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WHY DO FEMALES LIVE LONGER THAN MALES?

Jean Lemaire*

ABSTRACT

In most countries, females live several years longer than males. Many biological and behavioral reasons have been presented in the scientific literature to explain this “female advantage.” A cross-sectional regression study, using 45 explanatory variables and data collected from 169 countries, provides support to the behavioral hypothesis. Four variables, unrelated to biological sex differences, explain over 61% of the variability of the life expectancy differential. One variable (the number of persons per physician) summarizes the degree of economic development of a country. The three other selected variables (the fertility rate, the percentage of Hindus and Buddhists, and European countries of the former Soviet Union) are social/cultural/religious variables. This conclusion is slightly weakened when the presence of spatial autocorrelation in the data is specifically acknowledged.†

1. INTRODUCTION

Mortality rates have decreased drastically in the twentieth century. They continue to decrease, at a pace close to 0.5% per year. The life expectancy gap between affluent and poor, educated and less educated, and across races has narrowed considerably. However, the gender gap has become wider. In most countries, male fetuses, infants, children, and adults exhibit greater mortality, which directly affects the sex ratio of the population, as well as social and demographic factors such as the chances of marriage, the duration of widowhood, the stability of social security systems, the construction of unisex actuarial tables, the pricing of annuities and second-to-die policies, and the valuation of pension plans. The male/female sex ratio at conception is estimated to range between 1.2 and 1.5—the first and in some respects the only biological advantage of males. One hundred years (and nine months) later, females outnumber males by a ratio of four to one, which results in life expectancy differentials at birth averaging 4.51 years worldwide, with a maximum of 12.3 years in Belarus. In only five countries (Afghanistan, Bhutan, Namibia, Nepal, and Niger) do males live slightly longer than females.

A wide variety of variables, and interactions among them, influence sex differences in mortality. Factors explaining the “female advantage” (FA = difference in life expectancy between females and males) can be broadly subdivided into biological and behavioral causes.

Biological differences: Women are biologically fitter than men, due to genetic and hormonal differences; consequently they benefit more from advances in medical science and economic progress.

Behavioral differences: The lifestyle of men is damaging to their health. The FA was low 100 years ago due to gender discrimination; the effects of male lifestyles more or less offset the effects of discrimination. As females progressively achieve equality, the FA increases.

Identifying the causes of the FA is critical for an accurate forecast of mortality in the twenty-first century. If the larger part of the FA is the result of behavior (such as smoking, stress, exposure to AIDS, and driving patterns), the FA should shrink as behaviors of the two genders become similar in many societies. Indeed, the FA has begun to decrease in the United States and in most European

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countries; the U.S. 2001 FA is estimated at 5.68, down from a peak of 7.8 in 1970. If the larger part of the FA is due to biological causes, a significant difference will persist, barring any spectacular medical breakthrough.

The main goal of this article is to update and extend important research work by Preston (1976). In a comprehensive book, Preston analyzed the causes of mortality in 43 countries, nearly all of them developed, and performed a stepwise regression analysis that selected three variables that significantly impact age-standardized death rates. More than 25 years after its publication, the Preston study remains one of the most persuasive demonstrations of the influence of socioenvironmental factors on mortality. It is extended here in two significant ways. First, we use data collected from 169 countries in various stages of development. Extending the database to the entire world enables us to analyze causes of mortality like son preference that Preston could not consider in a study limited to developed countries. We use a much larger set of potential explanatory variables and perform a cross-sectional regression study, selecting four variables that significantly affect the FA. Second, we improve Preston’s model by explicitly acknowledging the presence of spatial autocorrelation in the data, as evidenced by a likelihood ratio test. The selected regression equation needs to be revised to account for this autocorrelation.

Section 2 summarizes major studies on the causes of the FA. Section 3 discusses the correlations observed between the FA and all explanatory variables. Section 4 reports the results of a “traditional” regression analysis, disregarding the existence of spatial correlation in the data. Spatial correlation is introduced in Section 5. The conclusions, in Section 6, provide support for the behavioral hypothesis.

2. **Literature Review—Causes of the Female Advantage**

Evolution is a fairly rapid and effective process of adaptation to environmental changes. The FA, however, has increased recently way too fast to be explained only by evolution; social, economic, and environmental factors must be influencing mortality. Historically, males tended to survive longer than females, a pattern that seems to have persisted from the origins of our species until well into the modern era. Survival rates only began to change 150 years ago. One century ago, the FA was small in a number of countries. It has grown significantly since (Berin, Stolnitz, and Tenenbein 1990). Table 1, from Nadarajah (1983) and recent data, shows the evolution of the FA in Sri Lanka since 1920.

A vast body of literature, from many different disciplines (medicine, biology, sociology, demography, and epidemiology) addresses the issue. Excellent summaries are Waldron (1985) and Nathanson (1984). A comprehensive survey by Kalben (2000) finds ample evidence to support both the behavioral and the biological explanations. The author mostly believes in the biological hypothesis, while stating that biological differences can be masked by behavioral factors that either decrease (poor maternal and childbirth practices) or increase (male cigarette smoking) the FA. She finds no support to the theory that the greater male labor force participation increases the FA—an opinion that Waldron (1991—reviewed below) does not fully share.

**Studies Supporting the Biological Hypothesis**

Wingard (1982) performs a multiple logistic analysis of the mortality of 6,928 Californians, followed up during nine years. The study controls death rates for 16 health, social, demographic, and psychological factors: age, race, socioeconomic status, occupation, health, use of health services, smoking and alcohol use, physical activity, weight, sleeping patterns, marital status, social contacts, church and group membership, and

<table>
<thead>
<tr>
<th>Year</th>
<th>Male</th>
<th>Female</th>
<th>FA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1920–22</td>
<td>32.7</td>
<td>30.7</td>
<td>-2.0</td>
</tr>
<tr>
<td>1945–47</td>
<td>46.8</td>
<td>44.7</td>
<td>-1.2</td>
</tr>
<tr>
<td>1953</td>
<td>58.8</td>
<td>57.5</td>
<td>-1.3</td>
</tr>
<tr>
<td>1958</td>
<td>59.8</td>
<td>58.8</td>
<td>-1.0</td>
</tr>
<tr>
<td>1961</td>
<td>63.0</td>
<td>62.4</td>
<td>-0.6</td>
</tr>
<tr>
<td>1964</td>
<td>63.0</td>
<td>63.6</td>
<td>+0.6</td>
</tr>
<tr>
<td>1966</td>
<td>63.6</td>
<td>65.0</td>
<td>+1.4</td>
</tr>
<tr>
<td>1970–72</td>
<td>64.0</td>
<td>66.8</td>
<td>+2.8</td>
</tr>
<tr>
<td>1988</td>
<td>68.4</td>
<td>72.6</td>
<td>+4.2</td>
</tr>
<tr>
<td>1999</td>
<td>71.0</td>
<td>76.0</td>
<td>+5.0</td>
</tr>
</tbody>
</table>
life satisfaction. The unadjusted ratio of men to women mortality is 1.5. Controlling for factors such as smoking and alcohol use decreases this ratio, because more men smoke and drink. Controlling for factors such as physical activity increases the ratio because more women than men are physically inactive. The adjustment for all 16 factors increases the mortality ratio to 1.7. So this large set of demographic and behavioral factors does not explain the FA. Other factors that differ among men and women, such as suicides, homicides, and fatal traffic accidents, only account for a small proportion of total deaths and cannot explain the FA either. It is concluded that an explanation of the FA needs to incorporate biologic factors.

Madigan and Vance (1957) study a group showing few behavioral differences between males and females: the teachers and staff of Roman Catholic brotherhoods and sisterhoods, who lead very similar lives as regards diet, housing, work, recreation, and medical care. Many potential sources of mortality differentials, such as pregnancies, employment differences, service in armed forces, and hazardous leisure activities, do not exist in this group. Variables that could not be controlled include smoking, alcohol consumption, and obesity. Over 41,000 subjects were observed during a 54-year period. Because of their lifestyle, both brothers and sisters experience lower mortality rates than the general population. However, sex mortality differentials are similar, and even greater after the age of 45. An analysis of the causes of death shows that women may be less resistant than men to infectious and contagious diseases, so that the gains achieved by women this century may be explained by progress on infectious diseases and a better constitutional resistance to degenerative diseases. The increasing FA may result from the transition from times where infectious diseases were the main causes of death, to modern times where death mostly results from degenerative diseases.

There is substantial evidence that males have not benefited from medical advances as much as females. Graney (1979) compares pre- and post-1946 mortality rates and shows that the introduction of antibiotics around that time reduced infant mortality much more for females than males. Female death rates from chronic heart disease in the United States declined by 22% from 1950 to

1969. Male death rates decreased by only 7%. Of course, females were the exclusive beneficiaries of the improvement in maternal mortality that dropped from 66 per 10,000 in the 1920s to 1.5 per 10,000 in 1969. Mortality from cancer of the reproductive organs is lower for males, so females are reaping more benefits from the improvement of cancer detection and treatment (Retherford 1975).

Nadarajah’s (1993) comparison of causes of death in the age group 15–44 in Sri Lanka in 1952–54 and 1970–72, summarized in Table 2, supports the theory that women have taken more advantage of medical improvements. Death rates for diseases and causes that affect females more (tuberculosis, pneumonia, infectious and parasitic diseases, and maternal deaths) have drastically declined during the period under study. Death rates for causes that affect males disproportionately (diseases of the circulatory system, accidents, suicide, and violence) have increased.

Graney (1979) provides a genetic explanation of the FA. While any X chromosome contains a large amount of genetic information, the Y chromosome carried by males is smaller, has fewer genes, and carries less information. Scheinfeld (1958) even suggests that a Y chromosome may act as no more than a blank. Males lack the genetic advantage of a second X chromosome; with their two X chromosomes, females use the immu-

<table>
<thead>
<tr>
<th>Cause of Death</th>
<th>1952–54</th>
<th>1970–72</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>Tuberculosis</td>
<td>30.4</td>
<td>34.6</td>
</tr>
<tr>
<td>Anemias</td>
<td>10.2</td>
<td>24.3</td>
</tr>
<tr>
<td>Pneumonias</td>
<td>19.2</td>
<td>33.5</td>
</tr>
<tr>
<td>Diseases of the digestive system</td>
<td>9.9</td>
<td>17.1</td>
</tr>
<tr>
<td>Cancer</td>
<td>6.9</td>
<td>10.3</td>
</tr>
<tr>
<td>Diseases of the circulatory system</td>
<td>21.8</td>
<td>25.4</td>
</tr>
<tr>
<td>Infectious and parasitic diseases</td>
<td>29.1</td>
<td>35.5</td>
</tr>
<tr>
<td>Accidents, suicides, violence</td>
<td>63.0</td>
<td>22.6</td>
</tr>
<tr>
<td>Maternal deaths</td>
<td>0.0</td>
<td>92.0</td>
</tr>
<tr>
<td>Other causes</td>
<td>89.2</td>
<td>117.3</td>
</tr>
<tr>
<td>All causes</td>
<td>280.2</td>
<td>412.6</td>
</tr>
</tbody>
</table>
nology system of both parents. Males do not have a second X if one is defective.

Waldron (1976) provides a hormonal explanation of the FA. Male androgens, particularly testosterone, raise blood pressure and increase liver production of LDL, the bad cholesterol. Female estrogens act on the liver to produce more immune globulin and more HDL, the good cholesterol, which makes the female biochemical environment better able to fight bodily stresses. After menopause, the decrease in estrogen levels seems to have an immediate impact on the cardiovascular risk. The male to female ratio for myocardial infarction drops from 3:1 before age 50 to less than 2:1 after. The hormonal explanation is supported by Hamilton and Mestler (1969), who compare the life expectancy at age 8 of castrated and intact men. Castrated men live 10.2 years longer.

The greater adaptability of the female body may arise from the need to adjust to the changes that take place during menstruation, childbearing, and menopause. Graney (1979) suggests that biological differences between the sexes are related to their differentiated social roles. To support the intense demands of pregnancy, childbirth, and nursing, females have biological reserves that are available in case of emergency at other times. Menopause eliminates maternal mortality and thus promotes longer life. The demands of hunting, shelter-building, and even combat with other males have maximized male size and muscle mass, leaving fewer reserves to combat emergencies such as acute infections—an opinion that is contradicted by some of the findings of Madison and Vance reported above.

**Studies Supporting the Behavioral Hypothesis**

There is considerable evidence that changes in smoking habits this century have contributed to the evolution of the FA. Retherford (1975) finds that the sex difference in life expectancy between the ages of 37 and 87 was 2.71 years for non-smokers and 5.13 years for smokers in 1962. He concludes that nearly half of this difference is due to tobacco smoking and that about 75% of the increase of the FA between 1910 and 1962 is due to changes in smoking habits. However, cigarette consumption is correlated with alcoholism, socio-economic status, psychological type, and marital status, and no attempt is made to control for these variables. This results in an overestimation of the effects of smoking.

There is some evidence that the greater male exposure to occupational hazards may contribute to the FA. Men are more likely to be employed in jobs exposed to carcinogens and have a higher rate of fatal work accidents. According to Waldron (1991), this can only account for at most 5% of the male excess mortality, of which about half can be explained by exposure to asbestos. The effects of occupational hazards have decreased substantially today because safety measures, better hygiene, and reduced working hours have improved work conditions, while most jobs with exposure to carcinogens have been eliminated. The decrease in cigarette consumption will further reduce any effect of occupational hazards, given the interaction between smoking and carcinogens. Consequently, men’s employment in riskier occupations only contributes modestly to the FA.

The FA is smaller in most developing countries. A first explanation of this phenomenon is that some causes of death favor males (who are less vulnerable to intestinal infections and tuberculosis, for instance) while some favor females (who are less prone to die from violence and accidents.) An excess mortality for women will automatically result in countries where the former causes are more prevalent.

A second explanation is son preference (Das Gupta and Bhat 1966). In several societies, particularly those with strong Hindu or Confucian traditions, the patriarchal family structure and the low status of women induce a preference for sons over daughters. Son preference is strong in Jordan, Syria, Bangladesh, Nepal, India, and Pakistan and only slowly fading in China, South Korea, and Taiwan (Arnold and Zhaoxiang 1986). Females get discriminated against throughout their lives, are weaned earlier than boys, and have less access to education, health care, food supplies, and other goods and benefits scarce in a poor society. Reasons for son preferences are numerous and are summarized by the South Indian proverb “Raising a daughter is like watering your neighbor’s plant.” Education of female children is perceived as an investment that will shift outside the family after marriage, after payment of dowry and wedding costs. Males are more valued in ag-
gricultural areas because of their larger contribution to household production. In addition, Hindu sons have to perform religious functions, such as the cremation of deceased parents.

Many other reasons have been put forward to explain the FA. They include the loss of iron during menstruation, pressure on men not to miss work, the higher use of health providers (including preventive care) by women, type A behavior among men, the fear of men to survive their spouse, and even the disappearance of whalebone corsets (Bowerman 1950).

Few papers provide an international analysis of the FA. They are usually descriptive, analyzing sex differentials by age groups and causes of death (Stolnitz 1955, 1956; UN Secretariat 1988). Studies focus on medical causes of death and do not explore the reasons for heart diseases, cancers, and violence. A notable exception is a regression analysis by Preston (1976), based on mortality data from 43 countries, most of them developed, during the period 1960–64. Preston finds that the variable most strongly correlated to the sex mortality differential is the percentage of the labor force in agriculture (correlation = −0.574.) He then applies a standard stepwise regression technique, which selects three variables: the percentage of the labor force in agriculture, forestry, hunting, and fishing; the percentage of population residing in cities of more than 1 million inhabitants; and an interaction term, the reciprocal of daily grams of animal protein per capita times the percentage of males in level 1 school enrollment. All three regression coefficients are significant at the 5% level. The square of the multiple correlation coefficient is 0.541. To this date, the Preston study is widely cited as the most impressive published proof of the influence of social/cultural/environmental factors on mortality.

Note that Preston uses the age-standardized crude death rates as the dependent variable, rather than the difference in life expectancies. The main reason for this choice is his interest in causes of death: the age-standardized crude death rates from individual causes add up to the death rate for all causes combined. The life expectancy of life does not enjoy this additivity property. In this study, life expectancies are used because (i) crude death rates are not available from most countries and (ii) this research does not focus on causes of death.

Interactions

Many authors emphasize the importance of interactions between biological and behavioral variables. According to Kitagawa (1977), “biological and environmental factors are so interdependent that it is not possible to determine the separate influence of each.” Some examples of interactions include:

- Melanoma, the deadliest form of skin cancer, which results from the conjunction of a biological cause—fair complexion—and a behavioral factor—over-exposure to sunlight (Kalben 2000);
- Breast cancer, where biological causes, including the BRCA gene mutation, family history of the disease, early menarchy, and late menopause, interact with behavioral factors like diet, age at first childbirth, use of birth control pills, and many other known and unknown causes (Lemaire et al. 2000);
- The better resistance of women to degenerative diseases can only show up in affluent countries, in conditions of low infant mortality and high life expectancy.

Examples of interactions between economic modernization and cultural variables also abound:

- Gender discrimination is likely to have more effect in countries where food is scarce and doctors are rare;
- There could be a synergistic effect between female literacy and availability of doctors and hospitals beds: infant mortality will reduce if mothers are able to recognize a life-threatening situation and if medical help is within reach.

Finally, it should also be acknowledged that different explanations might account for the FA at different ages: differentials in infants may be primarily biological, while social/behavioral reasons may explain more of the FA in older adults.

3. Correlation Analysis

Data on the possible causes of the FA were collected from 169 countries, with a total population of 5.96 billion. The values of 45 potential explanatory variables were recorded. Variables were subdivided into four categories, measuring economic modernization, social/cultural/religious values, health-care quality, and geographic
dummy variables. There is some overlap between categories. For instance, a decrease of infant mortality results not only from an improvement in health-care facilities, but also from better female education.

The Appendix provides the definition of each variable, its source, summary statistics, correlation with FA, and comments on data quality. Given the extreme skewness of the distribution of some variables, such as maternal mortality and persons per car, doctor, and hospital bed, variance-stabilizing logarithmic transformations were applied, resulting in all cases in a significant increase of the correlation coefficient. (All logarithms are natural in this study.)

The FA, defined as the difference between the life expectancy at birth between women and men, in years, is the dependent variable of this research. This measure of the overall sex differential in mortality is the most commonly used because it summarizes mortality at all ages. It is suitable to make comparisons among populations with different age structures because it is not affected by the age distribution. *Encyclopedia Britannica* considers it “the most accurate single measure of the quality of life in a given society,” summarizing in a single number all the natural and man-made damages that can affect an individual, ranging from poor health-care system and civil war to unhealthy nutrition and sexual behavior.

It was decided to use unweighted correlations rather than to assign each country a weight proportional to its population. Weighted correlations would have given too much importance to the 10 largest countries, with a combined population exceeding 60% of the world’s total. Also, it was felt that small countries, like Luxembourg or Norway, have their own specific cultural values and health-care systems. Using weighted correlations would have disregarded that information.

Comments on correlations between the FA and explanatory variables follow. In an independent sample, with data that exhibit no spatial autocorrelation, correlation coefficients exceeding 0.18 are significant at the 1% level. However, any cross-sectional study may be subject to some degree of spatial correlation, which would make correlation coefficients less significant than they appear to be. This issue is explored further in Section 5.

**Economic Modernization Variables**

High correlations, exceeding 0.50, are found between FA and child malnutrition, females working in agriculture, number of persons per car, and degree of urbanization.

Urbanization is strongly correlated with FA and with most measures of economic development. It is an indicator of the degree of economic modernization, but also a proxy for gender bias because discrimination occurs mainly in rural areas, due to the perceived larger value of men in an agricultural setting (Williamson 1973 concludes that lack of urbanization is the strongest determinant of son preference).

**Social/Cultural Variables**

For four variables (illiteracy, school enrollment ratios, school duration expectancy, and smoking) gender-specific data are available. In all cases correlations are stronger for women. For instance, an improvement in female literacy contributes more to a decrease of child mortality than a male increase because females are the main providers of child care.

Fertility shows the highest correlation (−0.6348) with FA. Four education-related variables (female illiteracy rates, male illiteracy rates, school enrollment ratio for women, and female school duration expectancy) exhibit correlation coefficients with FA in excess of 0.5. Variables related to education seem essential to understand the FA phenomenon. While all authors agree that the demographic transition to lower levels of mortality and fertility is linked to economic development, recent research (Murthi, Guio, and Drèze 1995) and our correlation coefficients show that the income effect can be slow and weak and that education-related variables have a more profound influence. A transformation of value and belief systems always parallels economic modernization. Education may be the most effective agent of change in the belief system.

Female education is considered to be crucial even if family income is controlled. For educated women, the desire for a large family lessens and the ability to achieve the planned number of births increases. They have other sources of fulfillment and are less dependent on their sons for old-age security. Time has a higher opportunity cost that reduces the value of the time-intensive activities of child bearing and education. Edu-
cated women are more likely to work; the burden of household work and employment then reduces fertility. Child mortality reduces because educated women are more knowledgeable about nutrition and health care.

Policies to improve female literacy are likely to be more efficient in reducing mortality rates than measures to change the nature of marriage systems or the ingrained discrimination against women. Laws outlawing dowry or arranged marriages for minors, specifying inheritance rights for women, or forbidding the use of ultrasound tests to determine the gender of fetuses have generally proved to be useless in changing century-old habits.

A comparison of correlations for all education variables demonstrates the importance of basic education. Enrollment figures at second and third levels are not as related to FA and illiteracy as variables measuring primary education.

Variables measuring the degree of female participation in the economic activity prove to be much less correlated with FA than education-related variables. Higher levels of female labor participation reduce sex discrimination because they raise the status of women in society, lower dowry levels (and consequently the costs of rearing daughters), and make women more able to resist male pressure to discriminate in favor of boys. However, the education effect seems to be much more important.

Of the world’s male population, 47.04% smokes, versus 11.34% of the female population. Male and female smoking are uncorrelated. There is little variability among male smoking, which leads to a low correlation with FA. The positive relationship between female smoking and FA does not mean that smoking increases life expectancy, but rather that the FA is larger in countries where more women smoke. Social pressures against female smoking exist in countries with a low FA. Higher correlations may have been obtained had we been able to factor in the lag time between smoking and death. Smoking patterns have changed drastically in some countries, but this has yet to affect mortality rates. The 32% smoking rate among males from Singapore represents a decrease from 74% due to legislation introduced in the 1970s. Cigarette consumption in China has increased more than three-fold since the 1950s, which is expected to increase the proportion of deaths due to smoking from 13% in 1987 to about 33% (Pokorski 2000).

The divorce rate shows no correlation with FA, despite the vast body of literature proving that marital status strongly influences survival, with divorced men appearing to be more vulnerable to the disruption of social relationships (Retherford 1975; Trowbridge 1994). Social ties seem to protect people against mortality, and women have more alternative ties outside marriage that they can fall back upon in case of marriage dissolution. The weak relationship may be explained by the fact that many emerging countries do not report a divorce rate and by the heterogeneous cultural approaches toward divorce.

Homicides only account for a small percentage of deaths, which explains the low correlation.

**Religious Variables**

Despite concerns about data quality, summarized in the Appendix, significant correlations appear. Christianity and atheism are more prevalent in countries with a high FA. Hinduism, Buddhism, Islam, and indigenous beliefs are associated with a lower FA, probably a consequence of gender discrimination.

**Health-Care Variables**

Strong correlations with FA are found in this category also, with four variables (the logarithms of the number of persons per doctor and per hospital bed, and the infant and maternal mortality rates) showing a coefficient above 0.5. The index measuring the performance of a country’s health-care system is also very significantly correlated with FA. Health-care quality seems to be a better predictor of the FA than health-care cost.

**Geographic Variables**

Significant positive correlations with FA are found for the developed countries and the former Soviet Union European countries. Africa shows a negative correlation.

4. **Regression Results—No Spatial Correlation in Data**

The literature review suggests that a combination of biologic, social, economic, medical, and behavioral factors, and the interplay between them,
explain the FA. Regression analysis was applied to identify the most significant among the 45 potential variables. This section reports the results of “traditional” ordinary least-squares (OLS) regression, assuming that no spatial correlation is present in the data. The models presented here are not the result of an “automatic” variable selection procedure, such as stepwise regression. Given the high correlations between the potential explanatory variables, our goal was to build a simple, parsimonious regression model, including few highly significant variables while passing diagnostic tests.

The selected regression model contains four variables: the logarithm of the number of persons per physician, the fertility rate, the percentage of people with Hindu or Buddhist beliefs, and the dummy variable representing European countries that belonged to the Soviet Union. The regression equation is

\[
\text{FA} = 9.9042 - 0.4731 \log (\text{persons per physician}) - 0.4444 (\text{fertility}) - 0.0179 (\% \text{of Hindus and Buddhists}) + 4.9218 (\text{Soviet Union dummy}).
\]

Standard errors and \( p \)-values are found in Table 3. Standard errors are low, indicating no or little multicollinearity among selected variables. Re-gressing the squared residuals on the regressors and squared regressors did not show any significant evidence of heteroscedasticity. The multiple correlation coefficient is 0.7815.

With these four variables selected, no other variable is significant at the 1% level. The best fifth variable to include is the percentage of the economic activity due to female labor, but its \( p \)-value stands at 4.06%, and the multiple correlation coefficient only increases from 0.7815 to 0.7881.

Four countries (Afghanistan, Bangladesh, Namibia, and Zimbabwe) exhibit a standardized residual under \(-2\); the FA in these countries is negative or at most \(+0.10\). Three countries, Brazil, Kazakhstan, and Mauritania, show a standardized residual exceeding \(2\). Brazil and Kazakhstan are the only countries out of the former Soviet Union European zone with a FA exceeding 10 years.

Several interaction terms were considered. Female education may help reduce child mortality by enabling women to take better advantage of available medical facilities. Female literacy and availability of doctors and hospital beds could have a synergistic effect. While several interaction terms prove to be mildly correlated with FA, none remains significant after inclusion of the selected variables.

The variable that exhibits the highest \( t \)-statistic is by far the dummy variable characterizing the Eastern European countries than formerly belonged to the Soviet Union. Living in one of these six countries increases the FA by close to five years. None of the other variables recorded in this study explains the dramatic collapse of the male life expectancy in these countries following the demise of communism: the FA exceeds 11 years in these six countries and only in these countries. Alcoholism has been proposed as a major reason for this phenomenon. Other factors commonly mentioned are rapidly declining social and economic conditions, increasing crime and corruption, a deteriorating health-care system, radiation produced by decades of nuclear irresponsibility, and birth defects provoked by environmental disasters.

The variable with the second-highest \( t \)-statistic is fertility, the number of births per woman. The FA increases by 0.44 years for each unit decrease of the number of children. Fertility is highly correlated with most education variables, such as female illiteracy (correlation \(=0.866\)), female school enrollment ratio \((-0.8084\)), maternal mortality \(0.8277\), employment in agriculture \(0.7746\), and even female smoking \((-0.6528\)). It is the best summary measure of the transformations in beliefs and values that result from increased female education and the parallel decrease of employment of women in agriculture. Fertility is also linked to son preference. In areas

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>( p )-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>9.9042</td>
<td>0.7661</td>
<td>0.16%</td>
</tr>
<tr>
<td>LNDOCS</td>
<td>-0.4731</td>
<td>0.1473</td>
<td>0.06</td>
</tr>
<tr>
<td>FERT</td>
<td>-0.4444</td>
<td>0.1278</td>
<td>0.06</td>
</tr>
<tr>
<td>HIND-BUDD</td>
<td>-0.0179</td>
<td>0.0056</td>
<td>0.17</td>
</tr>
<tr>
<td>SOV-UN</td>
<td>4.9218</td>
<td>0.6803</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>
where the education of daughters has little value, they are likely to be married earlier and start childbearing sooner.

The number of persons per physician is also highly significant; it is strongly correlated with many of the variables measuring economic modernization: urbanization (correlation = −0.7269), number of ears (0.7486), percentage working in agriculture (0.8290), and malnutrition (0.7842). It is also correlated with most health-care variables, such as infant mortality (0.7903), maternal mortality (0.8415), and health-care quality index (−0.6974). Therefore we consider the number of persons per physician to be the best variable summarizing not only the quality of a country’s health-care system but also its degree of economic modernization.

Also significant is the percentage of people with Hindu or Buddhist beliefs. There is a strong body of evidence of discrimination against women in countries where these two religions are prevalent. The Indian Medical Association estimates that three million female fetuses are aborted each year after sex-selection sonograms. Estimates of the number of annual female infanticides in India reach several million. Midwives in India earn the equivalent of $0.50 and a sack of grain for each live delivery of a girl, twice as much plus a sari if it is a boy—and 85 to get rid of a newborn female (The Wall Street Journal, May 9, 2000). A comparative study of male and female mortality during childhood by D’Souza and Chen (1980) shows abnormally high death rates among girls living in Bangladesh’s rural areas between the ages of one month and 15 years. Some countries officially recognize son preference; in several Chinese provinces, couples accepting a one-child certificate are compensated by a larger monetary bonus if their child is a daughter; additionally, in some rural areas, couples can have two children if the first is a girl. The maximum penalty for female infanticide is China is only 13 years in prison (Arnold and Zhaoxiang 1986).

The multiple correlation coefficient indicates that over 61% of the variability of the FA can be explained by the four selected variables (this is substantially higher than Preston’s 54.1%). Therefore, this study provides support to the hypothesis that behavior strongly influences differential mortality between males and females. Three of the selected variables are mostly determined by beliefs and family values. The fourth variable is linked to economic development.

**Alternative Models**

A model using the female illiteracy rate instead of the fertility rate is nearly equivalent to the selected model, not surprisingly since the correlation between these two variables is −0.7179. It has the advantage of making the impact of illiteracy on the FA more explicit. The multiple correlation coefficient is nearly identical (0.7829 vs. 0.7815). However, p-values, while still under 1%, are increased.

It does not seem possible to replace the Soviet Union dummy variable by another variable (or more variables) without causing a significant drop in the multiple correlation coefficient. The best variable to replace the Soviet Union dummy seems to be the World Health Organization’s index measuring the overall performance of the health-care system. All six European countries of the former Soviet Union have a poorly performing health-care system. The Russian system, for instance, ranks only 112 in the world, tied with Burkina Fasso and behind countries such as Bangladesh, Iraq, and Yemen. Thus, the health index appears to pick up some of the information contained in the Soviet Union dummy variable. However, the multiple correlation coefficient drops to 0.7065 from 0.7815, and the p-value for this index is 2.62%.

**5. Regression Results, Assuming Spatial Dependence in Data**

Regression analysis is based on the hypothesis that errors are independently distributed. This assumption may not be valid in a cross-sectional study, where the spatial unit of observation (the country, in this case) does not coincide with the spatial extent of the variable under study (son preference or indigenous beliefs, for instance). Countries tend to be surrounded by neighbors exhibiting similar behavior. Therefore, countries that are close together may exhibit correlated residuals, due to the influence of omitted or imperfect variables or unobservable factors that exhibit spatial dependence. For instance, son preference cannot be observed directly: proxy variables need to be used. Unobserved cultural
factors may lead Pakistan, India, and Bangladesh to common approaches to gender bias or fertility. Dietary similarities between Caribbean countries, not captured in the explanatory variables, may impact mortality. When spatial dependence is present, the data contain less information than an uncorrelated counterpart. If specific tests demonstrate significant spatial autocorrelation, this loss of information needs to be explicitly acknowledged in estimation and tests.

An overview of estimation techniques and tests for spatial dependence is provided by Anselin (1988). A consequence of correlation among error terms is that OLS estimators, while unbiased, are inefficient, and estimates of the variance of the estimators are biased. A maximum likelihood (ML) approach is necessary. The traditional $R^2$ is not an appropriate measure of fit; models need to be compared using the maximized log-likelihood or an adjusted form like the Akaike Information Criterion that takes into account the number of parameters in the model.

**First Technique: Specification of a Weight Matrix**

Two methods are commonly used to improve the quality of the estimates and the reliability of tests in the presence of spatial correlation. The first technique consists in modeling the process generating the errors through a weight matrix $W$. The correlation structure of the error terms is then a consequence of the specification of $W$. The model is

$$Y = X\beta + \epsilon,$$

where $\epsilon = \lambda W \epsilon + \xi$. $\epsilon$ is the vector of the correlated error terms, while $\xi$ is a vector of independent error terms, all $N(0, \sigma^2)$. The weight matrix $W$ is defined exogenously by the researcher, in an attempt to specify the interactions between neighbors through the cells of $W$. (As a consequence, all estimates and test results depend on this a priori specification of $W$.)

The simplest approach consists in defining $w_{ij} = 1$ when countries $i$ and $j$ are physical neighbors and $w_{ij} = 0$ otherwise. Rows are usually standardized so that $\sum_i w_{ij} = 1$.

A more sophisticated approach consists in using distances to reflect the fact that correlations among residuals will decline with distance. One possibility is $w_{ij} = 1$, if the distance between the observations $d_{ij} < \delta$, where $\delta$ is a cutoff value. Other models are $w_{ij} = 1/d_{ij}^a$, or $w_{ij} = e^{-|d_{ij}|}$, or $w_{ij} = b_{ij}/b_i$, where $b_{ij}$ is the length of the common border between $i$ and $j$, and $b_i$ is the total border length of $i$.

$\lambda$ is the spatial autoregressive parameter; it measures true contagion between countries, such as diffusion of beliefs. Tests for the null hypothesis $H_0$: $\lambda = 0$ are of paramount importance in spatial data analysis.

Table 4 compares the results of three regression analyses using the weight matrix approach, with the four variables selected in Section 4 as regressors. Columns 2 and 3 provide regression coefficients and $p$-values when no spatial correlation is assumed. Columns 4 and 5 provide regression coefficients and $p$-values when the weight matrix assumes the simplest form $w_{ij} = 1$, when countries $i$ and $j$ share a common border and $w_{ij} = 0$ otherwise, with the coefficients $w_{ij}$ row standardized to reflect the fact that, for instance, China has more influence on Mongolia than Mongolia on China (binary neighbors approach). In columns 6 and 7, the coefficients of the weight matrix are $w_{ij} = b_{ij}/b_i$, i.e., they are based on the length of the common border between $i$ and $j$ (boundary share approach).

For the binary neighbors approach, the esti-

<table>
<thead>
<tr>
<th>Variable</th>
<th>No Spatial Correlation</th>
<th>Binary Neighbors Matrix</th>
<th>Boundary Shares Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coeff.</td>
<td>$P$-Value</td>
<td>Coeff.</td>
</tr>
<tr>
<td>Intercept</td>
<td>9.9042</td>
<td>&lt;0.01</td>
<td>9.7630</td>
</tr>
<tr>
<td>LNDDOCs</td>
<td>-0.4731</td>
<td>0.16%</td>
<td>-0.4833</td>
</tr>
<tr>
<td>FERT</td>
<td>-0.4044</td>
<td>0.06</td>
<td>-0.3984</td>
</tr>
<tr>
<td>HIND-BUDD</td>
<td>-0.0179</td>
<td>0.17</td>
<td>-0.0138</td>
</tr>
<tr>
<td>SOV-UN</td>
<td>4.9218</td>
<td>&lt;0.01</td>
<td>4.3992</td>
</tr>
</tbody>
</table>
mate of $\lambda$ is 0.267. For the boundary shares approach, $\lambda$ is estimated to be 0.0787. In both cases, Moran’s test, the most commonly used test for the null hypothesis $H_0: \lambda = 0$, leads to a rejection of $H_0$ with a $p$-value under 1%: with the four selected variables, the data exhibit significant spatial autocorrelation.

A comparison of the three regressions leads to the conclusion that the variable measuring the percentage of individuals with Hindu or Buddhist beliefs becomes somewhat less significant when spatial autocorrelation is taken into account because its $p$-value increases from 0.15% to more than 1%. The other three variables remain highly significant.

**Second Technique: Specification of Covariance of Error Terms**

The second technique consists in directly specifying a functional form for the covariance matrix of the error terms, rather than modeling the basic diffusion process. Functions are selected in such a way that correlations decrease as the distance between two countries increase. We will assume here that the correlation $\psi_{ij}$ between error terms of any two countries $i$ and $j$ is a power function of the distance between their geographical centers $d_{ij}$:

$$\psi_{ij} = \rho^{d_{ij}},$$

where $\rho$ is a parameter to be estimated. An equivalent formulation is $\psi_{ij} = \exp(-d_{ij}/\theta)$. This particular structure for $\psi_{ij}$ was selected because it leads to better values than other forms on diagnostic tests (log likelihood, Akaike Information Criterion, Schwartz’s Bayesian Criterion). The covariance matrix of the errors is $V = \sigma^2\psi(\rho)$. An ML procedure is used to estimate the regression coefficients and the parameters of the correlation function simultaneously (Dubin 1988): the log likelihood function is maximized with respect to all the parameters ($\beta$, $\sigma^2$, and $\rho$) to obtain the ML estimates. Hypothesis testing is performed using a likelihood ratio test. In our case, the ML estimate of $\rho$ is 0.79912, when the distance unit is one degree. The likelihood ratio test leads to a rejection of the null hypothesis $H_0: \rho = 0$ that there is no spatial autocorrelation in the errors, when the four variables selected in Section 4 are included in the regression model. Table 5 compares ML estimates of regression parameters and $p$-values under the two assumptions: no spatial autocorrelation and positive power correlations between error terms.

The obvious conclusion of Table 5 is that the variable representing Hindu and Buddhist beliefs loses much of its significance when spatial correlation is explicitly acknowledged in the model. All other variables remain highly significant.

Figure 1 presents the observed and theoretical correlogram of residuals, the correlations between errors as a function of the distance, expressed in degrees, between corresponding countries. The acceptable match between the observed and theoretical correlograms somewhat justifies the use of the power function as covariance structure of errors. The match is not good for very short distances. This is due to the fact that the first two points of the observed correlogram are based on very few observations and that these few countries have not enjoyed peaceful relationships. For instance, only five pairs of countries have geographical centers that are within 1.5 degrees of each other. These are: Israel and Jordan (including the West Bank), Rwanda and Burundi, Croatia and Slovenia, Bahrain and Qatar, and Latvia and Lithuania. For the first three pairs, recent “cultural” across-border exchanges have unfortunately not been academic conferences but rather suicide bombers, massacres, and cannon shots.

For these reasons, we believe that the weight matrix approach provides a better representation of this particular spatial autocorrelation than any specification of the error covariance matrix.

**Table 5**

**Comparison of Regression Results, ML Estimates, Power Function Approach**

<table>
<thead>
<tr>
<th>Variable</th>
<th>No Spatial Correlation</th>
<th>Power Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
<td>$p$-Value</td>
</tr>
<tr>
<td>Intercept</td>
<td>9.9042</td>
<td>0.16%</td>
</tr>
<tr>
<td>LNDOSCS</td>
<td>-0.4731</td>
<td>0.06</td>
</tr>
<tr>
<td>FERT</td>
<td>-0.4444</td>
<td>0.17</td>
</tr>
<tr>
<td>HIND-BUDD</td>
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<td>&lt;0.01</td>
</tr>
<tr>
<td>SOV-UN</td>
<td>4.9218</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

6. **Conclusions**

Many events occurred in the twentieth century, concurrently with the increase in the sex mortal-
ity differential: huge declines in deaths from infectious and contagious diseases, declines in family sizes, declines in illiteracy rates, improvements in the status of women, and increased urbanization. As these changes occurred simultaneously, a high degree of multicollinearity between explanatory variables results, which makes it unrealistic to expect a definitive answer to the question, “Is the female advantage a consequence of biological or behavioral causes?”

While biological differences are undeniable, the fact that the sex mortality differential has changed rapidly over time is an indication that they are not the sole reason for the FA. Our regression study, which incorporates data from 169 countries at various stages of development, emphasizes the importance of behavior because three of the four selected variables are based on social/cultural/religious values. Our fourth selected variable summarizes the degree of economic modernization of a country. If no spatial correlation is assumed, the four variables that are unrelated to biological differences explain over 61% of the variability of the FA, a strong support of the behavioral hypothesis. This conclusion is somewhat weakened when the presence of spatial autocorrelation of errors is incorporated in the model because one of the four variables, representing Hindu and Buddhist beliefs, loses some of its significance.

**APPENDIX: DEFINITION OF VARIABLES AND COMMENTS**

Data on the possible causes of the FA were collected from 169 countries. In this Appendix, all variables are defined and summary statistics are provided, as well as correlation coefficients with FA. Tables provide unweighted means, standard deviations, skewness coefficients, and correlations with FA, as well as population-weighted means. All sources of data are provided. The Appendix concludes with comments on data quality.

**Sources of Data**

Most of the data have been extracted from the Encyclopedia Britannica’s Book of the Year 2000. Britannica collects data from a variety of sources: UNESCO for literacy estimates, the World Health Report of the WHO for infant mortality, the Human Development Report from the United Nations’ Development Program for maternal mortality, the World Bank’s World Development Report for health-care cost variables, and the FAO for calorie requirements.

Other sources of data have been used for some variables:

- The World Bank Atlas and Development Indicators for variables 2, 3, 4, 8, 17, 18, and 37.
- The United Nations’ Office for Drug Control and Crime Prevention for variable 25.
- The Central Intelligence Agency’s World Fact Book was considered for the religious variables, but deemed to be less reliable than Britannica.

**Dependent Variable**

FA. Female Advantage (life expectancy difference between females and males, in years).

**Variables Measuring the Degree of Economic Modernization**

1. URBAN. Percentage of population living in urban areas. Areas are classified as rural or urban according to the predominant economic activity, “urban” referring to an economy consisting of largely nonagricultural pursuits.
2. PPP. Gross National Product per capita, converted to international dollars using purchasing power parity rates. An international dollar has the same purchasing power as $1 U.S. in the United States.
3. GDP. Gross Domestic Product per capita.
4. GDP-SER. Percentage of GDP from the services sector.
5. LNCARS. Log(persons per car).
6. CAL. Daily per capita calorie intake (calories equivalent to the average daily supply of foodstuffs for human consumption divided by population).
7. FOOD%. Percentage difference between daily per capita calorie intake and requirements. The FAO determines the calories needed to sustain a person at normal levels of activity and health, as a function of age and sex distributions, average body weights, and environmental temperatures. The variable expresses, as a percentage, the difference (positive or negative) between actual and required intake.
8. MALNUT. Percentage of malnutrition among children under the age of five.
9. AGRI. Percentage of economically active females working in agriculture. The economically active population comprises all persons who furnish the supply of labor for the production of economic goods and services. Students, retired persons, and individuals occupied solely in household work are generally excluded.
10. WATER. Percentage of individuals who have access to safe water.

**Social, Cultural, Religious Variables**

11. SMOKM. Percentage of smokers in the male population age 15 and higher.
12. SMOKW. Percentage of smokers in the female population age 15 and higher.
13. ILW. Illiteracy rate (%) for women above the age of 15 (using each country’s own definition of literacy).
14. ILM. Illiteracy rate (%) for men above 15.
15. ENROLW. Enrollment ratio for women. Total school enrollment at first and second levels, using each country’s own definition of levels, divided by the population of the corresponding age groups.
16. ENROLM. Enrollment ratio for men.
17. SCHOOLM. Expected number of years of education for males.

**Table A1**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unweighted Mean</th>
<th>Weighted Mean</th>
<th>Standard Deviation</th>
<th>Skewness</th>
<th>Corr. with FA</th>
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<tbody>
<tr>
<td>FA</td>
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<td>4.51</td>
<td>2.51</td>
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<td>URBAN</td>
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<td>PPP</td>
<td>6,497.8</td>
<td>6,259.4</td>
<td>7,778.68</td>
<td>1.53</td>
<td>0.6360</td>
</tr>
<tr>
<td>GDP</td>
<td>6,975.8</td>
<td>6,379.9</td>
<td>7,708.30</td>
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<td>0.2631</td>
</tr>
<tr>
<td>GDP-SER</td>
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<td>14.91</td>
<td>0.05</td>
<td>0.3800</td>
</tr>
<tr>
<td>LNCARS</td>
<td>3.33</td>
<td>4.22</td>
<td>1.81</td>
<td>0.30</td>
<td>0.5147</td>
</tr>
<tr>
<td>CAL</td>
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</tr>
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<td>FOOD%</td>
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<td>17.99</td>
<td>12.04</td>
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<td>0.1392</td>
</tr>
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<td>0.6360</td>
</tr>
<tr>
<td>AGRI</td>
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<td>51.54</td>
<td>33.65</td>
<td>0.43</td>
<td>0.6325</td>
</tr>
<tr>
<td>WATER</td>
<td>71.66</td>
<td>77.01</td>
<td>22.92</td>
<td>-0.46</td>
<td>0.3675</td>
</tr>
</tbody>
</table>
18. SCHOOLW. Expected number of years of education for females.
19. LEVEL2. Females per 100 males enrolled, second educational level.
20. LEVEL3. Females per 100 males enrolled, third level.
21. LABOR. Females as a percentage of the labor force.
22. FEMSERV. Female contribution to the service industry, measured by percentage of working females in the service industry divided by percentage of GDP from the service sector.
23. ECOACT. Percentage of economic activity due to female labor.
24. FERT. Fertility. Number of children per childbearing woman (sum of the current age-specific birth rates for each of the child-bearing years, usually 15–49).
25. HOM. Homicide Rate. Number of homicides per 100,000 population.
26. DIV. Divorce rate. Number of legal, civilly recognized divorces annually per 1,000 population.
27. ISLAM. Percentage of Muslims. Assessed religious affiliation divided by mid-year population of the country.
28. CHRIS. Percentage of Christians.
29. BUDD. Percentage of Buddhists.
30. HIND. Percentage of Hindus.
31. INDIG. Percentage of people with indigenous beliefs, Africa.
32. NON-REL. Percentage of atheists, agnostics, and people affiliated with another religion.

### Variables Measuring the Quality of Health Care

33. HEALTH. Health-care expenses, as a percentage of GDP.
34. COSTHC. Log (cost of health care per capita, in international dollars).
35. LNDOSCS. Log(persons per physician).
36. LNBEDS. Log(persons per hospital bed).
37. DPT. Percentage of children under age one immunized by vaccination against diphtheria, pertussis, and tetanus.
38. INFMOR. Infant mortality rate. Number of children per 1,000 live births who die before their first birthday.
39. MATMOR. Log(maternal mortality rate). Deaths per 100,000 live births attributable to delivery or complications from pregnancy, childbirth, the period immediately following birth, or abortion.
40. INDEX. Index measuring the overall performance of the health-care system. Since 2000, the World Health Organization defines an index that attempts to measure the overall performance of national health-care systems, by evaluating how efficiently systems translate

### Table A2

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unweighted Mean</th>
<th>Weighted Mean</th>
<th>Standard Deviation</th>
<th>Skewness</th>
<th>Corr. with FA</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMOKM</td>
<td>41.76</td>
<td>47.04</td>
<td>11.46</td>
<td>0.46</td>
<td>0.1417</td>
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<td>SMOKW</td>
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<td>9.87</td>
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<td>ILW</td>
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<td>32.40</td>
<td>27.66</td>
<td>0.74</td>
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<td>17.56</td>
<td>18.02</td>
<td>19.00</td>
<td>1.34</td>
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<td>74.55</td>
<td>74.94</td>
<td>26.56</td>
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<td>21.18</td>
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<td>11.42</td>
<td>12.69</td>
<td>3.07</td>
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</tr>
<tr>
<td>SCHOOLW</td>
<td>11.27</td>
<td>12.37</td>
<td>3.50</td>
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</tr>
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<td>LEVEL2</td>
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<td>79.58</td>
<td>23.09</td>
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</tr>
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<td>LEVEL3</td>
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<td>77.60</td>
<td>57.42</td>
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<td>0.2789</td>
</tr>
<tr>
<td>LABOR</td>
<td>39.62</td>
<td>39.41</td>
<td>8.08</td>
<td>-0.98</td>
<td>0.2515</td>
</tr>
<tr>
<td>FEMSERV</td>
<td>88.67</td>
<td>65.47</td>
<td>51.90</td>
<td>0.38</td>
<td>0.3924</td>
</tr>
<tr>
<td>ECOACT</td>
<td>51.52</td>
<td>54.16</td>
<td>15.56</td>
<td>0.01</td>
<td>-0.0884</td>
</tr>
<tr>
<td>FERT</td>
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<td>2.82</td>
<td>1.79</td>
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<td>-0.6348</td>
</tr>
<tr>
<td>HOM</td>
<td>3,058.3</td>
<td>34,329*</td>
<td>10,289.5</td>
<td>5.85</td>
<td>-0.1543</td>
</tr>
<tr>
<td>DIV</td>
<td>2.06</td>
<td>1.61</td>
<td>3.12</td>
<td>5.12</td>
<td>0.0924</td>
</tr>
</tbody>
</table>

*The enormous difference between weighted and unweighted homicide rates is nearly exclusively due to India and the United States (and the fact that the value is missing for some populous countries, including China).
expenditures into health. The complex scoring procedure is outlined in the Statistical Annex of the World Health Report. The report has led to much controversy in the United States because this country only ranks 37th in the world. Yet a statistical proof of the validity of the index is that it exhibits a correlation of 0.85 with life expectancy!

Geographical Dummy Variables
41. ASIA. Dummy variable for the Asia and Pacific regions.
42. AFRICA. Dummy variable for Africa.
43. LA-CAR. Dummy variable for Latin America and the Caribbean.
44. DEV. Dummy variable for Europe, North America, Israel, Australia, and New Zealand.
45. SOV-UN. Dummy variable for the six former Soviet Union European countries: Belarus, Estonia, Latvia, Lithuania, Russia, and Ukraine.

Comments on Data Quality
Any international comparison performed at the country level disregards differences within each country. Some variables can show wide variations within large countries. For instance, India exhibits striking diversity. Gender discrimination is much more prevalent in the northern part of the country than in the south. The southern state of Kerala has features that are typical of a middle-income country: a life expectancy of 72 years, an infant mortality rate of 17 per thousand, fertility (1.8 births per woman) under replacement level, and a female/male ratio above unity (1.04). In the northern state of Uttar Pradesh, the infant mortality rate is six times as high as in Kerala, the fertility is 5.1 births per woman, and the female/male ratio is the lowest in the world, 0.88 (Murthi, Guio, and Drèze 1995).

The variables describing religious beliefs are subject to the most uncertainties. For instance, the CIA reports that Bulgaria is 86% Christian, while Britannica says it is 39%. Britannica assesses religious affiliation for each country on the best available figures, whether from census data, church membership figures, or estimates by external analysts. All of these techniques are subject to much criticism. Census methods usually include non-practicing individuals in a religion and assign to children the religion of their parents (this distorts percentages in countries where religion is fast disappearing). Church membership figures rely on baptismal certificates that do not specify the current nature of the individual’s beliefs: the individual may have lapsed, joined another religion, or become an atheist. The social context of religion also varies much: statistics from a country with a long-standing dominant religion will often show affiliations in excess of 90%, while only 10% of the population actually practices on a regular basis. This leads to under-

<table>
<thead>
<tr>
<th>Variable</th>
<th>Percentage of World Population</th>
<th>Correlation with FA</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISLAM</td>
<td>21.00%</td>
<td>-0.2382</td>
</tr>
<tr>
<td>CHRIS</td>
<td>28.70</td>
<td>0.2674</td>
</tr>
<tr>
<td>BUDH</td>
<td>6.91</td>
<td>-0.1375</td>
</tr>
<tr>
<td>HIND</td>
<td>14.49</td>
<td>-0.1593</td>
</tr>
<tr>
<td>INDIG</td>
<td>2.13</td>
<td>-0.2825</td>
</tr>
<tr>
<td>NON-REL</td>
<td>26.78</td>
<td>0.4004</td>
</tr>
</tbody>
</table>

Table A3
Summary Statistics and Correlation with FA: Religious Variables

Table A4
Summary Statistics and Correlation with FA: Variables Measuring the Quality of Health Care
counting of minority religions and possible manipulation by governments (particularly in communist countries, at least until 1989). After numerous interviews with international students of the University of Pennsylvania, we decided that the data from Britannica appear to be more reliable than the CIA data.

A number of variables—including most of the educational variables—may exhibit some inconsistency from country to country. There is no international standardization in the definition of literacy, for instance. In many countries the ability to read and write a language with some degree of competence is defined by the national census and tested by census enumerators, leaving room for subjectivity. Similarly, there is no international consensus on the definition of a first level of education.

There are numerous country discrepancies in the definition of many variables. For instance, the economically active population may or may not include armed forces or inmates of institutions. Each country has its own definition of what constitutes an “urban” area, which may depend on the population of a township, or upon factors like employment, administrative status, or density of housing. School enrollment figures may or may not include children who are withdrawn seasonally to participate in agricultural work. Or the variable measuring access to water is defined as the proportion of persons having “reasonable” access to an “adequate” supply of water within a “convenient” distance of the dwelling. Water is considered safe if the chemicals and biological pollutants it contains are not sufficient to cause “immediate” health problems, with each concept interpreted locally.

Table A5
Summary Statistics and Correlation with FA: Geographical Dummy Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Percentage of World Population</th>
<th>Corr. with FA</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASIA</td>
<td>60.82%</td>
<td>-0.1517</td>
</tr>
<tr>
<td>AFRICA</td>
<td>12.97</td>
<td>-0.4010</td>
</tr>
<tr>
<td>LA-CAR</td>
<td>8.41</td>
<td>0.1229</td>
</tr>
<tr>
<td>DEV</td>
<td>17.79</td>
<td>0.4817</td>
</tr>
<tr>
<td>SOV-UN</td>
<td>3.60</td>
<td>0.5130</td>
</tr>
</tbody>
</table>

References


Discussions on this paper can be submitted until April 1, 2003. The author reserves the right to reply to any discussion. Please see the Submission Guidelines for Authors on the inside back cover for instructions on the submission of discussions.