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Testosterone and Tendency to Engage in Self-Employment

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Abstract. Does testosterone increase the tendency to engage in self-employment? The results presented to date have been mixed. Using three different studies, we provide additional evidence on the relationship between testosterone and self-employment. Drawing on a cross section of 2,146 individuals (1,178 males and 968 females) from the National Health and Nutrition Examination Surveys' 2011–2012 sample, and controlling for endogeneity (with red blood cell count, percentage hematocrit, and zinc supplement intake in the past 30 days as instruments), we find that serum testosterone levels are positively associated with self-employment for males (marginally significant, two-tailed test). As testosterone levels could be affected by social, economic, and biological factors during one's life course, we draw more robust inferences by assessing whether the 2D:4D digit ratio, a marker of prenatal testosterone exposure, influences the likelihood of self-employment. From Understanding Society's Innovation Panel Wave 6, we tested separate models for 449 males and 525 females, and our results indicate that males (respectively, females) with a lower 2D:4D ratio in their left hand, or higher prenatal testosterone exposure, have a significantly greater (respectively, marginally significant) likelihood of self-employment (two-tailed test). Finally, we examine the twin testosterone transfer effect in a sample of opposite-sex and same-sex twins from the National Survey of Midlife Development in the United States and provide additional support for the marginally significant (two-tailed test) positive association between testosterone and self-employment.

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Keywords: testosterone • self-employment • biological perspective in entrepreneurship

1. Introduction

Self-employment has become an increasingly popular employment option. In a 2013 Gallup poll, 18% of adults worldwide reported being self-employed (Gallup 2014). Among those who engage in self-employment, there exists a wide range of variance with regard to the motivations, activities, and outcomes of such activities. Identifying and detailing antecedents to self-employment has become a central theme with regard to entrepreneurship research (Parker 2004). Prior research has revealed several precursors to self-employment, ranging from personality (Chlosta et al. 2012) and cognitive factors (Kolvereid and Isaksen 2006), to past work experience (Zissimopoulos and Karoly 2007) and demographic characteristics (Leoni and Falk 2010). Although there remains a debate over what factors drive the tendencies of individuals to engage in self-employment (Edwards and Field-Hendrey 2002, Leung 2006), a growing body of evidence has shown that biological factors might influence the likelihood of self-employment (Nicolaou et al. 2011, Shane and Nicolaou 2015).

One of the most widely studied biological influences on attitudes and behaviors is found in the hormone testosterone. Testosterone is a steroid hormone primarily produced by the testicles of males and the ovaries of females and in smaller amounts by the adrenal glands of both sexes. Many features that characterize entrepreneurship and self-employment are also highly correlated with the effects of testosterone (White et al. 2006, 2007). For example, testosterone levels have been shown to increase during competitive situations (Carré 2009, Carré et al. 2013), and this "challenge model" has been shown to hold true across a number of species, humans included (Carré 2009, Wingfield et al. 1990). Additionally, the "biosocial model" of testosterone influence, which has been the basis for a majority of the work on the effects of testosterone in humans, suggests that "winners" of such competitive situations will experience higher levels of testosterone than will "losers" (Carré 2009, Carré et al. 2013). Testosterone has also been linked with greater risk tolerance with regard to financial decision making (Coates and Herbert 2008) and other decision-making

contexts (Ronay and von Hippel 2010). Testosterone can enhance an individual's desire for dominance and the likelihood he or she will engage in situations where such dominance can be experienced (Mehta and Josephs 2006, 2010). Testosterone can also reduce the ability to empathize with others (Hermans et al. 2006a) as well as the level of fear experienced with regard to decision making (Hermans et al. 2006b), which could in turn lead to increased utilitarian decision making based on rational logic rather than emotional and irrational inputs (Carney and Mason 2010). Risk taking, which is considered a central theme of entrepreneurship and self-employment (Stewart and Roth 2001), has been shown to be substantially associated with testosterone (Apicella et al. 2008, Sapienza et al. 2009). This link has been further substantiated by more recent evidence indicating that testosterone levels are associated with financial risk preferences (Apicella et al. 2008, Coates and Herbert 2008) as well as economic performance (Branas-Garza and Rustichini 2011). (For an excellent review on testosterone and economic risk taking, see Apicella et al. 2015.) Testosterone is also important in social interaction and has been related to status seeking and social dominance (Eisenegger et al. 2011). The substantial amount of evidence with regard to the association between testosterone and individual attitudes and behaviors potentially related to self-employment further magnifies the need to understand how this biological influence might relate to separating the self-employed from the employed.

Building off of the interest in how testosterone influences attitudes and behaviors, scholars have shown an increased interest in how hormonal levels, specifically with regard to testosterone levels, might be associated with a greater likelihood of engaging in self-employment (White et al. 2006). Yet the results on this association have been mixed at best. While some studies have provided support for the link between testosterone and self-employment (Greene et al. 2014, White et al. 2006), other studies have failed to find evidence in support of this relationship (van der Loos et al. 2013). It is possible that the mixed findings regarding the association between testosterone levels and self-employment could be a result of potential endogeneity between self-employment and testosterone, as well as potential variances in the size and make-up of the samples studied. Self-employment provides the necessary freedom and autonomy, coupled with feelings of success, which could boost testosterone levels. For example, as self-employed individuals on average have higher relative prestige and recognition (Halevy et al. 2012, Hopp and Stephan 2012), the resulting experiences of social status could potentially boost testosterone levels. Additionally, as those who engage in self-employment are often categorized as risk takers and as individuals seeking dominance over competitors (Stewart and Roth 2001), self-employment could, in fact, increase levels of testosterone. Thus, the potential for reverse causality cannot be ruled out in explaining mixed findings. In addition to the potential for reverse causality, socioeconomic unobservables could affect both self-employment and testosterone levels. To assuage this concern, we also consider prenatal testosterone exposure that is less influenced by future life events that affect both testosterone and self-employment. While the mother's socioeconomic status could affect prenatal testosterone exposure, we also draw on twin samples to assess the relationship between variation in availability of testosterone in the womb for same-sex and opposite-sex twins.

We propose a three-study framework related to three distinct instances of testosterone influence: (i) freely available to bind, basal testosterone in adults; (ii) 2D:4D digit ratio (or the ratio of the length of the index finger to the length of the ring finger), a marker of prenatal testosterone exposure; and (iii) comparisons between same-sex and opposite-sex twin pairs. For our Study 1, to lower the potential for reverse causality between serum testosterone levels in adult participants and self-employment, we employ a two-stage least-squares (2SLS) model, where we use three instruments—zinc supplements (milligrams consumed in the past 30 days), red blood cell (RBC) count (million cells per microliter), and hematocrit (percentage), a determinant of blood viscosity based on the volume percentage of RBCs in the blood. Serum testosterone levels are a significant improvement in measurement over saliva-based measures of testosterone employed in previous studies (White et al. 2006), which is an advantage in our study since saliva-based measures of testosterone have been increasingly called into question (Hayes et al. 2015). The choice of instrument is based on the effect of diet (i.e., intake of zinc supplements in milligrams) that could temporarily increase testosterone levels but may not significantly affect the likelihood of a major labor market outcome—self-employment. There is a significant body of work that shows that zinc supplements enhance testosterone levels. For younger men, restriction of zinc in their diet lowers serum testosterone levels (Hunt et al. 1992). Zinc has also been found to increase testosterone levels among cyclists (Neek et al. 2011) and patients with infertility (Oteiza et al. 1995). Zinc is not only used to correct androgen deficiency in adult males with sickle cell anemia (Prasad et al. 1981) but also associated with reduced circulation levels of luteinizing hormone and testosterone in rats (Lei et al. 1976). While zinc supplement intake allows controlling for possible variation in testosterone levels based on dietary preferences, red blood cell count (Beggs et al. 2014) and hematocrit (Guo et al. 2013, Sih et al.

1997) have a more stable influence on testosterone levels through increases in erythropoietin and suppression of hepcidin (Bachman et al. 2013). Testosterone is positively related to iron metabolism in blood (Beggs et al. 2014), and the biochemical association among testosterone, red blood cell count, and hematocrit has a strong genetic basis (Zuk 1996). As males and females have systematically different levels of testosterone after puberty, and therefore have different residual variances across their groups, we conduct separate regressions for male and female samples using predicted values of standardized serum testosterone levels. We find that serum testosterone is positively related to self-employment among males (at marginal significance levels, two-tailed test), but we do not find broad support for this relationship among females.

However, adult testosterone levels and self-employment can both be affected by the same socioeconomic unobservables, and the use of instruments may not be sufficient to parse out these effects. Prenatal testosterone exposure does not change or vary after birth, while post-birth testosterone levels vary systematically between males and females, and adult testosterone levels can also vary within individuals as a result of social and physiological factors (Mazur and Booth 1998). To add further fidelity to our findings from Study 1, we assess the relationship between the 2D:4D ratio, a marker of prenatal testosterone exposure, and self-employment. Lower 2D:4D ratios are indicative of higher prenatal testosterone exposure (Manning et al. 1998). The 2D:4D ratio is sexually dimorphic, as the index finger is shorter in both males and females and the ring finger is generally longer for males. Prenatal testosterone exposure has been shown to affect neurological development and can lead to permanent behavioral changes in adolescents and adults (Hines 2006). Moreover, prenatal testosterone levels influence cognitive abilities (Finegan et al. 1992) and social development (Knickmeyer and Baron-Cohen 2006). Higher prenatal testosterone exposure can result in increased aggression and sensation seeking, greater comfort with rule breaking (Cohen-Bendahan et al. 2005a), and an increased propensity to take financial risks (Coates and Page 2009), all of which have been shown to influence the likelihood an individual will engage in self-employment (Nicolaou et al. 2011). Indeed, recent evidence has shown that prenatal testosterone exposure was positively related to intentions of university students to engage in self-employment (Bönte et al. 2015), but actual engagement in self-employment remains unexplored. Expanding upon prior research, our results indicate there is a significant positive relationship between the left-hand 2D:4D ratio among males and a marginally significant positive relationship between prenatal testosterone and self-employment for the left-hand 2D:4D ratio among females.

The 2D:4D ratio limits the effects of post-birth variables in influencing both testosterone and self-employment. However, it is plausible that mothers' socioeconomic status during pregnancy would influence 2D:4D ratios, and the effects of this socioeconomic status would also be reflected in future education and human capital outcomes. Because of this limitation of Study 2, in Study 3, we corroborate the association between prenatal testosterone exposure and self-employment through a unique research design that involves a comparison of dizygotic opposite-sex twins with monozygotic/dizygotic same-sex female twins. Research has shown that female fetuses gestated with a male co-twin are more likely than fetuses gestated with a female co-twin to have higher testosterone levels (McFadden 1993, Vuoksimaa et al. 2010). This can result from testosterone passing from one twin to the other through maternal circulation or through diffusion across fetal membranes (Miller 1994, Ryan and Vandenbergh 2002). Studies have found evidence in support of this testosterone transfer effect across a number of variables ranging from sensation seeking (Resnick et al. 1993) to verbal aggression (Cohen-Bendahan et al. 2005c) to mental rotation ability (Vuoksimaa et al. 2010). We find that dizygotic opposite-sex (DZOS) females were more likely to be self-employed than monozygotic/dizygotic same-sex (MZ/DZSS) females.

Although the associations found across the three studies are positive and marginally significant, the findings are important to understand based on the contributions they provide to the existing literature. First, while natural testosterone production has a complex biological basis, the study contributes additional insight into how biological and physiological factors are related to attitudes and behaviors later in life. While previous research has established that testosterone levels, in prenatal exposure as well as in adulthood, can have substantial effects on personality traits (Branas-Garza and Rustichini 2011, Chapman et al. 2006), cognitive abilities (Finegan et al. 1992), and behavioral changes (Auyeung et al. 2009, Hines 2006), relatively little research has been done examining how such effects might influence individuals' likelihood to engage in self-employment. We attempt to help bridge this gap by examining the relationship between biological factors (i.e., adult and prenatal testosterone) and self-employment. By uncovering marginally significant relationships between both prenatal exposure and adulthood levels of testosterone and the likelihood of engaging in self-employment, we offer an insight into the relationship between biology and behavior.

Our study also addresses the mixed findings on the relationship between testosterone and the likelihood of self-employment, and the contradictory results with

regard to the existence and significance of this relationship. While some studies have provided evidence in support of this relationship (Greene et al. 2014, White et al. 2006), others have failed to reproduce similar results with larger, more diverse samples (van der Loos et al. 2013). The results of our studies reinforce the marginal significance of the relationship between both serum (more specifically, for males) and prenatal (for both males and females) testosterone exposure and self-employment, in three large and diverse samples. In doing so, we further contribute to the current conversation regarding how biological factors are associated with self-employment.

Second, our study contributes to the recent literature that has adopted a genetics perspective in entrepreneurship. This research has identified significant heritability estimates in self-employment by using samples of identical and fraternal twins (Nicolaou et al. 2008b, Zhang et al. 2009) and samples of adoptees (Lindquist et al. 2015) to disentangle genetic from environmental components of variance in self-employment. If there is a genetic predisposition to self-employment, an important next question involves identifying the mediators (physiological attributes) through which genes may influence self-employment (Shane and Nicolaou 2015). Because testosterone has a genetic component (Harris et al. 1998), our study contributes to the genetics research in self-employment by pinpointing one of the mechanisms—testosterone—through which the genetic influence to self-employment might be manifested.

Third, we add to the literature by examining, for the first time to our knowledge, the twin testosterone transfer hypothesis for self-employment. While studies have shown evidence of this effect for other variables (Vuoksimaa et al. 2010), no research has attempted to evaluate this effect for self-employment. However, this effect is plausible given evidence of testosterone transfer for sensation seeking (Resnick et al. 1993) and evidence that sensation seeking is associated with self-employment (Nicolaou et al. 2008a).

Fourth, while recent research has provided evidence regarding the relationship between prenatal testosterone exposure (2D:4D ratio) and intentions to engage in self-employment (Bönte et al. 2015), there have been no investigations to date into how prenatal testosterone exposure might influence *actual* self-employment. Having intentions to engage in self-employment is often an important factor in eventually becoming self-employed, yet, intentions in and of themselves are not sufficient for individuals to actually "take the plunge" and become self-employed (Krueger et al. 2000).

2. Theoretical Background

Researchers have long been interested in identifying and understanding factors that could help to predict why certain individuals engage in self-employment while others prefer more traditional, wage-based forms of work (Blanchflower 2000, Parker 2004). Building on the literatures related to the associations between testosterone and attitudes and behavior (Apicella et al. 2008, Goudriaan et al. 2010), the effects of prenatal testosterone exposure (Chapman et al. 2006, Hines 2006), and biological influences on self-employment (Bönte et al. 2015), we develop and test this relationship in three biomarker studies.

2.1. Testosterone and Self-Employment

There exists a long history of research investigating the relationship between individual differences and the likelihood of self-employment (Douglas and Shepherd 2002, Gollin 2008). While prior studies have shown that the decision to become self-employed can be influenced by a wide variety of personality (Chlosta et al. 2012) and demographic (Leoni and Falk 2010, Wellington 2006, Zissimopoulos and Karoly 2007) factors, as well as by access to financial and social resources (Dunn and Holtz-Eakin 1996), a growing stream of scholarly interest has investigated the role that biological factors play in influencing self-employment (Nicolaou and Shane 2011). Genetic factors have been shown to affect key personality traits such as extraversion and openness to experience (Shane et al. 2010), which can be important influences on individual tendencies toward self-employment. Additionally, genes that influence hormone production, such as testosterone, can also influence self-employment (Nicolaou et al. 2011).

Whereas prior evidence has presented association between testosterone levels and self-employment (Greene et al. 2014, White et al. 2006), recently, van der Loos et al. (2013) failed to uncover a significant relationship between testosterone levels and self-employment, and they postulated a number of potential reasons for why they found contradictory results from previous studies. They contended that differences in the definition of entrepreneurship and self-employment, the methods employed to measure actual testosterone levels (i.e., saliva versus serum), and the limitations related to sample makeup and size are factors that could contribute to the discrepancy between the results of their study and previous findings.

Regardless of recent findings calling into question the relationship between testosterone and self-employment, several factors that are characteristic of entrepreneurship are also associated with testosterone levels (White et al. 2006). Specifically, risk taking, which is a central theme related to entrepreneurship and self-employment (Stewart and Roth 2001), has been shown to be associated with testosterone levels (Apicella et al. 2008, Coates and Page 2009, Goudriaan et al. 2010, Sapienza et al. 2009). Additionally, testosterone has

also been shown to increase abstract reasoning, which, when combined with increased propensity to take risks, can enhance efficacy in entrepreneurship-related activities ranging from decision making to opportunity identification (Branas-Garza and Rustichini 2011). Testosterone has been shown to reduce fear response in regard to decision making (Hermans et al. 2006b), which could also relate to whether or not individuals decide to become self-employed. Furthermore, testosterone can interact with other social factors, such as prior family business background, to create a biosocial influence that can positively influence the likelihood of engaging in self-employment (White et al. 2007). Using this reasoning, we propose the following.

Hypothesis 1. *Testosterone levels will be positively related to the likelihood of self-employment.*

3. Study 1

3.1. Sample

As previously noted, recent research regarding the relationship between testosterone and self-employment has brought to light the potential effects that small, relatively homogeneous samples can have on reported results (van der Loos et al. 2013). With regard to our current study, we employ a similar definition of self-employment to that of van der Loos et al. (2013) that is based on the most common definition utilized in the literature. Additionally, our measurement of testosterone levels does not employ the saliva-based tests that were brought into question (Hayes et al. 2015) but rather the more well-established serum-test procedures. Finally, to address previous concerns regarding the validity of small, homogeneous samples, we conducted our study on a large sample (N = 2,146) surveyed from a diverse population so as to further reduce the potential for spurious results.

We draw on the Centers for Disease Control and Prevention's (CDC's) National Health and Nutrition Examination Surveys (NHANES) of 2011–2012, where the serum testosterone was measured for a random sample of men and women. The NHANES are pooled, cross-sectional surveys conducted since the 1960s on a periodic basis; starting in 1999, NHANES cross-sectional surveys were conducted every year. Each year, a stratified sample of 5,000 individuals is identified for interviews at home and for completing a health examination component in a mobile examination center (MEC) to collect medical data in a controlled environment. The details on collection, storage, and measurement of testosterone are available at http://wwwn.cdc.gov/nchs/nhanes/2011-2012/TST_G.htm (accessed September 2, 2016).

Of the 13,431 respondents selected by the CDC for 2011–2012 data collection, 9,756 individuals completed the interviews and 9,338 respondents completed home health examinations. We dropped individuals below 18 years of age to include individuals fully eligible to participate in the labor force. We used pairwise deletion and only used cases where all information on the respondent on testosterone, employment, instrumental variables, and control variables was available. Using this filter, our final sample includes 2,146 observations with complete information.

3.2. Measures

The outcome variable is whether the individual is self-employed. In NHANES 2011–2012, the respondents were asked to describe their current job or work situation. Among the respondents, 11.73% of the individuals in the sample were self-employed.

Testosterone was measured using rigorous laboratory protocols in NHANES 2011–2012. While detailed description of the underlying laboratory science of its measurement is beyond the scope of this study, we refer interested readers to the NHANES 2011–2012 Lab Data Overview.[1] Testosterone is measured in nanograms per deciliter for both males and females. The method used for measuring testosterone levels is the isotope-dilution liquid chromatography–tandem mass spectrometry based on the National Institute for Standards and Technology's reference method.

We control for the age of the respondent in years at the time of study. Education is measured as highest grade or level of school (1 = less than 9th grade; 2 = 9–11th grade, including 12th grade with no diploma; 3 = high school graduate, or GED or equivalent; 4 = some college or associate degree; 5 = college graduate or above). We also control for marital status. As family socioeconomic condition could impact engagement in self-employment, a ratio of family income to poverty, or distance of income from the income at poverty line, is included in NHANES 2011–2012. This control also assuages concerns about the distinction between one's level of success and self-employment, as successful self-employed individuals are more likely to be distant from poverty levels (van der Loos et al. 2013) and may potentially have higher levels of testosterone as a result of entrepreneurial success.

We also controlled for overall general health, as reported on a self-reported health scale, ranging from 1 (excellent) to 5 (poor). Finally, we control for race (1 = Mexican American, 2 = other Hispanic, 3 = Non-Hispanic white, 4 = Non-Hispanic black, 5 = Non-Hispanic Asian, 6 = other race—including multiracial).

3.3. Results

Table 1 lists the means, standard deviations, and correlations among the variables.

3.3.1. Endogeneity. As there is a strong possibility of reverse causality between self-employment and levels of adult testosterone, we use three instruments:

Table 1. Study 1: Means, SDs, and Correlations

	Mean	SD	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12	13
1 *Self-employed*	0.1173	0.3218	0	1	1												
2 *Age*	43.2021	14.1247	20	80	0.1902	1											
3 *Education*	3.7891	1.1656	1	5	−0.0144	−0.077	1										
4 *Marital status*	2.6820	1.9504	1	6	−0.0625	−0.353	−0.0438	1									
5 *Ratio of family income to poverty*	2.8766	1.6763	0	5	0.0142	0.1737	0.4547	−0.21	1								
6 *General health*	2.5818	0.9129	1	5	−0.0508	0.0708	−0.2835	0.0396	−0.2635	1							
7 *Mexican American*	0.1117	0.3151	0	1	−0.0241	−0.0429	−0.2844	−0.0131	−0.1418	0.1367	1						
8 *Other Hispanic*	0.0997	0.2996	0	1	−0.0299	0.0003	−0.135	0.0503	−0.0859	0.0643	−0.118	1					
9 *Non-Hispanic white*	0.3806	0.4857	0	1	0.0792	0.0159	0.1468	−0.0558	0.0958	−0.1493	−0.278	−0.2608	1				
10 *Non-Hispanic black*	0.2392	0.4267	0	1	−0.049	0.0544	0.0008	0.0959	−0.0369	0.0617	−0.1989	−0.1866	−0.4396	1			
11 *Non-Hispanic Asian*	0.1377	0.3447	0	1	−0.0077	−0.0293	0.1566	−0.0777	0.1239	−0.0469	−0.1417	−0.133	−0.3132	−0.2241	1		
12 *Other race—Including multiracial*	0.0311	0.1735	0	1	0.0095	−0.0427	0.0255	0.0114	−0.0177	0.0001	−0.0635	−0.0596	−0.1404	−0.1004	−0.0715	1	
13 *Gender* (1 = male; 2 = female)	1.4465	0.4972	1	2	−0.0868	−0.0185	0.1073	0.0456	0.0041	0.0395	−0.0432	−0.0062	−0.0298	0.0910	−0.0179	−0.0157	1
14 *Standardized testosterone*	0.0967	0.9780	−0.9089	3.8288	0.0722	−0.0332	−0.0963	0.0126	−0.0157	−0.0925	0.0380	−0.0001	0.0320	−0.0630	−0.0006	−0.0023	−0.8363

Notes. $N = 2{,}146$. All correlations at $|0.04|$ or above are significant at $p < 0.05$ or below (two-tailed).

(i) zinc supplement intake in milligrams in the past 30 days (*dr1tzinc*)[2], (ii) red blood cell count (million cells per microliter; *lbxrbcsi*), and (iii) hematocrit (percentage; *lbxhct*). All three instruments are measured at the time of reported testosterone measurement in NHANES 2011–2012.

Zinc supplement intake is measured in milligrams using self-reported diet information for the past 30 days. Past work has shown that zinc supplementation can be used to correct testosterone levels among those with a variety of clinical conditions such as androgen deficiency among those with sickle cell anemia (Prasad et al. 1981). Evidence also suggests that zinc supplements can be used to increase testosterone levels among young men (Hunt et al. 1992) as well as to boost testosterone-driven performance among cyclists (Neek et al. 2011). Zinc is also related to reduced circulation of luteinizing hormone in rats (Lei et al. 1976). As zinc intake in the past 30 days is less likely to be associated with self-employment outcome, we construe that this instrument is strongly related to serum testosterone but weakly, if at all, related to self-employment.

In addition, we use two additional instruments—namely, red blood cell count (million cells per microliter) (Beggs et al. 2014) and hematocrit (percentage) (Guo et al. 2013, Sih et al. 1997)—that have been shown to have more stable influences on testosterone levels through increases in erythropoietin and suppression of hepcidin (Bachman et al. 2013). In both males and females, testosterone is known to regulate erythropoiesis, or the process of creating red blood cells (Shahani et al. 2009). Since the biochemical processes that link testosterone and red blood cell development are strongly influenced by genetic factors (Steinbicker and Muckenthaler 2013), it is less likely that red blood cell count will be associated with self-employment; this thereby provides another useful instrument for our analysis.

As males and females have systematically different levels of testosterone and therefore have different residual variances across their groups, we use predicted values (based on the three instruments) of standardized testosterone levels for males and females to separately analyze the association between testosterone levels and self-employment among males and females. For the female sample, the endogeneity test was rejected ($\chi^2 = 0.864$ (1), $p = 0.3527$); however, for the male sample, the endogeneity test was marginally significant ($\chi^2 = 2.630$ (1), $p = 0.1049$). To derive more conservative estimates, and for consistency, we proceed with predicted values of standardized testosterone levels for males and females.

We employ a two-stage least-squares (2SLS) logic using the *logit* command in Stata 14; on the basis of recommendations from the CDC on analyzing laboratory NHANES 2011–2012 data, we use the laboratory sample weighting variable *wtmec2yr*.[3] For the male

Table 2. Study 1: Logistic Regression

	Instrumented standardized T levels for males	Instrumented standardized T levels for females
Specification:	(1) *logit*	(2) *logit*
Variables	*self_employed*	*self_employed*
Predicted male testosterone	1.444^{+}	
	(1.867)	
Predicted female testosterone		2.823
		(0.570)
Age	0.0503***	0.0267*
	(5.508)	(2.106)
Education	0.0491	0.0899
	(0.387)	(0.456)
Marital status	0.0572	−0.0948
	(0.860)	(−0.944)
Ratio of family income to poverty	−0.0816	−0.156
	(−0.894)	(−1.576)
General health	−0.114	−0.344^{+}
	(−0.793)	(−1.725)
Mexican American	0.0217	0.462
	(0.0344)	(0.480)
Other Hispanic	0.441	−1.350
	(0.698)	(−1.251)
Non-Hispanic white	0.856	−0.0319
	(1.581)	(−0.0339)
Non-Hispanic black	0.321	−0.111
	(0.566)	(−0.118)
Non-Hispanic Asian	0.697	−0.0802
	(1.193)	(−0.0818)
Constant	−4.624***	−2.396
	(−4.530)	(−1.404)
Observations	1,178	968
χ^2	49.87	19.19
p-value	$6.61e-07$	0.0577

Note. Shown in parentheses are z-statistics.
$^{***}p < 0.001$; $^{**}p < 0.01$, $^{*}p < 0.05$; $^{+}p < 0.10$.

sample, the Cragg–Donald Wald F-statistic was 13.03 ($p = 0.0000$), and the Sargan test could not be rejected ($\chi^2 = 0.508$ (2), $p = 0.7757$). As endogeneity was not supported for the female sample, the related tests were not supported either (Cragg–Donald Wald F-statistic: 0.95, $p = 0.414$; Sargan test: $\chi^2 = 0.764$ (2), $p = 0.6824$). As presented in Table 2 for the male sample, predicted testosterone (T) levels are positively associated with self-employment, albeit with marginal significance ($\beta = 1.444$, $p = 0.062$); however, the association was not supported in the female sample. Winsorizing at the 1% and 5% levels also gave estimates consistent with the above estimates.

4. Prenatal Testosterone Exposure and Self-Employment

While Study 1 examined the relationship between serum testosterone levels and self-employment, it can be argued that testosterone levels can vary over time, and therefore the permanency and stability of this relationship are somewhat unreliable when it was measured in NHANES 2011–2012. Unobservables could affect both testosterone and self-employment. Therefore, to examine what, if any, lasting influence testosterone might have on self-employment, in Study 2 we investigated whether the 2D:4D digit ratio, a marker of prenatal testosterone exposure, is related to self-employment.

Prenatal testosterone levels have been shown to influence brain development of fetuses, which can produce permanent behavioral and psychological changes (Hines 2006). Additionally, prenatal testosterone exposure has been shown to influence social development (Knickmeyer and Baron-Cohen 2006) as well as key cognitive abilities (Finegan et al. 1992). For a more extensive review of the influences that prenatal testosterone levels can have on a variety of personality, cognitive, and psychological domains, we refer the reader to the work of Cohen-Bendahan et al. (2005c).

Evidence has long pointed to the potential that early exposure to higher levels of prenatal testosterone could likely produce more male-like characteristics and fewer female-like characteristics, while lower prenatal exposure to testosterone can lead to the reverse (Mazur and Booth 1998). Indeed, recent studies have provided direct evidence in support of the link between 2D:4D ratios and amniotic levels of both testosterone and estrogen (Lutchmaya et al. 2004), and a metaanalysis by Hönekopp et al. (2007) found support for the use of 2D:4D ratios as a suitable tool to study the effects of prenatal androgenization on adult behavior and cognitive processes. Additionally, results from laboratory studies have indicated that elevated levels of maternal testosterone resulted in significant changes in digit ratios for both male and female rats (Talarovičová et al. 2009, Zheng and Cohn 2011). In relation to Study 3 (presented later), finger length ratios show evidence of prenatal hormone transfer between opposite-sex twins, resulting in the masculinization of opposite-sex females (van Anders et al. 2006). Effects of exposure to elevated levels of prenatal testosterone have been shown to have a greater effect on the left hand of males as well as the right hand of females (Brown et al. 2002), with some evidence suggesting that the relationship between left-hand 2D:4D and adult behaviors is perhaps the most consistent of all potential variations of digit measurement (Putz et al. 2004). In examining the potential relationship between 2D:4D ratios and self-employment, we extend these previous lines of research and further enhance our understanding of how prelife biological factors can influence self-employment.

Amniotic testosterone concentrations, or the levels of prenatal testosterone exposure, are correlated with the 2D:4D digit ratio and are higher among female twins gestating with a male twin. 2D:4D ratios have been shown to manifest in reduced timidity as well as increased aggression, sensation-seeking behaviors, and rule-breaking personality traits in adulthood (Cohen-Bendahan et al. 2005c). When taken in combination, these characteristics can result in an increased likelihood for individuals to forgo conventional wisdom with regard to pursuing more traditional wage-based employment and instead strike out on their own and pursue self-employment opportunities. Aggression and sensation seeking have both been linked to increased propensity for risk taking (Zuckerman and Kuhlman 2000), which as previously noted is also a central theme with regard to entrepreneurship and self-employment (Stewart and Roth 2001). Furthermore, timidity has been linked to increased risk aversion with regard to decision making (Kahneman and Lovallo 1993), and risk aversion can negatively impact the likelihood of engaging in self-employment (Ekelund et al. 2005). From this reasoning, we propose the following.

Hypothesis 2. *Prenatal testosterone exposure, as indicated by the 2D:4D ratio, will be positively associated with likelihood of self-employment.*

5. Study 2

5.1. Sample

To assess the effects of exposure to prenatal testosterone on the likelihood of self-employment, we examined the Understanding Society's Innovation Panel Wave 6 (IP6). Understanding Society: The UK Household Longitudinal Study is a panel survey of individuals in the United Kingdom that uses a mixed-mode design, with face-to-face and online data collection. While baseline measures are assessed in each panel, different waves of innovation panels have unique questions for the specific panel. The innovation panels focus on a subset of 1,500 households in each panel to collect data. IP6 was conducted in the spring of 2013 and measured 2D:4D ratios. While a detailed description of the larger study of Understanding Society: The UK Household Longitudinal Study is beyond the scope of this study, we refer interested readers to the Understanding Society website www.understandingsociety.ac.uk.

For IP6, a previous sample of 993 households from Innovation Panel Wave 5 were included, and an additional 461 households were added. The individual-level response rate was 72.2%. Among the household respondents, 1,582 digit measures were obtained. Based on pairwise deletion of the sample, our final sample includes 971 cases.[4]

5.2. Measures

The outcome variable for the study is whether an individual is self-employed at the time of the survey. As not all variables related to self-employment behaviors are measured in all waves, we cannot conduct a panel analysis and only draw on a cross section of IP6. In the sample of 971 respondents, 148 (15.24%) respondents reported being self-employed in their most recent job.

The predictor variable is 2D:4D ratios of the (i) right hand and (ii) left hand. The length of index and ring fingers are measured from the midpoint of the bottom crease, where the finger joins the hand, to the tip of the finger. In the IP6 survey, the length is measured in millimeters. This ratio measure has been extensively employed as a proxy for the relative exposure to prenatal testosterone in previous studies (Lutchmaya et al. 2004, Manning et al. 1998). Consistent with Study 1, we conduct separate regressions for male and female samples.

We control for year of birth as a proxy for age. As education impacts the likelihood of self-employment, we include the level of education (no formal education; A-levels; college degree; other higher education). Next, as a significant number of respondents were white, we created a categorical variable related to race, which

we coded as 1 for white and 0 for nonwhite respondents. Again, as health could impact the choice of self-employment, we include a self-reported health score (1= excellent), 5= poor) from the general health questionnaire. As location influences self-employment, we control for location (0 = nonurban, 1 = urban). We also control for gross personal income that could proxy for general ability in the labor force. Finally, as dexterity could be related to digit ratio, we control for handedness (1 = right-handed, 2 = left-handed, 3 = ambidextrous).

5.3. Results

Table 3 lists the means, standard deviations, and correlations among the variables. The results from the logistic regression are presented in Table 4. As the digit ratio is related to testosterone exposure before birth, we do not expect reverse causality between self-employment and digit ratio. As discussed earlier, a lower (higher) ratio of index (2D) to ring (4D) finger indicates a higher (lower) exposure to testosterone in the womb. Thus, a higher ratio indicates lower testosterone exposure and therefore lower likelihood of self-employment. We find support for the left-hand digit ratio for males ($\beta = -7.606$, $p < 0.01$) and marginally significant support for females ($\beta = -4.019$, $p = 0.075$). While evidence suggests that in males, serum testosterone concentrations are negatively related to right-hand 2D:4D ratio (Manning et al. 1998), the effects of prenatal testosterone exposure is more likely to be seen in the left-hand 2D:4D ratio for men (Brown et al. 2002, Putz et al. 2004). Therefore, our findings support previous evidence that suggests that prenatal exposure to testosterone is more likely to affect the left-hand 2D:4D ratio in males (Brown et al. 2002). Similarly, our results are consistent with a recent review of the literature on the relationship between testosterone and economic risk taking that showed a greater number of significant findings between risk taking and left-hand 2D:4D than right-hand 2D:4D (Apicella et al. 2015).

6. Study 3

In Study 1, despite including instruments, unobservables could affect both testosterone and self-employment. To address this, in Study 2, we consider a marker of prenatal testosterone exposure, the 2D:4D ratio. However, a mother's socioeconomic status could affect amniotic testosterone concentration, and a mother's socioeconomic status could also affect future life outcomes that influence self-employment. Another way to examine the effects of prenatal testosterone on the tendency to engage in self-employment is to investigate prenatal hormone transfer in opposite-sex and same-sex twins. Studies have suggested that female fetuses gestated with a male co-twin are more likely than female fetuses gestated with a female co-twin to

Table 3. Study 2: Means, SDs, and Correlations

	Mean	SD	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12	13
1 *Self-employed*	0.1524	0.3596	0	1	1												
2 *Year of birth*	1,963.5780	15.5614	1,920	1,996	−0.0959	1											
3 *No formal education*	0.1432	0.3504	0	1	−0.0015	−0.3442	1										
4 *College degree*	0.0525	0.2232	0	1	−0.0356	−0.0634	−0.0962	1									
5 *Other education*	0.3934	0.4888	0	1	−0.0013	0.217	−0.3292	−0.1896	1								
6 *A-levels*	0.4109	0.4923	0	1	0.0185	0.0582	−0.3414	−0.1966	−0.6726	1							
7 *White*	0.8950	0.3068	0	1	−0.0416	−0.0873	0.0441	−0.0097	0.1521	−0.1781	1						
8 *General health*	3.4655	1.0471	1	5	−0.0107	0.2374	−0.179	−0.043	0.0366	0.1105	−0.0145	1					
9 *Living in urban area*	0.7415	0.4380	0	1	−0.0703	0.0451	0.0466	0.0547	−0.006	−0.0519	−0.1409	−0.079	1				
10 *Gross personal income*	2,939.21	21,883.65	−730.9302	666,546.4	−0.0218	−0.0125	−0.0266	−0.0159	0.0281	−0.0018	−0.004	0.0343	−0.0539	1			
11 *Handedness* (right- or left-handed)	1.1246	0.3771	1	3	0.0422	−0.0116	0.0053	0.0569	−0.0313	0.0016	−0.0026	0.0096	0.0205	−0.0123	1		
12 *Sex* (1 = male; 2 = female)	1.5386	0.4988	1	2	−0.1363	0.0501	−0.0051	0.042	−0.0201	0.0046	−0.0274	0.0248	−0.018	−0.0493	−0.0887	1	
14 *Right-hand digit ratio*	0.9969	0.0812	0.3295	2.1471	−0.0096	−0.0007	−0.0509	0.0259	−0.0167	0.0411	−0.0693	−0.043	0.077	0.0205	−0.0308	0.0081	1
15 *Left-hand digit ratio*	1.0026	0.0748	0.5733	2.3684	−0.0872	−0.0033	−0.0302	−0.0033	0.0497	−0.0263	−0.0336	−0.0407	0.0277	−0.0178	0.0015	0.0802	0.446

Notes. $N = 971$. All correlations at or above $|0.05|$ are significant at $p < 0.05$ or below. Difference in the sample size between the combined sample in the table and separate male and female samples in Table 4 is due to casewise deletion.

Table 4. Study 2: Logistic Regression

Variables	(1) Male	(2) Female	(3) Male	(4) Female
Right-hand digit ratio	0.520	−1.117		
	(0.256)	(−0.694)		
Left-hand digit ratio			−7.606**	−4.019+
			(−2.763)	(−1.782)
Year of birth	−0.0262**	−0.0175+	−0.0270**	−0.0176+
	(−3.109)	(−1.673)	(−3.152)	(−1.667)
No formal education	−0.313	−0.737	−0.487	−0.704
	(−0.819)	(−1.481)	(−1.235)	(−1.408)
College degree	−0.944	−0.639	−0.950	−0.640
	(−1.189)	(−0.958)	(−1.185)	(−0.958)
Other higher education	0.164	−0.531	0.234	−0.494
	(0.589)	(−1.526)	(0.832)	(−1.426)
White	−0.535	−0.562	−0.601	−0.634
	(−1.355)	(−1.325)	(−1.504)	(−1.484)
General health	0.168	−0.121	0.121	−0.123
	(1.381)	(−0.839)	(0.979)	(−0.845)
Living in urban area	−0.596*	−0.426	−0.543*	−0.436
	(−2.240)	(−1.327)	(−2.007)	(−1.366)
Gross personal income	−0.000176*	−0.000313*	−0.000185*	−0.000320*
	(−2.075)	(−2.153)	(−2.168)	(−2.185)
Handedness	0.285	0.303	0.280	0.327
	(1.106)	(0.736)	(1.070)	(0.781)
Constant	49.95**	34.98+	59.82***	38.08+
	(3.004)	(1.695)	(3.483)	(1.817)
Observations	450	524	449	525
χ^2	23.74	15.52	30.60	18.28
df	10	10	10	10
p-value	0.00832	0.114	0.000682	0.0504
Pseudo-R^2	0.0518	0.0436	0.0672	0.0513

Note. Shown in parentheses are z-statistics.
$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$; $^{+}p < 0.10$.

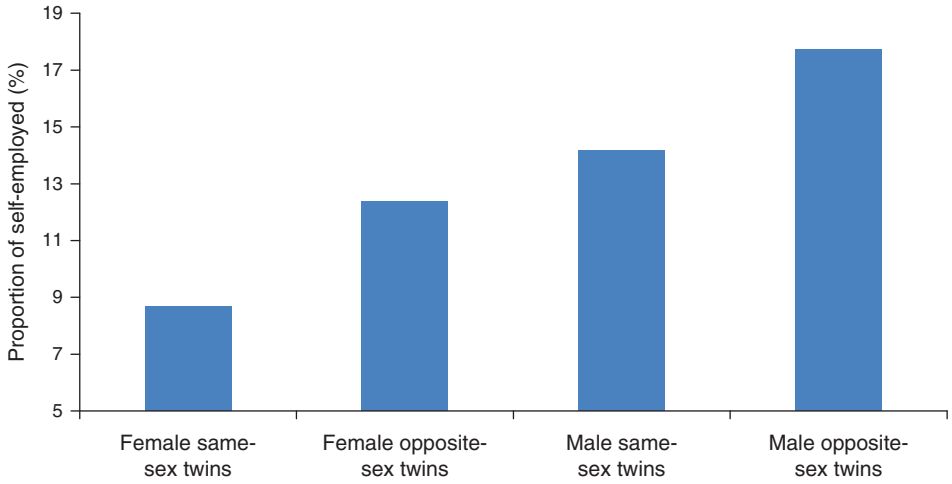
be "masculinized" in their development and to have greater testosterone levels (McFadden 1993, Vuoksimaa et al. 2010). This has been called the twin testosterone transfer effect and is likely to occur in two ways. First, testosterone may pass from one twin to the other through maternal circulation (Miller 1994), and second, testosterone may transfer across the twins by diffusing through fetal membranes (Ryan and Vandenbergh 2002).

Our research is perhaps the first ever to adopt this approach in the study of self-employment—or, for that matter, of any organizational variable. However, studies have provided evidence in support of the testosterone transfer effect in both animals and humans. For example, in mice, Vom Saal and Bronson (1980) found that female fetuses that develop next to male fetuses had greater levels of testosterone in their blood and amniotic fluid than female fetuses gestated next to female fetuses, while also differing on sexually related characteristics later in life. In their review of intrauterine position effects in mammals, Ryan and Vandenbergh (2002) also found evidence of these effects in rodents and swine. In humans, Vuoksimaa et al. (2010) found that females with male co-twins performed better in mental rotation ability than females with female co-twins. Similarly, studies have found that females with a male co-twin had higher sensation-seeking scores (Resnick et al. 1993), higher rates of verbal aggression (Cohen-Bendahan et al. 2005c), and lower rates of withdrawal (Cohen-Bendahan et al. 2005c) than females with a female co-twin. It is plausible, therefore, that the testosterone transfer hypothesis would also hold for self-employment, particularly since support for testosterone transfer has been found for sensation seeking (Slutske et al. 2011), which has been associated with self-employment (Nicolaou et al. 2008a). Evidence in support of the hypothesis would require opposite-sex female twins being more likely to engage in self-employment than same-sex female twins.

6.1. Sample and Measures

We drew from the National Survey of Midlife Development in the United States (MIDUS I), where a

Figure 1. (Color online) Study 3: Proportion of Self-Employed Among Opposite-Sex and Same-Sex Twins



representative sample of 50,000 individuals was initially screened for the presence of a twin. The twins who agreed to participate in the project provided the contact details of their co-twins. A total of 1,996 twins were initially recruited in the study. After excluding twins of unidentified zygosity, twins who did not have a record, and twins with missing values, we were left with a sample of 1,809 twins. For the purposes of our study, we focused our attention on female twins—the sample included 234 DZOS female twins, 390 DZSS female twins, and 369 MZ female twins with complete information.

6.2. Results

The proportion of self-employed twins was 12.393% among DZOS females ($N = 234$) and 8.696% among the combined sample of MZ/DZSS females ($N = 759$). DZOS females were more likely to be self-employed than MZ/DZSS females ($p = 0.094$; two-tailed), providing supporting evidence of our hypothesis (although many previous studies in this area used one-tailed tests—e.g., Cohen-Bendahan et al. (2005b) and McFadden (1993); we report two-tailed tests throughout). There were no statistically significant differences in age between (i) DZOS females and MZ/DZSS females ($p = 0.25$) or between (ii) DZOS females and DZSS females ($p = 0.97$). Figure 1 shows the proportion of twins that were self-employed for same-sex females, opposite-sex females, same-sex males, and opposite-sex males.

An alternative explanation for the higher levels of self-employment among DZOS female twins is that of sibling imitation; females from opposite-sex twin pairs may imitate their male co-twin (Slutske et al. 2011). To examine this alternative explanation, we compared the tendency to engage in self-employment between DZOS female twins with the combined sample of MZ/DZSS female twins that had a brother or brothers. We also examined whether there were any differences in self-employment between MZ/DZSS females without a brother and MZ/DZSS females with a brother or brothers.

Consistent with the twin testosterone transfer hypothesis, we found that DZOS females had marginally higher rates of self-employment than MZ/DZSS females with a brother ($p = 0.088$; two-tailed). As sibling imitation may be more likely with an older than with a younger brother, we also compared DZOS females with MZ/DZSS females that had an older brother or brothers. Again, we found that DZOS female twins were marginally more likely to be self-employed than MZ/DZSS female twins with an older brother or brothers ($p = 0.051$; two-tailed). In addition, we found no differences in self-employment between MZ/DZSS females without a brother and MZ/DZSS females with a brother ($p = 0.57$). These results lend additional support to the testosterone transfer hypothesis.

7. Discussion

In Study 1, positive association of testosterone with self-employment is marginally supported ($p < 0.10$, two-tailed test) among males but not among females; however, in Study 2, for the left-hand digit ratio, there is significant support for males and marginally significant support for females. A lack of significant effects of testosterone among females in Study 1 and marginally significant effects of testosterone among females in Study 2 could be explained as follows: prenatal testosterone exposure has a long-term influence on both males and females, resulting in continued, albeit marginal, effects on self-employment in adulthood. However, circulating testosterone is positively associated with self-employment among males but not among females. Circulating testosterone levels are influenced by social, behavioral, and physiological factors, whereas prenatal exposure to testosterone is not

gender specific and influences the digit ratio of both male and female fetuses. Suggesting lower influence of circulating testosterone in changing self-employment-related behavior for females than males, in a quasi-experimental design, Apicella et al. (2014) found that a treatment to increase testosterone in men was associated with greater risk taking, while Zethraeus et al. (2009) found that a four-week treatment with testosterone was not associated with increased risk taking in women. Female hamsters have fewer androgen-responsive neurons than male hamsters, making them less responsive to behavioral effects of testosterone (Wood and Newman 1999). Although testosterone levels for males increase in early adulthood, the prenatal exposure to testosterone seems to have continued influence on females and self-employment in the adulthood. Related to the testosterone transfer hypothesis, we find support for marginal significance where DZOS females were more prone to self-employment than MZ/DZSS females, and DZOS females were also marginally more likely to be self-employed than MZ/DZSS females with an older brother or brothers.

Cohen-Bendahan et al. (2005b) and McFadden (1993), in their studies on the twin testosterone transfer hypothesis, used single-tailed tests; however, our results are presented using a more conservative two-tailed test in Study 3. As this is one of the few studies on the testosterone and self-employment relationship, and with extant studies finding positive as well as a nonsignificant associations between testosterone and self-employment, we are not certain of the direction of effects of testosterone on self-employment. Therefore, for consistency—and more importantly, for conservative inferences—we use two-tailed tests (Braver 1975). As we are in the very early stages of exploring this relationship, two-tailed tests are warranted based on the statement by Cho and Abe (2013) that "the research hypotheses may take the form of non-directional ones [due to nonsignificance between testosterone and self-employment in some studies] and the subsequent use of two-tailed testing is appropriate" (p. 1264), and in exploring the testosterone and self-employment hypotheses, we are in the "context of discovery rather than in the context of justification" (p. 1265). Even with two-tailed inferences in Study 3, the long-term effects of testosterone transfer are marginally significant, with p-values ranging from 0.051 (difference in self-employment between DZOS female twins and MZ/DZSS female twins with an older brother or brothers) to 0.094 (difference in self-employment between DZOS females and MZ/DZSS females).

The findings are relevant to both entrepreneurship and management audiences, as noted by Heaphy and Dutton (2008), who called for "integrating physiological data into organizational research" (p. 137). As organizational psychology is deeply connected to the physiological response of the employees, focusing attention on physiological outcomes could further inform researchers on the "tie between human physiology and organizational research" (p. 137). Answering these calls, there has been a recent growing interest in examining organizational systems from a biological perspective (Arvey and Zhang 2015). These biopsychosocial models could explain differences in communication patterns among male and female employees (Case and Oetama-Paul 2015). Testosterone levels, in contexts of win–loss, influence behavioral, cognitive, and affective exchanges among employees (Vongas and Al Hajj 2015). Suppressive and aggressive behaviors are biologically manifested and could have long-term health consequences (Kim and James 2015). Whether from the perspective of evolutionary psychology, behavioral genetics, or physiological changes, evidence suggests that biology can advance and connect existing perspectives of organizational behavior (Becker et al. 2011) and entrepreneurship (Shane and Nicolaou 2015).

The current findings demonstrate the long-term effects of biology on future outcomes. Prenatal testosterone exposure or biological "luck" in gestating with a male or female twin is associated with self-employment. The psychophysiological systems and theories can also inform organizational scholars and help to further our understanding of the biological foundations of specific attitudes and behaviors (Akinola 2010). Building on prior research, we have extended these findings to examine the relationship between biological factors and self-employment. Our results represent an important first step into uncovering how key biological influences (e.g., testosterone levels) are related to self-employment and entrepreneurial activities. The biological basis of business behavior could contribute further to management research.

Previous research has demonstrated that hormones, specifically testosterone, can have a substantial influence on personality traits (Branas-Garza and Rustichini 2011, Chapman et al. 2006), cognitive abilities (Finegan et al. 1992), and attitudes and behaviors (Auyeung et al. 2009, Hines 2006). We attempt to address these issues with the results presented in this study, and we call on future studies to further untangle this relationship. We make a number of important contributions to furthering the understanding of the role of testosterone in self-employment. First, related to Study 1, by uncovering a marginally significant positive relationship between male testosterone and self-employment, we provide a richer and more nuanced understanding of how biological factors such as hormone levels are related to male self-employment. Equally important in the findings of Study 1 is the lack of significance for the association between female serum testosterone and

self-employment. Testosterone levels in adults can vary as a result of a number of social, psychological, and physiological factors (Mazur and Booth 1998), and the recent increase in interest regarding how to increase testosterone levels, particularly in men, via both natural (e.g., weight loss, exercise) and artificial (e.g., testosterone replacement therapy) methods has increased. We do not claim that increasing testosterone would increase tendencies toward self-employment for males or females; however, after controlling for endogeneity, it could be inferred that there are marginally significant differences in testosterone levels between employed and self-employed males.

Second, we contribute to the conversation regarding how prelife biological factors can influence self-employment by finding evidence supporting the positive association between prenatal testosterone exposure and self-employment; this relationship is significant for the male left-hand digit ratio and marginally significant for the female left-hand digit ratio.

Third, our study utilizes, for the first time to our knowledge, a new research design involving opposite-sex and same-sex twins to contribute to the ongoing debate regarding the significance and validity of the relationship between testosterone and self-employment. While some evidence has provided support for the link between testosterone and self-employment (Greene et al. 2014, White et al. 2006), other more recent findings have failed to replicate these results (van der Loos et al. 2013). This discrepancy has been attributed to a number of factors, primarily related to differences in the method of testosterone measurement (the less reliable saliva measures versus the more reliable serum testosterone used in the current study) between earlier versus more recent studies, as well as the size and homogeneity of the samples investigated. By employing the most recent and widely accepted methods available for measuring testosterone levels, and analyzing three samples with sufficient size and diversity, we attempt to address these issues: our results provide support in favor of the presence of a marginally significant relationship between hormone levels and the likelihood of engaging in self-employment.

Fourth, while studies have shown that the tendency to engage in self-employment is partly heritable (Nicolaou et al. 2008b, Shane 2010), researchers have advocated the need for additional studies on the mechanisms through which genes influence self-employment (Shane and Nicolaou 2015). Because testosterone has a genetic predisposition (Harris et al. 1998), it is likely that testosterone is one of the mechanisms through which genes may influence the likelihood of engaging in self-employment.

In addition to these contributions, this study also has important implications for the fields of both entrepreneurship and management in general. Higher levels of testosterone can not only enhance an individual's willingness to take risks but also diminish the likelihood that he or she feels fear with regard to risky situations; when coupled together, it is possible that individuals with higher levels of testosterone could be prone to engaging in entrepreneurial activities and self-employment (see Sapienza et al. 2009). While much time and effort has been put into examining the economic, psychological, and sociological factors that might influence entrepreneurial activities, the potential biological factors that could influence entrepreneurship remain relatively understudied. We attempt to continue to further this conversation by showing that there are potentially important considerations that should be considered from a biological perspective with regard to their relationship with entrepreneurship. While the factors that influence attitudes regarding risk taking and the fear of failure are complex in nature, it is possible that biological differences with regard to both prenatal exposure to testosterone and overall serum levels of testosterone could provide one explanation as to why such variations in attitudes exist. Our results also further extend the connection between the fields of "social neuroendocrinology" and entrepreneurship, and they provide a bridge that demonstrates how aspects of physiological development can be leveraged in order to further our knowledge and understanding of the field of entrepreneurship.

8. Limitations and Directions for Future Research

The present research has important limitations that should be taken into account. First, the data for Study 1 are cross-sectional in nature, and as such, causal directions cannot be empirically tested. This is less of an issue with the second and third study, since the theoretical direction of the relationship between prenatal testosterone exposure and adult behavior is temporally sequential. Nevertheless, for Study 1, we drew on three instruments, and the strength of the instruments was supported by endogeneity tests for the male sample. Second, although the data for the three studies were from two different national samples (Studies 1 and 3 from the U.S. samples and Study 2 from the UK sample), the individual investigations themselves are unable to examine what influence, if any, variations in culture or nationality might have on the reported relationships. Finally, our measure of self-employment is restricted to those individuals who were engaging in self-employment at the time of participation and, as such, does not capture the episodic nature of self-employment.

Despite these and other limitations, our findings suggest several potentially valuable lines of future

research. First, research could further investigate the causal direction between testosterone levels and self-employment using a longitudinal study design. Second, research on samples from a more diverse cultural and national population would help to determine the generalizability of our reported results, as well as potentially provide interesting insights and nuances as to how such factors might moderate the relationship between testosterone levels and self-employment. Third, as human biology and physiology are complex systems, further research is needed to better understand how the nuances of such systems can influence behaviors in the context of self-employment. For example, studies could examine not only testosterone levels but also levels of estradiol, a hormone that has been found to somewhat counteract the effects of testosterone in humans. It is therefore possible, even likely, that the seemingly conflicting results regarding the significance and validity of the relationship between testosterone and self-employment are in fact complementary. We are also not aware of any research that has examined the role of cortisol, oxytocin, dopamine, or serotonin in self-employment. Moreover, no work has examined the role of hormones in the identification of entrepreneurial opportunities, nor have dual-hormone interactions been explored in regard to their influence on self-employment. However, such interactions may be important; for example, in a different context, Mehta and Josephs (2010) found that cortisol and testosterone jointly regulated dominance in men and women.

In addition, future research could examine how environmental stimuli may moderate the influence of testosterone on the likelihood of engaging in self-employment. We encourage scholars to embrace a biosocial perspective in furthering our understanding of self-employment by considering the interactive role of hormones and the environment (White et al. 2007). Related research has examined gene–environment interactions in entrepreneurship (Quaye et al. 2012), but additional work is needed to further uncover the complexities underlying the interactions between biological and sociological influences in self-employment.

9. Conclusion

Overall, the present research is consistent with the suggestion that serum testosterone among adult males (Study 1), prenatal testosterone exposure for both males and females (2D:4D ratio, a marker for prenatal testosterone exposure in Study 2), and prenatal testosterone transfer among opposite-sex twins (Study 3) are positively associated with self-employment. This speaks to the central question posed by White et al. (2006, p. 21): "Are business behaviors learned, or can they, at least in part, be explained by our biology?" This research contributes to ongoing efforts to address this question, and our findings indicate that testosterone levels may constitute an important influence on the likelihood that individuals will engage in self-employment activities. Or, to pose an answer to the question posed by White and colleagues, it is indeed possible that at least a portion of certain business behaviors can, at least in part, be attributed to biological influences.

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The data and the associated code for replication is provided with the paper and available on Harvard Dataverse (https://dataverse.harvard.edu/dataverse/MS_selfemp_testos).

Endnotes

[1] Also refer to http://wwwn.cdc.gov/Nchs/Nhanes/2011-2012/TST_G.htm (accessed September 2, 2016).

[2] We list variable names in NHANES 2011–2012 in italics.

[3] From NHANES 2011–2012 (http://wwwn.cdc.gov/nchs/nhanes/2011-2012/DEMO_G.htm, accessed September 2, 2016): "The 2-year sample weights (WTINT2YR, WTMEC2YR) should be used for all NHANES 2011–2012 analyses." As WTMEC2YR pertains to sampling weight associated with those who took part in the MEC exam, we use this weighting variable using the *pweight* option in the *logit* command in Stata 14.

[4] Al Baghal et al. (2014) provide a detailed description of the data-collection process employed for the innovation panel.

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