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Life Expectancy of Monozygotic and Dizygotic Twins

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Abstract. White male twins from the NAS-NRC twin sample, who were born in the U.S. between 1917 and 1927 and served in the military, are used to estimate variability in hazard functions for those twins who died during the period 1974-1990. Roughly the same number of MZ and DZ twins died during this period, but their death rates are similar. DZ twins exhibit greater within-pair variation. Using hazard and other analyses, the only statistically significant variables are found to be being a DZ twin (in level equations), date of birth, and, sometimes, wife's religious preference. Variables not significant for level or within-pair equations, include own religion, parental education, working overtime frequently, and number of children. The greater variation in life expectancy of DZ twins is hardly surprising and may say something about the lack of comparability in phenotype variance of DZ twins, which in turn may be worrying.

Key Words: Mortality, DZ twins, MZ twins

INTRODUCTION

Why does life expectancy differ between individuals from the same country? This question has interested a number of authors [4, 9, 10, 11, 17, 20, 21]. These authors examine age at death in a variety of samples, using a number of techniques, such as, the difference between the actual and expected number of deaths at each age, and hazard rate analysis, in which the proportion of people who died in a given period are related to some right hand side (hopefully exogenous) variables.

A well-known deficiency in these and many other quantitative studies in the social sciences, is that other possible determinants of the outcome are not held constant, either by sample design or by direct measurement. A few health-related studies have employed the classic technique of a randomly selected control and an experimental group in which some variable that is held to be of interest is perturbed. For example, the effects of variations in the price of health on the use of medical care and on well-being, have been examined [7], but none of these types of study considers life expectancy.

Economists and others have long noted that analysis of differences in identical twins allows the researcher to control for both genetic endowments and family environment when examining the effect of, e.g., differences in education or marital status [23, 24]. Two recognized problems with this approach are, firstly, that measurement error in the difference in the independent variable has a higher noise-to-signal ratio, which can bias downward to a greater degree the coefficient of the independent variable, and, secondly, that the differences in the independent variable may not be truly exogenous.

Twins, of course, have been used to study the determinants of a number of outcomes (and their variances), such as IQ and earnings. Three different questions have been asked. The first is whether controlling for genetic endowments and common environment alters significantly and substantially the coefficient of right-hand-side variables. In the case of earnings functions, some authors have answered in the affirmative [2, 3], but others have answered negatively [1].

The second question is how the *variance* of any output is split between its genetic and environmental components (defined below). The results and the controversy are discussed in the papers cited above. Although this question is not raised here, our findings may have some bearing on assumptions made in these earlier studies. The third issue, which is discussed in detail by Behrman, Rosenzweig, and Taubman [3], is whether the residuals from a set of equations for DZ twins that restrict coefficients to those obtained from MZ within-pair equations are correlated across equations. Again, answering this question not the focus of this paper.

The first of two new questions our paper will consider, is whether there is more variability in life expectancy among DZ than MZ twins. Such a result is expected, because MZ twins possess the same genetic endowments and perhaps a greater correlation of environment. This issue and its economic interpretation have been fully discussed [3]. The second question addressed is whether there a difference in the average expected lifespan between identical and fraternal twins.

Twins have been used only a few times previously to examine mortality rates [14, 15, 16, 27]. However, none of these twins have been used to study hazard functions or differences between twins and twin types.

MATERIALS AND METHODS

The economic framework, which his usually ascribed to Grossman (1972), is that the i^{th} individual maximizes a utility function, U, which depends on the various N goods a person consumes, G_j, and leisure time, L.

$$U_i = U(G_1 \ldots G_N, L) \tag{1}$$

The (static) budget constraint is given in equation (2), where income consists of wages multiplied by hours worked plus unearned income from (inherited) assets and transfers, I_i. This income is spent on various goods, and we assume, for simplicity, that saving is zero.

$$W_i\ (24 - L_i) + I_i = \Sigma\ P_i\ G_i \tag{2}$$

Some of these goods can affect a person's level of healthiness, H_i, which eventually becomes so low that a person dies. A static version of a health production function is given in (3).[1]

$$H_t = H(E_i, N_i, T_i, G_i \ldots G_N, L) \tag{3}$$

In equation (3), health depends on genetic endowments, E, elements of one's childhood and adult environment that are not purchased goods (e.g., parents' care and teaching), N, tastes, T, and purchased goods and leisure. Of course, some goods may have no impact on health and can be excluded from (3), which would help in statistical identification of the various equations. In principle, it is possible to estimate both demand functions for the various G and L, and the health production function, though the data requirements are substantial.

In our particular study, we rely on information on date of death, which can be considered as the outcome of both the maximization, and a stochastic process. Hence, we can think of death as occuring when a (reduced) measure of well-being falls below a minimum health level, H*. Data on date of death of twins will be used to estimate a hazard model that-will allow for censoring, i.e., the fact that some people have not yet died.

Twins, Genotype and Environment

At this point, a formal definition of twins and the terms genotype and environment will be presented. Twins are usually thought to occur in two types: monozygotic (identical) and dizygotic (fraternal). We will frequently refer to these as MZ and DZ. MZ twins are conceived when an already fertilized egg splits. DZ twins, on the other hand, are conceived when the mother releases 2 eggs at the same time and both are fertilized by a different spermatozoon, of which the male usually ejaculates many when copulating.

The genes of each diploid organism occur as pairs of alleles. During meiosis, the members of a pair of alleles are segregated into gametes, and the offspring receive one member of a pair of genes randomly selected from each parent. When a fertilized egg (either a zygote, a morula or a blastocyst) splits, as in the case of MZ twins, each of the new fetuses has the same set of genes. The genotype is constituted by the combination of an individual's genes with respect to any specified combination of loci. In a polygenic model, many genes contribute to a phenotype, which is usually defined as the observable properties (structural and functional) of an organism, produced by the interaction between its genotype and the environment. The environment is understood to include everything that is not genetic, for example a good teacher who can increase test scores, or accidental causes of death.

Similarity and Differences in Twin Types

Why should DZ twins have different lifespans, and perhaps exhibit greater diversity within pairs? The latter is easy to explain, as DZ pairs possess greater variation in genetic endowments because of the random selection in each parent's genetic contribution, and perhaps because DZ twins have more variation in their childhood experiences and adult environment.

Why DZ twins might have a longer lifespan is more difficult to explain. Neither twin type in this sample is a random draw from the general population, since both had to be veterans who survived their military service and answered a 1974 questionnaire when they were about 47 years old. However, twins of both zygosity types were subject to the same health and IQ selection criteria by the armed forces. It is possible that military service eliminated the "weaker" or the "taller" member of a DZ pair, but no literature makes this point, and only 8% of the sample had died prior to 1974, when these men were surveyed to obtain information on various socioeconomic characteristics.

Can twins have different genotypes or environment? There exists some weak evidence on these subjects. It should be noted first of all that, before the introduction of fertility drugs, the MZ twining rate was independent of any variable that has been studied [2]. As has been illustrated [8], the DZ twining rate, however, rose considerably with maternal age (during the child bearing years). For example, a sample of twins born in Minnesota have been assembled for the period 1936-1951 [19]. On the basis of birth certificates, it was found that for males born between 1936 and 1955, the DZ twins' mothers were approximately 1½ years older on average when the twins were born than the mothers of MZ twins. Even in the decade between 1971 and 1981, when more effective birth control measures were available, mothers' average age at delivery was 6 months greater for the DZ twins. We suspect the age differential of mothers in the NAS-NAC twin sample, which we use, is even greater, since the twins were born between 1917 and 1927, when fewer birth control techniques were available and in use.

Older women may be more mature in terms of raising a child, have more resources, be more or less responsive to the child's needs, have more experience in raising children, have more children afoot, and be drawn from various genotypic or ethnic backgrounds. Both types of twins have a higher rate of lefthandedness compared to singletons, but it has not been argued that this has any effect on income, except in professional sports, or on health. Moreover, the incidence of lefthandedness is approximately equal for MZ and DZ twins. Most previous studies have found that equations estimating twins' earnings have the same coefficient on schooling as equations drawn from random samples of the same period. All these maternal differences could translate into a better health and human capital background for DZ twins. However, the little evidence available suggests that MZ twins tested as teenagers have no IQ gap, which is also true in our sample at the time of induction, although this may reflect the military's minimum IQ requirement. On the other hand, randomly drawn MZ twins seem to have lower verbal intelligence when tested as children, while the DZ twins are normal in this regard [2].

A study examines some 1507 twin pairs who participated in the 1962 National Merit Scholarship Test administered to highschool juniors [18]. A question was asked on the test if they were "a triplet, twin, or neither" (p. 5). Later, a set of interests and personality questions was administered to 1507 same sex pairs during their senior year and some 637 randomly selected singletons were added as controls.

On p. 10, they indicate that identical, fraternal, and non-twins score 101.8, 103.2, and 104.9 on the National Merit Scholarship Qualifying Test. On p. 22 and 23, they demonstrate that MZ and DZ twins display significant mean differences on some 1600 personality type questions in only 5 cases. Also, on 131 variables, twins performed much like singletons.

Studies that compare MZ and DZ twin correlations or covariance, often assume that the underlying and usually unobserved[2] genetic endowment and environmental variance are the same for the two twin types. Some people question this assumption on the grounds that parents react to the idea that MZ twins should be treated alike because they are MZ's. Others argue that parents respond to a child's genotype in making environmental choices [22]. It has also been maintained that such arguments are unimportant, as long as the exogenous genetic and environmental variables have the same distribution, but that they may be important in calculating heritability (which we are not concerned with here) [3].

Hazard Analysis

Hazard functions are a standard method of analyzing age of death. It has been found, for example, that using Cox's method or a maximum likelihood estimator of (1), estimate (1) does about as well as anything else [5]. Moreover, allowing for unobserved heterogeneity has only a modest effect on the outcomes. When we look at twin pairs, the age term vanishes and we can simply run regressions. A semiparametric method has been proposed [9] to estimate a model of the the form

$$\lambda_t = e^{at} e^{bx} e^{ut} \tag{1}$$

where

- λ_t is the probability of dying in the t^{th} time interval, given that a person is alive at time t.
- t is age
- X are measured variables
- u are unmeasured variables, including noise.

More complicated functional forms and estimation techniques have also been put forward.

Data and Division into Twin Types

In this study, we will use the NAS-NRC twin sample, which is discussed in detail elsewhere [2]. The sample was constructed by the National Research Council of the National Academy of Science, who tried to collect the names of all white male twins born between 1917 and 1927. They estimate that they obtained the names of more than 90% of this population group. They then restricted their attention to those pairs where both twins served in the armed forces[3]. Dates of death are obtained from V.A. records, which have been found to be almost 100% accurate [2]; these records have been updated through 1989, although some late postings may have been omitted. Most socioeconomic information was obtained from a 1974 survey. Much of our analysis will be based on the 1974-1989 period. Less than 2% of twins in the sample had died prior to 1974 [2]. By 1989, about 8% of those who answered the 1974 questionnaire had died. While 92% are still alive, research indicates that hazard functions can be estimated precisely, even with this high degree of censoring [6].

Means and variances on own and parental characteristics have been published for this sample [2]. Most of the differences reported are small and statistically insignificant, but DZ twins are found to have significantly more siblings and older siblings in 1940, and the number of years of their mothers' education to be slightly lower.

RESULTS

The distribution of these people by both their zygosity and the death status of their twin is given in Table 1.

Table 1 - Death of twins 1974-1990

Zygosity	Both dead		One dead	
	Number	%	Number	%
MZ	190	46.1	32	60.4
DZ	222	51.9	21	39.6
Total	412		53	

Slightly more DZ than MZ twins had died by the end of the sample period, but the death rates are about the same by zygosity. For both twin types, in most instances, by ages 63 to 73, either both brothers were dead, or both were still alive. One other study used Danish twins born between 1870 and 1900, who died after the age of 30 and no later than 1990, to examine this issue [26]. It reports a twin correlation in age of death of 0.58. However, a discussion of the construction of the Danish sample indicates that it was only able to trace about 20% of the twins in this birth cohort. One or both twins had died before the age of 15 and the DZ twins traced died earlier [13].

Our initial results are presented in Table 2, in which the only variables are zygosity, year of birth, and a scale parameter for those still alive by 1989. Once year of birth,

Table 2 - Effects of Zygosity on Date of Death

	Coefficient	P value	Coefficient	P value
Intercept	4.13	(.00)	4.47	(.00)
DZ	.01	(.13)	.01	(.01)
Birth year			−.016	(.00)
Scale parameter	.07		.05	
Log L	538.4		680.0	
Number of observations	4802		4802	

Dependent variable = ln (Age die)

Table 3 - Effects of zygosity on difference in date of death, later minus earlier when at least 1 twin died

	Coefficient	t value	Coefficient	t value
Intercept	15.05	(7.16)	12.49	(2.41)
DZ	1.81	(1.38)	1.83	(1.39)
Birth year			.09	(.42)
Scale parameter	7.98	(9.55)	7.98	(9.55)
Log L	−261.5		−261.4	
Number of observations	464		464	

which has a significant negative coefficient, is controlled for, DZ twins have a date of death about 1% later. As we will show, this result persists when we control for various characteristics of the twins. Within pairs, we find that the average difference in pairs where at least one twin died was about 15 years, when we order the data by date of death. The DZ dummy is positive, but not statistically significant. Presumably this coefficient represents the greater variation in endowments and possibly environment of DZ twins. The birth year effect is small and insignificant.

None of the differences in Tables 2 and 3 would give a clear indication of why DZ twins live longer[4]. We have regressed the same dependent variables on various combinations of parental education, own and wife's religion, working overtime frequently, changing employer, wife's working in various time periods, and number of children[5] (see Tables 4 and 5). The DZ zygosity variable is always found to be positive and to have a chi-square "p" value ranging from .00 to .18. Of course, the longer lifespan of the DZ twins may be explained by differences in the average genotype or environment between twin types. As noted earlier, in this sample the mothers of the DZ twins are slightly older, have less education, generally have more, and older, children, and are slightly more likely to be classified by their son as being a "housewife". Older mothers' greater experience in responding to children's health problems would seem to offer one possible explanation of the better health enjoyed by DZ twins.

To examine this question, we have re-estimated both equations in Tables 2 and 3 (other coefficients not shown), using various controls. In Table 4, birth year has a negative coefficient, which is usually significant. The wife's religion variable is often significant. The coefficients in these maternal variables are very small. In Table 5, the only significant variable, and only in specification, is the difference in frequency of overtime work.

Table 4 - Dependent variable hazard functions: log (AGEDIE) 1974-1989

intep	4.483(.00)*	4.467(.00)*	4.474(.00)*	4.379(.00)*	4.480(.00)*	4.373(.00)*	4.471(.00)*	4.487(.00)*	4.377(.00)
birthyr	−0.015(.00)*	−0.016(.00)*	−0.016(.00)*	−0.016(.00)*	−0.015(.00)*	−0.015(.00)*	−0.016(.00)*	−0.015(.00)*	−0.15(.00)*
zygosity		0.011(.03)*	0.010(.05)*	0.008(.18)	0.011(.03)*	0.010(.12)	0.011(.03)*	0.011(.02)	0.009(.16)
yrmarry			−0.000(.70)	−0.000(.80)	−0.000(.34)	−0.000(.71)		−0.000(.28)	−0.000(.68)
educpa	0.001(.37)	0.0001(.44)	0.000(.71)	−0.000(.72)	0.000(.59)	−0.001(.51)			
educma	−0.001(.09)	−0.001(.11)	−0.001(.14)	−0.001(.25)	−0.001(.10)	−0.001(.34)			
eductw	−0.001(.30)	−0.001(.42)	−0.010(.31)	−0.001(.50)	−0.001(.32)	−0.001(.56)	−0.001(.19)	−0.001(.13)	−0.001(.21)
cathotw	0.014(.22)	0.015(.20)	0.019(.13)	0.080(.00)	0.016(.21)	0.073(.00)*	0.014(.21)	0.014(.25)	0.075(.00)*
protetw	0.015(.17)	0.015(.17)	0.019(.09)	0.070(.00)	0.015(.21)	0.062(.01)	0.014(.20)	0.013(.29)	0.063(.01)
othertw	0.12(.60)	0.013(.56)	0.025(.30)	0.096(.00)	0.022(.40)	0.095(.01)*	0.016(.47)	0.027(.31)	0.103(.01)
cathowi				0.024(.19)		0.027(.14)			0.026(.15)
protwi				0.042(.03)*		0.046(.02)*			0.043(.02)*
jewiswi				0.114(.00)*		0.112(.00)*			0.114(.00)*
otherwi				0.023(.47)		0.025(.45)			0.022(.50)
chempl25	0.007(.14)	0.006(.15)	0.005(.28)	0.005(.36)	0.006(.21)	0.005(.42)	0.006(1.7)	0.006(.33)	0.006(.29)
chocc25	−0.003(.55)	−0.003(.50)	−0.003(.49)	0.001(.80)	−0.002(.66)	0.005(.45)	−0.003(.50)	−0.002(.62)	0.004(.54)
extrajob	−0.004(.33)	−0.004(.34)	−0.002(.70)	−0.001(.91)	−0.002(.72)	−0.002(.66)	−0.004(.31)	−0.002(.69)	−0.003(.60)
otfreq	0.001(.79)	0.001(.75)	0.00(.97)	0.002(.65)	−0.001(.79)	0.001(.87)	0.001(.71)	−0.001(.89)	0.001(.88)
wix42				−0.008(.30)		−0.007(.40)			−0.008(.30)
wi425				0.003(.75)		0.003(.71)			0.003(.68)
wi460				0.005(.52)		0.006(.45)			0.006(.48)
wi515				0.001(.92)		0.002(.81)			0.002(.80)
wi560				0.009(.24)		0.001(.17)			0.010(.22)
wi612				−0.007(.35)		−0.009(.21)			−0.008(.32)
num-kids					−0.001(.66)	0.001(.46)		−0.000(.82)	0.002(.37)
scale	0.054	0.953	0.053	0.052	0.053	0.052	0.053	0.053	0.052
logL	610.8	613.0	569.9	435.3	544.0	413.8	611.7	542.3	411.6
no. of obs.	3817	3817	3578	2652	3448	2562	3817	3448	2562

Prof (calculated chi^2) is in parentheses, * signif. at 5% level.

Table 5 - Dependent Variable: GAPDIE, 1974-1989 (Tobit estimates)

intcp	12.87 (5.97)*	12.08 (5.40)*	11.04 (3.90)*
zygosity	2.36 (1.67)	2.55 (1.70)	3.10 (1.51)
deductw	−0.07 (−0.24)	0.10 (0.31)	0.03 (0.08)
dchemp25	−0.07 (−0.07)	0.26 (0.26)	1.42 (1.10)
dchocc25	−0.19 (−0.19)	−0.22 (−0.22)	−0.59 (−0.45)
dextrjob	−0.36 (−0.43)	−0.25 (−0.28)	−0.62 (−0.55)
dotfreq	0.79 (1.00)	0.95 (1.10)	2.54 (2.21)*
dyrmarry		0.04 (0.45)	0.05 (0.40)
dnumkid		−0.29 (−0.80)	−0.17 (−0.31)
dwix42			−0.47 (−0.24)
dwi425			1.09 (0.59)
dwi460			0.52 (0.28)
dwi515			2.40 (1.22)
dwi560			−0.19 (−0.09)
dwi612			−2.32 (−1.54)
dheart			
ddiagge6			
½	1.40 (8.96)*	6.97 (8.30)*	6.16 (6.38)*
LogL	−214.3	−174.3	−95.1
no. of obs.	343	273	159

*t-values are in parentheses, signif 5% level. Those alive or who died at an older age placed first.

DISCUSSION

For reasons we can not explain, DZ twins have a slightly longer lifespan than MZ twins. This may have some implications for other studies of twins. The usual assumptions employed are that both types of twins are drawn from the same population and face the same environment and decision rules.

Consider, for example, an economic model on the acquisition of human capital. The optimal level of human capital investment should depend on a comparison of the present discounted value of future benefits (primarily wages) with current costs (primarily tuition and foregone earnings). The future benefits are those received during one's working lifetime and retirement. A reduction in career length or the annuity-drawing period will cause an individual to invest less. Will a 1% difference in life expectancy have much of an effect on schooling choices? It has been shown that DZ twins have a *shortfall* of 0.2 years [2]. Hence the difference is small and in the wrong direction.

Key to variable names used in Tables 4 and 5

birthyr	year born	wi515	wife worked before 1951-55 (1)
eductw	education of twin respondent	wi560	wife worked before 1956-60 (1)
vacatw	(0,1) 1 = highest educational attainment is vocational education	wi612	wife worked before 1961-72 (1)
		numkids	number of children
educpa	father's education (continuous)	gapdi	if both dead = year later twin died — year earlier twin died
educma	mother's education (continuous)		
cathotw	twin respondent is Catholic (1)	deductiv	difference in eductiv
protetw	twin respondent is Protestant (1)	dvocativ	difference in vocativ
othertw	twin respondent is other religion (1)	dcathotiv	difference in catholiv
cathowi	twin respondent's wife is Catholic (1)	dprotetic	difference in protetiv
protwi	twin respondent's wife is Protestant (1)	dothertiv	difference in othertiv
jewiswi	twin respondent's wife is Jewish (1)	dchemp25	difference in chemp25
otherwi	twin respondent's wife is other religion (1)	dchoc25	choc25
chempl25	times changed employer since age 25	dextrjob	extrjob
chocc25	times changed occupation since age 25	dotfreq	otfreq
extrajob	extra job in addition to regular employment 0 no; 1 yes, some time; 2 yes, regularly	dyrmarry	yrmarry
		dnumkid	numkids
otfreq	frequency of overtime work	divix42	x42
zygosity	zygosity, 1 MZ, 2 DZ	divi425	wi425
yrmarry	year married	dwi460	wi460
heart	diagnosed with heart ailment	dwi515	wi515
diagge6	diagnosed with at least 6 aliments	dwi560	wi560
wix42	wife worked before 1942 (1)	dwi612	wi612
wi425	wife worked before 1942-45 (1)	dheart	heart
wi460	wife worked before 1945-50 (1)	ddiagge6	diagge6

Note: each set of twin pair data was calculated such that the information on the twin who died earlier is subtracted from the information on the twin who died later (or who is still alive).

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Notes

[1] It is possible to formulate a dynamic version, but we can not implement it empirically, so we opt for simplicity.
[2] Samples with blood type and other genetic markers exist.
[3] Their intention was to study various illnesses with much of the information to be obtained from armed forces and V.A. records.
[4] A rapid perusal of other twin studies indicates that means comparing MZ and DZ twins have generally not been published. One study gives a few numbers, eg., mother's age at birth is approximately 17 months greater for the DZ twins born in Minnesota between 1936 and 1955 [19]. In the same sample, mothers and fathers of DZ twins each have about 6 months less education than those of MZ twins, which is a statistically significant but not substantial amount, and does not explain why it is that more educated mothers instill better and enduring health habits in their twins.
[5] Arguably some of these variables are not exogenous.