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2D:4D ASYMMETRY AND ACADEMIC PERFOMANCE: EVIDENCE FROM MOSCOW AND MANILA

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Exposure to prenatal androgens affects both future behavior and life choices. However, there is still relatively limited evidence on its effects on academic performance. Moreover, the predicted effect of exposure to prenatal testosterone (T) - which is inversely correlated with the relative length of the second to fourth finger lengths (2D:4D) - would seem to have ambiguous effects on academic achievement since traits like confidence, aggressiveness, or risk-taking are not uniformly positive for success in school. We provide the first evidence of a non-linear relationship between 2D:4D and academic achievement using samples from Moscow and Manila. We find that there is a quadratic relationship between high T exposure and markers of achievement such as grades or test scores and that the optimum digit ratio for women in our sample is lower (indicating higher prenatal T) than the average. The results for men are generally insignificant for Moscow but significant for Manila showing similar non-linear effects. Our work is thus unusual in that it draws from a large sample of nearly a thousand university students in Moscow and over a hundred from Manila for whom we also have extensive information on high school test scores, family background and other potential correlates of achievement. Our work is also the first to have a large cross country comparison that includes two groups with very different ethnic compositions.

JEL Classification: I21, D03.

Keywords: academic performance, university admissions, 2d4d ratio.

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Performance in schooling is known to be dependent on cognitive ability, family background, and social status, but it is also heavily influenced by biological and psychological traits independent of or even orthogonal to standard notions of cognitive ability. These include aggressiveness or self-confidence, conscientiousness, and/or willingness to take risks.

Some of these characteristics may derive partly from prenatal exposure to androgenic steroids. An extensive body of existing research has shown the links between this prenatal exposure and increased circulating testosterone. This in turn has been tied to various measures of performance in ways consistent with greater testosterone exposure. The most common marker for measuring prenatal androgens is the second-to-fourth finger digit length ratio (henceforth 2D:4D) with relatively longer fourth fingers (lower 2D:4D) indicating higher fetal androgens (See Manning, 2002 for a literature review). Previous work has shown links between digit ratios and success in competitive sports, preference for risk, and success in high frequency financial trading (e.g. Honekopp et al. 2006 and Manning, et al. 2007 for sports; Apicella, et al. 2008, Sapienza et al. 2009, and Stenstrom et al. 2011 for risk; and Coates, et al 2009 on financial trading).

There is also some limited work on the relationship between 2D:4D and academic performance but the findings are still mixed and often based on quite limited samples. Romano (2006) found that adult males' 2D:4D ratios positively predicted examination grades while females' marks were uncorrelated with these ratios. Brosnan (2008) studied British school children's digit ratios and their correlations with their numeracy and literacy. Digit ratios were not found to be significant for the group as a whole but there were sex based differences whereby lower digit ratios predicted numeracy for boys and higher digit ratios predicted higher literary SAT scores for girls though in both cases the effects were small.

Brosnan et al.'s 2011 study considered a small group of computer science students to see if prenatal testosterone exposure was related to performance and computer-anxiety however they found few differences and no sex-related differences in grades. However, lower computer anxiety was associated with lower 2D:4D ratios.

The diverse findings across existing work on 2D:4D suggests that there may be strongly sex differentiated effects; further, the unreliable findings across studies could be driven by nonlinearity in the relationship between testosterone and later outcomes. Some characteristics associated with

high testosterone could plausibly have non-linear effects on performance – some aggressiveness, for instance, may be beneficial, but too much may lead to destructive behavior (e.g. Kornhuber et al. 2011 shows low digit ratios correlated with increased tendency to alcohol dependency). Across samples of students that truncate at different portions of the testosterone distribution, regression estimates would find positive relationships in some samples and negative relationships in others. Surprisingly, formal tests of nonlinear specifications are absent in the literature.

In addition, low 2D:4D ratios may be correlated with important omitted factors. Consider the fact that prenatal androgen exposure may also be correlated to nutrition in the womb in which case the effects of low 2D:4D would be a joint product of the nutritional and hormonal components of the prenatal environment. By controlling for proxies of prenatal environment, we can investigate whether the 2D:4D relationship falls to statistical insignificance after controlling for prenatal environment proxies.

Our work takes advantage of detailed data on academic performance from two universities to study the (possibly non-linear) relationship between student achievement and digit ratios. The first is a large sample of several hundred students drawn from four different departments (economics, political science, law, and management) of the Higher School of Economics in Moscow, one of the leading universities in Russia.

Our Moscow findings suggest that (left hand) digit ratios significantly affect academic performance of females, but not males. In particular, women with slightly lower digit ratios (i.e. higher prenatal testosterone exposure) than average tend to perform better in school. Moreover, we often find evidence of nonlinearities in the effects of 2D:4D which indicates that there may be an optimum level of testosterone exposure when considering its effects on academic achievement.

Our second sample is based on a smaller survey of students from Manila, specifically from the University of the Philippines School of Economics (only economics majors) – the leading university of higher education in the Philippines. Using their current weighted averages in math subjects and in economics subjects as proxies for academic performance, we similarly find evidence of non-linear effects of digit ratios on grades. However, unlike the Moscow results, the effects are significant for the right hand, and not the left, and for males (and the entire sample), and not just for females. Furthermore, there is indication that the effect of testosterone in raising students' math grades is quantitatively the same for female Philippine students and female Russian students. That

is, the optimal digit ratio (which achieves the maximum math grades) is approximately the same across these samples. However, testosterone seems less beneficial in raising economics grades (major specific) of female Philippine students than in raising the cumulative grades of female Russian students. This is because the optimal digit ratio beyond which (economics) grades start decreasing is higher in the Philippine female sample than the optimal digit ratio generated by the Russian female sample.

Theoretical discussion

Most of the existing literature on digit ratios have looked at the correlation between increased androgen exposure (high testosterone, low 2D:4D) and risk taking or aggressiveness. A more recent literature focuses more specifically on success in school or work (cf. Coates et al. 2009 on successful bond traders). Our theory focuses on the latter, particularly on measures of success in school.

Note that a low ratio can indicate both 'success-promoting' (SP) and 'success-inhibiting' (SI) traits. This is because while some assertiveness may be beneficial, too much may be destructive. Also, the presence of one SP trait might be confounded by an associated SI trait. For instance, high risk-taking may be associated with low patience. If the SI influence of prenatal androgen gradually increases in importance as androgen exposure rises, while the SP effect remains relatively constant with increased androgen, then the result will be a nonlinear effect. In the most general form, an outcome of interest W, can be expressed as

$$W = F[SP(T,X), SI(T,Y)]$$

Where T denotes prenatal androgen exposure, and X and Y denote other (possibly overlapping) factors that may influence the outcome of interest. Because of the combined effect of T,X, and Y on SP and SI traits, and the possible interaction between these traits, the net effect of T on W may be negative or positive and may change signs as T rises. That is, $\frac{\partial W}{\partial T} \gtrless 0$, and $\frac{\partial^2 W}{\partial T^2} \neq 0$. Furthermore, the 2nd cross partial derivatives $\frac{\partial^2 W}{\partial T \partial X}$ and $\frac{\partial^2 W}{\partial T \partial Y}$ may have nonzero values: a person's sensitivity to T might be due to confounding physiological factors that make up X and Y, e.g. the presence of other hormones, metabolic processes, etc. Thus, that the second partial derivatives are non-zero means that W is non-linear in T.

Methodology

The foregoing theoretical model implies that if T affects academic outcomes, its net effect depends on the level of T (That is, the outcome is non-linear in T.). However, what we want to analyze is the net effect of digit ratios (DR) on academic performance, i.e. $\frac{\partial W}{\partial DR}$, which is also likely to depend on the level of DR since DR is a marker for T. Note, however, that $\frac{\partial W}{\partial T}$ is not necessarily equal to $\frac{\partial W}{\partial DR}$, since DR may not be a perfect marker for T. To obtain an actual estimate of $\frac{\partial W}{\partial DR}$, we need to specify the relationship between T and DR, and the non-linear relationship between T and W. Thus, let individual i's academic outcome W_i be determined by the following:

$$W_i = \alpha_0 + \alpha_1 T_i + \alpha_2 T_i{}^2 + Z_{i,W}\gamma + e_i$$

$$T_i = \delta_0 + \delta_1 DR_i + Z_{i,T}\mu + u_i$$

where $Z_{i,W}$ capture all other variables that affect academic performance, $Z_{i,T}$ are other variables that indicate the actual amount of prenatal testosterone in i, e.g. other hormones and prenatal nutrition, and e_i and u_i are random errors. Plugging the equation for T_i into the equation for W_i gives the following reduced form equation:

$$W_i = \beta_0 + \beta_1 DR_i + \beta_2 DR_i{}^2 + \alpha_1 Z_{i,T}\mu + \beta_3(Z_{i,T}\mu)^2 + Z_{i,Y}\gamma + \varepsilon_i,$$

where the parameters are equal to:

$$\beta_0 = \alpha_0 + \alpha_1 \delta_0 + 4\delta_0{}^2$$

$$\beta_1 = \alpha_1 \delta_1$$

$$\beta_2 = \alpha_2(\delta_0\delta_1)^2 + 2\alpha_2\delta_1{}^2$$

$$\beta_3 = (2 + \delta_0 + \delta_1{}^2)\alpha_2$$

and the composite error term is given by:

$$\varepsilon_i = \alpha_1 u_i + e_i + 5u_i{}^2$$

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Assuming that DR_i, DR_i^2, $Z_{i,T}\mu$, $(Z_{i,T}\mu)^2$, and $Z_{i,Y}$ are orthogonal to ε_i, we could obtain consistent estimates of parameters β_0, $\beta_1, \beta_2, \beta_3, \alpha_1, \gamma$ by OLS using data on DR_i, DR_i^2, $Z_{i,T}\mu$, $(Z_{i,T}\mu)^2$, and $Z_{i,Y}$.

We use a binary variable M_i which takes on 1 if the individual is male (and 0 otherwise) to proxy for $Z_{i,T}\mu$, $(Z_{i,T}\mu)^2$, and $Z_{i,Y}$. That is, we assume that gender differences can (a) capture the total linear and non-linear effect of other variables on T, and can also (b) proxy for other variables affecting W. While (a) may be reasonable in that T is sexually dimorphic – the effect of other hormones and prenatal nutrition differ by gender,(b) may seem tenuous in that factors such as environment and parental care may be gender neutral. However, if the latter factors have low correlation with DR (which is likely since DR is predetermined), omitting $Z_{i,Y}$(or elements of $Z_{i,Y}$ which cannot be captured by gender) may not lead to large biases.

Thus, making the simplifying assumption: $M_i = Z_{i,T}\mu = (Z_{i,T}\mu)^2 = Z_{i,Y}$

[7], the following equation can be consistently estimated by OLS:

$$W_i = \beta_0 + \beta_1 DR_i + \beta_2 DR_i^2 + \varphi M_i + \varepsilon_i,$$

where:

$$\varphi = \alpha_1 + \beta_3 + \gamma$$

An important implication is that if the estimated coefficients are $\hat{\beta}_1 > 0$ and $\hat{\beta}_2 < 0$, and if the W-maximizing digit ratio is within the observed data range, then this is consistent with the hypothesis that T has both SP and SI elements. It would also imply that too strong digit ratio asymmetry predicts poor outcomes.

Note that both the intercept and coefficients depend on gender M_i. For $M_i = 1$, the intercept would be $\beta_0 + \varphi$ (while for $M_i = 0$, it would be β_0). Coefficients β_1, β_2 (and errors ε_i) also differ by gender since the values of $\alpha_1, \delta_1, \delta_0$ (and u_i, e_i) depend on the inclusion of $Z_{i,T}\mu$ and $Z_{i,Y}$, which are proxied by M_i.

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[7] This may not be unreasonable if $Z_{i,Y}$ only includes other dimorphic traits and does not include, say, environment and parental care (which we can safely omit), and if, say hormones and prenatal nutrition predominantly affect T in a linear manner such that the squared terms in $(Z_{i,T}\mu)^2$ are close to zero.

Thus, we run OLS regressions on subsamples defined by gender, and expect to obtain estimates of coefficients, $\hat{\beta}_1$, and $\hat{\beta}_2$, (and intercepts $(\hat{\beta}_0 + \hat{\varphi})$ or $\hat{\beta}_0$) that differ across these subsamples.

Results

Moscow

Data on digit ratios, gender, and (proxies for) academic performance are drawn from students at Higher School of Economics in Moscow and represent four different departments (Economics, Law, Management, and Political Science). Both right and left 2D:4D digit ratio measurements were taken for all students using a laser caliper. We omit students who stated in a questionnaire that they had broken one of these fingers. In addition, our data set includes various admission criteria used for the students. In particular, we have information on which students were admitted with full or partial scholarship. In the Higher School of Economics, roughly a third of the students receive a full scholarship and a large number of the remainder receive partial scholarships. Admission to the university and offers of scholarship are heavily dependent on criteria which are a weighted average of high school test scores (the national Russian university entrance exam) and performance on various precollege competitions known as Olympiads which are offered in a number of subjects mostly in math and the sciences. We have information on student entrance exam scores, Olympiad results, and receipt of high school honors.

Since all scholarships are merit based, they are an indicator of precollege academic achievement and can serve as proxies for college academic performance, and are also outcome measures in their own right. We also use the actual test scores on the entrance exam and a dummy for admission via a high Olympiad score, information on high school honors, and current cumulative grade point average while in college.

In general there were no significant and systematic correlations between men's 2D:4D ratios and any relevant academic variables. However, for women there were a number of notable results, mostly from correlations with left hand 2D:4D measures. In the Moscow samples, a small number of students had 2D:4D measures that were far outside the normal range; the main estimates reported below omit students with 2D:4D measures more than three standard deviations from the mean.

Table 1: 2d4d and Female pre-college achievements

	Dependent variable				
	HS Honors	**Olympiad**	**Full Scholarship**	**Math Score**	**Russian Score**
Left Ratio	53.10*	2.51	26.38	2553.95**^	-629.61
	(31.55)	(27.38)	(28.18)	(1226.18)	(1001.22)
Left Ratio^2	-26.20*	-0.94	-13.18	-1289.44**^	302.32
	(14.89)	(13.79)	(14.20)	(615.88)	(502.89)
R^2	1.2%	0.3%	0.2%	3.4%^	1.4%
P(F-test)	7.5%	57%	61%	10.5%	39.0%
Beta$_i$=0					
L^{Max}	1.013			0.990	

Note: Estimated through via OLS; Honors, Olympiad, and Scholarship are dummy dependent variables; results unchanged if estimated via probit. Observations where 2d4d measure is greater than +/- 3 sigma omitted. L^{Max} is the value of left digit ratio that maximizes the dependent variable, equal to Beta^{Left}/(2*Beta^{LeftSquared}); only reported when digit ratio coefficients are statistically significant. * denotes 10% statistical significance; ** denotes 5%. ^ denotes that results are statistically significant at 5% level if all observations are included.

Table 1 shows that women's left hand 2D:4D ratios are has a statistically significant quadratic relationship with high school honors and math scores. Note that in both cases the quadratic term is the opposite sign from the linear term. This suggests that there is an optimal 2D:4D ratio associated with each outcome measure.

In the case of Math scores, the optimum 2D:4D ratio for women is significantly lower than average (i.e. more "masculine" women). High school honors seems to suggest the opposite with the optimal 2D:4D occurring at higher than average 2D:4D ratios.

Table 2: 2d4d and Female cumulative rating

	No department interaction	Department interaction included
Left	18404.95*	39603.66**
	(9957.65)	(19772.89)
L*Faculty 2		-12060.76
		(26295.77)
L*Faculty 3		-52815.62*
		(28978.92)
L*Faculty 4		-26426.87
		(32302.85)
Left^2	-9494.58*	-20216.88**
	(5017.17)	(9921.87)
L^2*Faculty 2		6152.08
		(13244.46)
L^2*Faculty 3		26971.09*
		(14545.06)
L^2*Faculty 4		13404.32
		(16274.81)
L^{Max}	0.969	0.979
Right	4119.36	
	(9017.37)	
Right^2	-2134.64	
	(4531.72)	

Note: Estimated through via OLS. Observations where 2D:4D measure is greater than +/- 3 sigma omitted. L^{Max} is the value of left digit ratio that maximizes the dependent variable, equal to $Beta^{Left}/(2*Beta^{LeftSquared})$; only reported when digit ratio coefficients are statistically significant. * denotes 10% statistical significance; ** denotes 5%.

Table 2 gives us the correlates of females' left hand 2D:4D measures and their performance at the Higher School of Economics; the HSE's preferred performance measure is the "cumulative rating." Students are ranked according to a cumulative measure which is a weighted mix of GPA in different subjects multiplied by a factor that is dependent on the length and relative importance of the course. This cumulative rating is used to rank all students and is also a determinant in selecting students eligible for upper class scholarships and awards.

The Left Hand 2D:4D measures are have a quadratic relationship with cumulative rating similar to that in Table 1. Just as with the Math exam scores, the optimal female 2D:4D is lower

than that of the average (i.e. more "masculinized" women). For students majoring in Law (Faculty 3), the quadratic relationship reverses: extreme 2D:4D predicts better performance. However, the Law faculty coefficients when summed with the all-HSE coefficients are small, less than 1/3 the size of the all-HSE coefficients.

The mean digit ratio for HSE women is 0.994, with a standard deviation of 0.036. Thus, the cumulative rating-maximizing value of 2D:4D is at least 1/3 of a standard deviation below the female mean. Outliers had no substantial influence on mean female 2D:4D.

The analogous regressions for men are insignificant for both tables; the mean male digit ratio was 0.983 with a standard deviation of 0.034.

Manila

Our second set of results comes from a smaller sample of a little over a hundred students drawn from the University of the Philippines School of Economics. All students are members of the same department and all were upper class men or women recruited voluntarily during registration for the school year 2011-2012. Their hands were photocopied and all completed a survey about their backgrounds and their grades in required courses.

We examined the relationship between measured 2D:4D ratios and grades for the subsamples of males, of females, and for the entire sample including men and women. In particular, we report their average weighted grades in economics subjects (EWA) and also their average weighted grades in math subjects (MWA). (As a general rule, most students at the UPSE have to take the same sequence of courses while completing the first few years of the economics major with optional courses tending to come later).

We observe the same pattern of nonlinear effects of digit ratios on grades in the Philippine sample. However, in this case, we get significant results for the subsamples of males and females (and the entire sample), and for the right hand digit ratio rather than the left.

Table 3 shows the relationship between measured right hand 2D:4D ratios for the full Manila sample against EWA and against MWA. In both cases, the quadratic term is significant and negative.

Table 4 shows this relationship broken down by gender and we also calculate an R_{max}, which is the implied optimal 2D:4D ratio for each outcome measure and subsample.

This threshold or optimum point, i.e. R_{max}, occurs at around 0.99 for MWA of females, the same as L_{max} for the math grades of the Moscow sample, below but close to the Moscow female mean. This means that consistently across the Manila and Moscow samples, women's maximum math grades can be achieved when their digit ratio is 0.99. However, R_{max} for EWA of female Manila students is 0.98, which is higher than L_{max} for cumulative grades of female Moscow students (i.e. 0.97). Roughly, this suggests that testosterone is less beneficial in increasing economics grades for female Manila students than in raising cumulative grades for female Moscow students.[8]

On the other hand, 2D:4D predicts grades of male students in Manila (while it is insignificant in Moscow). The R_{max} for males are lower at 0.96 for MWA and 0.94 for EWA, which suggests that testosterone is more beneficial for males since males' optimum/maximum grades are achieved with lower digit ratios. Of course, this assumes that males and females' digit ratios mark roughly the same amount of T.[9] It can very well be that males' digit ratios are more sensitive indicators of testosterone, in which case the R_{max} and L_{max} are not directly comparable across males and females. Nevertheless, the Manila results suggest that for male students, high grades are associated with even lower digit ratios.

Conclusion

Our work not only provides us with an unusually large sample of students from different cultures and ethnicities but also is the first analysis of 2D:4D to highlight the quadratic relationship in the effect of prenatal androgen exposure on academic performance. We have demonstrated the importance of considering the non-linear effects of prenatal testosterone exposure that suggests why inconsistent results might be found across studies in standard linear regressions. The potential interactions between testosterone as a hormonal effect and low 2D:4D as an indicator of potential nutrition-driven effects would also serve to confound simple estimates. Including a simple quadratic

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[8] The average right hand digit ratio for females is 0.99, while for males it is 0.97. Thus, the maximum math grades (MWA) of females are achieved at the average digit ratio, but maximum econ grades (EWA) are achieved at a digit ratio lower than the average. For males, maximum math and econ grades are achieved at digit ratios that are clearly lower than the average.

[9] In our regression model, this means that μ is very small.

term gives us a more accurate picture of the suggested direction of the influence of prenatal testosterone exposure on academic success.

Table 3. University of the Philippines Grades vs. Digit Ratios (Full Sample)

Explanatory Variables	EWA	EWA	MWA	MWA
Right_2d4d	-.3149615	49.90551***	-.558771	103.2116*
	(.9912529)	(28.68723)	(1.340431)	(38.12672)
Right_2d4d_sq		-25.39511***		-52.47218*
		(14.49782)		(19.26768)
Constant	2.172143	-22.61864	2.55761	-48.6706
	(.9772681)	(14.18597)	(1.321374)	(18.85504)
R squared	0.0008	0.0249	0.0014	0.0565
N	127	127	130	130

* significant at 1%
** significant at 5%
*** significant at 10%

Table 4. University of the Philippines Grades vs. Digit Ratios (Broken down by Gender)

Explanatory Variables	Female EWA	Male EWA	Female MWA	Male MWA
Right_2d4d	75.579***	100.584***	106.301**	170.847***
	(0.441)	(0.575)	(0.513)	(1.014)
Right_2d4d_sq	-38.483***	-53.681***	-53.709**	-88.873*
	(0.002)	(0.003)	(0.003)	(0.005)
Constant	-35.102	-22.61864	2.55761	-48.6706
	(22.159)	(14.18597)	(1.321374)	(18.85504)
R squared	0.0648	0.0249	0.0014	0.0565
N	73	127	130	130
Rmax	0.98	0.94	0.99	0.96

*significant at 1%
** significant at 5%
*** significant at 10%

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