instead the findings are consistent with high energy levels, induced by creatine, leading to productivity-enhancing traits such as a high propensity for effort, perseverance, and high-commitment. Alternatively, creatine may enhance cognitive ability by supplying additional energy to the brain, an ability that individuals are able to translate into better earnings and greater labour market attachment. If this is the case, future research will need to establish why this improvement in cognitive ability does not improve educational attainment. A third possibility is that creatine affects personality traits which, in turn, lead to positive labour market outcomes.

These results are suggestive of a causal linkage between creatine levels early in life and positive labour market outcomes in adulthood. However, we are unable to identify the causal mechanisms at play. It would be valuable if future research identified these mechanisms. For example, it is possible that creatine may be related to personality that constitutes a mechanism for the positive long-term labour market outcomes. Deeper knowledge of mechanisms is needed to draw policy conclusions.

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Table 1. Descriptive statistics.

Labour market outcomes	
University education indicator	0.281 (0.449)
Logarithm of the average annual total income	9.608 (0.745)
Logarithm of the average annual earnings	9.323 (1.210)
Average employment years	0.681 (0.267)
Biomarkers	
Height (cm)	141.779 (25.575)
Body fat (kg)	16.796 (7.748)
Pulse	80.504 (14.411)
Diastolic blood pressure	73.618 (11.425)
Triglyceride	-0.328 (0.333)
Insulin	9.547 (5.852)
Creatinine	2.007 (0.587)

Notes: N=3201. Biomarker information was obtained in 1980 when the participants were 3, 6, 9, 12, 15 and 18 years old. Triglyceride and creatinine are log-transformed. Education is measured in 2010. Income and employment measures are for the period 1990-2010.

Table 2. Correlation coefficients between biomarkers.

	Height	Body fat	Pulse	Diastolic blood pressure	Triglyceride	Insulin	Creatinine
Height	1						
Body fat	0.236***	1					
Pulse	-0.525***	-0.003	1				
Diastolic blood pressure	0.471***	0.154***	-0.255***	1			
Triglyceride	0.186***	0.244***	-0.055***	0.093***	1		
Insulin	0.576***	0.402***	-0.209***	0.283***	0.322***	1	
Creatinine	0.560***	0.171***	-0.288***	0.208***	0.093***	0.302***	1

Notes: N=3201. Significant at *** 1 % level. Triglyceride and creatinine are log-transformed.

Table 3. The baseline estimation results

	(1) University education	(2) Total Income	(3) Earnings	(4) Employment (years)
Height	0.0078*** (0.0012)	0.0105*** (0.0018)	0.0173*** (0.0033)	0.0028*** (0.0007)
Body fat	-0.0006 (0.0014)	-0.0047* (0.0027)	-0.0129** (0.0058)	-0.0013 (0.0010)
Pulse	0.0003 (0.0007)	0.0002 (0.0011)	0.0003 (0.0018)	0.0002 (0.0004)
Diastolic blood pressure	-0.0009 (0.0008)	0.0022 (0.0013)	0.0018 (0.0022)	-0.0000 (0.0005)
Triglyceride	-0.0073 (0.0245)	-0.0588 (0.0383)	-0.1031 (0.0649)	-0.0265* (0.0140)
Insulin	-0.0050*** (0.0017)	-0.0031 (0.0027)	-0.0015 (0.0047)	0.0009 (0.0010)
Creatinine	0.0153 (0.0168)	0.1014*** (0.0291)	0.1544*** (0.0480)	0.0315*** (0.0092)
Gender	x	x	x	x
Cohort	x	x	x	x
Birth month	x	x	x	x
R^2	0.0545	0.1584	0.0869	0.2030

Notes: N=3201. Significant at *10%, ** 5%, and *** 1% level. Heteroskedasticity-robust standard errors are reported in parentheses.

Table 4. Estimation results with education as a control variable.

	(1) Total income	(2) Earnings	(3) Employment (years)
Height	0.0083*** (0.0017)	0.0135*** (0.0032)	0.0027*** (0.0007)
Body fat	-0.0046* (0.0026)	-0.0126** (0.0057)	-0.0013 (0.0010)
Pulse	0.0002 (0.0010)	0.0001 (0.0017)	0.0002 (0.0004)
Diastolic blood pressure	0.0024* (0.0013)	0.0023 (0.0022)	-0.0000 (0.0005)
Triglyceride	-0.0568 (0.0378)	-0.0995 (0.0638)	-0.0264* (0.0140)
Insulin	-0.0017 (0.0026)	0.0010 (0.0047)	0.0009 (0.0010)
Creatinine	0.0970*** (0.0287)	0.1468*** (0.0470)	0.0313*** (0.0092)
University education	0.2842*** (0.0246)	0.4991*** (0.0372)	0.0093 (0.0084)
Gender	x	x	x
Cohort	x	x	x
Birth month	x	x	x
R^2	0.1862	0.1194	0.2032

Notes: N=3201. Significant at *10%, ** 5%, and *** 1% level. Heteroskedasticity-robust standard errors are reported in parentheses.

Table 5. Estimation results with C-reactive protein as an additional explanatory variable.

	(1) University education	(2) Total Income	(3) Earnings	(4) Employment (years)
Height	0.0087*** (0.0015)	0.0068*** (0.0016)	0.0107*** (0.0027)	0.0022*** (0.0007)
Body fat	0.0012 (0.0020)	0.0011 (0.0023)	-0.0062 (0.0070)	0.0002 (0.0010)
Pulse	-0.0001 (0.0009)	0.0004 (0.0009)	0.0009 (0.0019)	0.0005 (0.0004)
Diastolic blood pressure	-0.0005 (0.0011)	0.0005 (0.0011)	-0.0007 (0.0018)	-0.0007 (0.0005)
Triglyceride	-0.0332 (0.0319)	-0.0700** (0.0354)	-0.0426 (0.0633)	-0.0068 (0.0150)
Insulin	-0.0067*** (0.0021)	-0.0046* (0.0024)	-0.0033 (0.0048)	-0.0003 (0.0011)
Creatinine	0.0120 (0.0214)	0.0658** (0.0260)	0.1449*** (0.0513)	0.0269*** (0.0103)
C-reactive protein	-0.0138* (0.0079)	-0.0195** (0.0090)	-0.0283* (0.0169)	-0.0049 (0.0036)
Gender	x	x	x	x
Cohort	x	x	x	x
Birth month	x	x	x	x
R^2	0.0709	0.2885	0.1360	0.2683

Notes: N=2067. Significant at *10%, ** 5%, and *** 1% level. Heteroskedasticity-robust standard errors are reported in parentheses. C-reactive protein is log-transformed because of its skewed distribution. All biomarkers are measured in 1980.