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2D:4D AND LIFE OUTCOMES: EVIDENCE FROM THE RUSSIAN RMLS SURVEY

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2D:4D and Life Outcomes: Evidence from the Russian RMLS Survey *†

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Abstract

Using a large sample drawn from families in the Moscow and Moscow region which are part of the Russian RMLS longitudinal survey we observe clear links between measured 2D:4D digit ratios and a variety of life outcome measures, even with the inclusion of multiple controls. Contributing to existing empirical findings, we found statistically significant empirical associations of 2D:4D with higher educational attainment, occupational outcomes, knowledge of foreign language, smoking, engaging in sport activities and with some aspects of respondent's self-esteem. In general, the character of detected empirical associations are different for women and men, as it was documented in our previous studies.

JEL-Classification: D03, I12, J24
Keywords: Prenatal testosterone, 2D:4D, level of education, occupations, lifetime outcomes

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1 Introduction

Nowadays there is a growing body of literature, which links exposure to prenatal testosterone, proxied by measured second to fourth digit ratios (2D:4D) to various individual outcomes.

Brosnan and his colleagues [1] found that both women and men with lower 2D:4D ratios (i.e. higher prenatal T exposure) perform better in computer science disciplines (specifically, Java programming) and have lower levels of computer related anxiety. Honekopp [2] presented empirical evidence that lower male and female averaged digit ratio is positively associated with physical fitness. Kilduff [3] showed that left hand digit ratios are negatively correlated with levels of male aggression. However, in some studies a non-linear (quadratic) relationship has been observed. An extensive survey of statistical tests of various functional forms was published by Valla and Ceci [4]. Supporting evidence of nonlinear specification came from the studies of Nye et al. [5] .

Given the complex nature of the studied relationship between 2D:4D and cognitive skills, Luxen and Buunk [6] studied 44 men and 37 women to estimate potential correlation between digit ratios and verbal, numerical intelligence and a non-cognitive trait – agreeableness. They found a negative correlation of 2D:4D (right hand) with numerical intelligence, but a positive correlation between 2D:4D and verbal intelligence. Agreeableness and right 2D:4D was also positively correlated.

Researchers from Spain [7] showed a statistically significant inverse relationship between 2D:4D (for both the left hand and for the right hand) and results of cognitive reflection test, as developed by S. Frederick [8]. They used an ordered probit model and a non-random sample (623 students). They controlled for gender, mathematics grade and an indicator which measured patience. The inverse relationship was stronger for females than for males.

Branas-Garza and Rustichini [9], used a sample of 188 observations and showed that 2D:4D ratio (right hand) was negatively correlated to the level of intellectual development of men, measured by the Raven test.

Beaton [10], using correlation analysis and regression methods, estimated the influence of the difference (between 2D:4D of the right hand and the left hand) on the results of a test, which measures abilities to memorize the word order. The sample consisted of 68 observations. It was shown that larger differences corresponded to higher test scores.

Indirect statistical evidence about the association of 2D:4D with cognitive ability differences comes from the study of Maureen Jordan-Steen [11] who found that lower mean 2D:4D ratios (right hand) are related to higher mathematical orientation for female students who participated in pre-service teacher program and selected the mathematics major, rather than mathematics minor.

Nye, et al. [5] used a relatively large data set to study the relationship between 2D:4D and student academic performance in Moscow and Manila. The study revealed a nonlinear

association between 2D:4D and academic performance, but only for females.

Supporting findings of a non-linear relationship between 2D:4D and academic achievement were documented in the study of Angeles Snchez-Domnguez and colleagues [12]. In particular, an inverted U-shaped relationship was found between final first year mathematics grade and digit ratios, calculated as the average between the right hand and the left hand digit ratio (measured as in [1]. Interestingly, no associations of other academic courses grades and digit ratios were found.

Not only cognitive skills, but also personal psychological characteristics have been associated with 2D:4D. It was shown by Austin, Manning and others in 2002 [13], that left hand 2D:4D weakly but positively correlated to neuroticism on the general sample. Though, this correlation vanishes once male and female sub-sample are taken separately. Also, there is some evidence of statistically significant and negative correlation between both left and right hand 2D:4D and general sensation seeking, measured by Sensation Seeking Scale. Lindova and colleagues [14] estimated correlations of 2D:4D ratio of the right hand and Cattell test results. Lindova and others used a sample of 301 biology department students from Charles University in Prague. They employed mediator analysis and showed that 2D:4D linearly and negatively correlated with emotional stability and the ability to resolve problematic situations in the society (to give public speeches, to get a community leader, etc.). Also, they showed that emotional stability partially moderated 2D:4D impact.

Nevertheless, there are other studies that reject the link between 2D:4D and personal characteristics. Richard Lippa[15] used a sample of 1000 respondents and showed that links between 2D:4D and Big Five personal characteristics seem weak or non-significant. There is only weak positive correlation between 2D:4D and extroversion and weak negative correlation between 2D:4D and openness to new experience. He also conducted empirical analysis on a sample of more than 2000 individuals and showed that the correlation between 2D:4D and personal characteristics that are typical for men seem to disappear again. But, Lippa [15] showed that there is a link between 2D:4D and profession choices that are typical for women.

There is evidence in the literature that lower 2D:4D leads to overestimated problem statements (with respect to possibilities), which never get resolved[16]. It was also shown that there is a link between 2D:4D and the ability to administrate. Guiso and Rustichini [17] showed that administrators with lower 2D:4D manage bigger firms; meanwhile the profitability of such firms is significantly lower.

Empirical associations of self-esteem and digit ratios are also under ongoing examination. Manning and Quinton [18] documented evidence that digits ratio is negatively related to a number of self-esteems (reported by respondents): with body attractiveness, general attractiveness and facial attractiveness of men.

Wade and colleagues [19] found that higher 2D:4D correlated with higher reported self-perception of women's attractiveness.

There are some findings on health related outcomes. Specifically, an association between smoking and digit ratios was detected by Borkowska and Pawlowski [20]. Using a sample of students they found a positive relationship with female smoking. Manning and Fink [21] found a positive association between national means of 2D:4D and number of cigarettes consumed per capita per nation.

Another side of health related outcome concerns sports. Particularly, 2D:4D was found to be related to performance in endurance running by Manning and colleagues [22]. It was shown that higher level of prenatal testosterone (lower 2D:4D) positively correlates with performance in endurance running.

In this study we contribute to the existing state of the art as follows. First of all, we consider a wider set of educational outcomes. Specifically, we analyze whether 2D:4D digit ratios can be related to higher education of individuals as well as to the type of high educational study (full time study or study by correspondence). Secondly, we analyze whether one can attribute digit ratios to the level of individual's occupation by ISCO88. For example, a natural question here is whether digit ratios correlate with the likelihood of working in the major group 1 (legislators, senior positions, managers) or in the major group 2 (professionals). Thirdly, we consider relationship between digit ratios and knowledge of foreign language. Moreover, we study empirical relationships between digit ratios and health related outcomes. At the end of the day, relationships between digit ratios and many answers to self-esteem questions were covered, using regression analysis.

In short, results of the study show statistically significant relationships between digit ratios and lifetime outcomes. However, observed effects are different for women and men.

The rest of the paper is organized as follows. First, we introduce and describe our data set, then regression analysis is presented. Finally, we conclude and discuss results and their relationship to existing literature.

2 Data description

In this study we use data set drawn from 20th wave of Russian Longitudinal Monitoring Survey conducted in the year 2012 and it covers about four thousands individuals from Moscow and Moscow region who agreed to measure their fingers. Besides, finger measurement survey contains questions regarding individuals socioeconomic characteristics and family background. The finger measurements were taken using electronic caliper. Actual measurements were made from the palmar digital crease to the fingertip of index and ring fingers. Then measurements were rounded to millimeters. We include in our analysis individuals between 25 and 65 years old. We do this in order to restrict our cohort to working population. Moreover, according to the medical literature, the probability of arthritis rises dramatically after age of 65. Therefore, taking account population after 65 years old would potentially lead to systematical bias in finger

measurement, we restrict our sample to individuals aged in range from 25 to 65 years old. We selected the lower bound of age restriction in such a way that allows for a possibility to complete higher educational degree by the day of interview. Since there is no consensus in the literature, which hand better, represents testosterone exposure in utero, we use both left and right hand digit ratios and their mean in our analysis. On the general sample left hand 2D:4D ratio varies from minimum of 0.68 to maximum 1.35 with the standard deviation of 0.05. Mean is oscillated around unity. In our analysis we use only those observations where respondents reported absence of finger severe injury or phalanx brake for the corresponding hand. We also use averaged left and right hand digit ratios in order to avoid any speculations about which hand better to use as well as to show robustness and consistency of our results. Mean of averaged 2D:4D ratio is also one, though range of variation a little smaller then for left and right hand separately (from 0.82 to 1.30).

In addition to fingers ratios we use the set conventional predictors of educational and other lifetime outcomes. First of all, we control for parents education. For this purpose we constructed two binary variables for father's and mother's education, which take values of one if the respective parent has higher education and zero otherwise. From the table 1 (see Appendix) we can infer that about one third of the sample has a father with higher education and about one quarter a mother. Also, among classical predictors, especially for educational outcomes, we use type of the settlement of respondent's birth. From the literature we know that distance to college from individuals home is a valid instrument for educational attainment. Unfortunately, we do not have direct measure of distance to college. However, taking into account distribution of higher educational institutions in Russia, we can say that individuals who born in urban type settlement will more likely have a college or university close to his neighborhood then the one from rural area. Therefore, it would be reasonable to use type of settlement as a proxy for distance to higher educational institution. We construct variables Place of birth that takes value of one if individual was born in the urban type settlement city or town and zero otherwise (which implies rural type of the settlement). From the table 1 we can infer that about 57 percent of the respondents living in Moscow and Moscow region were born in urban type settlement.

The first dependent variable in our analysis as an outcome variable, indicating whether or not an individual holds higher education degree. We constructed a binary variables "Higher education diploma" that takes value of one if individual does have a higher education degree and zero otherwise. From the mean value this variables (see table 1 in Appendix) we can conclude that about 41 percent of population from our sample has a higher education degree.

Going further in analysis of impact digit ratios and other predictors on educational outcomes we considered whether or not an individual completed his degree at the full time program. Therefore, we constructed the other binary variables "Full time higher education diploma" that takes value of one, if the respondent holds a higher education degree completed full time and zero otherwise. From the summary statistics provided in tables 1 we can observe that

only about 27 percent of the sample attended and completed higher educational program full time. The next outcome variable that we attribute to educational outcomes is whether or no individual speaks any foreign language besides the ones spoken in former USSR. It takes value of one if he or she does and zero if not. In our sample about 37 percent of individuals speak any foreign language. Along with other educational and lifetime outcomes we paid specific attention to individual's occupational choice. In our sample we have detailed data about respondent's occupation classified by International Standard Classification of Occupations (ISCO88). It is important to note that ISCO classification is developed in such a way that gives specific emphasis to the skills required to perform job tasks. Though, it does not directly measure individual skills at the certain occupation. The whole ISCO code is four digits code that identifies individual area of specialization. Detailed information about design of classification could be found at the International Labor Organization (ILO) web-site[1]. In our analysis we reduce the classification of occupations held by individuals to the first digit of ISCO88 code. In such a way we get 10 major groups of occupations in range from legislators, senior officials and managers (group 1) to elementary occupations (group 9). The tenth group is Armed Forces (group 0). According to ILO official description, no skill reference was applied to this group. Therefore, individuals from this occupational group are exempted from our analysis and all observations for this group (about 0.7 percent) were deleted. Another group of occupations that is exempted from our analysis is skilled agriculture and fishery workers (group 6). The problem is that our sample covers only Moscow and Moscow region which is fairly large urban-type agglomeration and very little share of population is employed in agricultural work (about 0.3 percent of the sample). Therefore, for the purpose of correct referencing, we removed group 6 from our analysis. We deleted all observations from the data set where individuals reported to be employed in occupations attributed to this group. Afterward we constructed a new binary variable "Top codded occupations (by ISCO88)" that takes value of one if the individual belongs to the first or second ISCO88 occupational group and zero otherwise. In further analysis we treat this indicator as dependent variables that indicate if the individual takes top position. In the result we got 633 individuals employed and the top occupations which is about one third of the whole sample. Such a big share of population employed at the top positions is because of sample truncation to Moscow and Moscow region.

The next part of lifetime characteristics that we consider in this paper is related to health and sports activities. First of all we consider the fact if individual has ever smoked. We constructed a binary variables which takes value of one if smoking experience has ever occurred in individuals life and zero if not. As we can see from table 1, about 24 percent of population aged from 25 to 65 years old in the year 2012 have had smoking experience in their life. Another health related variable we use is whether or not individual involved in sport activities related to jogging, skating or skiing at least 12 times during the last 12 months. The variable " Participation in sports

[1]http://www.ilo.org/public/english/bureau/stat/isco/isco88/major.htm

activities" takes the value of one, if an individual was involved, and it equals zero otherwise. According to data provided, only 7 percent of the sample respondents reported to be involved in this kind of sporting activities.

The last part of life time outcomes we used in our analysis is four self-esteem variables. There are more than 17 questions regarding individual's self-esteem and his perception his position in society in the RLMS data sample available. Generally, these questions are covering individual's attitude toward his life. For instance, individuals were asked to which extent they believe that they can influence their own lives or whether or not they are able to overcome everyday life issues. Also, they were asked about self-confidence, such to which extent do you agree that you are looser? However, only some of them were used in this paper due to lack of available observations or low statistical significance revealed in regression analysis. The first variables "Self-esteem 1" shows on the scale from one to four to which extent respondent agrees with the following expression "I can do everything not worse than others", where 1 represent strong disagree and 4 stands for strong agree. Mean of this variable is 2.94 The same scales were used for the rest three self-esteem measures included in our analysis. Variable "Self-esteem 2" represents individual attitude toward the expression "I do not even feel myself inferior to others" with answers mean of 3.23. Pretty high mean of this variable indicates low perception of inequality among respondents in Moscow and Moscow region. "Self-esteem 3" stands for the expressions In General I am satisfied with myself. Mean for this indicator of self-esteem is 1.95. The last "Self-esteem 4" is the attitude to the expression Sometimes I feel myself useless. It has also mean of 3.12.

3 Regression analysis

Testing the 2D:4D associations and likelihood of having a higher education diploma, male sample (table 2, results of logistic regression). Let's inspect the first regression. Note that the regression as a whole (1167 observations, Chi-squared = 5.997, $Prob > Chi2 = 0.014$) is statistically significant and better, comparatively to the specification without covariates. The effect of the variable 2D:4D (left hand) is statistically significant. It is interesting to highlight that its value is equal to 3.3075 (p-value = 0.01). One can note that keeping all other variables constant, if we change (say, increase by one unit) the value of 2D:4D (left hand), it increases the log odds of having a higher education diploma by 3.3075. Take a look at the second regression. Note that the regression as a whole (1167 observations, Chi-squared = 1.775, $Prob > Chi2 = 0.183$) performs badly. The impact of the covariate 2D:4D (right hand) is statistically insignificant. Let's look at the third estimated specification. One can note that the whole model (1166 observations, Chi-squared = 4.558, $Prob > Chi2 = 0.033$) fits the data quite well, comparatively to the specification without covariates. The coefficient on averaged 2D:4D is significant. It is interesting to highlight that its corresponding value is equal to 3.2277 (p-value

= 0.03). Evidently, holding all other covariates constant, a one unit increase in averaged 2D:4D increases the log odds of having a higher education diploma by 3.2277.

Thus, without incorporating other covariates, averaged digit ratio and digit ratio of the left hand have a positive impact on having higher education diploma.

Let us examine the fourth estimated regression equation. A regression as a whole (431 observations, Chi-squared = 97.007, $Prob > Chi2 = 0$) is statistically significant and better, if one compare it to the specification without covariates. The influence of the variable 2D:4D (left hand) is statistically significant. Note that its value is equal to 5.0753 (p-value = 0.05). It is interesting to highlight that keeping all other variables constant, if we change (say, increase by one unit) the value of 2D:4D (left hand), it increases the log odds of having a higher education diploma by 5.0753. The impact of the covariate *Education of father* is statistically significant. One can see that the value of this estimated coefficient equals 1.2036 (p-value = 0.00). Apparently, holding all other variables constant, higher education of father increases the log odds of having a higher education diploma by 1.2036. The influence of the variable *Education of mother* is significant. Evidently, the value of the empirical coefficient equals 0.668 (p-value = 0.02). Note that higher education of mother increases the log odds of having a higher education diploma by 0.668. The influence of the variable *Place of birth* is significant. One can note that its value equals 1.2219 (p-value = 0.00). One can note that keeping all other variables constant, urban place of birth increases the log odds of having a higher education diploma by 1.2219.

It is worth noting that after controlling for classical predictors (parental education , proxy of distance to college), coefficients on digit ratios become larger. However, the significance of coefficient slightly decreases.

Let's explore the fifth estimated regression equation. A regression as a whole (431 observations, Chi-squared = 94.554, $Prob > Chi2 = 0$) is statistically significant and better, if one compare it to the specification without covariates. The coefficient on predictor 2D:4D (right hand) is insignificant. The effect of the variable *Education of father* is significant. Note that the value of this estimated coefficient is equal to 1.1644 (p-value = 0.00). One can note that holding all other variables constant, the fact that father have higher education increases the log odds of having a higher education diploma by 1.1644. The effect of the variable *Education of mother* is significant. It is interesting to highlight that the value of the empirical coefficient is equal to 0.6804 (p-value = 0.02). It is worth mentioning that keeping all other variables constant, if we change the variable of our interest, say, increase by one unit, assuming that mother now has a higher education degree, this fact increases the log odds of having a higher education diploma by 0.6804. The coefficient on predictor *Place of birth* is significant. It is worth mentioning that its value is equal to 1.214 (p-value = 0.00). Evidently, if all other variables of analysis stay the same, urban place of birth increases the log odds of having a higher education diploma by 1.214. Now let us turn to the next estimated specification (the last column of table 2). A regression as a whole (431 observations, Chi-squared = 96.245, $Prob > Chi2 = 0.00$) is statistically signifi-

cant. The effect of the variable averaged 2D:4D is significant. Note that its value equals 4.9427 (p-value = 0.08). Evidently, if all other variables of analysis stay the same, a one unit change (increase) in the value of averaged 2D:4D increases the log odds of having a higher education diploma by 4.9427. The coefficient on predictor *Education of father* is significant. It is worth highlighting that the value of this coefficient is equal to 1.1861 (p-value = 0.00). Evidently, keeping all other variables constant, if we change (say, increase by one unit, this means that father has higher education) the value of *Education of father* increases the log odds of having a higher education diploma by 1.1861. The coefficient on predictor *Education of mother* is significant. Evidently, the value of this coefficient is equal to 0.6775 (p-value = 0.02). It is worth noting that holding all other covariates constant, a one unit increase in *Education of mother*, from zero to one, implying higher education, increases the log odds of having a higher education diploma by 0.6775. The coefficient on *Place of birth* is statistically significant. Apparently, the value of this estimated coefficient is equal to 1.2078 (p-value = 0.00). It is worth noting that keeping all other variables constant, urban place of birth increases the log odds of having a higher education diploma by 1.2078. Estimated probabilities are presented in table 3.

Testing the 2D:4D associations and likelihood of having higher education diploma, female sample (table 4, results of logistic regression). Let's explore the first regression equation, which is estimated. A regression as a whole (1666 observations, Chi-squared = 0.754, $Prob > Chi2$ = 0.385) performs very poor. The impact of the covariate 2D:4D (left hand) is statistically insignificant. Take a look at the second estimated regression equation. One can note that the whole model (1665 observations, Chi-squared = 0.002, $Prob > Chi2 = 0.965$) fits the data very poorly. The influence of the variable 2D:4D (right hand) is statistically insignificant. Now review the third regression equation, which is estimated. Note that the regression as a whole (1664 observations, Chi-squared = 0.212, $Prob > Chi2 = 0.645$) performs badly. The coefficient on averaged 2D:4D is statistically insignificant.

So, contrary to the case of males, available females' data does not support the influence of prenatal testosterone (proxied by digit ratios) on higher education.

Now let us turn to the fourth estimated regression equation. A regression as a whole (633 observations, Chi-squared = 148.096, $Prob > Chi2 = 0.00$) is statistically significant. The influence of the variable 2D:4D (left hand) is insignificant. The influence of the variable *Education of father* is statistically significant. Apparently, the value of the empirical coefficient is equal to 0.9239 (p-value = 0.00). Holding all other variables constant, higher education of father increases the log odds of having higher education diploma by 0.9239. The coefficient on predictor *Education of mother* is statistically significant. It is worth highlighting that the value of this estimated coefficient equals 1.4259 (p-value = 0.00). One can note that higher education of mother increases the log odds of having higher education diploma by 1.4259. The coefficient on predictor *Place of birth* is statistically significant. Note that its corresponding value is equal to 0.9722 (p-value = 0.00). It is worth highlighting that keeping all other variables constant,

urban place of birth increases the log odds of having higher education diploma by 0.9722. Consider the fifth regression. Note that the regression as a whole (632 observations, Chi-squared = 147.962, $Prob > Chi2 = 0.00$) is statistically significant and better, comparatively to the specification without covariates. The influence of the variable 2D:4D (right hand) is insignificant. The coefficient on predictor *Education of father* is statistically significant. It is worth noting that the value of the empirical coefficient is equal to 0.9197 (p-value = 0.00). It is worth mentioning that if all other variables of analysis stay the same, a one unit change (increase, from zero to one (which means that father has higher education) in the value of *Education of father* increases the log odds of having higher education diploma by 0.9197. The effect of the variable *Education of mother* is statistically significant. One can note that the value of this coefficient equals 1.4217 (p-value = 0.00). Holding all other variables constant, mothers higher education increases the log odds of having higher education diploma by 1.4217. The effect of the variable *Place of birth* is significant. One can note that the value of this coefficient is equal to 0.9796 (p-value = 0.00). Evidently, keeping all other variables constant, urban place of birth increases the log odds of having higher education diploma by 0.9796. Let's explore the next estimated regression equation (the last column of table 4). Note that the regression as a whole (632 observations, Chi-squared = 147.967, $Prob > Chi2 = 0.00$) is statistically significant and better, comparatively to the specification without covariates. The coefficient on predictor averaged 2D:4D is statistically insignificant. The influence of the variable *Education of father* is significant. It is worth noting that the value of the empirical coefficient equals 0.9196 (p-value = 0.00). It is interesting to highlight that higher education of father increases the log odds of having higher education diploma by 0.9196. The coefficient on *Education of mother* is significant. It is worth noting that its corresponding value is equal to 1.4226 (p-value = 0.00). One can note that keeping all other variables constant, if we change the variable of our interest, say, increase by one unit, assuming that mother now has a higher education degree, this fact increases the log odds of having higher education diploma by 1.4226. The effect of the variable *Place of birth* is significant. Apparently, the value of this coefficient is equal to 0.9786 (p-value = 0.00). Interestingly, if all other variables of analysis stay the same, urban place of birth increases the log odds of having higher education diploma by 0.9786.

Hence, presented regressions give and evidence of the importance of education of mother in females' academic attainment. From the other side, prenatal testosterone does not show any significance.

Testing the 2D:4D associations and likelihood of having higher education diploma, completed full time, male sample (table 5, results of logistic regression). Now review the first regression. Note that the regression as a whole (1167 observations, Chi-squared = 5.376, $Prob > Chi2 = 0.02$) is statistically significant and better, comparatively to the specification without covariates. The coefficient on predictor 2D:4D (left hand) is statistically significant. Interestingly, its value equals 3.3795 (p-value = 0.02). One can see that if all other variables of analysis stay the same,

a one unit change (increase) in the value of 2D:4D (left hand) increases the log odds of having higher education diploma, completed full time by 3.3795. Let's investigate the second regression. Note that the regression as a whole (1167 observations, Chi-squared = 1.087, $Prob > Chi2$ = 0.297) performs badly. The coefficient on predictor 2D:4D (right hand) is insignificant. Let's explore the third estimated specification. One can see that this model as a whole (1166 observations, Chi-squared = 3.598, $Prob > Chi2 = 0.058$) is statistically significant and is better, comparatively to the regression specification without predictors. The coefficient on predictor averaged 2D:4D is statistically significant. Evidently, the value of this estimated coefficient equals 3.0952 (p-value = 0.06), and here digit ratio positively correlate with the log odds of having higher education diploma.

It is interesting to note that digit ratios without any additional covariates are significant. The larger are the digit ratios the more likely a man has a higher education diploma, completed full time.

Let's explore the fourth regression equation, which is estimated. Note that the regression as a whole (431 observations, Chi-squared = 100.372, $Prob > Chi2 = 0.00$) is statistically significant and better, comparatively to the specification without covariates. The coefficient on 2D:4D (left hand) is statistically significant. Note that the value of the empirical coefficient is equal to 6.0242 (p-value = 0.03). The positive value of coefficient on digit ratios says that they positively correlate with the log odds (and with likelihood) of having higher education diploma, completed full time. The effect of the variable *Education of father* is significant. Apparently, its value equals 1.51 (p-value = 0.00). It is worth noting that holding all other covariates constant, higher education of father increases the log odds of having higher education diploma, completed full time by 1.51. The coefficient on *Education of mother* is statistically significant. Note that its corresponding value equals 0.6201 (p-value = 0.04), and it is positively related to likelihood of having higher education diploma. The effect of the variable *Place of birth* is significant. Evidently, the value of the empirical coefficient is equal to 1.0439 (p-value = 0.00). Evidently, holding all other covariates constant, urban place of birth increases the log odds of having higher education diploma, completed full time by 1.0439. Let us examine the fifth regression equation, which is estimated. Note that the regression as a whole (431 observations, Chi-squared = 98.455, $Prob > Chi2 = 0.00$) is statistically significant and better, comparatively to the specification without covariates. The coefficient on predictor 2D:4D (right hand) is significant. One can note that the value of this estimated coefficient equals 4.3416 (p-value = 0.09). Thus, digit ratios positively correlate with log odds of having higher education diploma, completed full time. The effect of the variable *Education of father* is significant. Interestingly, the value of this coefficient equals 1.4655 (p-value = 0.00). Note that holding all other covariates constant, higher education of father increases the log odds of having higher education diploma, completed full time by 1.4655. The effect of the variable *Education of mother* is statistically significant. One can note that the value of this estimated coefficient equals 0.6364 (p-value = 0.03). Note

that holding all other regressors constant, mother's higher education increases the log odds of having higher education diploma, completed full time by 0.6364. The coefficient on predictor *Place of birth* is significant. It is worth noting that its value equals 1.0298 (p-value = 0.00). One can note that keeping all other variables constant, urban place of birth increases the log odds of having higher education diploma, completed full time by 1.0298. Consider the last regression equation (presented in column 6). A model as a whole (431 observations, Chi-squared = 100.287, $Prob > Chi2 = 0.00$) is statistically significant and is better, comparatively to the specification without covariates. The influence of the variable averaged 2D:4D is statistically significant. Interestingly, its value equals 6.45 (p-value = 0.03). Hence an increase in digit ratios increases the log odds of having higher education diploma, completed full time. The influence of the variable *Education of father* is statistically significant. One can see that its corresponding value is equal to 1.4941 (p-value = 0.00). Note that holding all other regressors constant, higher education of father increases the log odds of having higher education diploma, completed full time by 1.4941. The impact of the covariate *Education of mother* is statistically significant. Apparently, the value of the empirical coefficient equals 0.6313 (p-value = 0.03). One can note that higher education of mother increases the log odds of having higher education diploma, completed full time by 0.6313. The effect of the variable *Place of birth* is statistically significant. Evidently, its corresponding value is equal to 1.0258 (p-value = 0.00). Interestingly, keeping all other variables constant, urban place of birth increases the log odds of having higher education diploma, completed full time by 1.0258.

After incorporating classical predictors of educational attainment, digit ratios are still significant, their values go up. Estimated probabilities are given in table 6.

Testing the 2D:4D associations and likelihood of having higher education diploma, completed full time, female sample (table 7, results of logistic regression). Let's investigate the first regression equation, which is estimated. Note that the regression as a whole (1666 observations, Chi-squared = 7.972, $Prob > Chi2 = 0.005$) is statistically significant and better, comparatively to the specification without covariates. The effect of the variable 2D:4D (left hand) is significant. Note that its corresponding value is equal to -3.3309 (p-value = 0.01).Thus, an increase in digit ratios decreases the log odds of having higher education diploma, completed full time. Let's explore the second estimated regression equation. Note that the regression as a whole (1665 observations, Chi-squared = 1.111, $Prob > Chi2 = 0.292$) performs badly. The coefficient on predictor 2D:4D (right hand) is insignificant. Let's investigate the third estimated regression equation. One can see that this model as a whole (1664 observations, Chi-squared = 4.772, $Prob > Chi2 = 0.029$) is statistically significant and is better, comparatively to the regression specification without predictors. The influence of the variable averaged 2D:4D is statistically significant. It is worth highlighting that its value is equal to -2.9045 (p-value = 0.03). One can see that holding all other covariates constant, a one unit increase in averaged 2D:4D decreases the log odds of having higher education diploma, completed full time by 2.9045.

One can note some supporting evidence of the influence of digit ratios. However, the direction of impact is different from those directions, revealed on males sample. Now the low levels of digit ratios (high level of prenatal testosterone) are good for female academic attainment.

Let us examine the fourth estimated regression equation. A regression as a whole (633 observations, Chi-squared = 127.555, $Prob > Chi2 = 0.00$) is statistically significant and better, if one compare it to the specification without regressors. The influence of the variable 2D:4D (left hand) is insignificant. The coefficient on predictor *Education of father* is significant. Evidently, its corresponding value equals 1.2688 (p-value = 0.00). It is worth mentioning that keeping other factors constant, higher education of father increases the log odds of having higher education diploma, completed full time by 1.2688. The effect of the variable *Education of mother* is statistically significant. Note that the value of this coefficient equals 0.7223 (p-value = 0.00). Evidently, keeping other factors constant, higher education of mother increases the log odds of having higher education diploma, completed full time by 0.7223. The coefficient on *Place of birth* is statistically significant. Interestingly, the value of this estimated coefficient is equal to 1.0904 (p-value = 0.00). It is worth mentioning that keeping all other variables constant, urban place of birth increases the log odds of having higher education diploma, completed full time by 1.0904. Let's look at the fifth regression equation, which is estimated. Note that the regression as a whole (632 observations, Chi-squared = 127.309, $Prob > Chi2 = 0.00$) is statistically significant and better, comparatively to the specification without covariates. The coefficient on 2D:4D (right hand) is statistically insignificant. The coefficient on *Education of father* is significant. Evidently, its value is equal to 1.2649 (p-value = 0.00). It is interesting to highlight that keeping all other variables constant, higher education of father increases the log odds of having higher education diploma, completed full time by 1.2649. The impact of the covariate *Education of mother* is significant. One can see that the value of the empirical coefficient equals 0.7279 (p-value = 0.00). It is worth highlighting that holding all other covariates constant, a one unit increase in *Education of mother*, from zero to one, implying higher education, increases the log odds of having higher education diploma, completed full time by 0.7279. The coefficient on *Place of birth* is significant. Apparently, the value of this coefficient is equal to 1.0941 (p-value = 0.00). It is worth mentioning that keeping other factors constant, urban place of birth increases the log odds of having higher education diploma, completed full time by 1.0941. Let us examine the last estimated equation in column 6. Note that the regression as a whole (632 observations, Chi-squared = 127.406, $Prob > Chi2 = 0.00$) is statistically significant and better, comparatively to the specification without covariates. The influence of the variable averaged 2D:4D is statistically insignificant. The coefficient on predictor *Education of father* is statistically significant. It is worth noting that its corresponding value is equal to 1.2653 (p-value = 0.00). One can note that holding all other covariates constant, higher education of father increases the log odds of having higher education diploma, completed full time by 1.2653. The effect of the variable *Education of mother* is statistically significant. Interestingly, the value

of this estimated coefficient is equal to 0.7233 (p-value = 0.00). It is worth noting that holding all other covariates constant, a one unit increase in *Education of mother*, from zero to one, implying higher education, increases the log odds of having higher education diploma, completed full time by 0.7233. The coefficient on predictor *Place of birth* is statistically significant. It is interesting to highlight that the value of this coefficient equals 1.0958 (p-value = 0.00). It is worth highlighting that holding all other covariates constant, urban place of birth increases the log odds of having higher education diploma, completed full time by 1.0958. Estimated probabilities are given in table 8.

Note that the significance of digit ratios disappeared. From the other side, when we include the proxy for distance to college we substantially shrink the sample. That is why we additionally run regression without this proxy, including digit ratios and parental education. In these specifications digit ratios were significant. The corresponding coefficients were as follows: coefficient on the digit ratios of the right hand was equal to -4.1439 (p-value = 0.01), coefficient on the averaged digit ratios was equal to -4.0852 (p-value = 0.01). Again, one can note the tendency that lower values of digit ratios correspond to higher likelihood of higher female academic attainment full time.

Testing the 2D:4D associations and likelihood of having knowledge of foreign language, male sample (table 9, results of logistic regression). Let's explore the first estimated regression equation. One can note that the whole model (1172 observations, Chi-squared = 2.403, $Prob > Chi2$ = 0.121) fits the data very poorly. The effect of the variable 2D:4D (left hand) is insignificant. Let's explore the second estimated regression equation. One can see that this model as a whole (1172 observations, Chi-squared = 0.153, $Prob > Chi2 = 0.696$) fits data badly. The effect of the variable 2D:4D (right hand) is insignificant. Now review the third regression. A model as a whole (1171 observations, Chi-squared = 0.426, $Prob > Chi2 = 0.514$) is statistically insignificant. The influence of the variable averaged 2D:4D is insignificant. Hence, neither of digit ratios show significance.

Let us turn to the fourth estimated regression equation. A regression as a whole (430 observations, Chi-squared = 118.191, $Prob > Chi2 = 0.00$) is statistically significant and better, if one compare it to the specification without covariates. The coefficient on predictor 2D:4D (left hand) is significant. It is interesting to highlight that the value of this estimated coefficient is equal to 4.8934 (p-value = 0.06). It is worth noting that holding all other variables constant, if we slightly increase (by one unit) the value of 2D:4D (left hand) increases the log odds of knowledge of foreign language by 4.8934. The coefficient on predictor *Education of father* is statistically significant. Interestingly, the value of this estimated coefficient is equal to 1.2862 (p-value = 0.00). Evidently, if all other variables of analysis stay the same, a one unit change (increase from zero to one, allowing father to have higher education) in the value of *Education of father* increases the log odds of knowledge of foreign language by 1.2862. The coefficient on predictor *Education of mother* is significant. Apparently, its value is equal to 0.9874 (p-

value = 0.00), and mother's higher education increases the log odds of knowledge of foreign language by 0.9874. The influence of the variable *Place of birth* is significant. Evidently, the value of this coefficient equals 1.2405 (p-value = 0.00). Interestingly, if all other variables of analysis stay the same, urban place of birth increases the log odds of knowledge of foreign language by 1.2405. Let us turn to the case of the fifth regression. One can note that the whole model (430 observations, Chi-squared = 114.697, $Prob > Chi2 = 0.00$) fits the data quite well, comparatively to the specification without any regressors. The impact of the covariate 2D:4D (right hand) is insignificant. The influence of the variable *Education of father* is statistically significant. It is interesting to highlight that its corresponding value equals 1.2432 (p-value = 0.00). Again, *Education of father* (which means that father has higher education) increases the log odds of having knowledge of foreign language. The coefficient on predictor *Education of mother* is significant. It is worth highlighting that the value of this estimated coefficient equals 0.9836 (p-value = 0.00). One can note that keeping other factors constant, higher education of mother increases the log odds of having knowledge of foreign language by 0.9836. The coefficient on *Place of birth* is significant. Interestingly, its corresponding value is equal to 1.2636 (p-value = 0.00). Not surprisingly, urban place of birth increases the log odds of having knowledge of foreign language. Let's explore the next regression (the last column, column 6). A model as a whole (430 observations, Chi-squared = 115.631, $Prob > Chi2 = 0.00$) is statistically significant and is better, comparatively to the specification without covariates. The influence of the variable averaged 2D:4D is insignificant. The influence of the variable *Education of father* is statistically significant. It is worth mentioning that its value is equal to 1.2563 (p-value = 0.00). It is worth mentioning that holding all other regressors constant, higher education of father increases the log odds of having knowledge of foreign language by 1.2563. The impact of the covariate *Education of mother* is statistically significant. Note that the value of this coefficient is equal to 0.9881 (p-value = 0.00). The impact of the covariate *Place of birth* is significant. Estimated probabilities are presented in table 10.

Thus, after controlling for parental education and place of birth (proxy of distance to college), the impact of digit ratios (left hand) became significant, though marginally.

Testing the 2D:4D associations and likelihood of having a top-coded occupation, male sample (table 11, results of logistic regression). Let us turn to the case of the first regression. One can note that the whole model (919 observations, Chi-squared = 7.091, $Prob > Chi2 = 0.008$) fits the data quite well, comparatively to the specification without any variables . The impact of the covariate 2D:4D (left hand) is significant. One can note that the value of this coefficient equals 4.314 (p-value = 0.01). It is worth mentioning that holding all other covariates constant, a one unit increase in 2D:4D (left hand) increases the log odds of having a top-coded occupation by 4.314. Now review the second estimated regression equation. Note that the regression as a whole (918 observations, Chi-squared = 1.074, $Prob > Chi2 = 0.3$) performs badly. The influence of the variable 2D:4D (right hand) is statistically insignificant. Let's look at the third estimated

specification. A regression as a whole (918 observations, Chi-squared = 4.321, $Prob > Chi2$ = 0.038) is statistically significant and better, if one compare it to the specification without independent variables. The coefficient on averaged 2D:4D is significant. Note that its value is equal to 3.7272 (p-value = 0.04). Interestingly, holding all other covariates constant, a one unit increase in averaged 2D:4D increases the log odds of having a top-coded occupation by 3.7272.

Note that both digit ratios of left hand and averaged digit ratio became significant. The direction of impact is consistent to the previous findings.

Consider the fourth estimated regression equation. A regression as a whole (747 observations, Chi-squared = 89.002, $Prob > Chi2 = 0.00$) is statistically significant and better, if one compare it to the specification without covariates. The coefficient on predictor 2D:4D (left hand) is significant. One can see that its value is equal to 3.5706 (p-value = 0.06). One can see that keeping other factors constant, a one unit increase the value of 2D:4D (left hand) increases the log odds of having a top-coded occupation by 3.5706. The impact of the covariate *Age* is statistically insignificant. The coefficient on predictor *Education of father* is significant. One can see that its corresponding value equals 1.0953 (p-value = 0.00). One can note that holding all other covariates constant, a one unit increase (from zero to one, meaning that father has a higher education degree) in *Education of father* increases the log odds of having a top-coded occupation by 1.0953. The impact of the covariate *Education of mother* is significant. Apparently, the value of this coefficient equals 0.7096 (p-value = 0.00). Note that higher education of mother increases the log odds of having a top-coded occupation by 0.7096.

So, after including additional controls the impact of digit ratio (left hand) became smaller, significance went down. However, the coefficient on digit ratios is still significant.

Let us examine the fifth estimated specification. Note that the regression as a whole (747 observations, Chi-squared = 86.008, $Prob > Chi2 = 0.00$) is statistically significant and better, comparatively to the specification without covariates. The coefficient on predictor 2D:4D (right hand) is statistically insignificant. The effect of the variable *Age* is statistically insignificant. The influence of the variable *Education of father* is statistically significant. One can see that the value of this estimated coefficient is equal to 1.0913 (p-value = 0.00). Interestingly, keeping all other variables constant, if we change (say, increase by one unit, allowing father to have a higher education degree) the value of *Education of father* increases the log odds of having a top-coded occupation by 1.0913. The effect of the variable *Education of mother* is significant. It is interesting to highlight that the value of the empirical coefficient equals 0.7174 (p-value = 0.00). Note that higher education of mother increases the log odds of having a top-coded occupation by 0.7174.

Evidently, only the specification number 4 shows relatively significant results. Partially, it may be caused by the substantial shrink of the data set (when we include the place of birth as a proxy for distance to college). From the other side, if the place of birth is not included only digit ratios of the left hand show relative statistical significance. Estimated probabilities are in

table 12.

Testing the 2D:4D associations and likelihood of a positive answer to the question "Have you ever smoked?", male sample (table 13, results of logistic regression). Consider the first regression. One can see that this model as a whole (391 observations, Chi-squared = 10.987, $Prob > Chi2 = 0.027$) is statistically significant and is better, comparatively to the regression specification without predictors. The coefficient on *Age* is significant. Evidently, the value of this coefficient is equal to 0.0249 (p-value = 0.01). One can note that holding all other covariates constant, a one unit increase in *Age* increases the log odds of a positive answer to the question "Have you ever smoked?" by 0.0249. The effect of the variable 2D:4D (left hand) is significant. It is interesting to highlight that the value of this estimated coefficient equals 4.4929 (p-value = 0.06). Evidently, if all other variables of analysis stay the same, a one unit change (increase) in the value of 2D:4D (left hand) increases the log odds of a positive answer to the question "Have you ever smoked?" by 4.4929. The influence of the variable *Education of father* is insignificant. The impact of the covariate *Education of mother* is insignificant. Let's look at the second estimated regression equation. One can see that this model as a whole (391 observations, Chi-squared = 11.005, $Prob > Chi2 = 0.027$) is statistically significant and is better, comparatively to the regression specification without predictors. The impact of the covariate *Age* is statistically significant. Interestingly, its value equals 0.0248 (p-value = 0.01). It is interesting to highlight that holding all other covariates constant, a one unit increase in *Age* increases the log odds of a positive answer to the question "Have you ever smoked?" by 0.0248. The coefficient on predictor *Education of father* is insignificant. The effect of the variable *Education of mother* is insignificant. The impact of the covariate averaged 2D:4D is statistically significant. It is worth noting that the value of this estimated coefficient is equal to 5.1554 (p-value = 0.06), and an increase in digit ratios increases the log odds of a positive answer to the question Have you ever smoked?. Let's inspect the third regression equation, which is estimated. One can note that the whole model (391 observations, Chi-squared = 9.571, $Prob > Chi2 = 0.048$) fits the data quite well, comparatively to the specification without any covariates. The coefficient on predictor *Age* is statistically significant. Apparently, its corresponding value equals 0.0235 (p-value = 0.02). One can note that holding all other variables constant, if we slightly increase (by one unit) the value of *Age* increases the log odds of a positive answer to the question "Have you ever smoked?" by 0.0235. The coefficient on *Education of father* is insignificant. The influence of the variable *Education of mother* is insignificant. The influence of the variable 2D:4D (right hand) is insignificant. Estimated values of probabilities are presented in table 14.

It is worth mentioning that when we included into regressions digit ratios only, they were insignificant. Thus, only after including age and parental education coefficients on digit ratios became significant.

Testing the 2D:4D associations and likelihood of jogging, skating, skiing, at least 12 times during last 12 months, female sample (table 15, results of logistic regression). Now let us

turn to the first estimated regression equation. Note that the regression as a whole (1316 observations, Chi-squared = 30.658, $Prob > Chi2 = 0.00$) is statistically significant and better, comparatively to the specification without covariates. The impact of the covariate "Age" is statistically significant. Evidently, the value of the empirical coefficient equals -0.042 (p-value = 0.00). Apparently, if all other variables of analysis stay the same, a one unit change (increase) in the value of *Age* decreases the log odds of jogging, skating, skiing, at least 12 times during last 12 months by 0.042. The coefficient on predictor 2D:4D (left hand) is statistically insignificant. The coefficient on the factor *Education of father* is statistically insignificant. The effect of the variable *Education of mother* is significant. One can see that the value of this coefficient is equal to 0.5891 (p-value = 0.05). It is worth mentioning that higher education of mother increases the log odds of jogging, skating, skiing, at least 12 times during last 12 months by 0.5891. Take a look at the second estimated regression equation. Note that the regression as a whole (1315 observations, Chi-squared = 33.877, $Prob > Chi2 = 0.00$) is statistically significant and better, comparatively to the specification without covariates. The influence of the variable Age is significant. It is interesting to highlight that its value equals -0.041 (p-value = 0.00). Apparently, keeping all other variables constant, if we change (say, increase by one unit) the value of *Age* decreases the log odds of jogging, skating, skiing, at least 12 times during last 12 months by 0.041. The influence of the variable *Education of father* is statistically insignificant. The coefficient on predictor *Education of mother* is statistically significant. Note that its corresponding value is equal to 0.5821 (p-value = 0.05). It is worth highlighting that higher education of mother increases the log odds of jogging, skating, skiing, at least 12 times during last 12 months by 0.5821. The effect of the variable 2D:4D (right hand) is significant. Interestingly, its value is equal to 5.3014 (p-value = 0.03). It is interesting to highlight that if all other variables of analysis stay the same, a one unit change (increase) in the value of 2D:4D (right hand) increases the log odds of jogging, skating, skiing, at least 12 times during last 12 months by 5.3014. Now review the third regression equation, which is estimated. Note that the regression as a whole (1314 observations, Chi-squared = 32.579, $Prob > Chi2 = 0.00$) is statistically significant and better, comparatively to the specification without covariates. The coefficient on Age is statistically significant. Apparently, the value of this coefficient equals -0.0413 (p-value = 0.00). One can see that holding all other covariates constant, a one unit increase in *Age* decreases the log odds of jogging, skating, skiing, at least 12 times during last 12 months by 0.0413. The effect of the variable *Education of father* is insignificant. The coefficient on *Education of mother* is statistically significant. One can note that the value of this coefficient equals 0.5939 (p-value = 0.04). Interestingly, keeping all other variables constant, if we change , say, increase by one unit, assuming that mother now has a higher education degree, this fact increases the log odds of jogging, skating, skiing, at least 12 times during last 12 months by 0.5939. The coefficient on averaged 2D:4D is significant. It is interesting to highlight that its corresponding value equals 5.1057 (p-value = 0.07). It is worth noting that if all other variables

of analysis stay the same, a one unit change (increase) in the value of averaged 2D:4D increases the log odds of jogging, skating, skiing, at least 12 times during last 12 months by 5.1057. Estimated probabilities are given in table 16.

Interestingly, when we included only digit ratios, they were also significant. The coefficient on the averaged digit ratio was equal to 5.7709 (p-value = 0.018), the coefficient on the digit ratios (right hand) was also significant (p-value = 0.003), and it was equal to 6.2450. Their values (as well as) decreased to some extent, after we included parental education (that turned out to be insignificant) and age.

To study the effect of prenatal testosterone, using measured 2D:4D biomarker, we run ordered logistic regressions. Results are presented in tables 17-20. First of all, let us consider specifications, in which the answer to the statement "In General I am satisfied with myself" (table 17) is the dependent variable in male sample. Note that all specifications as a whole are statistically significant, moreover they satisfy so-called proportional odds assumptions (based on the Brant test statistics). However, only the impact of 2D:4D (left hand) is statistically significant. Note that the value of coefficient on 2D:4D (left hand) equals to the value of -2.8584 (p-value = 0.03). Hence, a unit increase in the value of 2D:4D results in a 2.8584 decrease in the log odds of being in the high category (strongly agree) of the answer to the statement, comparatively to combined all lowest categories, given that all other variables fixed. Figure 1 contains information about estimated probabilities for different categories of answers to this statement.

Next, let us inspect specifications, in which the answer to the statement "I do not feel inferior to others" (table 18, results of ordered logistic regression) is the dependent variable, female sample. Contrary to the previous case, only the specification in the middle satisfies proportional odds assumption (based on the Brant test statistics), however only marginally. The impact of 2D:4D (right hand) is statistically significant. Note that the value of coefficient on 2D:4D (right hand) equals to the value of -1.9528 (p-value = 0.08). Thus, a unit increase in the value of 2D:4D results in a 1.9528 decrease in the log odds of being in the high category (strongly agree) of the answer to the statement, comparatively to combined all lowest categories, given that all other variables are staying constant. In Figure 2 one can see estimated probabilities for different categories of the answer to this statement.

Thirdly, let us see estimated regressions, in which the dependent variable is the answer to question "Sometimes I feel myself useless", estimated on females sample (table 19, results of ordered logistic regression). The middle specification is the best in terms of the significance of digit ratios. Based on the Brant test statistic one can conclude that parallel assumption is satisfied, the whole model is statistically significant. The coefficient on 2D:4D (right hand) equals 1.7302 (p = 0.09). Therefore, a unit increase in the value of digit ratios results in a 1.7302 increase in the log odds of being in the high category (strongly agree) of the answer to the statement, comparatively to combined all lowest categories, assuming that all other

variables stay the same. Note that Figure 3 contains information about estimated probabilities for different categories of the answer to this statement.

Finally, table 20 (results of ordered logistic regression) contains information about estimated coefficients of the model with covariates, predicting the answer to the statement "I can do everything not worse than others", estimated on female sample. At the end of the day, the last specification shows the significance of the digit ratio term (2D:4D, left hand). The coefficient on 2D:4D (left hand) is significant (p-value = 0.09) and equals -1.9247. It follows that increasing 2D:4D (left hand) by one unit, implies a 1.9247 decrease in the log odds of being in the high category (strongly agree) of the answer to the statement, comparatively to combined all lowest categories, presuming that all other variables stay constant. In Figure 4 one can note estimated probabilities for different categories of the answer to this statement.

4 Conclusion and Discussion

In this study we documented evidence of the statistically significant associations of 2D:4D ratio (which is the proxy of prenatal testosterone) on life time outcomes.

First of all, we considered individual educational attainment. Specifically, we detected statistically significant positive relationship between 2D:4D (of the left hand as well as of the averaged digit ratio) and higher education of men. Moreover, 2D:4D is positively associated with higher education of men, completed full time. From the other side, in terms of female all types of higher education no significant results were found. However, in the case of females, 2D:4D is negatively correlated to higher education, completed on the full time basis (controlling for parental education). Though, here it should be mentioned that when we included the place of birth (urban, rural) as a proxy for distance to college significance of the digit ratios disappeared. Partially, it may be the case that we have a limited small number of observations of the place of birth or it may be driven by some other fact.

Secondly, we found that for men 2D:4D is positively related to knowledge of foreign language. However this is only in the case, when we incorporate parental education and place of birth in regressions.

Thirdly, for men 2D:4D is positively associated with top-coded ISCO88 occupations, in other words men with higher digit ratios are in positive relationship with a higher chance to have occupation in group 1 (legislators, senior positions, managers) or in the major group 2 (professionals).

It is a common knowledge that both cognitive and non-cognitive skills are necessary for academic attainment and occupational success. In this sense, our results for women are partially in line with findings of Bosch-Domenech and colleagues [7], Luxen and Buunk [6], Ostatnikova [23], who documented evidence of inverse relationship between level of cognitive skills (measured by various methods) and 2D:4D. Results of our studies for female are partially in line with

previous findings of Nye and colleagues[5] and [24].

However, only results for male's knowledge of foreign language are slightly in line with Luxen and Buunk [6]. Other results for men are quite different, because regressions show a negative association between prenatal testosterone and males' academic achievements and occupational success.

Regression analysis evidences that there are positive associations between trials of men smoking and 2D:4D ratio. This finding has no direct relationship to literature, however, indirectly results are in line with findings of Borkowska and Pawlowski [20] and with empirical regularities, revealed by Manning and Fink [21].

Females' engagement in sports activities like jogging and skating was found to be positively related to digit ratios of the right hand and averaged digit ratios.

Some empirical relationships between 2D:4D were also found. For instance, for males a strong agreement with the statement "In General I am satisfied with myself" is inversely related to digit ratios of the left hand. In the case of female 2D:4D of the right hand and of the left hand is in inverse relationship to a strong agreement with the statements "I do not feel inferior to others", "I can do everything not than others" correspondingly. Additionally, female digit ratios (right hand) are in direct relationship with the strong agreement to the question "Sometimes I feel myself useless".

Given the complexity of human nature, and complexity of prenatal period, obtained empirical associations should be treated with caution. In general, our results do not imply causality of the true effect of prenatal testosterone and may suffer from various forms of endogeneity. In regressions we have not account for potential heterogeneity also. Thus, results are potentially not robust to arbitrary or particular heteroscedasticity. All these questions will be studied in the future.

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Appendix

Table 1: Summary statistics

	Mean	St. Deviation	Min	Max
2D:4D (right hand)	1.00	0.05	0.68	1.35
2D:4D (left hand)	1.00	0.05	0.74	1.37
averaged 2D:4D	1.00	0.04	0.82	1.30
Education of father	0.28	0.45	0.00	1.00
Education of mother	0.25	0.43	0.00	1.00
Age	43.18	12.08	25.00	65.00
Place of birth (urban/rural)	0.57	0.49	0.00	1.00
Top-coded occupation (by ISCO88)	0.30	0.46	0.00	1.00
Higher education diploma	0.41	0.49	0.00	1.00
Ever smoke	0.24	0.43	0.00	1.00
Sport activities (Jogging, skating, skiing)	0.07	0.25	0.00	1.00
Full time higher education diploma	0.27	0.44	0.00	1.00
Knowledge of foreign language	0.37	0.48	0.00	1.00
Self esteem 1	2.94	0.59	1.00	4.00
Self esteem 2	3.23	0.57	1.00	4.00
Self esteem 3	1.95	0.68	1.00	4.00
Self esteem 4	3.12	0.56	1.00	4.00

Table 2: Dependent variable: At least higher education, males

	(1)	(2)	(3)	(4)	(5)	(6)
2D:4D (left hand)	3.31**			5.08*		
	(1.36)			(2.59)		
2D:4D (right hand)		1.77			2.91	
		(1.33)			(2.41)	
averaged 2D:4D			3.23**			4.94*
			(1.52)			(2.80)
Education of father				1.20***	1.16***	1.19***
				(0.29)	(0.28)	(0.29)
Education of mother				0.67**	0.68**	0.68**
				(0.29)	(0.29)	(0.29)
Place of birth (urban/rural)				1.22***	1.21***	1.21***
				(0.26)	(0.26)	(0.26)
Constant	-3.91***	-2.38*	-3.83**	-7.07***	-4.91**	-6.94**
	(1.36)	(1.33)	(1.52)	(2.60)	(2.41)	(2.80)
Number of Observations	1167	1167	1166	431	431	431
Chi-squared	5.997	1.775	4.558	97.007	94.554	96.245
$Prob > Chi2$	0.014	0.183	0.033	0.000	0.000	0.000

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 3: Esimated probalities of having at least higher education diploma, males

	2D:4D (left hand)			Averaged 2D:4D		
	Grid	Margin	$P > \|z\|$	Grid	Margin	$P > \|z\|$
1.	0.737	0.155	0.040	0.836	0.220	0.001
2.	0.837	0.218	0.000	0.936	0.295	0.000
3.	0.937	0.296	0.000	1.036	0.383	0.000
4.	1.037	0.386	0.000	1.136	0.478	0.000
5.	1.137	0.483	0.000			
Observations	431			431		

Table 4: Dependent variable: At least higher education diploma, females

	(1)	(2)	(3)	(4)	(5)	(6)
2D:4D (left hand)	-0.90			0.26		
	(1.04)			(1.98)		
2D:4D (right hand)		0.045			0.0011	
		(1.04)			(2.01)	
averaged 2D:4D			-0.54			0.17
			(1.17)			(2.28)
Education of father				0.92***	0.92***	0.92***
				(0.24)	(0.24)	(0.24)
Education of mother				1.43***	1.42***	1.42***
				(0.26)	(0.26)	(0.26)
Place of birth (urban/rural)				0.97***	0.98***	0.98***
				(0.19)	(0.19)	(0.19)
Constant	0.71	-0.24	0.35	-1.62	-1.36	-1.53
	(1.04)	(1.05)	(1.18)	(1.99)	(2.01)	(2.28)
Number of Observations	1666	1665	1664	633	632	632
Chi-squared	0.754	0.002	0.212	148.096	147.962	147.967
$Prob > Chi2$	0.385	0.965	0.645	0.000	0.000	0.000

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 5: Dependent variable: Full time higher education diploma, males

	(1)	(2)	(3)	(4)	(5)	(6)
2D:4D (left hand)	3.38**			6.02**		
	(1.46)			(2.77)		
2D:4D (right hand)		1.49			4.34*	
		(1.43)			(2.56)	
averaged 2D:4D			3.10*			6.45**
			(1.64)			(2.99)
Education of father				1.51***	1.47***	1.49***
				(0.29)	(0.29)	(0.29)
Education of mother				0.62**	0.64**	0.63**
				(0.30)	(0.30)	(0.30)
Place of birth (urban/rural)				1.04***	1.03***	1.03***
				(0.28)	(0.28)	(0.28)
Constant	-4.39***	-2.50*	-4.10**	-8.30***	-6.62***	-8.72***
	(1.46)	(1.43)	(1.64)	(2.79)	(2.56)	(3.00)
Number of Observations	1167	1167	1166	431	431	431
Chi-squared	5.376	1.087	3.598	100.372	98.455	100.287
$Prob > Chi2$	0.020	0.297	0.058	0.000	0.000	0.000

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 6: Esimated probalities of having full time higher education diploma, males

	2D:4D (left hand)			Averaged 2D:4D			2D:4D (right hand)		
	Grid	Margin	$P > \|z\|$	Grid	Margin	$P > \|z\|$	Grid	Margin	$P > \|z\|$
1.	0.737	0.105	0.076	0.836	0.154	0.004	0.702	0.128	0.080
2.	0.837	0.163	0.001	0.936	0.234	0.000	0.802	0.174	0.004
3.	0.937	0.240	0.000	1.036	0.335	0.000	0.902	0.230	0.000
4.	1.037	0.335	0.000	1.136	0.453	0.000	1.002	0.295	0.000
5.	1.137	0.444	0.000				1.102	0.370	0.000
6.							1.202	0.451	0.000
7.							1.302	0.536	0.001
Observations	431			431			431		

Table 7: Dependent variable: Full time higher education diploma, females

	(1)	(2)	(3)	(4)	(5)	(6)
2D:4D (left hand)	-3.33***			-0.96		
	(1.19)			(2.14)		
2D:4D (right hand)		-1.24			-0.58	
		(1.18)			(2.19)	
averaged 2D:4D			-2.90**			-1.01
			(1.34)			(2.46)
Education of father				1.27***	1.26***	1.27***
				(0.24)	(0.24)	(0.24)
Education of mother				0.72***	0.73***	0.72***
				(0.25)	(0.25)	(0.25)
Place of birth (urban/rural)				1.09***	1.09***	1.10***
				(0.22)	(0.22)	(0.22)
Constant	2.32*	0.24	1.90	-1.26	-1.64	-1.21
	(1.19)	(1.18)	(1.34)	(2.15)	(2.19)	(2.47)
Number of Observations	1666	1665	1664	633	632	632
Chi-squared	7.972	1.111	4.772	127.555	127.309	127.406
$Prob > Chi2$	0.005	0.292	0.029	0.000	0.000	0.000

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 8: Esimated probalities of having full time higher education diploma, females

Average 2D:4D			
	Grid	Margin	$P > \|z\|$
1.	0.824	0.424	0.000
2.	0.924	0.344	0.000
3.	1.024	0.271	0.000
4.	1.124	0.209	0.000
5.	1.224	0.157	0.000
Observations	1309		

Table 9: Dependent variable: Knowledge of foreign language, males

	(1)	(2)	(3)	(4)	(5)	(6)
2D:4D (left hand)	2.08			4.89*		
	(1.34)			(2.64)		
2D:4D (right hand)		-0.52			-0.20	
		(1.32)			(2.45)	
averaged 2D:4D			0.98			2.74
			(1.50)			(2.83)
Education of father				1.29***	1.24***	1.26***
				(0.29)	(0.29)	(0.29)
Education of mother				0.99***	0.98***	0.99***
				(0.29)	(0.29)	(0.29)
Place of birth (urban/rural)				1.24***	1.26***	1.24***
				(0.26)	(0.26)	(0.26)
Constant	-2.66**	-0.078	-1.57	-6.94***	-1.88	-4.80*
	(1.34)	(1.32)	(1.50)	(2.65)	(2.43)	(2.82)
Number of Observations	1172	1172	1171	430	430	430
Chi-squared	2.403	0.153	0.426	118.191	114.697	115.631
$Prob > Chi2$	0.121	0.696	0.514	0.000	0.000	0.000

Table 10: Esimated probalities of knowledge of foreign language, males

	2D:4D (left hand)		
	Grid	Margin	$P > \|z\|$
1.	0.735	0.178	0.026
2.	0.835	0.240	0.000
3.	0.935	0.313	0.000
4.	1.035	0.396	0.000
5.	1.135	0.486	0.000
6.	1.235	0.579	0.000
7.	1.335	0.669	0.000
Observations	430		

Table 11: Dependent variable: Top-coded occupation (by ISCO88), males

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
2D:4D (left hand)	4.31***			3.57*			1.18		
	(1.64)			(1.91)			(2.83)		
2D:4D (right hand)		1.64			1.31			-0.050	
		(1.58)			(1.79)			(2.60)	
averaged 2D:4D			3.73**			2.97			0.65
			(1.80)			(2.07)			(3.03)
Age				0.0076	0.0064	0.0070			
				(0.0085)	(0.0085)	(0.0085)			
Education of father				1.10***	1.09***	1.09***	0.76**	0.76**	0.76**
				(0.21)	(0.21)	(0.21)	(0.31)	(0.31)	(0.31)
Education of mother				0.71***	0.72***	0.71***	0.62**	0.63**	0.63**
				(0.22)	(0.22)	(0.22)	(0.32)	(0.32)	(0.32)
Place of birth (urban/rural)							0.98***	0.99***	0.99***
							(0.31)	(0.31)	(0.31)
Constant	-5.23***	-2.57	-4.64***	-5.36***	-3.07*	-4.75**	-3.38	-2.16	-2.85
	(1.64)	(1.58)	(1.80)	(1.97)	(1.84)	(2.12)	(2.81)	(2.59)	(3.01)
Number of Observations	919	918	918	747	747	747	364	364	364
Chi-squared	7.091	1.074	4.321	89.002	86.008	87.551	42.675	42.500	42.546
$Prob > Chi2$	0.008	0.300	0.038	0.000	0.000	0.000	0.000	0.000	0.000

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 12: Esimated probalities of taking top occupation, males

	2D:4D (left hand)		
	Grid	Margin	$P > \|z\|$
1.	0.737	0.156	0.010
2.	0.837	0.202	0.000
3.	0.937	0.255	0.000
4.	1.037	0.317	0.000
5.	1.137	0.386	0.000
Observations	747		

Table 13: Dependent variable: Having smoking experience ever, males

	(1)	(2)	(3)
Age	0.025**	0.025**	0.024**
	(0.0100)	(0.010)	(0.0099)
2D:4D (left hand)	4.49*		
	(2.40)		
Education of father	-0.018	-0.015	-0.021
	(0.29)	(0.29)	(0.29)
Education of mother	-0.27	-0.26	-0.24
	(0.30)	(0.30)	(0.30)
averaged 2D:4D		5.16*	
		(2.74)	
2D:4D (right hand)			3.61
			(2.46)
Constant	-5.97**	-6.64**	-5.05**
	(2.50)	(2.84)	(2.55)
Number of Observations	391	391	391
Chi-squared	10.987	11.005	9.571
$Prob > Chi2$	0.027	0.027	0.048

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 14: Esimated probalities of having smoking experience, males

	2D:4D (left hand)			Average 2D:4D		
	Grid	Margin	$P > \|z\|$	Grid	Margin	$P > \|z\|$
1.	0.737	0.151	0.058	0.836	0.199	0.005
2.	0.837	0.217	0.001	0.936	0.292	0.000
3.	0.937	0.301	0.000	1.036	0.406	0.000
4.	1.037	0.400	0.000	1.136	0.530	0.000
5.	1.137	0.509	0.000			
Observations	391			391		

Table 15: Dependent variable: Participation in Sports activities (jogging, skating, skiing), females

	(1)	(2)	(3)
Age	-0.042***	-0.041***	-0.041***
	(0.012)	(0.012)	(0.012)
2D:4D (left hand)	2.73		
	(2.55)		
Education of father	0.33	0.33	0.33
	(0.29)	(0.29)	(0.29)
Education of mother	0.59**	0.58**	0.59**
	(0.29)	(0.29)	(0.29)
2D:4D (right hand)		5.30**	
		(2.50)	
averaged 2D:4D			5.11*
			(2.85)
Constant	-4.16	-6.79***	-6.58**
	(2.63)	(2.61)	(2.94)
Number of Observations	1316	1315	1314
Chi-squared	30.658	33.877	32.579
$Prob > Chi2$	0.000	0.000	0.000

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 16: Estimated probability of sports activities (jogging, skating, skiing), females

	2D:4D (Right hand)			Average 2D:4D		
	Grid	Margin	$P > \|z\|$	Grid	Margin	$P > \|z\|$
1.	0.680	0.011	0.225	0.824	0.025	0.055
2.	0.780	0.019	0.082	0.924	0.041	0.000
3.	0.880	0.032	0.003	1.024	0.065	0.000
4.	0.980	0.053	0.000	1.124	0.103	0.001
5.	1.080	0.085	0.000	1.224	0.157	0.044
6.	1.180	0.134	0.006			
7.	1.280	0.204	0.050			
Observations	1315			1314		

Table 17: Ordinal logistic regression of the response to the statement: "In General I am satisfied with myself", males

	(1)	(2)	(3)
2D:4D (right hand)	-0.39		
	(1.34)		
Age	-0.022***	-0.022***	-0.022***
	(0.0052)	(0.0052)	(0.0052)
averaged 2D:4D		-2.08	
		(1.52)	
2D:4D (left hand)			-2.86**
			(1.36)
Number of Observations	1169	1168	1169
Section	17.438	18.830	21.278
Chi-squared	0.000	0.000	0.000
$Prob > Chi2$	1.851	1.771	3.205
Brant Chi-Squared	.763	.778	.524

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 18: Ordinal logistic regression of the response to the statement: "I do not even feel inferior to others", females

	(1)	(2)	(3)
averaged 2D:4D	-1.19		
	(1.23)		
Age	-0.0077*	-0.0081*	-0.0075*
	(0.0043)	(0.0043)	(0.0042)
2D:4D (right hand)		-1.95*	
		(1.10)	
2D:4D (left hand)			0.088
			(1.08)
Number of Observations	1665	1666	1667
Section	4.062	6.326	3.147
Chi-squared	0.131	0.042	0.207
$Prob > Chi2$	4.955	7.305	4.333
Brant Chi-Squared	.292	.121	.363

Table 19: Ordinal logistic regression of the response to the statement: "Sometimes I feel myself useless", females

	(1)	(2)	(3)
averaged 2D:4D	1.39		
	(1.14)		
Age	0.0093**	0.0095**	0.0091**
	(0.0039)	(0.0039)	(0.0039)
2D:4D (right hand)		1.73*	
		(1.01)	
2D:4D (left hand)			0.46
			(1.01)
Number of Observations	1668	1669	1670
Section	6.768	8.241	5.498
Chi-squared	0.034	0.016	0.064
$Prob > Chi2$	1.005	.829	1.346
Brant Chi-Squared	.909	.93	.854

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 20: Ordinal logistic regression of the response to the statement: "I can do everything not worse than others", females

	(1)	(2)	(3)
averaged 2D:4D	-1.60		
	(1.27)		
Age	-0.016***	-0.016***	-0.016***
	(0.0044)	(0.0044)	(0.0044)
2D:4D (right hand)		-0.59	
		(1.14)	
2D:4D (left hand)			-1.92*
			(1.12)
Number of Observations	1664	1665	1666
Section	14.369	13.088	15.787
Chi-squared	0.001	0.001	0.000
$Prob > Chi2$	5.069	4.89	3.919
Brant Chi-Squared	.28	.298	.417

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

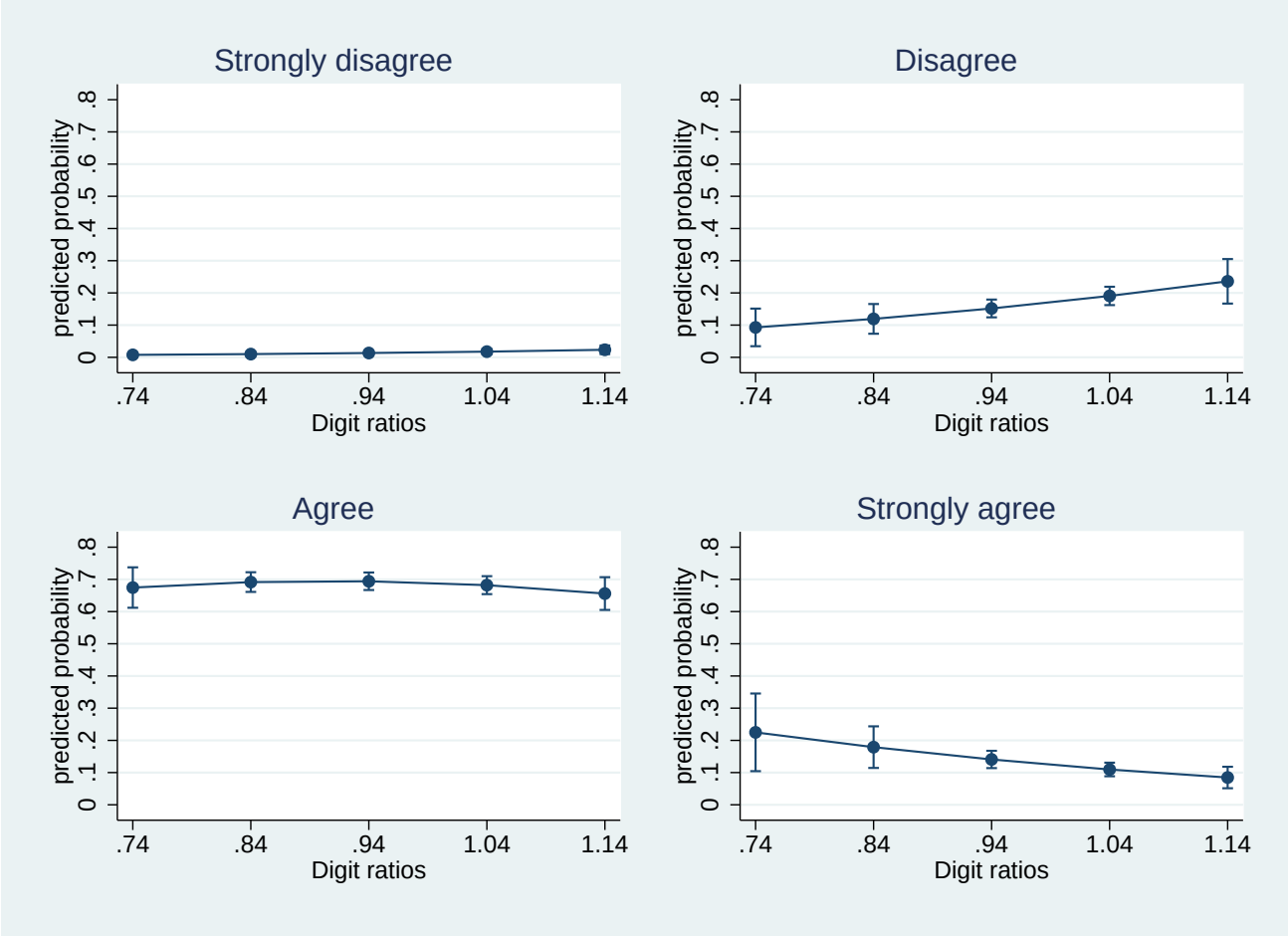

Figure 1: Estimated probabilities for different categories of answers to the statement: "In General I am satisfied with myself", males (left hand)

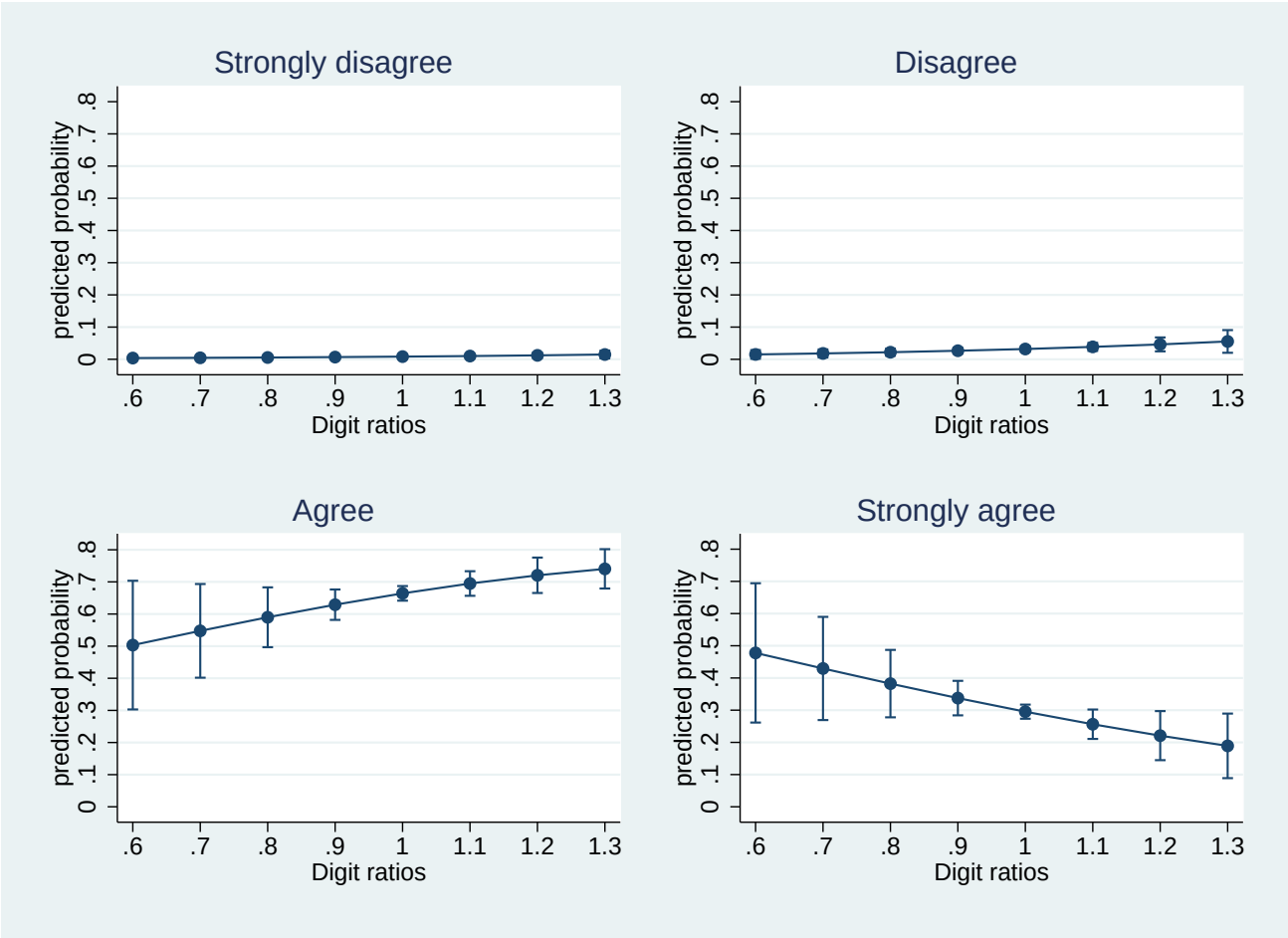

Figure 2: Estimated probabilities for different categories of answers to the statement: "I do not feel inferior to others", females (right hand)

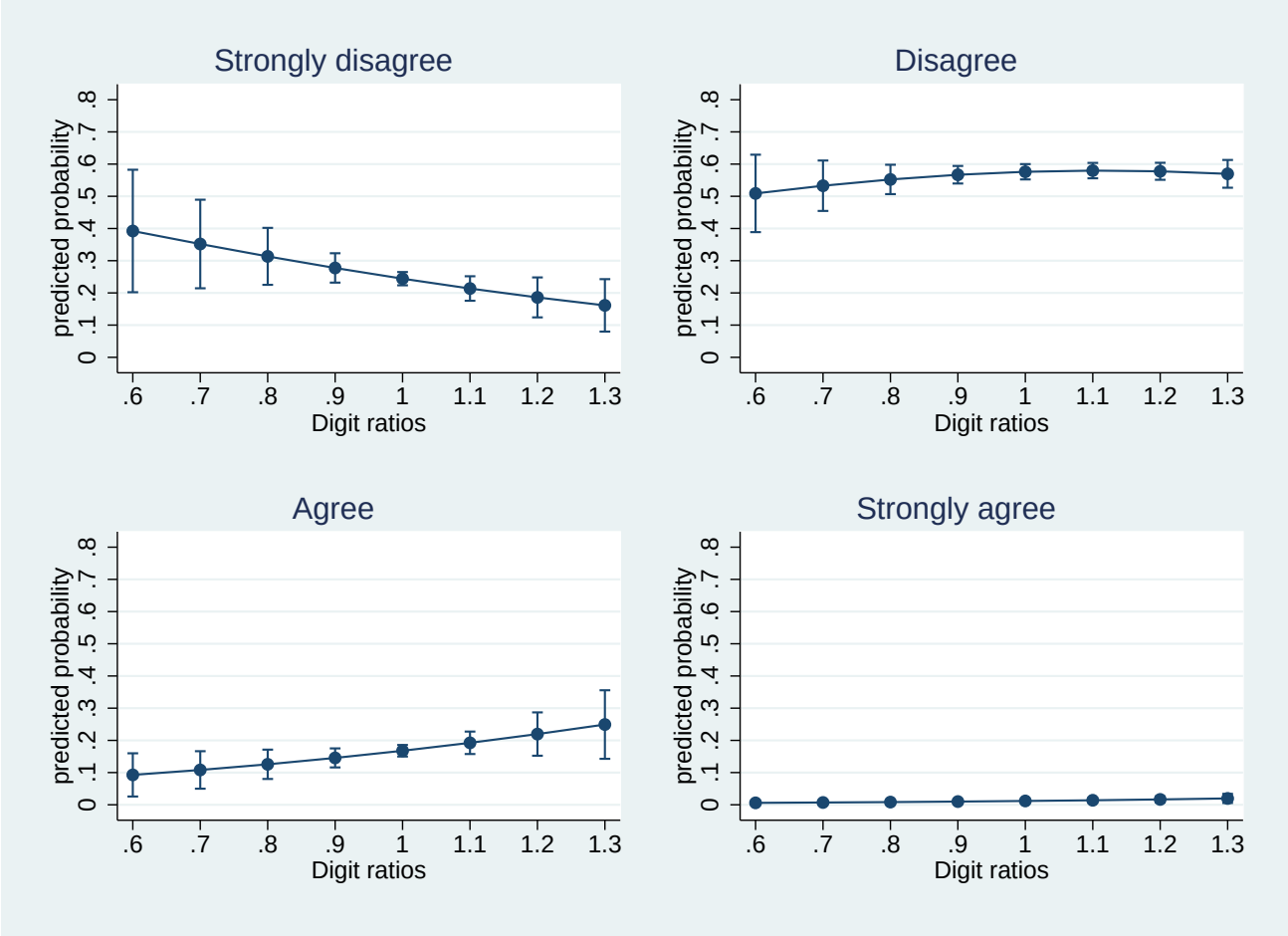

Figure 3: Estimated probabilities for different categories of answers to the statement: "Sometimes I feel myself useless", females (right hand)

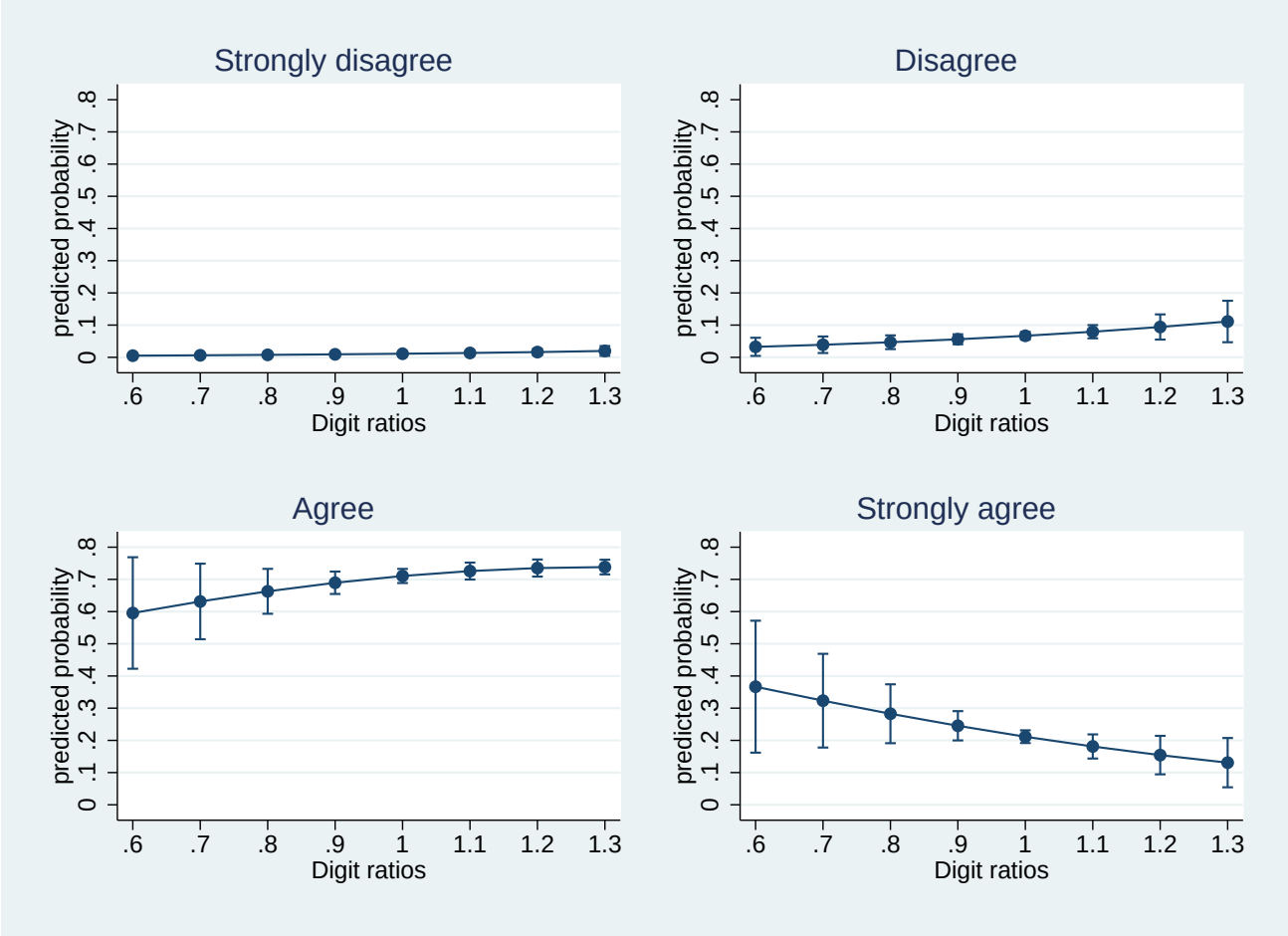

Figure 4: Estimated probabilities for different categories of answers to the statement: "I can do everything not worse than others", females (left hand)

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