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The Wages of Sinistrality: Handedness, Brain Structure, and Human Capital Accumulation†

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Roughly 12 percent of humans are left-handed, with somewhat higher rates among males than females (Vuoksimaa, Koskenvuoa, Rosea, and Kaprio 2009). For much of history, left-handedness was viewed with deep suspicion. During the Middle Ages, left-handed writers were thought to be possessed by the Devil, generating the modern sense of the word sinister from *sinistra*, the Latin word for left. The English word left itself comes from the Old English *lyft*, meaning idle, weak, or useless. The French word for left, *gauche*, also means clumsy or awkward. Similarly negative connotations of the word left are found in numerous languages, including German, Italian, Russian, and Mandarin (Coren 1992).

Superstitions about left-handedness take numerous forms (Perelle and Ehrman 2005). In many Middle Eastern countries, food and drink should be taken with the right hand and bodily functions performed with the left. Hindu tradition forbids the left hand from performing many of the central religious rituals. Left-handedness suggested to Eskimos that the individual was a sorcerer and to colonial Americans that the individual might be a witch. The Jewish scholar Maimonides listed left-handedness among the 100 blemishes that disqualified someone from being a Jewish priest.

Left-handers have often been compelled by their parents and schools to use their right hand for writing and other tasks. Such practices are now more common in developing countries so that, for example, 11 percent of Turks and 16 percent of Nigerians report attempts to switch their handedness earlier in life (Medland, Perelle, De Monte, and Ehrman 2004). Such compelled switching is increasingly rare

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in the United States and other high-income nations. If anything, left-handedness has come into vogue, with modern proponents who argue that left-handedness is overrepresented among highly talented individuals. Proponents of this view cite either anecdotal evidence, such as the fact that four of the last seven US presidents have been left-handed (Gerald Ford, George H. W. Bush, Bill Clinton, and Barack Obama), or studies that purport to demonstrate unusual intelligence (Perelle and Ehrman 1983) or creativity among left-handers (Coren 1995).

In this paper, I argue that the phenomenon of handedness can provide insight into some of the issues surrounding economists' recent exploration of early biological and environmental influences on people's long-run outcomes. I review prior research showing that left- and right-handed individuals have different brain structures, particularly with regard to language processing. Using five datasets from the United States and the United Kingdom, I show that, consistent with prior research, both maternal left-handedness and poor infant health increase the likelihood of a child being left-handed. Thus, handedness can be used to explore the long-run effects of differential brain structure generated in part by genetics and in part by poor infant health.

Lefties exhibit economically and statistically significant human capital deficits relative to righties, even conditional on infant health and family background. Compared to righties, lefties score a tenth of a standard deviation lower on measures of cognitive skill and, contrary to popular wisdom, are not overrepresented at the high end of the distribution. Lefties have more emotional and behavioral problems, have more learning disabilities such as dyslexia, complete less schooling, and work in occupations requiring less cognitive skill. Differences between left- and right-handed siblings, which offer a way of controlling for qualities of family upbringing, are similar in magnitude. Interestingly, lefties with left-handed mothers show no cognitive deficits relative to righties. Some of these facts have been documented previously, though not across the range of datasets used here.

Lefties also have 10–12 percent lower annual earnings than righties, roughly equivalent to the return to a year of schooling in these samples. A large fraction of this gap can be explained by observed differences in cognitive skills and emotional or behavioral problems. Lefties work in more manually intensive occupations than do righties, further suggesting that their primary labor market disadvantage is cognitive rather than physical. This paper is the first to document these patterns.

These findings touch on three strands in the prior research literature. First, previous work on handedness has either focused on short-run outcomes (Johnston, Nicholls, Shan, and Shields 2009, 2010) or used single datasets to explore long-run outcomes (Ruebeck, Harrington, and Moffitt 2007; Denny and O'Sullivan 2007). I explore both short- and long-run outcomes in multiple datasets and show that prior mixed results on earnings appear less ambiguous than previously documented. Second, the burgeoning drive to integrate neuroscience into the modeling of cognitive and noncognitive skill formation is impeded by the absence in most datasets of measures of neurological wiring (Heckman 2007). Handedness may provide such a measure. Third, research on the fetal origins hypothesis stresses the long-run impact of shocks to fetal and infant health (Almond and Currie 2011). Handedness is related in part to neural developments triggered by such early shocks and thus deserves attention.

Handedness

The Biology of Handedness

Modern biological and medical evidence points to differentiation of the left and right hemispheres of the brain as the primary source of hand preference given that each hemisphere controls the opposite side of the body. Such hemispheric differentiation generates early hand preferences in humans in the form of fetal thumb sucking (Vuoksimaa et al. 2009), as well as hand, foot, and eye preferences not only in humans but also in primates, rodents, birds, fishes, and lizards (Bisazza, Rogers, and Vallortigara 1998). Because the left hemisphere processes language, studies of handedness and brain function focus on linguistic differences between left- and right-handed individuals. Functional magnetic resonance imaging reveals that, when exposed to language, only 4 percent of right-handed individuals show any right hemisphere activity, compared to 24 percent of left-handed individuals (Pujot, Deus, and Losilla 1999). Relatedly, brain lesions on the right hemisphere are more than twice as likely to cause language disorders in the left-handed as in the right-handed (Hardyck and Petrinovich 1977). This pattern of greater bilateral activation among the left-handed may be related to the corpus callosum, the bundle of neural fibers connecting the two hemispheres, which is on average 11 percent larger in the left-handed than the right-handed (Witelson 1985).

In short, left-handedness appears to be related to differential brain structure and usage, particularly with respect to language processing. This differentiated brain structure appears to have both genetic and environmental origins. Genetic evidence comes from two sets of facts. First, the rate of left-handedness is 10 percent for children of two right-handed parents, 20 percent for children of one left- and one right-handed parent, and about 26 percent for children of two left-handed parents (McManus and Bryden 1991). Children are also more likely to share handedness with their mother than with their father (Harkins and Michel 1988). Though suggestive of genetic influence, these facts could also be explained by children learning handedness from their parents, given that most children spend more time in early childhood with their mothers than with their fathers. The second set of evidence for genetic origins comes from comparison of mono- and dizygotic twin pairs, which yields estimates that genes account for 24 percent of the variance in left-handedness (Medland et al. 2009).

Genetic factors do not, however, entirely explain handedness, given that 20–25 percent of identical twins differ in their handedness (Carter-Salzman, Scarr-Salapatek, Barker, and Katz 1975). Evidence on the specific environmental factors affecting handedness come largely from studies of "pathological" left-handedness, which refers to the theory that stress during gestation or birth may induce normally left hemispheric functions to shift to the right hemisphere. Left-handedness is, for example, more prevalent among infants requiring resuscitation after delivery, infants born as twins or triplets, and infants with low birthweights (Medland et al. 2009; Vuoksimaa et al. 2009). These facts are consistent with the theory that stressors during pregnancy or birth may contribute to the differential brain structures typical of left-handed individuals.

Handedness and Human Capital Accumulation

Coren (1995) has helped popularize the notion that left-handedness is associated with creativity, arguing that the larger corpus callosum and greater bilateral activation exhibited by the left-handed allows for faster connection between ideas. According to this theory, the left-handed should excel at tasks requiring divergent thinking, where the individual begins from prior knowledge and works outwards toward new concepts. In a series of experiments, he found that left-handed males performed better on some divergent thinking tasks. The effect was, however, neither consistent across tasks nor significant for left-handed females. The empirical evidence for greater creativity among the left-handed turns out to be fairly weak. Also weak is the evidence that the left-handed are disproportionately represented at the high end of the cognitive spectrum. Studies arguing that left-handed individuals are overrepresented among precocious SAT takers, high-performing MCAT takers, and Mensa Society members all suffer from one or more problems such as selection bias, small sample size, or mixed results (Benbow 1986; Halpern, Haviland, and Killian 1998; Perelle and Ehrman 2005).

Evidence that the left-handed are overrepresented at the low end of the cognitive spectrum is clearer. The rate of left-handedness among those considered intellectually disabled is between 20 and 28 percent, roughly twice the rate in the general population (Perelle and Ehrman 2005). Prior work with the National Child Development Survey has observed that the left-handed fare worse than the right-handed on tests of overall cognitive ability, even when the lowest performing 5 percent are excluded (McManus and Mascie-Taylor 1983). These lower cognitive skills may be at least partly explained by higher rates of learning disabilities like dyslexia among the left- and mixed-handed, as well as higher rates of behavioral problems such as attention-deficit/hyperactivity disorder (Rodriguez, Kaakinen, Moilanen, Tannila, McGough, Loo, and Järvelin 2010). Patients suffering from schizophrenia also display high rates of left-handedness (Dragovic and Hammond 2005). Studies of young children in Australia and the United States also find that left-handed children have significantly lower cognitive and noncognitive skills than right-handed children (Johnston et al. 2009, 2010).

There are two primary reasons to think that handedness might relate to labor market outcomes. The first is that the physical preference for one hand over the other may create a comparative advantage or disadvantage in the labor market. The Book of Judges records the story of the left-handed Ehud, who assassinated an oppressive king by sneaking a sword past the king's guards on his right thigh. The guards never searched that thigh because no right-hander could draw a weapon from the right side. Modern examples come from the overrepresentation of left-handers among top performing athletes in interactive sports such as table tennis, fencing, and baseball, in which their opponents more frequently play against right-handed competitors (Raymond, Pontier, Dufour, and Moller 1996). Other than interactive sports, it seems difficult to devise examples of occupations where left-handedness would provide a comparative advantage.

The second reason that handedness may impact longer-run outcomes is that it may indicate differential brain structure. If the structure of lefties' brains affects the accumulation of skills, this may be reflected in labor market outcomes and measures of productivity. Left-handed individuals might fare poorly in the labor market not due to the manual nature of left-handedness, but as a consequence of the underlying neurological wiring that leads to it.

Data and Determinants of Handedness

Measuring Handedness

I use five longitudinal datasets. Two from the United States—the National Longitudinal Survey of Youth 1979 (NLSY79) and 1997 (NLSY97) cohorts—follow teenagers through adulthood, so I pool these and refer to them as the US sample. A third dataset, the Children and Young Adults survey (NLS-C), follows all children born to the women in the NLSY79, though many of those children have not yet reached adulthood. The two British datasets are the National Child Development Study (NCDS58) and the British Cohort Study (BCS70), which respectively follow all people born in Great Britain in one week in March 1958 and April 1970. I pool these and refer to them as the UK sample.[1] All five datasets contain information on handedness, as well as measures of cognitive skill and other evidence of human capital accumulation.[2]

Each of the five datasets asks somewhat different questions regarding handedness. Some ask adults; some ask mothers; some use data from interviewers who observed children. For each question asked about handedness, I assign a value of one to answers that clearly favor the left hand (such as "always left" or "usually left") and a value of zero to answers that clearly favor the right hand. I assign a value of one-half to answers indicating mixed-handedness or a lack of hand preference. I compute for each individual in each year the mean response to handedness questions and also compute the mean of these values across all years. Most individuals can be easily categorized as right- or left-handed. To construct a binary measure of left-handedness, I round this continuous measure to the nearest integer.

[1] Because sample sizes differ across these individual datasets, estimates using these pooled datasets are generated using weights that accord each individual dataset equal weight.

[2] An online Appendix available with this article at http://e-jep.org provides more detailed background. The structure and content of these datasets is described in more detail in online Appendix 1.1. The specific questions each dataset asks about handedness are described in more detail in online Appendix 1.2. Online Appendix Figure 1 shows the distribution of the continuous measure of handedness in each sample.

Table 1
Summary Statistics
(mean values of variables)

	NLS-C	*NLSY79*	*NLSY97*	*NCDS58*	*BCS70*
		US		*UK*	
A: Controls					
Year of birth	1988	1961	1982	1958	1970
Left-handed (rate)	0.11	0.13	0.16	0.11	0.11
Female (rate)	0.49	0.52	0.49	0.48	0.49
Birth order	1.95	2.92	1.77	2.32	2.16
Mother's age at birth	26.66	26.02	25.67	27.42	25.88
Mother's education (years)	13.05	11.57	12.80	9.50	9.72
Black (rate)	0.14	0.12	0.16		
Hispanic (rate)	0.08	0.07	0.14		
Mother left-handed (rate)	0.11				
Birthweight (lbs)	7.37			7.31	7.27
Birth complications (rate)	0.05			0.09	0.10
B: Outcomes					
Cognitive skill z-score	0.00	0.00	0.00	0.00	0.00
Behavior problem (rate)	0.08	0.08	0.06	0.06	0.05
Learning disability (rate)	0.04		0.09		0.01
College graduate (rate)		0.22	0.29	0.18	0.21
Annual earnings (1,000s $ (US) or £ (UK)		23.95	24.52	17.06	22.32
N	4,956	5,532	6,183	16,712	13,863

Notes: I use five longitudinal datasets. Two from the United States—the National Longitudinal Survey of Youth 1979 (NLSY79) and 1997 (NLSY97) cohorts—follow teenagers through adulthood, so I pool these and refer to them as the US sample. A third dataset, the Children and Young Adults survey (NLS-C), follows all children born to the women in the NLSY79, though many of those children have not yet reached adulthood. The two British datasets are the National Child Development Study (NCDS58) and the British Cohort Study (BCS70), which respectively follow all people born in Great Britain in one week in March 1958 and April 1970. I pool these and refer to them as the UK sample.

Summary Statistics

Table 1 shows the mean values of selected variables from these samples. Individuals in the NLSY97 sample range from 25 to 29 years old as of the most recent wave, while the remaining three studies' subjects are all observable through at least their mid-30s. The average individual in the NLS-C is 20 years old at the most recent wave, so that long-run outcomes such as college graduation and labor market earnings are not yet observable for the majority of the sample. In nearly all of the samples, the rate of left-handedness is a consistent 11 to 13 percent. This measure is well within the range observed in studies of other populations, which suggests that the constructed measure of handedness is fairly accurate.

In all of the studies, I observe gender, birth order, mother's age at birth, and mother's education. I observe race in the US studies. Various measures of infant health are recorded in the NLS-C and the UK studies, including birthweight and indications of infant health challenges around the time of birth.[3] Because the NLS-C children can be connected to their mothers in the NLSY79, I can construct a dummy for each child indicating whether his or her mother was left-handed.

Panel B shows selected outcomes, the construction of which is discussed in more detail below. For all samples, I observe a measure of cognitive skill that I transform into an age-normed Z-score (that is, a measure showing how many standard deviations the measure is from the mean), as well as an indicator for the prevalence of behavioral problems. For the samples in which I observe individuals into adulthood, I observe educational attainment and hourly wages (as measured in 2009 US dollars or UK pounds sterling). Below panel B is listed each sample's size, which refers to the number of individuals for whom handedness is observed. Most outcomes are observed for slightly smaller numbers of individuals due to attrition and missing data.

Determinants of Left-Handedness

Before studying the relationship between handedness and human capital accumulation, I first explore some observable determinants of left-handedness by looking at sample means in Table 2.[4] Gender and maternal left-handedness are strongly related to left-handedness in this data, consistent with previous studies. Across all samples, men are roughly 3 percentage points more likely than women to be left-handed. Rates of left-handedness in these samples thus range from 9–13 percent for females and from 12–16 percent for males. In the NLS-C sample, nearly 16 percent of children with left-handed mothers are themselves left-handed, compared to fewer than 11 percent of those with right-handed mothers. Maternal left-handedness therefore raises the probability of child left-handedness by about 50 percent. Maternal education and age at birth, conversely, bear little relation to a child's handedness. The strong correlation between maternal- and child-handedness suggests a genetic component of handedness. The possibility remains, however, that left-handed mothers influence their children's handedness through their own behavior if, for example, children try to imitate their parents' physical gestures.

Other evidence from the sample means in the data suggests an environmental component of left-handedness. Complications around the time of birth are also associated with an increase in the rate of left-handedness. US babies that remain more than a week in the hospital post-birth are 5 percentage points more likely to be left-handed, while UK babies whose labors were complicated are 1.5 percentage points more likely to be left-handed. In the UK datasets, lower birthweight babies are more likely to be left-handed, with each additional pound at birth associated with a 0.6 percentage point decrease in the rate of left-handedness. Similar estimates

[3] For the NLCS samples, the dummy for birth complications indicates that the child remained in the hospital for more than a week after being born. For the UK samples, it indicates that the birth was a breech birth or that forceps or a vacuum were used during delivery.

[4] The sample means presented here are quite similar to the coefficients from linear probability models that regress an indicator for left-handedness on a vector of possible explanatory variables. Detailed results of these regressions are available in online Appendix Table 2.

Table 2
Rates of Left-Handedness in Subgroups

	NLS-C	*US*	*UK*
A: Gender			
Male	0.126	0.161	0.124
Female	0.094	0.132	0.100
Male − female	0.032	0.029	0.024
	(0.009)	(0.007)	(0.004)
p-value	0.000	0.000	0.000
B: Maternal handedness			
Those with left-handed mother	0.156		
Those with right-handed mother	0.104		
Left-handed mother − right-handed mother	0.052		
	(0.016)		
p-value	0.001		
C: Infant health			
Birth complications	0.162		0.125
No complications	0.108		0.110
Birth complications − No complications	0.054		0.015
	(0.024)		(0.006)
p-value	0.025		0.020

Notes: The proportion of left-handers in each sample and subgroup are shown in the top two rows of each panel. Below that is the difference in that proportion between the two subgroups, the standard error of that difference and its associated *p*-value. The birth complications subgroup is defined as those children who, in the NLS-C sample, remained in the hospital for more than a week after birth in the NLS-C sample or, in the UK sample, had a breech birth or required the use of forceps or vacuum during delivery.

of the relationship between birthweight and the likelihood of left-handedness from the NLS-C are also negative, although smaller sample sizes render them less precise. In the NLS-C and UK samples, the two infant health measures of birth complications and birthweight are at least marginally jointly significant predictors of left-handedness. The US samples also suggest that black children are 2 to 3 percentage points more likely to be left-handed than white children. Given that black infants in the US have substantially worse health at birth than do white infants and that these data lack extensive information on fetal and infant health, race may be serving as a proxy for unobserved fetal and infant health measures (Currie and Moretti 2007).

Human Capital Accumulation

I turn now to a discussion of the relationship between handedness and human capital accumulation, where human capital is measured in a variety of ways. Here

I present evidence based solely on differences in sample means and medians between lefties and righties. In more detailed analysis, I run ordinary least squares regressions of the form

$$Y_i = \beta_0 + \beta_1 Lefty_i + \beta_2 X_i + \varepsilon_i,$$

where Y is the outcome of interest, *Lefty* indicates left-handedness for individual i, and X is a vector of control variables, including gender, race, infant health measures, and maternal characteristics. The coefficient of interest, β_1, represents the difference in the outcome between left- and right-handed people, controlling for those other covariates. However, the regression analyses yields very similar results to the sample means.[5]

Cognitive Skills

I construct a standardized measure of cognitive skill as the average of math and reading scores generated by a variety of tests administered to subjects in these datasets. Table 3 shows that, across the samples, lefties show statistically significantly lower cognitive skills than righties. In the NLS-C, for example, lefties have cognitive skills 0.13 standard deviations lower than righties.[6] In both the US and UK samples, lefties score 0.07–0.08 standard deviations lower than righties on average. These cognitive gaps appear to be quite similar in magnitude across both math and reading, which suggests that, even if differential language processing is responsible for these cognitive gaps, such differences affect math and reading skills similarly.

The tails of the skill distribution also vary between lefties and righties. Across all samples, lefties are 3–4 percentage points more likely to be in the bottom 10 percent of the distribution than are righties. In the US sample, lefties are also 2 percentage points less likely to be in the top 10 percent of the distribution, though that difference is smaller and statistically insignificant in the other samples. Tests of the probability of being in the top 5 or 1 percent of the distribution show similar results. These estimates are inconsistent with claims that lefties are unusually skilled, at least as measured by math and reading tests.

Further evidence of cognitive gaps comes from tests administered in only some of the studies. In the US sample, subjects took a coding speed test in which subjects matched words to numbers based on a key. Given that the task requires nearly no prior knowledge and that subjects have only seven minutes to complete as many matches as possible, the test is thought to measure raw mental speed or "fluid intelligence" (Heckman 1995; Segal 2012). By this measure, lefties in both samples score

[5] The online Appendix available with this paper at http://e-jep.org offers regression-adjusted versions of the estimates discussed here. The tables in the main body of this paper are numbered so that each has an equivalent regression-adjusted version in the online Appendix. The online Appendix also offers additional details, such as plots of the kernel density estimates of the full distribution of cognitive skills and earnings, in online Appendix Figures 2 and 3.

[6] The gap between left- and right-handed siblings, shown in the online Appendix, is an even larger 0.16 standard deviations.

Table 3
Cognitive Skills of Left- and Right-handed

	NLS-C	*US*	*UK*
A: Cognitive z-score			
Left-handed	−0.117	−0.069	−0.061
Right-handed	0.014	0.012	0.008
Left − right difference	−0.131	−0.080	−0.069
	(0.050)	(0.029)	(0.020)
p-value	0.009	0.005	0.001
B: Portion in bottom 10%			
Left-handed	0.138	0.133	0.122
Right-handed	0.095	0.095	0.097
Left − right difference	0.042	0.038	0.025
	(0.016)	(0.009)	(0.006)
p-value	0.008	0.000	0.000
C: Portion in top 10%			
Left-handed	0.093	0.086	0.097
Right-handed	0.101	0.103	0.100
Left − right difference	−0.008	−0.017	−0.003
	(0.014)	(0.008)	(0.006)
p-value	0.538	0.032	0.592

Notes: Each panel shows the mean value of the listed outcome for left- and right-handed individuals in the given sample. Below that is the difference between those two groups, the standard error of that difference, and its associated *p*-value. Panel A uses cognitive z-scores defined as standardized averages of math and reading skills. Panels B and C use indicators for being in the bottom or top 10 percent of that cognitive score distribution.

roughly a tenth of a standard deviation worse than righties. The British studies also administered a test requiring little prior knowledge, in which children ages four to seven were shown images of circles, crosses, and other shapes and were asked to copy those designs on a sheet of paper. Lefties again scored a tenth of a standard deviation worse on this test than righties. Both the coding speed and copying designs results suggest that the observed cognitive gaps are not only about acquired knowledge itself but also about deeper cognitive skills that may contribute to the acquisition of knowledge.

Disabilities

Nearly all of these samples contain a binary measure of whether the subject suffers from an emotional or behavioral problem. Some also contain continuous measures of behavioral problems reported by a parent. I construct an indicator for having a behavior problem that takes a value of 1 if either the binary measure equals 1 or if the age-standardized continuous measure falls in the top 5 percent of

Table 4
Behavioral Problems and Learning Disabilities

Portion with:	*NLS-C*	*US*	*UK*
A: Behavior problem			
Left-handed	0.116	0.083	0.070
Right-handed	0.077	0.071	0.055
Left − right difference	0.039	0.012	0.015
	(0.015)	(0.007)	(0.005)
p-value	0.007	0.100	0.003
B: Speech problem			
Left-handed	0.032	0.039	0.180
Right-handed	0.012	0.034	0.159
Left − right difference	0.020	0.005	0.021
	(0.008)	(0.007)	(0.007)
p-value	0.012	0.436	0.003
C: Learning disability			
Left-handed	0.066	0.121	0.020
Right-handed	0.042	0.088	0.014
Left − right difference	0.024	0.033	0.006
	(0.011)	(0.011)	(0.005)
p-value	0.030	0.003	0.221

Notes: Each panel shows the mean value of the listed outcome for left- and right-handed individuals in the given sample. Below that is the difference between those two groups, the standard error of that difference, and its associated *p*-value. All three panels use indicators for having the listed problem or disability. In panels B and C, the US sample includes only the NLSY97. In panel C, the UK sample includes only the BCS70.

the distribution. As seen in Table 4, in the NLS-C sample, lefties are 4 percentage points more likely to have behavior problems than righties.[7] Given that 8 percent of righties in the NLS-C sample have behavior problems, this implies that lefties are about 50 percent more likely than righties to have such problems. The US and UK samples also show statistically significant differences, with lefties in those samples more than 1 percentage point more likely to have behavior problems, relative to a 6–7 percent rate of such problems among righties. Prior research on child mental health and behavioral problems suggests that such conditions may have long-run impacts on children as well as on their peers (Currie and Stabile 2006; Aizer 2009).

[7] Within-family comparisons yield similar results. Left-handed siblings are 5 percentage points more likely to have a behavior problem than their right-handed siblings.

Previous research has suggested that left-handedness is unusually common among individuals with an intellectual disability.[8] This fact is sometimes cited in support of the theory of "pathological" left-handedness, the idea that some left-handedness can be thought of as brain damage, perhaps due to fetal trauma. Each of the datasets used in this paper allow construction of an indicator for intellectual disability, either through parental reporting, self-reporting, or interviewers' observations of the subject. Although it is not reported on Table 4, in all of the samples, a high proportion of those with intellectual disabilities are left-handed. Across the samples, lefties are consistently 1 percentage point more likely to exhibit intellectual disability than righties. Given the low rate of intellectual disability among righties in these samples, this represents somewhere between a 50 and 300 percent increase in that likelihood.

Given the biological evidence that lefties process language differently than righties, I construct two further measures of disability related to language, shown in panels B and C of Table 4. In the NLS-C and UK samples, lefties are 2 percentage points more likely to have speech problems, such as a stutter or other speech impairment. In the US sample, the difference is a statistically insignificant half a percentage point. The second measure is an indicator for having a learning disability, survey questions about which often mention dyslexia specifically. In both the NLS-C and US samples, lefties are 2–3 percentage points more likely to report such a learning disability than righties. In the UK sample, the difference is a statistically insignificant half a percentage point. Across all of these samples, the estimated differences suggest that left-handers are roughly 50 percent more likely than right-handers to have a learning disability.

Finally, though not shown here, the NLS-C and BCS70 administered to children ages 7–11 a "digit span test" to find the maximum number of digits a subject can memorize and recite forward (in both studies) or backward (in the NLS-C only). There is little evidence that lefties are worse at reciting digit lists in the forward direction, which is generally considered a test of short-term auditory memory. Lefties are, however, substantially worse at reciting the digits backwards, which is thought to measure the child's ability to manipulate verbal information in temporary storage (NLSY79 Child & Young Adult Data Users Guide, 2009, p. 103). This inability to reverse the order of a list may be further evidence of a dyslexia-like impairment or other difficulties with language processing.

Education, Occupation, and Earnings

These observed differences in cognitive skills, behavioral problems, and learning disabilities are also associated with differences in education, occupation, and earnings. Table 5 shows mean differences in educational attainment and occupational characteristics between lefties and righties for the US and UK samples.

[8] These studies often use the term "mental retardation" in their survey questions. However, it is now more common to describe such individuals as having an "intellectual disability," and I follow that convention here.

Table 5
Educational Attainment and Occupation

	US	*UK*
A: College graduate		
Portion left-handed	0.233	0.185
Portion right-handed	0.256	0.195
Left − right difference	−0.023	−0.010
	(0.011)	(0.007)
p-value	0.038	0.170
B: Professional/manager		
Portion left-handed	0.204	0.226
Portion right-handed	0.239	0.240
Left − right difference	−0.036	−0.014
	(0.011)	(0.008)
p-value	0.001	0.062
C: Cognitive skill index for job (difference from mean)		
For the left-handed	−0.068	
For the right-handed	0.011	
Left − right difference	−0.080	
	(0.028)	
p-value	0.005	
D: Manual skill index for job (difference from mean)		
Portion left-handed	0.073	
Portion right-handed	−0.012	
Left − right difference	0.085	
	(0.029)	
p-value	0.003	

Notes: Each panel shows the mean value of the listed outcome for left- and right-handed individuals in the given sample. Below that is the difference between those two groups, the standard error of that difference, and its associated *p*-value. Panels A and B use indicators for being a college graduate or having a professional or managerial occupation. Panels C and D use standardized measures of the cognitive and manual skill required by the individual's occupation.

In the US sample, I measure the maximum level of education reported within ten years of the start of the study, at which point subjects were in their mid-20s to early 30s. In the UK sample, subjects were asked at age 33–34 for their highest academic qualification. In the US sample, lefties are 2 percentage points less likely to complete college than righties, a difference that is statistically significant. Given that 26 percent of righties in this sample complete college, this represents a roughly 10 percent difference in the rate of college completion. In the UK sample, lefties are a statistically insignificant 1 percentage point less likely to complete college. Though not shown, they are also a marginally significant 1 percentage point more likely to drop out of high school.

All of the datasets record the occupations of individuals, coded by a standardized scheme. I construct three mutually exclusive categories of professional/managerial occupations, other occupations, and missing occupation. In panel B of Table 5, lefties in the US sample are a significant 4 percentage points less likely to have professional or managerial occupations, which is not unexpected given their lower rates of college completion. Though not shown, lefties are strikingly more likely to be missing occupational information. This is not due to differential attrition within the dataset, but instead from the fact that lefties are more likely not to report having any occupation at all, even over multiple waves. A similar but weaker pattern is seen in the UK samples.

I also take advantage of the US Department of Labor's Occupational Information Network (ONET), which contains measures of various skills required by each occupation in the Standard Occupational Classification scheme. ONET groups such skills into four categories: cognitive, psychomotor, physical, and sensory. Each category contains multiple sub-skills, the importance of which to each occupation is measured on a scale from 1 to 5. For each occupation, I construct a measure of cognitive skill from the mean of all cognitive sub-skills and a measure of manual skill by averaging all sub-skills that mention hands, including "arm-hand steadiness," "finger dexterity," "manual dexterity," and "wrist-finger speed." I standardize all of these occupational skill measures across the population of individuals for whom I observe occupation and show mean differences in these measures in panels C and D.

Consistent with, and nearly identical to the gaps in cognitive test scores, lefties in the US work in occupations requiring 0.08 standard deviations less cognitive skill. Though not shown here, I find a nearly identical gap if cognitive skill is instead constructed only from the two sub-skills that plausibly measure creativity, namely "originality" and "inductive reasoning." This suggests that lefties work in occupations requiring less, not more, creativity than righties. Finally, if lefties are at a manual disadvantage due to the fact that they use different hands to work, such a disadvantage is not apparent in occupational choice. Lefties work in occupations requiring 0.09 standard deviations more manual skill than righties. These occupational skill measures strengthen the case that the primary disadvantage of being a lefty involves cognitive deficits, not manual ones.

I construct annual earnings in a way that makes the US samples comparable to each other and the UK samples comparable to each other. For the US sample, I define earnings by the last nonmissing value observed from ages 25–29. In the UK sample, I construct earnings at age 33–34 for all respondents reporting earnings, including full-time workers, part-time workers, and the self-employed. The constructed distributions include nonworking individuals as having zero earnings or wages. US and UK earnings are expressed in 2009 dollars and pounds sterling, respectively.

Table 6 shows the median handedness earnings gap across the entire samples in panel A and by gender in panels B and C.[9] The median US lefty earns $1,300

[9] I use median differences here to diminish the influence of outliers. Mean differences yield very similar results, as do specifications using the logarithm of earnings, as shown in online Appendix Table 6.

Table 6
Annual Earnings
(median value)

	US (1,000s of $)	*UK (1,000s of £)*
A: Annual earnings		
Lefty	21.12	17.31
Righty	22.42	17.09
Lefty − righty difference	−1.31	0.22
	(0.662)	(0.472)
p-value	0.049	0.647
B: Male earnings		
Lefty	25.00	22.61
Righty	27.45	24.24
Lefty − righty difference	−2.45	−1.63
	(0.821)	(0.588)
p-value	0.003	0.006
C: Female earnings		
Lefty	14.46	8.25
Righty	17.86	8.84
Lefty − righty difference	−3.40	−0.59
	(0.872)	(0.658)
p-value	0.000	0.369

Notes: Each panel shows the median value of annual earnings for left- and right-handed individuals in the given sample. Below that is the difference between those two groups, the standard error of that difference, and its associated *p*-value. Earnings are observed in the US sample at ages 25–29 and in the UK sample at ages 33–34. Estimates include all individuals reporting earnings, even zero earnings. US and UK earnings are expressed in thousands of 2009 dollars and pounds sterling respectively. Panel A includes all individuals, while panels B and C separate the samples by gender.

a year, or about 6 percent, less than the median righty, who earns $24,400. In the UK sample, lefties very slightly out-earn righties, by a statistically insignificant £200 a year. These differences are, however, substantially biased by the fact that men both earn more and are more likely to be left-handed than women.

Separating the samples by gender reveals larger and clearer earnings gaps. In the US sample, male lefties' median annual earnings are $2,500 lower than those of male righties, a gap of roughly 9 percent. In the UK sample, male lefties earn £1,600 less a year than righties, a gap of roughly 7 percent. Both of these differences are statistically significant. In the US sample, female lefties earn $3,400 less than female righties, a highly statistically significant 19 percent gap. The female UK sample is the only one not to exhibit a statistically significant earnings gap between lefties and righties, although the regression-adjusted logarithmic specification shows a marginally significant left-handedness penalty of about 7 percent.

Similar to the cognitive skill gap, a substantial difference in earnings is particularly visible at the low end of the distribution. I identify people as having low earnings if their annual earnings are below $3,000 or £2,000. The majority of such people have zero earnings. Though not shown here, in all samples but the NCDS58, lefties are 4 percentage points, or 25 percent, more likely to have low earnings. These observed gaps are not gender-specific.

The disproportionate number of lefties with low or no earnings partly explains why the previous study by Ruebeck, Harrington, and Moffitt (2007) found little earnings gap by handedness. That study, which also used the NLSY79, excluded individuals with particularly low earnings and thus missed an important part of the earnings distribution. Their earnings analysis also controlled for cognitive skill and schooling, covariates I have shown are endogenous. Including such controls causes underestimation of the handedness gap in earnings, as those are channels through which the gap at least partially arises. I also note that the earnings gap that I observe in the UK sample is driven almost entirely by the BCS70 sample, with the NCDS58 showing no statistically significant gaps. This is consistent with the findings of Denny and O'Sullivan (2007), who also find no earnings gaps in that same data. Of the four adult samples used here (two each underlying the US and UK samples), the NCDS58 is the only one not to show such earnings gaps. Within the US sample, both the NLSY79 and NLSY97 show gaps that are remarkably similar in magnitude.

Robustness and Heterogeneity

These estimated handedness gaps in cognitive skills and earnings are robust to a number of alternate specifications, including using the continuous instead of the binary measure of left-handedness, excluding the few individuals identified as intellectually disabled, and removing mixed-handed individuals from the sample. All of the results discussed here in terms of mean or median differences are substantially similar to those generated by the multivariate regression analysis, as discussed previously.

Given that left-handedness has both genetic and environmental origins, I also attempt to determine whether the "type" of left-handedness matters. In one approach, I divide lefties into those with good infant health, who were born with neither complications nor low birthweight, and those with poor infant health, who were born with either complications or low birthweight. Although this method of dividing the sample is crude, those with good infant health are more likely to be left-handed due to genetics and those with poor infant health are more likely to be left-handed due to environmental causes such as health shocks. I find no evidence of differences in the handedness gap in cognitive skills by infant health status. This could be evidence that the environmental factors generating left-handedness, and not the genetic factors, are responsible for the observed earnings gap. Left-handedness may thus be an indicator of even poorer infant health than the measures available in these datasets suggest.

The NLS-C provides another way potentially to separate the two types of left-handedness. Lefties born to left-handed mothers are more likely than other lefties to carry left-handed genes. A regression analysis in which I interact the child's and mother's left-handedness suggests that lefties born to right-handed mothers have cognitive skills roughly two-tenths of a standard deviation lower than righties. Lefties born to left-handed mothers exhibit, however, no statistically significant cognitive skill deficits. This could be evidence that left-handedness of genetic origin is substantially less associated with human capital deficits than left-handedness of environmental origin.

Alternatively, this could suggest that left-handed children benefit from being raised by left-handed mothers, perhaps because those mothers model the physical act of writing or perform other cognitive tasks in styles that match their children's capacities more closely. Intriguingly, the right-handed children of left-handed mothers exhibit cognitive gaps similar to those of left-handed children. In short, mismatch between parental and child handedness appears to be a key factor in the association between handedness and cognitive deficits. This may suggest that nurture is an important component of the handedness penalty, though other explanations cannot be ruled out.

Discussion and Conclusion

Across the multiple samples used in this paper, left-handed individuals show consistently lower cognitive skills and higher rates of mental and behavioral disabilities. This finding has been documented in previous research. This paper is the first to demonstrate that lefties also have consistently lower labor market earnings than right-handed individuals. The evidence on occupational choice suggests that the primary disadvantage of left-handedness is not manual but cognitive. In ordinary least squares regressions, the cognitive and behavioral gaps observed explain one-third of the estimated handedness gap in earnings.

The magnitudes of these handedness gaps are economically substantial. In these samples, the handedness gaps in cognitive skill and college graduation rates are equivalent to having a mother with two-thirds of a year less schooling. The earnings gap is even larger, the equivalent of having one less year of schooling or a mother with two fewer years of schooling.

This paper documents the gaps between left- and right-handed individuals but leaves for future work the question of whether such gaps are caused by left-handedness or instead arise from other factors for which left-handedness is simply a proxy. Identifying left-handedness as the cause of these gaps would be difficult for a host of reasons, not least of which is that we do not have a clear way to manipulate handedness (Rubin 1974). More importantly, handedness is generated by neurological wiring that may affect a number of important channels relevant to labor market outcomes. Isolating the impact of any one of these channels would be challenging.

The patterns discussed in this paper nonetheless raise a number of questions for future research, including the following.

First, the cognitive and behavioral gaps observed in these datasets statistically explain at most one-third of the earnings gap. What unobserved factors might explain the rest of that gap? Could differences in mental health explain why the left-handed are more likely to have no meaningful earnings or occupation?

Second, to what extent is handedness simply a proxy for fetal health differences that happen to have rewired the brain? Would some form of early health interventions, such as those discussed in this journal by Almond and Currie (2011), reduce the incidence of left-handedness or otherwise diminish its long-run impact?

Third, why do left-handed children of left-handed mothers exhibit no cognitive deficits while right-handed children of left-handed mothers do? Why should the match between child and maternal handedness matter? Does this imply something important about the behavioral interactions between parents and children? If such interactions matter, could schools tailor pedagogy in a way that benefits left-handed children?

Fourth, although most left-handed children will not experience substantial cognitive or behavioral problems, left-handedness does increase the odds of such problems substantially. Would paying added attention to left-handed children at early developmental stages improve the chance that those with learning disabilities are diagnosed early or at all?

Finally, the handedness gaps documented here and in previous research prompt an interesting question about the extent to which historical biases against the left-handed were grounded in some small, albeit highly exaggerated, truth. It seems unlikely that small mean differences in cognitive skill could drive this. High rates of left-handedness among the intellectually disabled or those with substantial behavioral problems might, however, have been sufficiently clear to early observers to encourage such prejudices.

Ultimately, the fact that this easily observable proxy for brain structure has a substantial relationship to human capital accumulation is itself noteworthy. Recent scholarship in this journal has reviewed research on the question of the extent to which human genetic endowments are intimately connected to economic behaviors, as well as the pitfalls of attributing such behaviors to specific genes (Beauchamp et al. 2011). We know even less about how genes or environmental factors affect human neurological wiring and the other biological systems that contribute to such behaviors. The facts about handedness documented here suggest that such research is worth pursuing.

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References

Aizer, Anna. 2009. "Peer Effects, Institutions and Human Capital Accumulation: The Externalities of ADD." Brown University Working Paper.

Almond, Douglas, and Janet Currie. 2011. "Killing Me Softly: The Fetal Origins Hypothesis." *Journal of Economic Perspectives* 25(3): 153–72.

Beauchamp, Jonathan P., David Cesarini, Magnus Johannesson, Matthijs J. H. M. van der Loos, Philipp D. Koellinger, Patrick J. F. Groenen, James H. Fowler, J. Niels Rosenquist, A. Roy Thurik, and Nicholas A. Christakis. 2011. "Molecular Genetics and Economics." *Journal of Economic Perspectives* 25(4): 57–82.

Benbow, Camilla Persson. 1986. "Physiological Correlates of Extreme Intellectual Precocity." *Neuropsychologia* 24(5): 719–25.

Bisazza, Angelo, L. J. Rogers, and Giorgio Vallortigara. 1998. "The Origins of Cerebral Asymmetry: A Review of Evidence of Behavioural and Brain Lateralization in Fishes, Reptiles and Amphibians." *Neuroscience and Biobehavioural Reviews* 22(3): 411–26.

Carter-Saltzman, Louise, Sandra Scarr-Salapatek, William B. Barker, and Solomon Katz. 1975. "Left-Handedness in Twins: Incidence and Patterns of Performance in an Adolescent Sample." *Behavior Genetics* 6(2): 189–203.

Coren, Stanley. 1995. "Differences in Divergent Thinking as a Function of Handedness and Sex." *American Journal of Psychology* 108(3): 311–25.

Currie, Janet, and Enrico Moretti. 2007. "Biology as Destiny? Short-and Long-Run Determinants of Intergenerational Transmission of Birth Weight." *Journal of Labor Economics* 25(2): 231–64.

Currie, Janet, and Mark Stabile. 2006. "Child Mental Health and Human Capital Accumulation: The Case of ADHD." *Journal of Health Economics* 25(6): 1094–1118.

Denny, Kevin, and Vincent O'Sullivan. 2007. "The Economic Consequences of Being Left-Handed: Some Sinister Results." *Journal of Human Resources* 42(2): 353–74.

Dragovic, M., and G. Hammond. 2005. "Handedness in Schizophrenia: A Quantitative Review of Evidence." *Acta Psychiatrica Scandinavica* 111(6): 410–419.

Gabrieli, John D. E. 2009. "Dyslexia: A New Synergy between Education and Cognitive Neuroscience." *Science* 325(5938): 280–83.

Halpern D. F., M. G. Haviland, and C. D. Killian. 1998. "Handedness and Sex Differences in Intelligence: Evidence from the Medical College Admission Test." *Brain and Cognition* 38(1): 87–101.

Hardyck, Curtis, and Lewis F. Petrinovich. 1977. "Left-Handedness." *Psychological Bulletin* 84(3): 385–404.

Harkins, Debra A., and George F. Michel. 1988. "Evidence for a Maternal Effect on Infant Hand-Use Preferences." *Developmental Psychobiology* 21(6): 535–41.

Heckman, James J. 2007. "The Economics, Technology, and Neuroscience of Human Capability Formation." *PNAS* 104(33): 13250–55.

Johnston, David W., Michael E. R. Nicholls, Manisha Shah, and Michael A. Shields. 2009. "Nature's Experiment? Handedness and Early Childhood Development." *Demography* 46(2): 281–301.

Johnston, David W., Michael E. R. Nicholls, Manisha Shah, and Michael A. Shields. 2010. "Handedness, Health and Cognitive Development: Evidence from Children in the NLSY." IZA Discussion Papers 4774.

McManus, I. C., and M. P. Bryden. 1991. "Geschwind's Theory of Cerebral Lateralization: Developing a Formal, Causal Model." *Psychological Bulletin* 110(2): 237–53.

McManus, I. C., and C. G. N. Mascie-Taylor. 1983. "Biosocial Correlates of Cognitive Abilities." *Journal of Biosocial Science* 159(3): 289–306.

Medland, Sarah E., David L. Duffy, Margaret J. Wright, Gina M. Geffen, David A. Hay, Florence Levy, Catherina E. M. van-Beijsterveldt, Gonneke Willemsen, Grant C. Townsend, Vicki White, Alex W. Hewitt, David A. Mackey, J. Michael Bailey, Wendy S. Slutske, Dale R. Nyholt, Susan A Treloar, Nicholas G. Martin, Dorret I. Boomsma. 2009. "Genetic Influences on Handedness: Data from 25,732 Australian and Dutch Twin Families." *Neuropsychologia* 47(2): 330–37.

Medland, Sarah E., Ira Perelle, Veronica De Monte, and Lee Ehrman. 2004. "Effects of Culture, Sex, and Age on the Distribution of Handedness: An Evaluation of the Sensitivity of Three Measures of Handedness." *Laterality: Asymmetries of Body, Brain and Cognition* 9(3): 287–97.

NLSY79 Child & Young Adult Data Users Guide. 2009. Center for Human Resource Research, Ohio State University, June. http://www.nlsinfo.org/pub/usersvc/Child-Young-Adult/2006ChildYA-DataUsersGuide.pdf.

Perelle, Ira B., and Lee Ehrman. 1983. "The Development of Laterality." *Behavioral Science* 28(4): 284–97.

Perelle, Ira B., and Lee Ehrman. 2005. "On the Other Hand." *Behavior Genetics* 35(3): 343–50.

Pujot, Jesus, Joan Deus, and Josep M. Losilla. 1999. "Cerebral Lateralization of Language in

Normal Left-handed People Studied by Functional MRI." *Neurology* 52(5): 1038–43.

Raymond, Michel, Dominique Pontier, Anne-Beatrice Dufour, and Anders Pape Moller. 1996. "Frequency-Dependent Maintenance of Left Handedness in Humans." *Proceedings of the Royal Society B: Biological Sciences* 263(1377): 1627–33.

Rodriquez, Alina, Marika Kaakinen, Irma Moilanen, Anja Taanila, James J. McGough, Sandra Loo, and Marjo-Riita Järvelin. 2010. "Mixed-Handedness is Linked to Mental Health Problems in Children and Adolescents." *Pediatrics* 125(2): 340–48.

Rubin, Donald B. 1974. "Estimating Causal Effects of Treatments in Randomized and Nonrandomized Studies." *Journal of Educational Psychology* 66(5): 688–701.

Ruebeck, Christopher S., Joseph E. Harrington Jr., and Robert Moffitt. 2007. "Handedness and Earnings." *Laterality* 12(2): 101–120.

Segal, Carmit. 2012. "Working When No One is Watching: Motivation, Test Scores, and Economic Success." *Management Science* 58(8): 1438–57.

Vuoksimaa E., Koskenvuoa M., Rosea R.J., Kaprio J. 2009. "Origins of Handedness: A Nationwide Study of 30,161 Adults." *Neuropsychologia* 1294–1301.

Witelson, S. F. 1985. "The Brain Connection: The Corpus Callosum is Larger in Left-Handers." *Science* 229: 665–68.