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Human Capital and Economic Development

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Abstract: This paper develops a general equilibrium model of fertility and human capital investment with young adult mortality. Parents maximize expected utility producing a precautionary demand for children. Because young adult mortality is negatively related to average young adult human capital, human capital accumulation lowers mortality, inducing a demographic transition and an industrial revolution. Data confirm the model prediction that young adult mortality affects human capital investments. The model prediction of a positive relationship between infant mortality and young adult mortality is confirmed. Further, the data indicate a negative relationship between total factor productivity growth and accumulation of schooling. The model fits the data on world and country populations, per capita incomes, age at entry into the labor force, total fertility rates, infant mortality, life expectancy, and conditional life expectancy.

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HUMAN CAPITAL AND ECONOMIC DEVELOPMENT

INTRODUCTION

This paper develops a general equilibrium model of fertility and human capital investment choice under uncertainty. Uncertainty exists because not all young adults survive to old age.[1] Parents maximize expected utility arising from their own consumption, their fertility and the discounted utility of their children. Expected utility maximization produces precautionary fertility demand. Fertility depends positively on the probability of an early death, or a young adult death. Because human capital investments are made prior to the realization of survival from young adult to old adult, higher young adult mortality, by increasing the number of children born, reduces human capital investment in each child. This is the standard Becker and Lewis (1973) interaction of quality and quantity of children. If young adult mortality depends on the average human capital of young adults, then an endogenous demographic transition occurs. The economy evolves from high mortality, high fertility, slow human capital accumulation, and slow (if any) economic growth to low mortality, low fertility, rapid human capital accumulation and rapid economic growth. Human capital accumulation reduces young adult mortality, which in turn induces lower fertility. Lower fertility reduces the cost of human capital investment, and thus parents increase their human capital investments per child. This leads to a virtuous cycle in which human capital growth leads to lower fertility and more rapid human capital growth. Of course there exists a limit to the cycle, since young adult mortality is bounded below by zero.

This paper makes three fundamental contributions: (1) it derives and analyzes a general equilibrium model of fertility and human capital accumulation with an expected dynastic utility function, (2) it estimates a structural model of young adult mortality and empirically evaluates the model, further it provides evidence on a complementary model developed by Galor (2004) of the rising demand for education arising from technological progress, and (3) it numerically solves the model and provides goodness of fit tests of the solution to historical data on population, income per capita, total fertility rates, age at entry into the labor force, infant mortality, life expectation and conditional life

[1] In the empirical work I consider young adult mortality to be measured as the probability of dying between the ages of 1 and X, where X varies from 25 to 55. This specification clearly lumps child deaths with young adult deaths, see Hazan and Zoabi (2004) for the importance of this. However the model assumes all human capital investments are made before survival is known. The data clearly has partial human capital investment. I thank an anonymous referee for making this explicit.

expectation for 28 countries and regions.[2]

Reductions in young adult mortality through increases in the human capital of young adults occurs on many levels. When a mother teaches her child to wash her hands before preparing and eating food, her mortality risk is lowered. Thus higher own human capital lowers an individual's young adult mortality risk. A community that separates drinking water from waste water and collects garbage for disposal lowers young adult mortality risk as well, c.f. Melosi (2000). Hence higher average human capital in a community reduces young adult mortality risk. If any society discovers antibiotics and vaccines for immunization against disease, then all societies can benefit from these discoveries, c.f. Haines (2002). This body of knowledge, modeled as the maximum human capital in the world, lowers young adult mortality risk.

In the empirical section I estimate the relationship between young adult mortality and young adult human capital. The estimates are consistent with the model specification. The model predicts that young adult mortality affects parental investments in their children's human capital, but infant mortality and middle age mortality do not. The model also predicts that infant mortality and young adult mortality positively effect fertility. Empirically three of the model's predictions are confirmed, only the strong negative relationship between infant mortality and human capital investment rejects the predicted insignificant relationship. I present detailed goodness of fit tests that verify that the model explains the long transition from a classical Malthusian economy to modern economic growth via a demographic transition. This is done by not only matching the two different development regimes, but picking up the timing of the Demographic Transition for 28 countries and regions. Consistent with the data, the preferred model contains human capital spillovers in both the accumulation technology and in the young adult mortality function.[3]

This paper is complementary to the recent work on long run development by Doepke (2004), Galor and Weil (2000), Galor and Moav (2002), Hansen and Prescott (2002), Jones (2001) Kalemli-Ozcan (2002,2003), Lagerlöf (2003), Weisdorf (2004) and Tamura (2002).[4] These papers examine various aspects of long run development including demographic transitions into modern sustained growth.

[2] The preferred model fits almost 3500 observations.

[3] The careful reader will note that I identify poor countries or regions with current levels of income. Certainly some of these regions were at times richer than the rich countries. For example, parts of Latin America, China and India were at times richer than Western European countries, Japan and Korea and the early settlers of North America, Australia and New Zealand. Acemoglu, Johnson and Robinson (2002) and Maddison (2001) present convincing evidence on this point. I show that the model solutions do support the Acemoglu, et al (2002) hypothesis of reversal of fortune.

[4] For an outstanding summary of current research see Galor (2004).

Doepke (2004) blends Hansen and Prescott (2002) with Becker and Barro (1988) and allows for differential human capital investments in children. He uses this model in quantitative exercises to show that policy interventions such as child labor restrictions are much more likely to induce a demographic transition to economic growth than educational subsidies. Galor and Weil (2000) examine the switch from a subsistence economy to a classical economy characterized by a Malthusian relationship between living standards and population growth, until human capital accumulation accelerates the evolution through a demographic transition into modern growth. In their model rising population increases the rate of return to human capital investment inducing a demographic transition. In Galor and Moav (2002) natural selection pressures eventually favors parents that care the most about human capital investment. They are the first group to increase population via the Malthusian positive relationship between income and fertility, but they also invest more in the human capital of their children. With a spillover of human capital, eventually all members of society will choose to switch to human capital investment and lower levels of fertility. Hansen and Prescott (2002) examine a model with two technologies: an agricultural technology (classical technology), with constant returns to scale in capital, labor and a fixed factor, land, and a second technology (neoclassical technology) with constant returns to scale in capital and labor. Both technologies have exogenous technological growth. Eventually the neoclassical technology becomes more productive than the classical technology causing a switch from the classical technology to the neoclassical technology. Jones (2001) modifies the model of Kremer (1993b) by introducing mortality. Faced with high mortality parents choose high levels of fertility. Economic growth raises consumption, which lowers mortality. Population growth allows for idea creation, which raises productivity. However it is not until the last few centuries that living standards have risen indicating that population reached a size large enough to accelerate the creation of new ideas sufficient to offset the lower the amount of land per person.[5] Kalemli-Ozcan (2002,2003) develops a model of expected utility to produce a precautionary demand for children.[6] Similar to the model of Jones (2001), rising consumption induces a decline in mortality, which causes an increase in human capital investment per child and a reduction in fertility. Lagerlöf (2003) develops a model with mortality and epidemics. A high mortality regime has a high probability of epidemics. Human capital lowers the death risk,

[5] Jones (2001) still requires an exogenous increase in the productivity of population in producing ideas during the last few centuries to produce this result. A feature that also exists in this paper's model. This is consistent with improved private property right enforcement, see North (1981), Rosenberg and Birdzell (1986).

[6] Eckstein, Mira and Wolpin (1999) show that mortality decline played a role in the Demographic Transition in Sweden.

but greater population density raises the probability of dying. There is exogenous technological progress that leads to a demographic transition toward lower mortality, weaker epidemics, and lower fertility and greater investment in human capital. Wesidorf (2004) modifies Galor and Weil (2000) by introducing child mortality. Child mortality is inversely related to parental living standards. An exogenous shock to technology which raises the return to human capital accumulation, as well as productivity induces a "mortality revolution" and is succeeded by a Demographic Transition. Finally Tamura (2002) uses a model of perpetual human capital accumulation to analyze the switch from a classical technology to a constant returns to scale endogenous growth technology. For low levels of human capital the classical technology with the fixed factor land is more productive than the modern technology. However perpetual human capital investment eventually raises the productivity of the modern technology above the classical technology. Upon the switch, population growth and human capital accumulation accelerates.

In this paper human capital accumulation is the engine of development. Young adult mortality is negatively related to young adult human capital. Perpetual accumulation lowers mortality risk, causing the precautionary demand for children to disappear, and results in a demographic transition to modern growth.[7] The model therefore does not require exogenous technological progress as in Hansen and Prescott (2002), or Lagerlöf (2003) to induce the switch from a classical economy to a modern economy. Falling mortality arises from human capital accumulation, not rising living standards as in Kalemli-Ozcan (2002,2003) and Jones (2001). In Galor and Weil (2000) and Galor and Moav (2002) rising rates of technological progress raises the return to human capital accumulation and hence increases the demand for human capital investment. In the former rising population raises the return to human capital investment, and in the latter the changing composition of the population raises the returns to human capital investment.

The paper conducts a data fitting or model calibration exercise motivated by the innovative work of Jones (2001). Jones (2001) develops a model with 19 parameters, and some "exogenous shocks" to

[7] The model here is complementary to Meltzer (1996). In his model rising adult longevity directly raises the rate of return to human capital accumulation and induces the switch from child quantity to child quality. His mechanism was also identified in Nerlove (1974), Ehrlich and Lui (1991) and Cervellati and Sunde (2002). However Hazan and Zoabi (2004) argue that rising longevity raises the return proportionally for all levels of education and hence does not affect human capital investments. They argue that rising levels of early health capital enhanced human capital investment and induced the transition from stagnation to growth. Here young adult mortality is measured as the probability of dying between ages 1 and X, where $25 \leq X \leq 55$. The probability of dying during the early years captures much of the Hazan and Zoabi effect.

fit world population history and average per capita consumption as well as the relationship between consumption and mortality for 25000 BC to 2000 AD. All told his model fits about 50 different data points.[8] Unlike the model here, his model is not designed to fit the differential individual behavior of population, per capita income, total fertility rates, age at entry into the labor force, infant mortality, life expectation at birth and life expectation at entry into the labor force for 28 different countries or regions. The model of this paper with 26 parameters is able to fit almost 3500 observations.[9] The goodness of fit test that the model is subjected to is novel to this paper. Recent work by Doepke (2005) and Fernandez-Villaverde (2001) argue that reductions in mortality cannot explain the fall in fertility. Dopeke (2005) does not allow for changes in human capital investment, and Fernandez-Villaverde (2001) emphasizes capital specific technological change and capital skill complementarity.

The next section specifies preferences and technologies for output production and human capital production. I illustrate the connection between high fertility, arising from a precautionary demand for children, and slow human capital accumulation. With declining young adult mortality the precautionary demand for children falls and human capital accumulation accelerates. In Section 2 the model is solved numerically and calibrated to fit world population from 25000 BC to 2000 AD, as well as rich world population from 1 AD to 2000 AD using the method of Jones (2001). Section 3 empirically evaluates the model. I estimate the relationship between young adult mortality and young adult human capital and potential international spillovers. I show that the model's functional form is consistent with the data. I confirm the model's prediction that young adult mortality affects parental investment in human capital, while middle age mortality is much more weakly associated with human capital accumulation. However the prediction that young adult human capital is independent of infant mortality is rejected. The model's predictions regarding fertility are confirmed: fertility is positively related to infant mortality and young adult mortality. Finally I calibrate the model so that the numerical solutions fit world population and the population of the rich countries, life expectation from 1800 and infant mortality from 1850. I evaluate the model's fit with the historical evidence on population, per capita income, age at entry into the labor force, total fertility rates, life expectancy at birth, life expectancy at age of entry into the labor force

[8] It is true in Jones (2001) that the number of parameters and the number of shocks is roughly the same as the number of observations. This is not the case with my model, because I exploit the panel information and not just the world aggregates. Using 70 degrees of freedom, the model fits almost 3500 observations.

[9] The difference between the 26 parameter figure and 70 degrees of freedom are: (1) exogenous population shocks to rich (18) and poor (13) regions, and (2) 12 different values of aglommeration returns to specialization.

and infant mortality for 22 rich countries and 6 poor "countries." Section 4 presents the predictions of the model for the world income distribution from 2000 onward. Section 5 concludes.

1. MODEL

The typical person lives two periods, young and old.[10] While young a girl passively receives investment in her human capital from her mother. As a woman she chooses her consumption, fertility and human capital investment per child. A mother receives utility from her own consumption and the expected utility from the infinitely lived dynasty. The expectation arises because there is mortality, and not all girls live to become a mother. Mothers have expected utility concerning surviving children, and expected utility from the infinitely lived dynasty. Therefore preferences are given by:

$$U\left(h_t\right) = \max_{\{n_i, h_{i+1}\}_{i=t}^{\infty}} E_t \left\{ \sum_{i=t}^{\infty} \beta^{i-t} \left\{ \alpha \ln \widetilde{c}_t + (1-\alpha) \ln \widetilde{n}_t \right\} \right\}, \tag{1}$$

where $\widetilde{c}_t$ is the consumption of a mother in time period t, and $\widetilde{n}_t$ is the number of her surviving children at time t; the mathematical expectation is taken with respect to the information available to the mother at time t. The information available to the mother is the mortality rate of young women, the fraction of girls that will die before motherhood, δ_t. The mortality of young women strikes after all human capital investment has been made.[11] Future consumption is random because output is produced with land, and with random population, land per person is random. Mothers choose fertility, human capital investment per child and their own adult consumption. Their choice of human capital for the next generation induces their daughters to choose their fertility and human capital investment per child and their adult consumption as if their mothers chose it for them. In this way a dynastic mother "commits" her progeny to maximizing dynastic utility.

I assume mortality of a young adult is a function of her human capital, the average human capital in the population and potentially the minimum young adult mortality in the world. The latter two arguments represent two types of externalities from human capital, one at the national level and one at the international level. Let h_{it+1} be the human capital of a young woman born in period t in country i, $\overline{h}_{it+1}$ is the average human capital of young women born in period t in country i and $\overline{\overline{h}}_{t+1}$ is the maximum human capital in the world. The probability that a girl born in period t in

[10] Reproduction is asexual. I will refer to all individuals as females.

[11] Thus mortality raises the cost of human capital investment since a parent does not know which child, if any, will die before reaching adulthood.

country i dies before becoming a young woman is given by:

$$\delta_{it} = \Delta \exp\left(\varphi\gamma_1 \overline{\overline{h}}_{t+1}^{\gamma_2} + (1-\varphi)\left[\zeta\gamma_1 h_{it+1}^{\gamma_2} + (1-\zeta)\gamma_1 \overline{h}_{it+1}^{\gamma_2}\right]\right) \tag{2}$$

where $\gamma_1 < 0, \gamma_2 > 0, 0 \leq \zeta \leq 1, 0 \leq \varphi \leq 1, \Delta > 0$.[12] A daughter, having been taught by her mother or teacher or doctor, who knows to wash her hands after going to the bathroom, and before preparing and eating food lowers her risk of disease. This is an example of the direct effect of *own* human capital on young adult mortality, h_{it+1}. Community spending to keep sewage separate from the drinking water or organizing garbage collection and disposal are examples of the *aggregate effect* from average human capital in a country, $\overline{h}_{it+1}$. The development of vaccines for immunization anywhere in the world and available outside of the country of discovery is an example of the *international spillover* from $\overline{\overline{h}}_{t+1}$.[13] Thus a mother's human capital stock only matters to the extent that it determines the human capital stock of her daughter. Rising average human capital causes falling young woman mortality rates. If average human capital accumulates without bound, then young woman mortality goes to zero.

A dynastic mother chooses fertility, and a fixed proportion survive to motherhood. I assume that a law of large numbers applies for each dynasty.[14] Let x_t be the number of infants per mother. The number of children surviving to old age in t+1 is given by:

$$\widetilde{n}_t = x_t (1 - \delta_t) \tag{3}$$

Population of the dynasty grows if the number of surviving daughters per household surviving into

[12] In equilibrium all individuals within a country are identical, hence $h_{it+1} = \overline{h}_{it+1}$, and young adult mortality is given by:

$$\delta_{it} = \Delta \exp\left(\varphi\gamma_1 \overline{\overline{h}}_{t+1}^{\gamma_2} + (1-\varphi)\gamma_1 \overline{h}_{it+1}^{\gamma_2}\right)$$

A more detailed model would allow for the international spillover to depend on the connectedness or closeness of country i to the leader. If the leader and i are trading partners, geographic neighbors, etc., one would expect greater spillovers than if they had little contact.

[13] See Melosi (2000) for a history of urban sanitation in the United States as well as the importance of Edwin Chadwick of England for the idea of urban sanitation in the United States.

[14] Since a mother does not know which of her daughters will survive, she makes human capital investment in each daughter knowing that some will not survive. I ignore the possibility of specialized human capital investment as in Tamura and Sadler (2002). The assumption that the law of large numbers applies to each dynasty has no effect on this choice. The expected utility formulation here, taken from Kalemli-Ozcan (2002), is an approximation to the binomial distribution of survival outcomes facing a mother. A mother will choose the same investment for each daughter and ignoring different survival realizations across families only effects the distribution of land holdings not human capital. Per capita income is negligibly affected by this assumption.

their old age exceeds one. The law of motion of dynastic population is given by:

$$p_{t+1} = p_t x_t (1 - \delta_t) \tag{4}$$

A country is made up of identical dynasties, and each dynasty within a country chooses the same human capital investment and fertility. Therefore a country's population at time t is the dynastic population times the number of initial dynasties.

Household output is produced by combining the mother's land with market goods produced via specialization of labor.[15] An adult at t produces output given by:

$$y_t = Z_t \left(\frac{L}{p_t}\right)^{\sigma} h_t^{1-\sigma}, \tag{5}$$

where $\frac{L}{p_t}$ is the land per mother in the dynasty,[16] h_t is the human capital of the typical person in the economy, and as in McDermott (2002) and Tamura (2002) the intermediate market goods produced via specialization is reflected by Z_t, Total Factor Productivity, TFP.[17] To the typical person the level of TFP, Z_t, is taken as given.

A woman chooses how many children to have and how much time is spent educating her daughters. Each child takes θ units of time to rear. A mother chooses education time, τ_t, per child. Therefore the typical mother faces the following budget constraint:

$$c_t = y_t \left[1 - x_t (\theta + \tau_t)\right], \tag{6}$$

where x_t is the number of children that survive infancy.[18]

As in Tamura (1991, 1996) in order to allow for diffusion of the Industrial Revolution, I assume human capital accumulation across generations is given by:

$$h_{t+1} = A\overline{\overline{h}}_t^{\varepsilon} h_t^{1-\varepsilon} \tau_t^{\rho} \tag{7}$$

[15] In the year $t = 0$ I assume that each household receives the same amount of land. For all $t > 0$, the land holdings per dynasty are given by their own level of surviving fertility.

[16] In the numerical solution I assume that the intial land holdings for each mother of the 22 "rich countries" and the 6 "poor countries" are $\frac{L_{rich}}{P_{rich}}$ and $\frac{L_{poor}}{P_{poor}}$, where L_i is the arable land for each region and P_i is total population of each region, $i = rich, poor$. In 2000, there is only a trivial difference between arable land per person in the rich region compared to the poor region.

[17] I introduce Z_t in order to capture the accelerating rate of growth of per capita income even though human capital grows at a constant rate after the transition from the stagnant Malthusian classical world to the dynamic modern growth world. See Appendix A and Tamura (2002) for more details about this aglommeration economy from specialization.

[18] In the numerical solutions I will introduce infant mortality, m. As with young adult mortality, it will have a logistic functional form. I assume that infants who die impose no rearing time cost, their births are costless, and are immediately replaced, therefore $tfr = 2x/(1 - m)$.

where $0 \leq \varepsilon < 1, \rho > 0$, and $\overline{\overline{h}}_t = \max\{h_{it}\}$.

Following the seminal work of Kalemli-Ozcan (2002,2003), I approximate the expected utility function by using the Delta method, see Appendix B for details. Ignoring terms not including current choice variables, preferences are given by:[19]

$$\max_{x_t,\tau_t} \left\{ \begin{array}{l} \alpha \ln y_t + \alpha \ln\left[1 - x_t\left(\theta + \tau_t\right)\right] + \left(1 - \alpha - \dfrac{\alpha\beta\sigma}{1-\beta}\right) \ln x_t + (1-\alpha)\ln\left(1 - \delta_t\right) \\ -\dfrac{\left(1 - \alpha - \dfrac{\alpha\beta\sigma}{1-\beta}\right)\delta_t}{2x_t\left(1-\delta_t\right)} + \beta\alpha(1-\sigma)\ln h_{t+1} + \beta\alpha\ln\left[1 - x_{t+1}\left(\theta + \tau_{t+1}\right)\right] \end{array} \right\} \tag{8}$$

The first order conditions determining optimal fertility and optimal human capital investment are given by:

$$\frac{\alpha(\theta+\tau_t)}{1 - x_t\left(\theta+\tau_t\right)} = \frac{1 - \alpha - \frac{\alpha\beta\sigma}{1-\beta}}{x_t} + \frac{(1 - \alpha - \frac{\alpha\beta\sigma}{1-\beta})\delta_t}{2x_t^2(1-\delta_t)} \tag{9}$$

$$\frac{\alpha x_t \tau_t}{1 - x_t\left(\theta+\tau_t\right)} = \beta\alpha\rho(1-\sigma) + \frac{\beta\alpha x_{t+1}\tau_{t+1}\left(1-\varepsilon\right)}{1 - x_{t+1}\left(\theta+\tau_{t+1}\right)} + \Psi_{t+1} \tag{10}$$

where

$$\Psi_{t+1} = \frac{\rho\left(1-\varphi\right)\zeta\gamma_1\gamma_2\delta_t}{1-\delta_t}\left(1 - \alpha + \frac{(1 - \alpha - \frac{\alpha\beta\sigma}{1-\beta})}{2(1-\delta_t)x_t}\right) h_{t+1}^{\gamma_2}$$

Notice that from (9) the first order condition for fertility depends on the mortality rate of young women, δ_t. The introduction of expected utility produces the precautionary demand for children, otherwise the Euler condition would contain only the first term of the right hand side of (9). If human capital directly affects the probability of surviving young adulthood, $\zeta > 0$, then parents increase their investments in their children's human capital relative to the direct benefit of higher productivity. As human capital accumulates over time, young adult mortality goes to 0, and, given the functional form of young woman mortality, the second right hand side term in (9) as well as Ψ_{t+1} in (10) vanish.

[19] Although a parent cares about the expected utility of the entire dynasty, she only can affect this by her choice of human capital investment. Thus she commits the future generations to follow her "plan" by leaving them with her utility maximizing level of human capital. Observe that while the formulation looks like an overlapping generations model, it is in fact a dynastic utility function. Appendix B. shows that the time separable log preferences and the delta method approximation for expected utility produces a specification of preferences that enfolds the infinite future terms involving choice variables, (x_t, τ_t), into a "two period" specification. This can be seen by the presence of the additional term $\frac{\alpha\beta\sigma}{1-\beta}$ in terms involving x_t. A parent internalizes the effect of *her* fertility today on all future dynastic population because it effects land holdings per her dynastic adult progeny.

The model is solved numerically in order to characterize the long run history of the world. However I show in Appendix C that:

$$\frac{\partial x_t}{\partial \delta_t} > 0 \tag{11}$$

$$\frac{\partial \tau_t}{\partial \delta_t} < 0 \tag{12}$$

High young adult mortality raises the price of human capital investment relative to the number of children. If preferences were logarithmic and depended on the expected number of surviving children, $x(1-\delta)$, then fertility and human capital investment time would be independent of δ. Thus the assumption of expected utility is one way to generate a Demographic Transition to an Industrial Revolution via reductions in young woman mortality.[20] Since δ is a decreasing function of the average human capital stock, rising human capital levels reduces young woman mortality. This in turn reduces the demand for children and raises the demand for human capital investment. This positive reinforcement leads to more rapid human capital accumulation and still lower fertility. This continues until young woman mortality is zero. At this point fertility and human capital investment are given by their stationary values in (13) and (14), respectively.[21]

$$x = \frac{\left[1-\alpha-\frac{\alpha\beta\sigma}{1-\beta}\right]\left[1-\beta(1-\varepsilon)\right]-\alpha\beta\rho(1-\sigma)}{\left[1-\frac{\alpha\beta\sigma}{1-\beta}\right]\left[1-\beta(1-\varepsilon)\right]\theta} \tag{13}$$

$$\tau = \frac{\alpha\beta\rho(1-\sigma)\theta}{\left[1-\alpha-\frac{\alpha\beta\sigma}{1-\beta}\right]\left[1-\beta(1-\varepsilon)\right]-\alpha\beta(1-\sigma)\rho} \tag{14}$$

2. NUMERICAL SOLUTION

In this section I present the results of a numerical solution to the model. Parameters are chosen in order to fit the population history of the world from 25,000 BC to 2000 AD, the population history of the rich world from 1 AD to 2000 AD, and the history of income per capita, age at entry into the labor force, total fertility rates, infant mortality, life expectancy at birth, and life expectancy at labor force entry. Parameters are chosen to induce a long term population growth rate of 5 percent per generation (40 years), and long term schooling of 16 years. Given a value for the time discount

[20] An alternative method is contained in Jones (2001), where preferences display an elasticity of substitution of fertility and consumption greater than 1.

[21] Appendix D shows that falling young woman mortality leads to increases in population growth rates for the case $\zeta = 0$.

rate across generations, β, and the time cost of child rearing, θ, assumed steady state values for x and τ, equations (13) and (14) generate values for α and ρ. Hence the values for α and ρ in all solutions are dictated by my choice of the long run values for x and τ and β and θ.

The numerical solutions are for 28 "countries;" 22 are "rich countries" and the remaining 6 are "poor countries."[22] The advantage of having 28 countries is the ability to track the behavior of income inequality in the world, as well as the differential timing and speed of demographic transitions. In particular, the earlier arrival of the Demographic Transition and Industrial Revolution in the rich countries and the delayed diffusion of the Demographic Transition and Industrial Revolution to the poor countries will produce large increases in income inequality. Consistent with Gerschenkron (1962), later developers experience more rapid transitional growth than early developers. For example the Demographic Transition took 250 years to occur in Northern and Western Europe, and less than 50 years to occur in South Korea. Per capita income growth rates in excess of 5 percent per year over several decades occurred in Japan and South Korea, and per capita income growth rates in excess of 7 percent per year over the past 20 years have occurred in China.

All residents within a country are endowed with identical levels of human capital, but countries can differ in their initial human capital, however per capita incomes and human capital at 25000 B.C. are within three percent of each other. I assume that within each region land is equally distributed among all individuals in the region. Throughout most of human history the typical market size is smaller than the population of the country.[23] As human capital accumulates, however, the optimal market size in a country exceeds the population of the country. When this occurs there exists an incentive to integrate markets across county borders.[24] In the numerical solution the rich region becomes a single market incorporating all 22 rich countries, and eventually integrates each of the six poor countries. The highest human capital country in the poor region will integrate first, and the lowest human capital country will be the last to integrate. This occurs because the benefits of an additional person are increasing in their human capital and the costs, dilution of the average human capital, are decreasing in human capital. Appendix F presents the solution algorithm for

[22] See Appendix G. for a list of the countries used in the solution. I used "rich countries" to identify rich countries as of 2000 A.D., however in the numerical solutions going back in time, these countries look identical to poor countries in per capita income, i.e. the human capital differences are vanishingly small. I used "poor countries" because some of the countries are in fact regions, e.g. Latin America, Central and Eastern Europe, Africa and Asia without China and India. From now on, I will drop the quotation marks.

[23] The level of TFP, Z, is a function of the optimal market size, N. See Appendix A for both Z and optimal market size, N.

[24] Appendix E presents the integration of regional markets.

the numerical solutions.

I chose human capital and population for year 2000 A.D. for each of the rich countries to match year 2000 A.D. per capita incomes and populations, and year 2200 A.D. human capital for each of the poor regions in order to match 2000 A.D. per capita incomes and populations.[25] Assume that the human capital stock for 2000 is such that the young mortality rate, δ_{2000}^{rich}, is very close to 0 in the rich countries and δ_{2200}^{poor} is very close to 0 in the poor countries. Assume that human capital growth is such that in 2040, $\delta_{2040}^{rich} = 0$, and thus fertility and the human capital investment rate attain their long run values given by (13) and (14). With these assumptions, for the rich countries, $(x_{2040}, \tau_{2040}) = (x, \tau)$. Notice that (9) and (10) are two first order difference equations in (x_t, τ_t) and (x_{t+1}, τ_{t+1}). We can now solve for (x_{2000}, τ_{2000}) recursively. Given solutions for (x_{2000}, τ_{2000}) and values for P_{2000} and h_{2000}, P_{1960} and h_{1960} can be calculated. The iteration continues until time hits 25,000 B.C.

In order to fit the world population and rich region population time series, I used a technique pioneered by Jones (2001), which is to assume the existence of zero mean random young adult mortality rate shocks.[26] Let ξ_t be the generation t young adult mortality rate shock, then the law of motion of population and human capital are given by:

$$P_t = \frac{P_{t+1}}{x_t\left(1 - \delta_t - \xi_t\right)} \tag{15}$$

$$h_t = \left\{ \frac{h_{t+1}}{A\overline{\overline{h}}_t^{\varepsilon} \tau_t^{\rho}} \right\}^{\frac{1}{1-\varepsilon}} \tag{16}$$

Some of the parameters were chosen in order to fit specific moments under zero young adult mortality, e.g. steady state fertility and time spent educating the next generation. I assumed a full lifetime consists of two 40 year periods, or a generation of 40 years. I assumed steady state population growth of 5 percent population per generation, $n = 1.05$, and steady state schooling of 16 years. I chose an intergenerational discount rate $\beta = .52$ (an annual discount rate of .98). I consider two cases one with international spillovers in human capital accumulation $\varepsilon = .1$, a child rearing time of 4.24 years, $\theta = .106$; and one without international spillovers, $\varepsilon = 0$, $\theta = .0582$. For all cases I assume land's share of output $\sigma = .10$.[27] These parameter values uniquely determine α and ρ via equations (13) and (14). Reporting only the first three significant digits they are $\alpha = .446$ (.491)

[25] In the solutions a period is 40 years, so that year 2200 represents the fifth generation since year 2000.

[26] My methodology of matching the actual time series of population, income per capita, age at entry into the labor force, life expectancy at birth, life expectancy upon entry into the labor force, total fertility rates and infant mortality for 28 countries is similar to that contained in Mulligan (2002a,b).

[27] I do not take the share of output that goes to landowners prior to the 19th century in Europe or China as measures

and $\rho = 1.02$ (.920). Finally for balanced growth of per capita output of 1.7 percent per annum, given $n = 1.05$, $\sigma = .10$, $\varepsilon = .10$ (0), $\theta = .106$ (.0582), $\rho = 1.02$ (.920), $\alpha = .446$ (.491), the returns to specialization, $\omega = 1.295$, the value of $A = 5.395$ (4.855) is determined.[28] The remaining eight parameters are the young adult mortality parameters and the parameters of coordination costs of task specialization, contained in Appendix A. The latter three parameters are chosen in order to roughly fit the implied market sizes with evidence from Bairoch (1988) on city sizes in Europe. The five young adult mortality function parameters are essentially free parameters that I chose in order to "parsimoniously" fit the overall data. Sensitivity of the numerical solutions required that own effect of human capital on young adult mortality be extremely small, $\zeta = .007$.[29] I assumed $\varphi = .25$, $\gamma_1 = -\frac{1}{95}$, $\gamma_2 = 2.2$ and $\Delta = .535$. Table 1 presents the parameter values for the model both with and without human capital spillovers.

Total fertility rates are close to 5 throughout most of human history, 25,000 BC until the 15th century AD. Total deaths are close to 3 children per mother over this same period.[30] Figure 1 contains the simulated world population and the actual world population over time, separated into two graphs for BC and AD, and the experience of the 22 countries of the rich region in AD. Actual values are presented by the labels, pop and Δ, the base model solution, $\varepsilon = 0$, is presented by $\bigcirc$, and

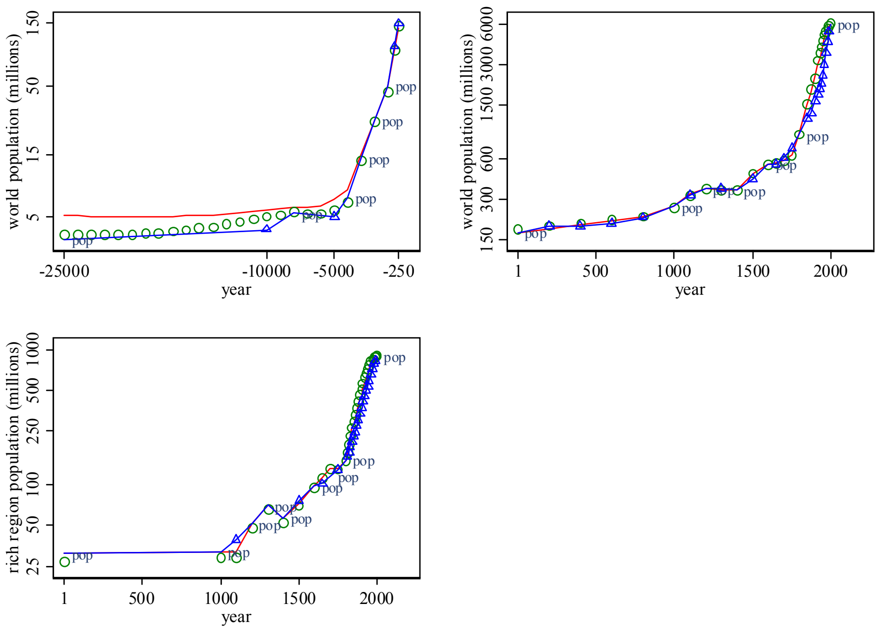
of σ. I do not consider either of those observations to be consistent with competitive factor markets. If agriculture is roughly 5 percent of output and land receives 20 percent of agricultural output, residential and office land rents must be 9 percent of output. Obviously in places like San Francisco or Boston, land rents can constitute as much as 90 percent of property values, but in South Carolina, land rents constitute around 15 percent of property values. If 33 percent of income goes to housing, office and property expenses, $\sigma = .1$ implies that land rents are roughly 25 percent of property values, i.e. $\sigma = .1 \approx .05 * .20 + .33 * .25$.

[28] Actually ω is a time varying parameter. Prior to 1640, $\omega = 1.0005$, and after 2000 $\omega = 1.295$. The values for 1600-2000 are 1.045, 1.055, 1.075, 1.100, 1.125, 1.175, 1.200, 1.260, 1.265, 1.295 and 1.295, respectively. As in Jones (2001) and consistent with North (1981), Rosenberg and Birdzell (1986) and Acemoglu, Johnson and Robinson (2002), the model indicates that there was a rise in the return to human capital coinciding with the increased protection of private property in the West, and particularly the differential behavior of offshoots of the West. My assumption of time varying returns to specialization is also similar to the assumption of time varying rates of return to investment as in Azariadis and Drazen (1990), although I do not explicitly tie the ω parameter to the average level of h.

[29] A value of $\zeta = .007$ implies that the overwhelming incentive for accumulation of human capital arises from its direct effect on production of consumption. If mortality reductions occur via public investments in health, then as long as the investments were modeled as forgone time spent discovering improved public health rules, and if the productivity in these exercises were proportional to the private productivity gains the qualitative results remain. I thank Kevin Murphy for each of these points.

[30] These deaths include infant mortality that I have yet to specify. Infant mortality is included in order to match life expectation, life expectation at age of entry into the labor force and infant mortality itself.

spillover model solution, $\varepsilon = .1$, $\varphi = .25$, is connected. In the solution the young adult mortality shocks were chosen in order to fit the model to the population values labeled by pop. The actual data represented by Δ were not used, but serve as a test of the fit of the model.



World Population B.C. & A.D. and Rich Region Population A.D.

Data for the rich countries come from McEvedy and Jones (1978) and were aggregated into the rich region population. The connected plot is the human capital and young adult mortality spillover model solution. The base model without spillovers, represented by $\bigcirc$, and the spillover model (connected) are quite similar in their population predictions. The labeled, pop, values are the historical values; as before the observations labeled with triangles were not used to fit the solution. Observe that there is one pronounced population cycle in the world and in the rich region, the Black Death between 1300 and 1400.

3. EMPIRICAL EVALUATION OF THE MODEL

In this section, I present empirical evidence supporting the model. There are three parts to this evaluation. The first is nonlinear estimation of the relationship between young adult human capital, international spillovers of young adult human capital and young adult mortality. The data clearly identifies a connection between young adult human capital and young adult mortality as well as the existence of international human capital spillovers. The second part evaluates two predictions of the model: human capital investment should be negatively related to young adult mortality, and independent of infant mortality,[31] and fertility should be positively related to young adult mortality and infant mortality. Except for infant mortality's significant negative relationship to young adult schooling in the data, I find the model is confirmed. I then produce time series on these seven indicators for each of 22 rich countries and 6 poor countries using the calibrated model. In the third subsection, I report the results of goodness of fit regressions in which these time series are compared with the actual time series for these countries. The model of spillovers in human capital accumulation and young adult mortality best fits the data.

3a. Human capital, young adult mortality and spillovers

Using data from Keyfitz et al. (1968,1990) and Preston et al. (1972), as well as years of schooling from Baier, Dwyer and Tamura (2004), I estimate the relationship between the probability of dying between the ages of 1 and 40 (45) as a nonlinear function of the lowest young adult mortality in the world at the time and the young adult human capital of the country. The data ranges from 1850-1990, covering 92 (127) countries and 634 (1420) observations. The smaller data set comes from the observations in Keyfitz et al. and Preston et al. This data is augmented with predicted mortality rates for an additional 786 observations. These additional observations come from both increasing the number of countries by 35 as well as adding earlier observations from the original 92 countries. I took data on life expectation at birth as well as infant mortality in order to predict the age specific mortality rates based on the original 634 observations. Hence the 786 observations are predicted values of young adult mortality.

Consistent with the theory, I posit the following nonlinear relationship for a country's young adult mortality rate, δ_t, and its young adult human capital, h_{t+1} measured as the years of schooling of the average 25 year old, and the lowest young adult mortality rate in the world:[32]

$$\delta_{it} = \left(\min_j \{\delta_{jt}\}\right)^{\varphi} \Delta^{1-\varphi} \exp\left((1-\varphi)\gamma_1 h_{it+1}^{\gamma_2}\right) \tag{17}$$

[31] The model predicts that infant mortality should have no effect on human capital investment. This assumes that infant mortality imposes no costs on parents. However a full term pregnancy that results in an infant that does not survive to age 1 reduces a woman's reproductive capacity by between 9 months and 1 year. Since reproductive capacity is finite, lasting roughly 30 years, infant mortality is not costless.

[32] Even in a world with life expectation at birth of 35, the average conditional life expectation at age 1 (5) can exceed 41 (49).

where $0 \leq \varphi \leq 1$ measures the spillover of best practices in young adult survival, $\gamma_1 < 0$, $\gamma_2 > 0$.[33] Taking the logs of both sides and using nonlinear least squares allows for the identification of the parameters. Table 2 presents the results based on both samples.[34] The upper panel presents the estimation based on the 634 observations, and the lower panel present the results based on the augmented sample. Convergence in the smaller sample was much more difficult than in the larger sample, thus for the smaller sample I fixed a value of $\Delta = .535$, the value used in the numerical solutions, and estimated the remaining parameters. The two sets of estimates are quite similar. The first and third columns of Table 2 contain the results of the nonlinear regression using the specification in (17), where the minimum young adult mortality in the world today, or in the past, measures the state of the art in survival. Observe that the parameter φ is roughly .3 in the smaller sample and about .12 in the larger sample. These estimates indicate that a substantial portion of a country's young adult mortality is correlated with the lowest young adult mortality in the world. Young adult human capital is negatively related to young adult mortality. The second and fourth columns contain the results of a nonlinear regression where in the place of the minimum young adult mortality rate, I used the maximal young adult human capital, $\overline{\overline{h}}_{t+1}$, today or in the past, and assumed that it affected young adult mortality in a similar manner as a country's young adult human capital, i.e.:

$$\delta_{it} = \Delta \exp\left(\varphi\gamma_1 \overline{\overline{h}}_{t+1}^{\gamma_2} + (1-\varphi)\gamma_1 h_{it+1}^{\gamma_2}\right) \tag{18}$$

Observe that the estimates of (Δ, φ, γ_1, γ_2), contained in columns two and four of Table 2, are precisely estimated and quite similar to the estimates in the previous specification. The results in Table 2 is consistent with the possibility that a typical country's young adult mortality rate is affected by the best survival technology in the world.[35]

3b. Human capital investments, fertility and mortality

In this subsection I test two empirical predictions of the model: human capital investments are negatively related to young adult mortality and independent of infant mortality, and fertility is

[33] Inherent in this specification is that the minimum young adult mortality term includes Δ^{φ}.

[34] The model assumes that there is simultaneity between human capital of the young adult and young adult mortality. When I included income as a regressor, the significance of human capital does not change. Other than income I cannot think of any instruments for IV estimation. My prior is that any bias in the estimates is unlikely to be large.

[35] These results are complementary to the micro level evidence. An inverse relationship between education and adult mortality risk is found using birth cohorts in the US by Lauderdale (2000), Lleras-Muney (2002), and is also found internationally and historically, see Brehaut, Raina and Lindsay (2002) and the references therein.

positively related to infant mortality and young adult mortality. Except for the prediction that human capital investments should be independent of infant mortality, the other three predictions are confirmed. I report the results obtained from regressions of young adult years of schooling on three measures of male mortality and current overall average years of schooling.[36] One model prediction is that young adult mortality affects human capital investments, but infant mortality and middle age mortality do not. Accordingly I constructed three measures of mortality, infant mortality, measured as the probability of dying before age 1, young adult mortality, measured as the probability of dying between 1 and various cut off ages (25, 30, 35, 40, 45, 50, 55), and middle age mortality, measured as the probability of dying between various cut off ages (25, 30, 35, 40, 45, 50, 55) and 60.[37] The results of these fixed effects regressions are contained in Table 3.[38] As with the previous table, I present the results both for the sample of 92 countries and 634 observations in the upper panel, as well as the larger sample of 127 countries and 1420 observations in the lower panel.

The key feature from these regressions is that years of schooling is negatively related to the probability that a child dies as a young adult. A reduction of young adult mortality by 7 percentage points raises young adult schooling by .3 years.[39] Inconsistent with the theory is the strong negative relationship between infant mortality and young adult years of schooling. A reduction in infant mortality of 5 percentage points, which is equal to the average change in infant mortality, raises young adult schooling by .5 years. The evidence from middle age mortality suggests that young adult mortality risk can be thought to include dying between the ages of 1 and 45 or up to 55. As

[36] Although I have referred to individuals as female, it is likely that the model best fits males. I use the same data as in the previous subsection.

[37] It is fair to question whether deaths of children from 1 to say 6 are measuring young adult mortality risk. This clearly is consistent with Hazan and Zoabi's (2004) model that improvements in child nutrition and health increased the return to human capital investments. The model assumes that all human capital investments are made before young adult mortality occurs. Clearly children who die before the age of 6 have not received all of their human capital investments. However in the absence of a more complicated model of young child deaths and incomplete human capital investments, I lumped these early deaths as part of young adult mortality. A model of sequential fertility, as in Doepke (2005), with human capital investment would better identify the effects of child mortality and young adult mortality. I thank an anonymous referee for making this point.

[38] The results using OLS and random effects were similar, and those from random effects with AR(1) corrections are also similar. These are available on request.

[39] The mean initial probability of dying between the ages of 1 and X, where X varies from 25 to 55, ranges from 11 percent to 28 percent in the data. In comparison the mean final probability of dying between the ages of 1 and X ranges from 6 percent to 19 percent. A 7 percentage point reduction in young adult mortality is roughly 1 standard deviation of the young adult mortality and is equal to the 7 percentage point reduction in average young adult mortality.

the cutoff age for young adulthood rises, the importance of middle age mortality drops predictably.[40] The mean increase in years of schooling is 3.7 years, whereas the mean predicted increase in years of schooling is 3.9. Hence the model does an extremely good job of explaining the increase in average years of schooling of young adults. Finally the baby boom time dummy for years 1946-1970 for the western countries, is strongly negatively related to human capital accumulation. The expanded sample produces similar results. A reduction of young adult mortality by 15.6 percentage points raises young adult schooling by .45 years.[41] As in the smaller sample, infant mortality is strongly negatively related to years of schooling of young adults. The mean reduction in infant mortality is 11 percentage points, and it raises young adult schooling by almost 1 year. The mean increase in years of schooling is 5.8 years, whereas the predicted mean increase in years of schooling is 6.1 years. Thus the model does an excellent job in predicting mean increases in schooling.

The results for fertility, in Table 4, are consistent with the model. Years of schooling of parents have the expected negative effect on total fertility rates. Infant mortality is positive and significant in 4 (5) of 7 regressions at the 5 (10) percent level in the small sample and 6 (7) of 7 regresions at the 5 (10) percent level in the large sample. Initial infant mortality is 113 (165) per 1000 live births and final infant mortality is 59 (59) per 1000 live births in the small (large) sample. Taking a value of 2.5 for the coefficient on infant mortality, implies that the reduction in infant mortality reduced fertility by .14 (.25) children. Total fertility is positively related to young adult mortality in all of the regressions. The average reduction in young adult mortality is .07. Taking the average implied reduction in fertility induced by falling young adult mortality produces a reduction in fertility of .14 (.28) children. Falling mortality reduces fertility by approximately .28 (.53) children. The model predicts a reduction in fertility of roughly 1.2 children. In the small sample the mean reduction in fertility is 1.4 children. In the larger sample the model predicts a reduction in fertility of 1.9 children while the data has a mean reduction in fertility of 1.57 children.[42]

An alternative, and complementary, explanation of falling fertility and rising human capital accumulation is postulated by Galor and coauthors, see Galor (2004) for an excellent summary of this research program. In Galor's models rising rates of technological progress raised the incentive for

[40] However these results do not discriminate between the model of this paper and a model where rising adult life expectation increases the rate of return to a fixed level of human capital accumulation as in Meltzer (1996).

[41] This is the mean reduction in young adult mortality among the 127 countries. A standard deviation is about 7.5 percentage points.

[42] The baby boom time dummy is significant and indicates that during the period 1946-1970, total fertility rates were about .4 higher than predicted.

human capital accumulation, specifically schooling. Rapid technological progress depreciates old human capital, but rising levels of schooling provides an individual with ability to protect themselves from technological change, as well as to benefit from the creation of valuable specific technology. Rising demand for schooling puts pressure for fertility to fall. In this data, as well as data presented in Galor (2004), there is evidence that fertility rates often rose in the early stages of rising living standards and falling mortality rates. The Galor (2004) model predicts a positive association between schooling and technological growth in equilibrium. Table 5 contains the regression results of young adult years of schooling on infant mortality rates, young adult mortality rates, middle age mortality rates and total factor productivity growth. Total factor productivity growth comes from Baier, Dwyer and Tamura (2004). I used the annualized growth rate between the year of observation and 10 years in the future the identical temporal pattern of young adult schooling. Using the lagged value, or the centered value of TFP growth, do not alter the results. The evidence is unambiguous; young adult years of schooling is negatively related to the growth rate of TFP. The model of this paper also postulates that TFP growth is positively related to human capital accumulation so this result contradicts this prediction.[43] However the sign on young adult mortality remains negative and strongly significant. This is further evidence of the importance of young adult mortality in determining human capital accumulation as posited here, as well as by Nerlove (1974), Ehrlich and Lui (1991), and Meltzer (1996).

Table 6 provides an additional attempt at discriminating between the model proposed here and those of Galor (2004). Fertility should be negatively related to TFP growth. While the estimate is of the right sign, it is never significant in the regressions. However notice that the measures of infant mortality and young adult mortality are always positively and significantly related to fertility. These results do not change if I use the centered value or the lagged value of TFP growth. It is interesting to note that if I use the log of the level of TFP in years of schooling regression, they are of the right sign and highly significant, however they are insignificant in the fertility regression. Finally Table 7 considers the possibility that technological diffusion could be causing the spurious result. If diffusion of technology is important, then the Galor (2004) prediction would only unambiguously hold for those countries where TFP growth is negative. Countries with positive TFP growth could have slower human capital accumulation if the negative effect of technological innovation is ameliorated by the diffusion of production technologies suitable for the country. The small sample of countries

[43] When only focusing on the 22 rich countries of the paper, there is still a negative relationship between TFP growth and years of schooling of young adults.

does not provide any support for this hypothesis, however the large sample confirms the prediction that more rapid TFP decline is associated with smaller increases in schooling of young adults. The Galor prediction of a negative relationship between TFP growth and fertility is not found in either the small or large sample for countries with negative TFP growth. For space considerations I do not report the results for fertility. However in all of these results, the negative relationship of young adult mortality on young adult schooling as well as the positive relationship between young adult mortality and fertility holds.

3c. Goodness of Fit of simulation

The previous subsections have shown: (1) the data supports the model's connection of young adult human capital and young adult mortality, and the existence of spillovers in human capital, and (2) the model of young adult mortality is consistent with the historical evidence of human capital accumulation and total fertility. In this subsection I provide a measure of goodness of fit. I exploit the fact that the model produces exact time series solutions for population, income per capita, age at entry into the labor force, total fertility rates, infant mortality, life expectation at birth and life expectation at entry into the labor force.[44] In Appendix H, I present evidence from the stacked series, simultaneously fitting all seven series. That evidence is consistent with the results contained in this section that the model does an exceptional job of fitting the data.

Typical goodness of fit tests involve examining deviations of the predicted values of an econometric model from actual values of the data. Most test of models involve attempting to fit several moments of a distribution, e.g. standard deviation of hours worked over the business cycle. My goal, by contrast, is to predict the actual time series history for 28 countries of many different variables: population, income per capita, age of entry into the labor force, total fertility rates, infant mortality, life expectancy at birth and life expectancy at age of entry into the labor force. Since the units of each of the variables vary greatly, i.e. population is measured in thousands, income per capita is measured in dollars and total fertility rates are measured in live births, I created normalized variables for each series. Let y_{it}^{j} and x_{it}^{j} be the actual observation and numerical solution, respectively, on

[44] I calculated the average age of the population not enrolled in school and less than 65. I subtracted the measure of years of schooling to produce potential experience, X. To create a years of schooling equivalent, E, I used the following formula: E = (.049X-.00095X^2)/.134. The parameters chosen for this conversion are taken from labor economics wage regressions pioneered by Jacob Mincer (1974). I use the value of .134 return per year of schoooling in order to calculate the schooling equivalent.

variable j for country i in year t. Then for variable j, let $\overline{x}^j$ and s^j be the mean and standard deviation of the solution series for all countries and years. I then normalized both the actual value and the solution value by subtracting the mean value and dividing by the standard deviation of the solution series.

$$Y_{it}^j = \frac{y_{it}^j - \overline{x}^j}{s^j},\ Y^j = \left\{Y_{it}^j\right\}_{i,t} \tag{19}$$

$$X_{it}^j = \frac{x_{it}^j - \overline{x}^j}{s^j},\ X^j = \left\{X_{it}^j\right\}_{i,t} \tag{20}$$

I run the following regressions:

$$Y^j = a + bX^j + u \tag{21}$$

where I assume $u \sim N\left(0, \sigma^2\right)$.

Before continuing it is useful to count the number of parameters of the model that are used to fit the data. Preference parameters include α, the weight on adult consumption, β, the intergenerational discount rate. Equation (4) contains the five young adult mortality parameters, which include φ the importance of "international best practices" spillover, γ_1, γ_2 human capital parameters and ζ the individual's own direct impact on young adult mortality and Δ a scale parameter on young adult mortality. Goods production given by (31) contains two parameters, σ, land's share of output, and ω the agglomeration economy from task specialization.[45] The constant per child rearing time is θ. The human capital accumulation technology, (7), has three parameters, A, ε the importance of the international human capital spillover, and ρ the marginal returns to teaching time. In total the model consists of 16 parameters to fit almost 3500 observations.[46]

To get a feel for the importance of the mortality changes in producing the observed time series, I compared a model with constant young adult mortality, $\delta = .5345$, and hence constant fertility, and constant human capital investment, with versions of the model with endogenous young adult

[45] See Appendix A for a description of ω and the coordination costs of specialization. Coordination costs, given by (32), are a negative function of average human capital, and takes three parameters, λ_1, λ_2, and λ_3. To better fit the data, the model assumes that the rich and poor regions have different time series on the returns to specialization, ω. I assume that the return to specialization in the poor region follows $\omega_t^{poor} = \omega_{t-1}^{rich}$. This captures the earlier institutional development of the rich region, greater protection of private property rights as identified by North (1981), Rosenberg and Birdzell (1986), and the differential diffusion of these institutions as identified by Acemoglu, et al. (2002), I thank an anonymous referee for this point.

[46] Following Jones (2001) I do not include the unexpected young adult mortality shocks, nor the few time variations in the returns to specialization, ω, as additional numbers of parameters. These are presented in Appendix I, and footnote 27.

mortality.[47] The base model assumes no spillovers in mortality nor in human capital accumulation. To fit the data on infant mortality and conditional life expectation more precisely, I assumed that infant mortality and conditional life expectation are simple functions of the per capita income in the country (region). The values were chosen in order to match the average rich country infant mortality (model solution and data are each 79 per 1000 live births) and the average poor country infant mortality (model solution and data 123 and 125 per 1000 live births, respectively). The model solution averages for conditional life expectation at labor force entry age are 69 and 64 for rich and poor regions, respectively. The data are 68 and 65, respectively. The specifications for infant mortality and conditional life expectation are:

$$Infant\ Mortality_{it} = m_{it} = \begin{cases} .125000\ if\ y_{it} < 22500 \\ .001700\ if\ y_{it} \geq 22500 \end{cases} \tag{22}$$

$$Conditional\ Life\ Expectation_{it} = \begin{cases} 76.0\ if\ y_{it} < 22500 \\ 64.0\ if\ y_{it} \geq 22500 \end{cases} \tag{23}$$

The results of the constant δ model, and the base model for population and income per capita are contained in Table 8. Table 9 contains the analogous results for total fertility rates and age at entry into the labor force.[48] Tables 10-12 contain the results for infant mortality, life expectation at birth and conditional life expectation at entry into the labor force, respectively. If the model explained the data perfectly, then the regressions should produce a slope coefficient on the solution of one, a zero intercept and an $\overline{R}^2 = 1$.[49] The row marked with $\beta = 1$ contains the relevant F statistics. Beneath each of these rows is the p value of the F statistic.

The base model fits the data better than the constant young adult mortality model, as measured by $\overline{R}^2$ and F statistics on the hypotheses $\beta = 1$, for population, incomes per capita, total fertility rates, and life expectation at birth. Since the infant mortality and conditional life expectation functions are set to essentially match the mean of the data under constant young adult mortality, it is not too surprising that infant mortality, conditional life expectation at labor force entry age in

[47] In the constant young adult mortality model, I calibrated the young adult mortality rate to the same rate as the baseline model with endogenous young adult mortality without an international spillover.

[48] All of the results presented in the paper are estimated using fixed effects regression. The results do not change substantively, either in estimates of α or β or in F statistic, or in $\overline{R}^2$ when estimated using OLS, or random effects with AR(1) corrections. Those results are not presented here for the sake of brevity and clarity and are available from the author on request.

[49] With fixed effects regressions, the interpretation of the constant term is not as interesting as in the OLS case. Suffice it to say, a joint test of $\alpha = 0$ and $\beta = 1$ is rejected at all levels of significance in the OLS case.

the base case fit more poorly than under constant young adult mortality. Therefore I modify the endogenous young adult mortality model by introducing human capital spillovers in the production of human capital, and an international spillover in the young adult mortality function.[50] The human capital accumulation technology and the young adult mortality function become:

$$h_{t+1} = A\overline{\overline{h}}_t^{.1} h_t^{.9} \tau_t^{\rho} \tag{24}$$

$$\delta_{it} = \Delta \exp\left(.75\left[\zeta\gamma_1 h_{it+1}^{\gamma_2} + (1-\zeta)\gamma_1 \overline{h}_{it+1}^{\gamma_2}\right] + .25\gamma_1 \overline{\overline{h}}_{t+1}^{\gamma_2}\right) \tag{25}$$

These parameters assume that over a 40 year generation, the implied human capital convergence term is $.1/40 = .0025$ per year and the implied international young adult mortality convergence term is $.25/40 = .00625$ per year. These are quite small, and even if a generation is only 20 years, they are only .005 per year and .0125 per year, respectively. These values are within the plausible range, estimated by Tamura (1996) and Barro and Sala-i-Martin (1992) of .01 and .02 per year. The results are contained in the columns headed by $\varepsilon = .1$, $\varphi = .25$. With the addition of these two parameters, there is improvement across all series.[51]

While the base model fits the income per capita data almost as well as the spillover model, the out of sample predictions lead one to prefer the model with spillovers to the base model. The goodness of fit regressions for income per capita cover incomes from 1 AD to 2000 AD. About 90 percent of the 500 observations are from 1700-2000, and all but 14 of the observations are from 1500-2000. In the spillover model predicted per capita incomes are 400 dollars in 8000 BC, and average world per capita income ranges from 400 dollars from 25000 BC to 300 dollars in 1 AD. At the start of the Industrial Revolution in 1800 AD world per capita income is 750 dollars, rich per capita income is 1150 dollars and poor per capita income is 675 dollars.[52] Average age at labor force entry is about 20 years for the rich region and 18 poor region in 2000 AD and remains at that level for the rich region and grows to that value by 2040 in the poor region. In contrast the model without spillovers

[50] Table 1 contains these modifications. I adjusted the unexpected shocks in order to maintain the fit of the model for world population and rich population; they remain zero mean. In the spillover model, $A = 5.3949394$, compared with the no spillover model value $A = 4.8554455$.

[51] The adjustment on the $\overline{R}^2$ to take into account of the additional 2 parameters would be essentially $\frac{M-2}{M}\overline{R}^2$, where M is the number of observations in the goodness of fit regressions, the smallest of which is 337.

[52] By 1500 AD rich per capita incomes are essentially identical, at 270 dollars, however the model has poor per capita incomes of 240 dollars for Latin America, China and India or ten percent lower than in the United States, Australia and New Zealand. The model does not capture the reversal of fortune that has occurred between these sets of regions. If $\omega^{poor} > \omega^{rich}$, as suggested by Acemoglu et al. (2002), the model would fit better in the 1500-1800 period. I thank an anonymous referee for this comment.

produces ridiculous values for per capita incomes in the past. Per capita incomes in 8000 BC are less than a penny, and remain below a dollar until 2700 BC! World per capita income does not reach 365 dollars until 1840. Also due to extremely low fertility, world population will fall dramatically between 2000 A.D. and 2240 A.D. from 6076 million to 415 million! Average age at labor force entry is to peak at 51 years in 2000 in the rich region before falling to 40 in 2040 and 28.5 in 2080 and 18.3 from 2120 onward! All of these out of sample predictions are unpalatable.

Historically infant mortality has been much higher in cities than in the countryside, c.f. Bairoch (1988), Diamond (1998), and McNeil (1976), and there has been tremendous improvement in infant survival rates. Furthermore the diffusion of lower infant mortality throughout the world is one of the amazing health developments of the twentieth century. In order to better capture this fact, I modified the infant mortality specification. I assumed that infant mortality is a negative function of the average human capital of the parents in the economy, but it is positively related to the average market size:[53]

$$Infant\ Mortality_{it} = m_{it} = 1 - \max\left\{.80, \frac{\exp\left(\left[\frac{\overline{h}_{it}}{\eta_1}\right]^{\eta_2}\right)}{\max\left\{\eta_3, \eta_4 N_{it}^{\eta_5}\right\} + \exp\left(\left[\frac{\overline{h}_{it}}{\eta_1}\right]^{\eta_2}\right)}\right\} \tag{26}$$

The second specification allows for an international spillover in infant mortality

$$m_{it} = 1 - \overline{M}_t^{\psi} \max\left\{.80, \frac{\exp\left(\left[\frac{\overline{h}_{it}}{\eta_1}\right]^{\eta_2}\right)}{\max\left\{\eta_3, \eta_4 N_{it}^{\eta_5}\right\} + \exp\left(\left[\frac{\overline{h}_{it}}{\eta_1}\right]^{\eta_2}\right)}\right\}^{1-\psi} \tag{27}$$

where $\overline{M}$ is the maximum infant survival rate.[54]

Assume that conditional life expectation at entry into the labor force also takes a logistic form:

$$Conditional\ Life\ Expectation = clife_{it} = 80\frac{\exp\left(\left[\frac{\overline{h}_t}{\upsilon_1}\right]^{\upsilon_2}\right)}{\upsilon_3 + \exp\left(\left[\frac{\overline{h}_t}{\upsilon_1}\right]^{\upsilon_2}\right)} \tag{28}$$

When an international spillover exists, conditional life expectation becomes:

$$Conditional\ Life\ Expectation = clife_{it} = \overline{clife}_t^{\Upsilon}\left\{80\frac{\exp\left(\left[\frac{\overline{h}_t}{\upsilon_1}\right]^{\upsilon_2}\right)}{\upsilon_3 + \exp\left(\left[\frac{\overline{h}_t}{\upsilon_1}\right]^{\upsilon_2}\right)}\right\}^{1-\Upsilon} \tag{29}$$

[53] Market size, N, is derived in Appendix A. Schultz (1993, 1997) provides strong evidence that rising levels of maternal education reduce young child mortality.

[54] In contrast, Schultz (1999) finds that there is little evidence of a "time trend" representing improved health infrastructure or worldwide health technological progress in infant survival rates in Africa from 1960-1985.

In the solution, using a grid search over possible international spillover values for infant mortality there was little change in the R^2. The tables report the results for the infant mortality international spillover, $\psi = .1$ and conditional life expectation spillover, $\Upsilon = .4$. These two modifications add 6 more parameters to the model.[55]

Life expectation becomes:[56]

$$Life\ Expectation_{it} = \{40\,(\theta + \tau_{it})\,(\delta_{it} + \xi_t) + clife_{it}\,(1 - \delta_{it} - \xi_t)\}\,(1 - m_{it}) \tag{30}$$

The effects of these modifications are contained in the final columns of Tables 9-12. Since these changes do not affect population, incomes per capita, age at entry into the labor force, Table 8 does not include any additional columns. For the other variables, these changes improve the overall fit of the model. A final test of the model is contained in the last row in each table, labeled TIME $\overline{R}^2$. For each time series, I transformed the actual data by subtracting the data mean and dividing by the standard deviation of the data. I then regressed these normalized actual values against a quartic in time. All told for the 7 variables, this alternative model uses 28 degrees of freedom compared with the 26 parameters of the full spillover model above. The TIME model never matches the full spillover model in explaining the variation in the data.

4. RICH AND POOR AND THE FUTURE

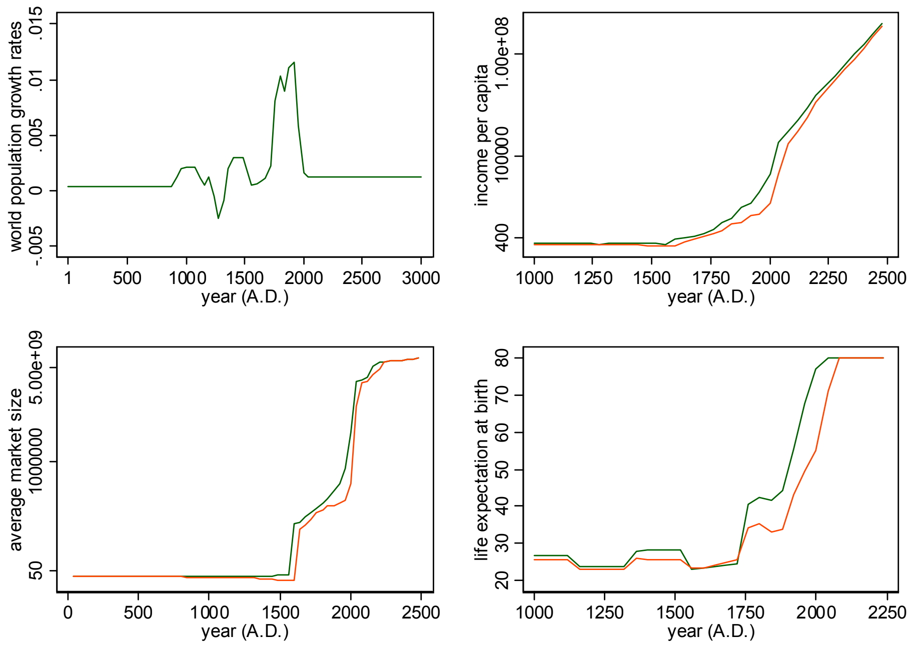
Having demonstrated that the model can fit the actual behavior of the rich and poor, in this section I present the time series from the model solution for the rich and poor regions from the past into the future. This is an out of sample prediction from the model as to the evolution of the world distribution of per capita income and the other 6 variables, and is an extension of Lucas (2000). As in Prichett (1997) there is divergence between the rich and poor as the rich region countries undergo their demographic transition to economic growth. However with spillovers from human capital, the poor region will undergo their own demographic transition and an even more accelerated transitional growth phase.

I present the results through graphs. Figure 2 illustrates the demographic transition in the world. There exists an increase in population around 800 A.D. The subsequent negative population growth and population boom is the Black Death and resultant population recovery. The next pattern, humped population growth rates are the Demographic Transition in the rich group followed by the

[55] The bottom panel to Table 1 contains the additional parameters used to fit the time series.

[56] I allow the unexpected young adult mortality shocks, ξ, to affect life expectation.

Demographic Transition in the poor group. Figure 2 also details the change in average per capita income for the rich and poor regions from A.D. 1000 (top right panel), average market size (bottom left panel) and life expectation at birth for the rich and poor regions (bottom right panel) from 1000 A.D. The income graph details the industrial revolution in the rich region, and predicts the consequences of the diffusion of the industrial revolution to the poor. It details the explosive change in the income distribution between the rich and the poor, and the predicted convergence starting from 2040. It is evident that the explosive increase in inequality between the rich and the poor occurred with the initial industrial revolution in the rich region. In 1400 A.D. the rich region is less than 10 percent richer per capita than the poor region. By 1600 A.D. the gap had grown to 50 percent, and by 1800 A.D. it had reached 70 percent. In 2040 A.D., the gap will be as wide as ever, the rich region per capita income will be over 8 times greater than the poor region per capita income. However by 2240, the rich region premium will only be 45 percent, smaller than the gap in 1600 A.D.[57]



Population growth rates, regional average: income per capita, market size & life expectancy at birth

Figure 2 also contains the time series evidence of the average market size in the rich and poor regions. The final linear portion of the figure from 2200 A.D. onward shows that the market is the entire world population. Market size is 32 from the start of the agricultural revolution, say

[57] From 25000 B.C. to 1 A.D. incomes per capita are roughly 400 dollars.

8000 BC. In 1500 AD, market size has only increased to 34. Market size grows rapidly from 1500 to 1700, increasing from 34 to over 7500. By 1800 market size grows to 22,500.[58] Comparing life expectation at birth across regions reveals the creation of a gap between rich and poor from 1720 to 2000 as the result of the earlier demographic transition in the rich region. However by 2080 this gap is completely eliminated.

Despite the rising relative income gap from 1800-2040, there is great heterogeneity amongst the "countries" in the poor group. Suppose one identifies 1876 as the date of the US industrial revolution, and income of roughly 3000 dollars. Then using this income figure as the threshold value to signify the industrial revolution, the model generates quite different start dates for industrial transformation among the poor. The model has Latin America individualization shortly after World War II in 1954. Central and Eastern Europe's Industrial Revolution dates at 1962. For China the model indicates a start date of 1983. Asia not including China and India began its industrialization in 1993. India's industrial revolution began in 2002, and Africa's Industrial Revolution will begin in 2009. Thus it takes about a generation from the onset of industrialization in China, India, Africa and the rest of Asia to begin to close the relative income gap. However the explosive growth of income inequality does not imply any differences in policies, but rather could be merely an indication of slight differences in initial conditions.

5. CONCLUSION

The paper presents a general equilibrium model of human capital investment and fertility. When young adult mortality is a function of the average human capital of young women in the population, human capital accumulation produces a Demographic Transition to an Industrial Revolution. The model assumes that individuals maximize expected discounted dynastic utility. Although preferences are logarithmic, expected utility maximization produces a precautionary demand for children. Therefore in high young adult mortality environments fertility is high and human capital investments are low. Human capital accumulation eventually lowers young adult mortality. Falling young adult mortality produces falling fertility. Lower levels of fertility reduces the cost of human capital investments, and hence the rate of human capital accumulation accelerates.

The model predicts that human capital investment should be negatively related to young adult

[58] The average size of cities serves as a useful proxy for market size. Bairoch (1988) presents evidence on the average size of cities. In 1800 the average sizes of European cities, conditional on being at least 2000, 5000 and 20000, are 7800, 16,700 and 54,900.

mortality, but independent of infant mortality. The first prediction is confirmed, but the second is not. The model's prediction that total fertility rates should be positively related to young adult mortality and infant mortality is also consistent with the data. The model was calibrated to fit the world population experience from 25,000 BC to 2000 AD. and the rich world population from 1 AD to 2000 AD. The zero mean unexpected young adult mortality shocks were chosen in order to fit both the population histories for the rich and poor regions. The model was also calibrated to fit the infant mortality and life expectation series of the rich countries. With these choices, the model was able to fit the behavior of 22 rich countries, and 6 poor regions. This behavior includes population, total fertility rates, infant mortality rates, life expectancy at birth, conditional life expectancy, age at entry into the labor force and income. These individual series are matched well by the model solutions both at the world level and at the disaggregated regional level.

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Table 1: Parameter values for base model and model with human capital spillovers

parameter	δ=.5345	base	ε=.1 φ=.25	m	m ψ=.1	m, ψ=.1 clife	m, ψ=.1 clife, Υ=.4
α	.4913	.4913	.4461	.4461	.4461	.4461	.4461
β	.5200	.5200	.5200	.5200	.5200	.5200	.5200
σ	.1000	.1000	.1000	.1000	.1000	.1000	.1000
ω	1.295	1.295	1.295	1.295	1.295	1.295	1.295
θ	.0582	.0582	.1060	.1060	.1060	.1060	.1060
A	4.855	4.855	5.395	5.395	5.395	5.395	5.395
ε	0	0	.1000	.1000	.1000	.1000	.1000
ρ	.9201	.9201	1.019	1.019	1.019	1.019	1.019
λ_1	3.922	3.922	3.922	3.922	3.922	3.922	3.922
λ_2	.6300	.6300	.6300	.6300	.6300	.6300	.6300
λ_3	.0250	.0250	.0250	.0250	.0250	.0250	.0250
Δ	.5345	.5350	.5350	.5350	.5350	.5350	.5350
φ	0	0	.25	.25	.25	.25	.25
ζ	0	.0070	.0070	.0070	.0070	.0070	.0070
γ_1	0	-.0105	-.0105	-.0105	-.0105	-.0105	-.0105
γ_2	0	2.200	2.200	2.200	2.200	2.200	2.200
η_1				1.2	1.2	1.2	1.2
η_2				1.26	1.26	1.26	1.26
η_3				12	12	12	12
η_4				.005	.005	.005	.005
η_5				.58	.58	.58	.58
ψ				0	.1	.1	.1
υ_1						2.05	2.05
υ_2						1.5	1.5
υ_3						4	4
Υ						0	.4

Table 2: Young Adult Mortality Regressions (standard error)
significance at 1 percent ***

variable	probability of dying between 1 & 45	probability of dying between 1 & 45	probability of dying between 1 & 40	probability of dying between 1 & 40
$\ln(\Delta)$	-.6255	-.6255	-.6255	-.6255
φ	.2309***	.3115***	.2453***	.3158***
	(.0250)	(.0356)	(.0273)	(.0338)
γ_1	-.1939***	-.2670***	-.2435***	-.3101***
	(.0441)	(.0332)	(.0518)	(.0362)
γ_2	.9340***	.8699***	.9020***	.8610***
	(.0845)	(.0500)	(.0774)	(.0470)
instrument	$\min_j \{\delta_{jt}\}$	$\max_j \{h_{jt}\}$	$\min_j \{\delta_{jt}\}$	$\max_j \{h_{jt}\}$
$\overline{R}^2$	.6242	.5954	.6379	.6168
N	634	634	634	634

$\ln(\Delta)$	-.4557***	-.5558***	-.5102***	-.6316***
	(.0761)	(.0835)	(.0821)	(.0881)
φ	.1072***	.1153***	.1225***	.1244***
	(.0156)	(.0216)	(.0167)	(.0207)
γ_1	-.3106***	-.3022***	-.3158***	-.3047***
	(.0396)	(.0399)	(.0406)	(.0402)
γ_2	.8415***	.8529***	.8768***	.8906***
	(.0442)	(.0446)	(.0450)	(.0451)
instrument	$\min_j \{\delta_{jt}\}$	$\max_j \{h_{jt}\}$	$\min_j \{\delta_{jt}\}$	$\max_j \{h_{jt}\}$
$\overline{R}^2$	.7208	.7166	.7264	.7223
N	1420	1420	1420	1420

Table 3: Regressions of Young Adult Schooling (standard error)

significance 10 percent *, 5 percent **, 1 percent ***

young adult age	X=25	X=30	X=35	X=40	X=45	X=50	X=55
h	.891***	.893***	.895***	.897***	.897***	.898***	.896***
	(.041)	(.041)	(.041)	(.041)	(.041)	(.041)	(.041)
infant mortality	-9.62***	-9.23***	-8.65***	-8.16***	-8.07***	-7.72***	-8.41***
	(2.5)	(2.6)	(2.6)	(2.7)	(2.7)	(2.7)	(2.7)
p(death [1,X])	-1.87	-3.02	-4.08**	-4.75***	-4.88***	-5.16***	-4.76***
	(2.3)	(2.2)	(2.0)	(1.9)	(1.8)	(1.7)	(1.5)
p(death [X,60])	-7.28***	-6.93***	-6.26***	-5.61**	-5.55*	-4.70	-8.18
	(1.9)	(2.0)	(2.3)	(2.6)	(3.2)	(4.4)	(7.6)
babyboom	-.506***	-.508***	-.516***	-.523***	-.524***	-.532***	-.513***
	(.15)	(.15)	(.15)	(.15)	(.15)	(.15)	(.15)
$\overline{R}^2$	.7993	.7988	.7984	.7983	.7983	.7983	.7983
N	634	634	634	634	634	634	634
h	.856***	.857***	.858***	.860***	.860***	.860***	.857***
	(.024)	(.024)	(.024)	(.024)	(.024)	(.024)	(.024)
infant mortality	-9.63***	-9.23***	-8.80***	-8.48***	-8.51***	-8.52***	-9.40***
	(1.5)	(1.5)	(1.6)	(1.6)	(1.6)	(1.6)	(1.6)
p(death [1,X])	-2.40	-2.91**	-3.29**	-3.39***	-3.10***	-2.88***	-2.22**
	(1.6)	(1.5)	(1.4)	(1.2)	(1.1)	(1.0)	(.91)
p(death [X,60])	-1.68*	-1.14	-.436	.309	.747	1.70	.501
	(1.1)	(1.3)	(1.5)	(1.7)	(2.1)	(2.7)	(4.5)
babyboom	-.353***	-.361***	-.369***	-.378***	-.380***	-.383***	-.364***
	(.12)	(.12)	(.12)	(.12)	(.12)	(.12)	(.12)
$\overline{R}^2$	.8403	.8404	.8405	.8406	.8406	.8406	.8404
N	1420	1420	1420	1420	1420	1420	1420

Table 4: Regressions of TFR (standard error)

significance 10 percent *, 5 percent **, 1 percent ***

young adult age	X=25	X=30	X=35	X=40	X=45	X=50	X=55
h	-.237***	-.235***	-.233***	-.230***	-.228***	-.226***	-.223***
	(.019)	(.019)	(.019)	(.019)	(.019)	(.019)	(.019)
infant mortality	1.02	1.57	2.09*	2.71**	3.16***	3.47***	2.97**
	(1.2)	(1.18)	(1.2)	(1.2)	(1.2)	(1.2)	(1.2)
p(death [1,X])	3.36***	2.51**	1.99**	1.59*	1.49*	1.61**	2.15***
	(1.1)	(.99)	(.93)	(.87)	(.81)	(.75)	(.69)
p(death [X,60])	3.01***	3.73***	4.54***	5.77***	7.33***	9.77***	13.2***
	(.86)	(.94)	(1.0)	(1.2)	(1.5)	(2.0)	(3.5)
babyboom	.406***	.398***	.389***	.377***	.365***	.355***	.353***
	(.067)	(.067)	(.067)	(.067)	(.067)	(.067)	(.068)
$\overline{R}^2$	.6263	.6268	.6282	.6307	.6330	.6345	.6322
N	634	634	634	634	634	634	634
h	-.235***	-.234***	-.233***	-.232***	-.231***	-.231***	-.233***
	(.015)	(.015)	(.015)	(.015)	(.015)	(.015)	(.015)
infant mortality	1.91*	2.32**	2.67***	2.98***	3.11***	3.06***	2.69***
	(.98)	(1.0)	(1.0)	(1.0)	(1.0)	(1.0)	(1.0)
p(death [1,X])	2.96***	2.16**	1.67*	1.38*	1.35*	1.46**	1.72***
	(1.1)	(.96)	(.87)	(.79)	(.72)	(.65)	(.59)
p(death [X,60])	1.05	1.47*	1.93**	2.45**	2.84**	3.10*	2.40
	(.77)	(.86)	(.96)	(1.1)	(1.3)	(1.7)	(2.9)
babyboom	.239***	.232***	.226***	.219***	.215***	.215***	.224***
	(.074)	(.074)	(.075)	(.075)	(.075)	(.075)	(.076)
$\overline{R}^2$	.5481	.5477	.5476	.5477	.5478	.5478	.5476
N	1414	1414	1414	1414	1414	1414	1414

Table 5: Regressions of Young Adult Schooling (standard error)

significance 10 percent *, 5 percent **, 1 percent ***

young adult age	X=25	X=30	X=35	X=40	X=45	X=50	X=55
h	.838***	.839***	.840***	.841***	.842***	.843***	.843***
	(.040)	(.040)	(.040)	(.040)	(.040)	(.040)	(.040)
infant mortality	-7.58***	-7.31***	-6.92***	-6.50***	-6.30**	-5.83**	-5.97**
	(2.3)	(2.3)	(2.4)	(2.4)	(2.5)	(2.5)	(2.4)
p(death [1,X])	-4.18**	-5.28***	-6.26***	-7.00***	-7.34***	-7.80***	-7.76***
	(2.1)	(2.0)	(1.9)	(1.7)	(1.6)	(1.5)	(1.4)
p(death [X,60])	-10.7***	-10.6***	-10.2***	-9.80***	-9.78***	-9.04**	-10.7
	(1.7)	(1.9)	(2.1)	(2.4)	(3.0)	(4.1)	(7.0)
TFP growth	-28.5***	-28.6***	-28.6***	-28.6***	-28.6***	-28.6***	-28.5***
	(3.0)	(3.0)	(3.0)	(3.0)	(3.0)	(3.0)	(3.0)
babyboom	-.420***	-.420***	-.424***	-.429***	-.431***	-.440***	-.434***
	(.13)	(.13)	(.13)	(.14)	(.14)	(.14)	(.14)
$\overline{R}^2$	.8357	.8351	.8346	.8343	.8342	.8341	.8342
N	620	620	620	620	620	620	620
h	.821***	.822***	.824***	.825***	.825***	.826***	.835***
	(.028)	(.024)	(.028)	(.028)	(.028)	(.028)	(.028)
infant mortality	-10.2***	-9.90***	-9.46***	-9.08***	-9.07***	-9.02***	-9.56***
	(1.6)	(1.7)	(1.7)	(1.7)	(1.7)	(1.7)	(1.7)
p(death [1,X])	-2.78*	-3.37**	-3.88***	-4.15***	-4.00***	-3.89***	-3.47***
	(1.7)	(1.5)	(1.4)	(1.3)	(1.2)	(1.1)	(.98)
p(death [X,60])	-3.53***	-3.13**	-2.50	-1.79	-1.44	-.670	-1.12
	(1.3)	(1.4)	(1.6)	(1.8)	(2.1)	(2.8)	(4.7)
TFP growth	-8.27***	-8.25***	-8.23***	-8.21***	-8.20***	-8.20***	-8.24***
	(1.5)	(1.5)	(1.5)	(1.5)	(1.5)	(1.5)	(1.5)
babyboom	-.373***	-.379***	-.387***	-.396***	-.398***	-.383***	-.390***
	(.12)	(.12)	(.12)	(.12)	(.12)	(.12)	(.12)
$\overline{R}^2$	.8350	.8350	.8351	.8351	.8351	.8352	.8350
N	1195	1195	1195	1195	1195	1195	1195

Table 6: Regressions of TFR (standard error)

significance 10 percent *, 5 percent **, 1 percent ***

young adult age	X=25	X=30	X=35	X=40	X=45	X=50	X=55
h	-.226***	-.225***	-.223***	-.222***	-.220***	-.218***	-.221***
	(.019)	(.019)	(.019)	(.019)	(.019)	(.019)	(.019)
infant mortality	1.41	1.85	2.27*	2.78*	3.17***	3.53***	3.11***
	(1.1)	(1.1)	(1.2)	(1.2)	(1.2)	(1.2)	(1.2)
p(death [1,X])	3.49***	2.73***	2.24**	1.84**	1.70**	1.70**	2.13***
	(1.0)	(.97)	(.91)	(.85)	(.80)	(.74)	(.69)
p(death [X,60])	2.50***	3.08***	3.73***	4.73***	5.98***	8.19***	10.7***
	(.85)	(.92)	(1.0)	(1.2)	(1.4)	(2.0)	(3.4)
TFP growth	-.953	-.958	-.945	-.928	-.955	-1.01	-1.10
	(1.5)	(1.5)	(1.5)	(1.4)	(1.4)	(1.4)	(1.4)
babyboom	.402***	.396***	.388***	.378***	.368***	.358***	.358***
	(.066)	(.066)	(.066)	(.066)	(.066)	(.066)	(.067)
$\overline{R}^2$	.6287	.6284	.6290	.6306	.6322	.6339	.6321
N	620	620	620	620	620	620	620
h	-.221***	-.221***	-.220***	-.219***	-.219***	-.219***	-.220***
	(.016)	(.016)	(.016)	(.016)	(.016)	(.016)	(.016)
infant mortality	2.07**	2.43**	2.72***	2.92***	3.00***	2.96***	2.72***
	(.96)	(.97)	(.99)	(1.0)	(1.0)	(1.0)	(.98)
p(death [1,X])	3.90***	3.12***	2.63***	2.36***	2.29***	2.32***	2.44***
	(.97)	(.89)	(.82)	(.75)	(.68)	(.62)	(.57)
p(death [X,60])	1.24*	1.56*	1.88**	2.15**	2.26*	2.14	.829
	(.73)	(.81)	(.90)	(1.0)	(1.2)	(1.6)	(2.7)
TFP growth	-.951	-.938	-.928	-.919	-.916	-.918	-.927
	(.89)	(.89)	(.89)	(.89)	(.89)	(.89)	(.89)
babyboom	.305***	.300***	.295***	.291***	.290***	.291***	.298***
	(.070)	(.70)	(.070)	(.070)	(.070)	(.071)	(.071)
$\overline{R}^2$	.5942	.5932	.5929	.5928	.5928	.5928	.5929
N	1194	1194	1194	1194	1194	1194	1194

Table 7: Regressions of Young Adult Schooling

for TFP growth < 0, (standard error)

significance 10 percent *, 5 percent **, 1 percent ***

young adult age	X=25	X=30	X=35	X=40	X=45	X=50	X=55
h	.863***	.866***	.869***	.873***	.877***	.881***	.881***
	(.088)	(.089)	(.089)	(.089)	(.089)	(.089)	(.089)
infant mortality	-1.61	-1.33	-.979	-.527	.072	.962	1.12
	(3.73)	(3.8)	(3.9)	(4.0)	(4.0)	(4.0)	(3.9)
p(death [1,X])	-8.84***	-10.0***	-10.9***	-11.6***	-12.2***	-12.8***	-12.8***
	(3.0)	(2.9)	(2.8)	(2.6)	(2.5)	(2.3)	(2.2)
p(death [X,60])	-16.6***	-16.1***	-15.6***	-15.0***	-13.8**	-10.8	-7.92
	(3.1)	(3.5)	(3.9)	(4.6)	(5.6)	(7.5)	(12)
TFP growth	8.19	9.11	9.84	10.5	11.2	12.2	12.3
	(8.7)	(8.7)	(8.8)	(8.8)	(8.8)	(8.8)	(8.7)
babyboom	.244	.249***	.258	.264	.263	.245	.230
	(.31)	(.32)	(.32)	(.32)	(.32)	(.32)	(.32)
$\overline{R}^2$	.8719	.8703	.8694	.8688	.8685	.8685	.8686
N	195	195	195	195	195	195	195
h	.613***	.615***	.617***	.621***	.624***	.627***	.627***
	(.050)	(.050)	(.050)	(.050)	(.050)	(.050)	(.050)
infant mortality	-13.9***	-13.4***	-12.9***	-12.2***	-11.6***	-11.0***	-11.1***
	(2.4)	(2.4)	(2.5)	(2.5)	(2.6)	(2.6)	(2.5)
p(death [1,X])	-6.57***	-7.30***	-7.89***	-8.34***	-8.51***	-8.54***	-8.17***
	(2.2)	(2.1)	(2.0)	(1.8)	(1.7)	(1.6)	(1.4)
p(death [X,60])	-6.92***	-6.25***	-5.31**	-3.90	-2.02	1.33	8.03
	(1.9)	(2.1)	(2.4)	(2.8)	(3.4)	(4.4)	(7.4)
TFP growth	9.23***	9.30***	9.38***	9.49***	9.62***	9.75***	9.78***
	(2.8)	(2.8)	(2.8)	(2.8)	(2.8)	(2.8)	(2.8)
babyboom	.389	.387***	.381***	.369	.350	.321	.298
	(.28)	(.28)	(.28)	(.28)	(.29)	(.29)	(.29)
$\overline{R}^2$	.8501	.8501	.8503	.8507	.8511	.8516	.8350
N	482	482	482	482	482	482	482

Table 8: Goodness of fit: population & income (standard error)

significance at the 1 percent level, ***, 5 percent level, **, 10 percent level, *

	population			income		
	$\delta = .5345$	base	spillover $\varepsilon = .1$ $\varphi = .25$	$\delta = .5345$	base	spillover $\varepsilon = .1$ $\varphi = .25$
β	.7630	.8300	.7964	.6400	.9211	.9636
	(.0124)	(.0110)	(.0119)	(.0226)	(.0142)	(.0089)
α	-.1168	-.0928	-.0986	-.7389	.1850	-.0671
	(.0085)	(.0076)	(.0082)	(.0177)	(.0137)	(.0084)
R^2	.8460	.8922	.8674	.6301	.8991	.9616
N	719	719	719	500	500	500
$\beta = 1$	354.73	239.70	294.98	253.80	30.79	16.77
Prob	.0000	.0000	.0000	.0000	.0000	.0000
TIME R^2	.0945	.0945	.0945	.5630	.5630	.5630

Table 9: Goodness of fit: total fertility rate & age at entry into labor force (standard error)

	tfr					labor force entry age		
	$\delta = .5345$	base	spillover $\varepsilon = .1$ $\varphi = .25$	m	m, $\psi = .1$	$\delta = .5345$	base	spillover $\varepsilon = .1$ $\varphi = .25$
β	3.6694	.8210	1.5737	1.3101	1.3131	-40.7642	.2480	1.2733
	(.1897)	(.0281)	(.0485)	(.0355)	(.0356)	(.8342)	(.0072)	(.0193)
α	-5.7040	-.0001	-.2558	-.2161	-.2043	63.569	-.2432	.0482
	(.1631)	(.0249)	(.0465)	(.0331)	(.0333)	(.7323)	(.0068)	(.0187)
R^2	.4142	.6171	.6654	.7202	.7199	.8699	.7698	.9241
N	558	558	558	558	558	386	386	386
$\beta = 1$	197.98	40.53	139.83	76.28	77.30	2506.38	10791.0	200.07
Prob	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
TIME R^2	.4535	.4535	.4535	.4535	.4535	.6989	.6989	.6989

Table 10: Goodness of fit: infant mortality (standard error)

	$\delta = .5345$	base	spillover $\varepsilon = .1$ $\varphi = .25$	m	m, $\psi = .1$
β	.9722	.5976	.6009	1.0742	1.0802
	(.0424)	(.0998)	(.0972)	(.0214)	(.0213)
α	.0367	.4820	.4626	-.1834	-.1533
	(.0719)	(.4194)	(.3904)	(.0328)	(.0326)
R^2	.5000	.0639	.0677	.8271	.8307
N	555	555	555	555	555
$\beta = 1$	0.43	16.27	16.85	12.00	14.21
Prob	0.5123	.0001	.0000	.0006	.0002
TIME R^2	.7002	.7002	.7002	.7002	.7002

Table 11: Goodness of fit: life expectation at birth (standard error)

	$\delta = .5345$	base	spillover $\varepsilon = .1$ $\varphi = .25$	m	m $\psi = .1$	m, $\psi = .1$ clife	m, $\psi = .1$ $\Upsilon = .4$
β	1.0249	.9278	.9126	1.0673	1.0697	1.0427	1.0483
	(.1381)	(.0553)	(.0619)	(.0504)	(.0502)	(.0283)	(.0270)
α	3.9774	1.1780	1.6679	1.4640	1.4572	.0733	-.0064
	(.1092)	(.0456)	(.0578)	(.0450)	(.0451)	(.0226)	(.0227)
R^2	.1430	.4293	.3677	.5450	.5480	.7843	.8007
N	403	403	403	403	403	403	403
$\beta = 1$	0.03	1.70	1.99	1.78	1.93	2.28	3.19
Prob	.8571	.1929	.1588	.1829	.1660	.1315	.0748
TIME R^2	.7343	.7343	.7343	.7343	.7343	.7343	.7343

Table 12: Goodness of fit: conditional life expectation at entry into labor force (standard error)

	$\delta = .5345$	base	spillover $\varepsilon = .1$ $\varphi = .25$	m, $\psi = .1$ clife	m, $\psi = .1$ clife, $\Upsilon = .4$
β	.8529	.7977	.8497	1.8068	1.8479
	(.0744)	(.3262)	(.2936)	(.1151)	(.1154)
α	-.1299	2.6042	2.3082	-1.7215	-2.1258
	(.0597)	(.3121)	(.2785)	(.0778)	(.0877)
R^2	.2991	.0190	.0265	.4443	.4543
N	337	337	337	337	337
$\beta = 1$	3.91	0.38	0.26	49.11	53.98
Prob	.0490	.5355	.6092	.0000	.0000
TIME R^2	.3756	.3756	.3756	.3756	.3756

A. TOTAL FACTOR PRODUCTIVITY

In this appendix I describe the Total Factor Productivity term, Z_t, in equation (41). As in Tamura (2002) the model assumes an agglomeration economy in market participation, limited by the coordination costs of specialization. This technology produces more rapid transition dynamics in income growth than models without specialization gains. I assume that per capita production of the final output depends on the land per person and on the provision of intermediate goods. There exists an agglomeration economy in specialization, but specialization is costly to coordinate. Ignoring time subscripts, the reduced form for the aggregate production technology is:

$$Y = L^{\sigma}\left[\frac{P}{N}\left\{\sum_{i=1}^{N} h_i^{\frac{1}{\omega}}\right\}^{\omega} q\left(\overline{h}\right)^{N}\right]^{1-\sigma} \tag{31}$$

where L is the land holdings in the economy, P is the population of the economy; N is the optimal market size, and hence, $\frac{P}{N}$ is the number of markets in the economy; the term in curly brackets represents the gains from specialization because $\omega > 1$, and $q\left(\overline{h}\right)^{N} < 1$ is the cost of coordinating specialization, which depends negatively on the average level of human capital in the market. Like Kremer (1993a) and Tamura (2002) the specialization coordination costs is represented by the term q^N, where

$$q = \frac{\exp\left(\lambda_1 \overline{h}^{\lambda_2}\right)}{\lambda_3 + \exp\left(\lambda_1 \overline{h}^{\lambda_2}\right)}, \lambda_i > 0 \tag{32}$$

Coordination costs are falling in the average level of human capital in the market and rising in the number of participants in the market. As in Tamura (2002), the optimal market size is a simple function of the average human capital in the market. If all individuals in the economy are identical, $h_i = \overline{h}$, the size of the market that maximizes per capita output is given by:

$$N = -\frac{(\omega - 1)}{\ln q\left(\overline{h}\right)} \tag{33}$$

Per capita output becomes:

$$y = \left(\frac{L}{P}\right)^{\sigma}\left\{N^{\omega-1}\overline{h}q\left(\overline{h}\right)^{N}\right\}^{1-\sigma} \tag{34}$$

Therefore as average human capital rises, the optimal coalition grows. How does this translate into TFP, Z? As long as the optimal market size is less than the population, $N < P$, it is easy to show the value of TFP.[59] It is important to notice that while there is an agglomeration economy

[59] With human capital accumulation, eventually $N > P$, and hence regional economies arise by merging national economies into a single market. Appendix D examines this evolution.

in the number of people in a coalition, there are constant returns to scale in human capital of all the individuals in the market production of intermediate goods. Thus if individuals in the market are paid the marginal product of their human capital, then output is exactly exhausted.[60] Assume there is a Lebesgue measure N workers in the market. Further assume that each individual is a set of measure 0 within the market, and within type. The wage per unit of human capital for a worker of type s, which the worker takes as exogenous, is:

$$w_s = \left\{ \sum_{i=1}^{N} h_i^{\frac{1}{\omega}} \right\}^{\omega-1} q\left(\overline{h}\right)^N h_s^{\frac{1}{\omega}-1} \tag{35}$$

where N is given by equation (33). If $N < P$, then TFP, Z, can be written as:

$$\begin{aligned} TFP &= Z = \left[\left\{ \sum_{i=1}^{N} h_i^{\frac{1}{\omega}} \right\}^{\omega-1} h_s^{\frac{1}{\omega}-1} e^{1-\omega} \right]^{1-\sigma} \\ &= \left[N^{\omega-1} e^{1-\omega} \right]^{1-\sigma} \end{aligned} \tag{36}$$

where the third equality arises when all individuals are identical. When individuals in an economy are identical, per capita output can be written as:

$$y = Z\left(\frac{L}{P}\right)^{\sigma} h^{1-\sigma} = \left[N^{\omega-1}e^{1-\omega}\right]^{1-\sigma}\left(\frac{L}{P}\right)^{\sigma} h^{1-\sigma} \tag{37}$$

Observe that as human capital accumulates, the optimal market size grows. Thus TFP growth arises from the increasing extent of the market. With perpetual accumulation of human capital, the optimal market size will exceed the population of any country and eventually will encompass the entire world.

B. PREFERENCES: DERIVATION OF APPROXIMATION OF EXPECTED UTILITY FUNCTION

The paper uses an approximation of the expected utility arising from young adult mortality risk. Preferences are given by:

$$U(h_t) = \max_{\{n_i, h_{i+1}\}_{i=t}^{\infty}} E_t \left\{ \sum_{i=t}^{\infty} \beta^{i-t} \left\{ \alpha \ln \widetilde{c}_t + (1-\alpha) \ln \widetilde{n}_t \right\} \right\}, \tag{38}$$

A parent chooses the number of live births net of infant mortality, x, but only a fraction will survive to adulthood to perpetuate the dynasty. The proportion that survive is given by $(1-\delta_t)$. The average number of adult survivors is given by:

[60] For more on agglomeration economies of market participation see Tamura (1992).

$$\widetilde{n}_t = x_t (1 - \delta_t) \tag{39}$$

Population of the dynasty, p, grows by:[61]

$$\widetilde{p}_{t+1} = p_t x_t (1 - \delta_t) \tag{40}$$

A country is made up of identical human capital dynasties, obviously each dynasty within a country chooses the same human capital investment and fertility. Therefore a country's population at time t is the dynastic population times the number of initial dynasties.

Household output is produced by combining the mother's land with market goods produced via specialization of labor.[62] An adult at t produces output given by:

$$y_t = Z_t \left(\frac{L}{\widetilde{p}_t} \right)^{\sigma} h_t^{1-\sigma}, \tag{41}$$

where $\widetilde{p}_t$ evolves according to (3). Consumption of the adult is given by:

$$c_t = y_t \left[1 - x_t (\theta + \tau_t) \right]$$

Focusing on the consumption terms in preferences, observe that consumption depends on the land per adult. I assume that each family initially receives the same land holdings as any other member of the economy. Furthermore in order to abstract of distributional issues within a country, I assume that the mortality rate of children across families in a country from parents with identical human capital is identical. Since all parents in an economy are identical in human capital and I abstract from differential human capital investments in children, all families within a country will have the same mortality experience over time. Thus land holdings per adult is common across all families within a country. This is similar to assumptions in Doepke (2004) and Jones (2001). Therefore the expectation of utility from *future* consumption depends on the number of adults in the dynasty. From equation 41 observe that output at time t depends on the land per person at time t, $\frac{L_0}{\widetilde{p}_t}$, where $L_0 = \frac{L}{P_0}$ and L is total land in the region and P_0 is regional population at the very start of time, and $\widetilde{p}_t$ is the number of surviving adults in the *dynasty* in year t and $\widetilde{p}_0 = 1$. An adult at time t, is endowed with land in the amount of $\frac{L_0}{p_t}$. She cares about her own consumption, but also of the

[61] At $t = 0$, I assume that the population of a dynasty is 1, and that a region's population is given by the number of dynasties.

[62] In the year $t = 0$ I assume that each household receives the same amount of land. For all $t > 0$, the land holdings per dynasty are given by their own level of surviving fertility.

consumption of her children and their progeny.

$$E_t\left\{\sum_{i=t}^{\infty}\beta^{i-t}\alpha\ln\widetilde{c}_i\right\}=E_t\left\{\sum_{i=t}^{\infty}\beta^{i-t}\alpha\left[\begin{array}{c}\ln Z_i+\sigma\ln\left(L_0\right)-\sigma\ln\widetilde{p}_i+(1-\sigma)\ln h_i\\+\ln\left[1-x_i\left(\theta+\tau_i\right)\right]\end{array}\right]\right\} \tag{42}$$

Consider only the terms that depend on dynastic population:

$$E_t\left\{-\sum_{i=t}^{\infty}\beta^{i-t}\alpha\sigma\ln\widetilde{p}_i\right\} \tag{43}$$

Population follows:

$$\widetilde{p}_{i>t}=p_t\prod_{j=t}^{i-1}\widetilde{n}_j \tag{44}$$

Hence her preferences over current and all future consumptions include the future terms:

$$\begin{aligned}E_t\left\{\sum_{i=t}^{\infty}-\beta^{i-t}\alpha\sigma\ln\widetilde{p}_i\right\} &= E_t\left\{-\alpha\sigma\ln p_t-\sum_{i=t+1}^{\infty}\beta^{i-t}\alpha\sigma\left[\ln p_t+\sum_{j=t}^{i-1}\ln\widetilde{n}_j\right]\right\}\\ &= -\frac{\alpha\sigma\ln p_t}{1-\beta}-E_t\left\{\alpha\beta\sigma\ln\widetilde{n}_t\right\}-E_t\left\{\sum_{j=t+2}^{\infty}\beta^{i-t}\alpha\sigma\sum_{i=t}^{j-1}\ln\widetilde{n}_i\right\}\\ &= -\frac{\alpha\sigma\ln p_t}{1-\beta}-\frac{\alpha\beta\sigma E_t\left\{\ln\widetilde{n}_t\right\}}{1-\beta}-E_t\left\{\sum_{j=t+2}^{\infty}\beta^{i-t}\alpha\sigma\sum_{i=t+1}^{j-1}\ln\widetilde{n}_i\right\}\end{aligned} \tag{45}$$

Each child from a family faces a probability of dying as a young adult. Under the assumption of independent mortality risk across siblings, a parent has expected utility from the number of surviving children which is distributed as a binomial distribution. The Delta method is the expectation of the utility function that has been expanded in a Taylor series approximation around the mean of the distribution. In this paper I borrow the innovative technique of Kalemli-Ozcan (2002,2003), and use a third degree approximation arising from the underlying binomial distribution of mortality risk. Thus:

$$\begin{aligned}\ln\widetilde{n}_t &= \ln x_t(1-\delta_t)+\frac{\left(\widetilde{n}_t-x_t(1-\delta_t)\right)}{x_t\left(1-\delta_t\right)}-\frac{\left(\widetilde{n}_t-x_t\left(1-\delta_t\right)\right)^2}{2!\left[x_t\left(1-\delta_t\right)\right]^2}\\ &\quad+\frac{2\left(\widetilde{n}_t-x_t\left(1-\delta_t\right)\right)^3}{3!\left[x_t\left(1-\delta_t\right)\right]^2}+\cdots\end{aligned} \tag{46}$$

Taking the expectation implies:

$$\begin{aligned}E\left\{\ln\widetilde{n}_t\right\} &= \ln x_t(1-\delta_t)+E\left\{\frac{\left(\widetilde{n}_t-x_t(1-\delta_t)\right)}{x_t\left(1-\delta_t\right)}\right\}-E\left\{\frac{\left(\widetilde{n}_t-x_t\left(1-\delta_t\right)\right)^2}{2!\left[x_t\left(1-\delta_t\right)\right]^2}\right\}\\ &\quad+E\left\{\frac{2\left(\widetilde{n}_t-x_t\left(1-\delta_t\right)\right)^3}{3!\left[x_t\left(1-\delta_t\right)\right]^2}\right\}+\cdots\end{aligned} \tag{47}$$

$$E\left\{\ln\widetilde{n}_t\right\} = \ln x_t(1-\delta_t) + 0 - \frac{x_t\delta_t\left(1-\delta_t\right)}{2\left[x_t\left(1-\delta_t\right)\right]^2} + 0 + \cdots \tag{48}$$

the second and fourth terms are 0 because they are an odd moments of a symmetric function, the third term depends on the variance of the distribution, which comes from the binomial distribution of mortality risk. Thus as an approximation of the expected utility function term:

$$E\left\{\ln\widetilde{n}_t\right\} \approx \left[\ln x_t(1-\delta_t) - \frac{\delta_t}{2x_t\left(1-\delta_t\right)}\right]. \tag{49}$$

Focusing only on the terms that contain x_t, the preferences of an adult become:

$$-\frac{\alpha\beta\sigma E_t\left\{\ln\widetilde{n}_t\right\}}{1-\beta} \approx -\frac{\alpha\beta\sigma\ln x_t}{1-\beta} - \frac{\alpha\beta\sigma\ln\left(1-\delta_t\right)}{1-\beta} + \frac{\alpha\beta\sigma\delta_t}{(1-\beta)2x_t(1-\delta_t)} \tag{50}$$

Returning to the problem of an adult in period t choosing fertility, x_t, and human capital investment, h_{t+1}, her problem can be written as:

$$\begin{aligned}
& \max_{\{x_i,h_{i+1}\}_{i=t}^{\infty}} E_t\left\{\sum_{i=t}^{\infty}\beta^{i-t}\left\{\alpha\ln\widetilde{c}_t + (1-\alpha)\ln\widetilde{n}_t\right\}\right\} \\
= & \max_{\{x_i,h_{i+1}\}_{i=t}^{\infty}} E_t\left\{\begin{array}{c}\sum\limits_{i=t}^{\infty}\beta^{i-t}\alpha\left[\ln Z_i + \sigma\ln\left(L_0\right) - \sigma\ln\widetilde{p}_i + (1-\sigma)\ln h_i + \ln\left[1-x_i\left(\theta+\tau_i\right)\right]\right] \\ +\sum\limits_{i=t}^{\infty}\beta^{i-t}\left(1-\alpha\right)\ln\widetilde{n}_i\end{array}\right\} \\
= & \frac{\alpha\sigma\ln(L_0)}{1-\beta} - \frac{\alpha\sigma\ln p_t}{1-\beta} + \alpha\left(1-\sigma\right)\ln h_t + \sum_{i=t}^{\infty}\beta^{i-t}\alpha\ln Z_i \\
& + \max_{\{x_i,h_{i+1}\}_{i=t}^{\infty}} E_t\left\{\begin{array}{c}(1-\alpha)\ln\widetilde{n}_t - \frac{\alpha\beta\sigma\ln\widetilde{n}_t}{1-\beta} + \ln\left[1-x_t\left(\theta+\tau_t\right)\right] + \\ +\sum\limits_{i=t+1}^{\infty}\beta^{i-t}\alpha\left[(1-\sigma)\ln h_i + \ln\left[1-x_i\left(\theta+\tau_i\right)\right]\right] \\ -\left\{\sum\limits_{j=t+2}^{\infty}\beta^{i-t}\alpha\sigma\sum\limits_{i=t+1}^{j-1}\ln\widetilde{n}_i\right\} + \sum\limits_{i=t+1}^{\infty}\beta^{i-t}\left(1-\alpha\right)\ln\widetilde{n}_i\end{array}\right\}
\end{aligned} \tag{51}$$

Now taking only the choices that are available to a mother at period t, it is clear that her choice of fertility and human capital investments commit the next generation to selecting their fertility and human capital investments as if period t's mother made the choice, etc. Thus the choices facing a mother in period t, ignoring non choice terms, is given by:

$$\max_{x_t,h_{t+1}} E_t\left\{\left(1-\alpha-\frac{\alpha\beta\sigma}{1-\beta}\right)\ln\widetilde{n}_t + \ln\left[1-x_t\left(\theta+\tau_t\right)\right] + \beta\alpha\left(1-\sigma\right)\ln h_{t+1} + \beta\alpha\ln\left[1-x_{t+1}\left(\theta+\tau_{t+1}\right)\right]\right\}$$

Replacing the $E_t\left\{\ln\widetilde{n}_t\right\}$ with the results from above produces:

$$\max_{x_t,h_{t+1}} E_t\left\{\begin{array}{c}\left(1-\alpha-\frac{\alpha\beta\sigma}{1-\beta}\right)\left[\ln x_t(1-\delta_t) - \frac{\delta_t}{2x_t(1-\delta_t)}\right] \\ +\ln\left[1-x_t\left(\theta+\tau_t\right)\right] + \beta\alpha\left(1-\sigma\right)\ln h_{t+1} + \beta\alpha\ln\left[1-x_{t+1}\left(\theta+\tau_{t+1}\right)\right]\end{array}\right\}$$

C. YOUNG ADULT MORTALITY & INFANT MORTALITY

In order to see the effects of mortality on fertility and human capital investment, assume that there is an unexpected one generation change to the young adult mortality function δ, that leaves all future young adult mortality unchanged. Recall that $\delta_t = \Delta \exp(\bullet)$, where I will assume that the change occurs from a change in Δ. Consider the case where there is no direct effect of young adult human capital on young adult mortality, $\zeta = 0$. The first order conditions for optimal fertility and optimal human capital investment time are repeated below:

$$\frac{\alpha(\theta+\tau_t)}{1-x_t\left(\theta+\tau_t\right)} = \frac{1-\alpha-\frac{\alpha\beta\sigma}{1-\beta}}{x_t} + \frac{(1-\alpha-\frac{\alpha\beta\sigma}{1-\beta})\delta_t}{2x_t^2(1-\delta_t)} \tag{52}$$

$$\frac{\alpha x_t \tau_t}{1-x_t\left(\theta+\tau_t\right)} = \beta\alpha\rho(1-\sigma) + \frac{\beta\alpha x_{t+1}\tau_{t+1}\left(1-\varepsilon\right)}{1-x_{t+1}\left(\theta+\tau_{t+1}\right)} \tag{53}$$

Since δ_{t+1} is assumed to be unaffected by the change in δ_t, observe that the optimal (x_{t+1}, τ_{t+1}) is unaffected by the change in δ_t. Thus totally differentiating () with respect to Δ produces:

$$\frac{\partial \tau_t}{\partial \Delta} = -\frac{\tau_t}{x_t}(1-x_t\theta)\frac{\partial x_t}{\partial \Delta} \tag{54}$$

Totally differentiating () with respect to Δ and simplifying produces:

$$\left\{\frac{\alpha\theta(1-x\tau_t)}{x_t\left[1-x_t(\theta+\tau_t)\right]^2} + \frac{\left(1-\alpha-\frac{\alpha\beta\sigma}{1-\beta}\right)\delta_t}{2x_t^3(1-\delta_t)}\right\}\frac{\partial x_t}{\partial \Delta} = \frac{\left(1-\alpha-\frac{\alpha\beta\sigma}{1-\beta}\right)}{2x_t^2(1-\delta_t)}\frac{\partial \delta_t}{\partial \Delta} > 0 \tag{55}$$

The coefficient in curly brackets on the left hand side of the equation is positive and hence:

$$\frac{\partial x_t}{\partial \Delta} > 0,\ \frac{\partial \tau_t}{\partial \Delta} < 0 \tag{56}$$

D. FERTILITY UNDER CONSTANT MORTALITY

In the range where mortality is essentially constant, fertility is the positive solution to the following quadratic equation:

$$a_{ss}x_{ss}^2 + b_{ss}x_{ss} + c_{ss} \tag{57}$$

$$a_{ss} = \left(1-\frac{\alpha\beta\sigma}{1-\beta}\right)\left(1-\beta\left[1-\varepsilon\right]\right)\theta \tag{58}$$

$$b_{ss} = \alpha\beta\left(1-\sigma\right)\rho - \left(1-\alpha-\frac{\alpha\beta\sigma}{1-\beta}\right)\left(1-\beta\left[1-\varepsilon\right]\right)\left(1-\frac{\theta\delta}{2\left(1-\delta\right)}\right) \tag{59}$$

$$c_{ss} = -\left(1-\alpha-\frac{\alpha\beta\sigma}{1-\beta}\right)\left(1-\beta\left[1-\varepsilon\right]\right)\frac{\delta}{2\left(1-\delta\right)} \tag{60}$$

If there is an increase in the population growth rate over the range where mortality is roughly constant then:

$$\frac{\partial x_t}{\partial \delta_t}(1-\delta_t) - x_t < 0 \tag{61}$$

Replacing for $\frac{\partial x_t}{\partial \delta_t}$ from the previous appendix, rearranging and simplifying produces the following:

$$\frac{\left(1-\alpha-\frac{\alpha\beta\sigma}{1-\beta}\right)(1-\beta[1-\varepsilon])\tau}{2\alpha\beta(1-\sigma)\rho} < \left(\frac{1-\beta[1-\varepsilon]+\beta(1-\sigma)\rho(\theta+\tau)}{1-\beta[1-\varepsilon]+\beta(1-\sigma)\rho}\right)\theta x \tag{62}$$

Replacing for τ from the steady state mortality Euler equation and simplifying produces the following quadratic equation:

$$\begin{aligned}
0 &< a_\delta x_\delta^2 + b_\delta x_\delta + c_\delta & (63)\\
a_\delta &= \left(1-\beta[1-\varepsilon]+\beta(1-\sigma)\rho\theta\left[\frac{1-\beta[1-\varepsilon]}{1-\beta[1-\varepsilon]+\beta(1-\sigma)\rho}\right]\right)\theta & (64)\\
b_\delta &= \frac{\left(1-\alpha-\frac{\alpha\beta\sigma}{1-\beta}\right)(1-\beta[1-\varepsilon])\theta}{2\alpha} + \frac{\beta^2(1-\sigma)^2\rho^2\theta}{1-\beta[1-\varepsilon]+\beta(1-\sigma)\rho} & (65)\\
c_\delta &= -\frac{\left(1-\alpha-\frac{\alpha\beta\sigma}{1-\beta}\right)(1-\beta[1-\varepsilon])}{2\alpha} & (66)
\end{aligned}$$

Comparing the quadratic equation for steady state fertility with the quadratic equation in fertility for the change in the growth rate of population will suffice to show that falling young adult mortality increases population growth over the range where young adult mortality is roughly constant. It is clear that $0 < a_{ss} < a_\delta$. It is also clear that $c_{ss} < c_\delta < 0$ if $\frac{\delta}{1-\delta} > \frac{1}{\alpha}$, which in the simulations holds over this range in young adult mortality. Comparing the coefficients on the linear term, $b_{ss} < b_\delta$ if $\theta\delta < 2(1-\delta)$ and $\alpha < \frac{\beta(1-\sigma)\rho\theta}{1-\beta[1-\varepsilon]+\beta(1-\sigma)\rho}$. These are sufficient conditions under which evaluation of (56) will be positive. Hence the population growth rate is increasing as young mortality rates fall. Unfortunately this analysis does not hold during the transition phase of rapidly changing young adult mortality. The figure below indicates the relationship between young adult mortality and population growth in the numerical solution.

E. INTEGRATION OF REGIONS INTO A SINGLE MARKET

As human capital in a country grows eventually the optimal market size grows more rapidly than population. With accumulation the optimal market size in the rich region will exceed the population of any individual country in the rich region and eventually the total population of the rich region. At this point partial or full economic integration with the poor region may occur. I present the

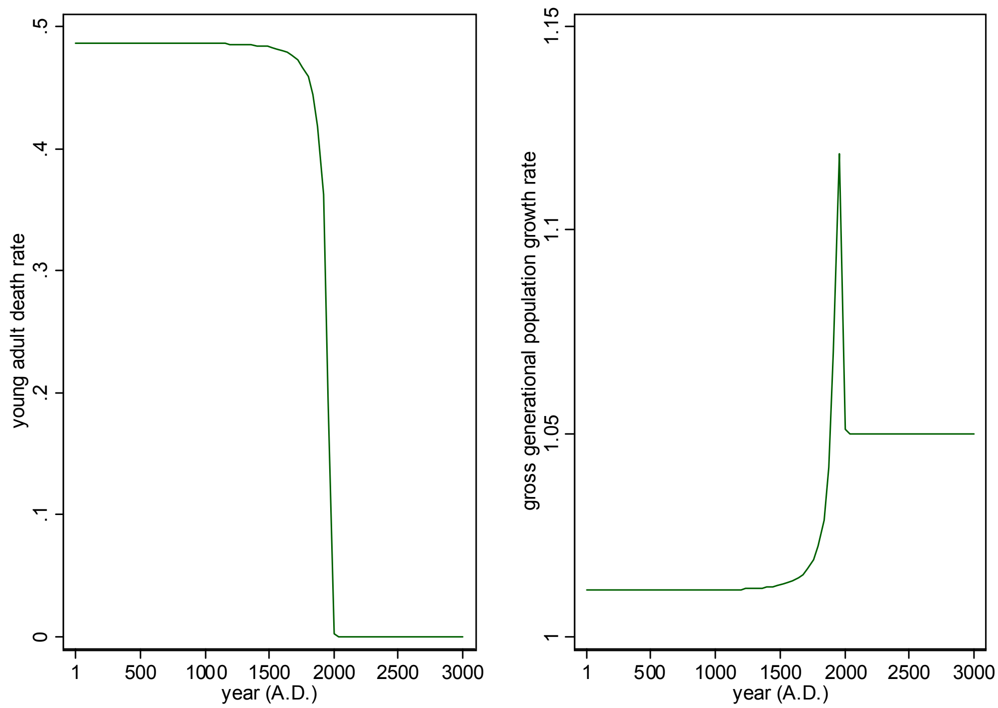

FIG. 1. Time series of young adult mortality rate (left graph) and gross generational population growth rate (right graph)

calculus determining the integration of any country with an amalgam that I call the rich region. Each region is characterized by its population and the human capital of residents in the region. Aggregate integrated production between the P^{rich} rich individuals with h^{rich} human capital and $M \leq P^{poor}$ poor individuals with h^{poor} human capital is:

$$Y^{int} = L^{\sigma} \left[\left\{ P^{rich} \left(h^{rich}\right)^{\frac{1}{\omega}} + M \left(h^{poor}\right)^{\frac{1}{\omega}} \right\}^{\omega} q \left(\overline{h}\right)^{P^{rich}+M} \right]^{1-\sigma} \tag{67}$$

where $\overline{h} = \left(h^{rich}\right)^{\frac{P^{rich}}{M+P^{rich}}} \left(h^{poor}\right)^{\frac{M}{M+P^{rich}}}$. Since each individual is a set of measure 0, all individuals act competitively and act as if they have no effect on the wage rate of others. However in the integration issue, coordinated action on the part of the high human capital individuals is necessary in order to determine the number of poor individuals to integrate. Therefore I assume that high human capital individuals cooperate to choose the number of poor individuals to integrate. High human capital individuals tradeoff gains from greater specialization, $\omega > 1$ the curly bracket term in (67), versus greater costs of coordination, lower $\overline{h}$ and greater numbers, $M + P^{rich}$. Each high human capital individual has income that is proportional to

$$\left[\left\{ P^{rich} \left(h^{rich}\right)^{\frac{1}{\omega}} + M \left(h^{poor}\right)^{\frac{1}{\omega}} \right\}^{\omega-1} q \left(\overline{h}\right)^{P^{rich}+M} \right]^{1-\sigma} \tag{68}$$

Thus I assume that each high human capital individual chooses the number of poor individuals to integrate with as long as it maximizes (68). Each high human capital individual votes on the number of poor individuals to integrate with, and because each high human capital individual has income that is proportional to (68) the vote will be unanimous.[63]

F. SOLUTION ALGORITHM FOR TRANSITION DYNAMICS

In this appendix I present the solution algorithm for the numerical solution. The first order conditions for optimal fertility and human capital investments are repeated below

$$\frac{\alpha(\theta+\tau_t)}{1-x_t\left(\theta+\tau_t\right)} = \frac{1-\alpha-\frac{\alpha\beta\sigma}{1-\beta}}{x_t} + \frac{(1-\alpha-\frac{\alpha\beta\sigma}{1-\beta})\delta_t}{2(1-\delta_t)x_t^2} \tag{70}$$

$$\frac{\alpha x_t \tau_t}{1-x_t\left(\theta+\tau_t\right)} = \beta\alpha\rho(1-\sigma) + \frac{\beta\alpha x_{t+1}\tau_{t+1}\left(1-\varepsilon\right)}{1-x_{t+1}\left(\theta+\tau_{t+1}\right)} + \Psi_t \tag{71}$$

[63] In this case the TFP term for a resident of the rich region becomes:

$$\left[\left\{ P^{rich} \left(h^{rich}\right)^{\frac{1}{\omega}} + M \left(h^{poor}\right)^{\frac{1}{\omega}} \right\}^{\omega-1} \left(h^{rich}\right)^{\frac{1}{\omega}-1} q \left(\overline{h}\right)^{P^{rich}+M} \right]^{1-\sigma} \tag{69}$$

where

$$\Psi_t = \frac{\rho(1-\varphi)\zeta\gamma_1\gamma_2\delta_t}{1-\delta_t}\left(1-\alpha+\frac{1-\alpha-\frac{\alpha\beta\sigma}{1-\beta}}{2(1-\delta_t)x_t}\right)h_{t+1}^{\gamma_2}$$

Notice that if $h_{t+1}, \tau_{t+1}, x_{t+1}$ are known then there is a recursive algorithm for solving h_t, τ_t, x_t. Define the variables $M_{t+1}$and O_{t+1}as

$$M_{t+1} = \frac{\beta\alpha x_{t+1}\tau_{t+1}(1-\varepsilon)}{1-x_{t+1}(\theta+\tau_{t+1})} \tag{72}$$

$$O_{t+1} = \frac{\rho(1-\varphi)\zeta\gamma_1\gamma_2\delta_t}{1-\delta_t}h_{t+1}^{\gamma_2} \tag{73}$$

Taking the ratio of the two Euler equations produces

$$\frac{(\theta+\tau_t)}{\tau_t} = \frac{\left[1-\alpha-\frac{\alpha\beta\sigma}{1-\beta}\right]\left[1+\frac{\delta_t}{2(1-\delta_t)x_t}\right]}{\beta\alpha\rho(1-\sigma)+M_{t+1}+O_{t+1}\left(1-\alpha+\frac{1-\alpha-\frac{\alpha\beta\sigma}{1-\beta}}{2(1-\delta_t)x_t}\right)} \tag{74}$$

Solving for the rate of human capital investment as a function of fertility and young adult mortality produces

$$\tau_t = \frac{\left[\beta\alpha\rho(1-\sigma)+M_{t+1}+O_{t+1}\left(1-\alpha+\frac{1-\alpha-\frac{\alpha\beta\sigma}{1-\beta}}{2(1-\delta_t)x_t}\right)\right]\theta}{\left[1-\alpha-\frac{\alpha\beta\sigma}{1-\beta}\right]\left[1+\frac{\delta_t}{2(1-\delta_t)x_t}\right]-\left[\beta\alpha\rho(1-\sigma)+M_{t+1}+O_{t+1}\left(1-\alpha+\frac{1-\alpha-\frac{\alpha\beta\sigma}{1-\beta}}{2(1-\delta_t)x_t}\right)\right]} \tag{75}$$

Replacing this back into the second Euler equation and simplifying produces the following quadratic equation

$$a_t x_t^2 + b_t x_t + c_t = 0 \tag{76}$$

$$a_t = \frac{1-\frac{\alpha\beta\sigma}{1-\beta}}{1-\alpha-\frac{\alpha\beta\sigma}{1-\beta}}\theta \tag{77}$$

$$b_t = \frac{\delta_t\theta}{2(1-\delta_t)} + \frac{\beta\alpha(1-\sigma)\rho+M_{t+1}+O_{t+1}(1-\alpha)}{1-\alpha-\frac{\alpha\beta\sigma}{1-\beta}} - 1 \tag{78}$$

$$c_t = \frac{-\delta_t+O_{t+1}}{2(1-\delta_t)} \tag{79}$$

Since young adult mortality, δ_t, is a function of generation t+1 human capital, all the coefficients are known for known values of (x_{t+1}, τ_{t+1}). As a quadratic equation, as long as $O_{t+1} < \delta_{t+1}$ it is clear that there are two roots to (76), however only one is positive. Once (x_t, τ_t) are determined from (76) and (75), it is simple to use (15) and (16) to determine period t population and human capital. Continuing in this recursive manner produces the time series on population and human capital.

G. COUNTRIES IN RICH AND POOR REGIONS

Rich group: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Korea (South), Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, United States.

Poor group: Latin America (Group I), Central and Eastern Europe (Group II), China (Group III), Asia without China or India (Group IV), India (Group V) and Africa (Group VI).

The data used for the paper come from a variety of sources. Most of the population, income per capita, age at labor force entry come from Baier, Dwyer and Tamura (2003), hereafter abbreviated BDT. Schooling data for the US prior to 1880 comes from Baier, Mulholland, Tamura and Turner (2004), BMTT. Earlier per capita income comes from Maddison (1995,2001), Mn95 & Mn01. To convert Mn95 values of per capita income, 1820, 1850, 1870, 1890 into comparable values from BDT, I used 6 overlapping years to construct the geometric mean conversion rate. For values prior to 1820, Mn01 was used. To convert pre-1820 income values into comparable values from BDT, I used the overlapping US value for 1820 value in Mn01 compared to the corrected value for 1820 from Mn95. Early population comes from McEvedy and Jones (1978), MJ. Historical life expectation come from Keyfitz and Flieger (1968,1990), KF1 and KF2 and Mitchell (2003), M. Recent life expectation comes from Human Development Reports, HDR. Conditional life expectation comes from KF1, KF2 and Preston, et al, P. All are calculated as life expectation at reaching the age of $40\,(\theta+\tau)$, where I typically interpolated between the ages of 10, 15 and 20. Total fertility rates for 1950-1990, at the quinquennial frequency, come from Keyfitz and Flieger (1990), KF2. The 2000 figure comes from *Human Development Report 2001*. Earlier total fertility rates come from Keyfitz and Flieger (1968), KF1, Wrigley and Schofield, WS, and calculated from population statistics from Mitchell (2003), M.[64] Infant mortality rates primarily come from KF1, KF2, P, M and various issues of the HDR and the *World Development Reports*, WDR.

[64] When using Mitchell's historical data, I use the following transformation to generate total fertility rates: I took the birthrate, b_t, from the specified date, and multiplied by the population of the country at that date, P_t. I then divided this value by the total female population aged 15-44, and multiplied by 30. Thus:

$$tfr_{it} = \frac{30 * b_{it} P_{it}}{\sum_{j=15}^{44} f_{ijt}} \tag{80}$$

where f_{ijt} is the female population in country i at time t aged j. A similar method is used to calculate the total fertility rate using KF1.

Australia:

Population (1, 1000, 1500, 1600, 1700, 1800, 1820, 1840-2000): The population values for 1, 1000, 1500, 1700 and 1820 come from Mn01. The 1600 and 1800 observations are from MJ. Values over the 1840-2000, at the decadal frequency, are from BDT.

Per capita income (1820, 1850-2000): Values for 1820, 1850 and 1870 are from Mn95. All values from 1880 onward, at the decadal frequency, are from BDT.

Age at labor force entry (1870-2000): All values, at the decadal frequency, are from BDT.

Life expectation (1900-2000): All even year values except 2000, at the decadal frequency, are from KF1, KF2 P. In addition 1955 and 1965 are from KF1, and 1975 and 1985 values are from KF2. The 2000 value comes from *HDR 2001*.

Conditional life expectation (1911, 1921, 1933, 1950-1985): The 1911, 1921, 1933, 1950, 1960 and 1965 values are from KF1. The 1970-1985 values, at the quinquennial frequency, are from KF2.

Total fertility rates (1850-1930,1950-2000): The 1850-1930 values are at the decadal frequency and are from M. The 1910 and 1920 values are calculated from KF1. The 1950-1990 values, at the quinquennial frequency, are from KF2. The 2000 figure is from *HDR 2001*.

Infant mortality rates (1870-1900, 1911, 1921, 1933, 1950-2000): The 1870-1900 data are at the decadal frequency, and they are from M (1998). The 1911, 1921 and 1933 values are from KF1. The 1950-1985 values are quinquennial and are from KF2. The 1990, 1995 and 2000 values are from various WDR and HDR.

Life tables information are available for: 1911, 1921, 1933, 1940, 1951, 1954, 1957, 1960, 1963, 1964, 1965, 1971, 1975, 1980, 1983 and 1985.

Austria:

Population (1, 1000, 1500, 1600, 1700, 1800, 1810-2000): The 1, 1000, 1500, 1700 values are from Mn01. The 1600, 1800 values are from MJ, and the rest, at the decadal frequency, are from BDT.

Per capita income (1500, 1600, 1700, 1820, 1850, 1870-2000): Values for 1500, 1600 and 1700 are from Mn01. Values for 1820, 1850 and 1870 are from Mn95. All values from 1880-2000, at the decadal frequency, are from BDT.

Age at labor force entry (1850-2000): All values 1850-2000, except 1860, at the decadal frequency are from BDT.

Life expectation (1950-2000): All even year values, except for 2000, are from KF1, P. The 2000 value is from *HDR 2001*. In addition 1955, 1965, 1975 and 1985 are from KF2.

Conditional life expectation (1950-1985): All values are at the quinquennial frequency. The

1950-1965 values are from KF1. The 1970-1985 values are from KF2.

Total fertility rates (1820-2000): All values 1820-1950 at the decadal frequency. The 1950-1990 values are at the quinquennial frequency. The 1820-1940 values are from M. The 1950-1990 values are from KF2. The 2000 value is from *HDR 2001*.

Infant mortality rates (1810-1940,1950-2000): The 1810-1940 values are at the decadal frequency and are from M. The 1950-2000 values are at the quinquennial frequency. The 1950-1985 values are from KF2. The 1990, 1995 and 2000 values are from various WDR and HDR.

Life tables information are available for: 1951, 1954, 1957, 1960, 1963, 1964, 1965, 1970, 1975, 1980 and 1985.

Belgium:

Population (1, 1000, 1500, 1600, 1700, 1720, 1760, 1800-2000): Values for 1, 1000, 1500 and 1700 are from Mn01. The 1600, 1720 and 1760 three values are from MJ. The 1800-1840 values, at the decadal frequency are from M. The final figures, at the decadal frequency are from BDT.

Per capita income (1500, 1600, 1700, 1820, 1850, 1870-2000): Values for 1500, 1600 and 1700 are from Mn01. Values for 1820, 1850, 1870-1920 (decadal frequency) are from Mn95. All values from 1930-2000, at the decadal frequency, are from BDT.

Age at labor force entry (1850-2000): All values are at the decadal frequency. The 1850-2000 figures are from BDT.

Life expectation (1880-2000): All even year values except for 2000, at the decadal frequency, from KF1, P. The 2000 figure is from *HDR 2001*. In addition 1955, 1965, 1975 and 1985 values are from KF2.

Conditional life expectation (1900-1985): The 1900-1960 values are at the decadal, and are from KF1. The 1970-1985 values, at the quinquennial frequency, are from KF2.

Total fertility rates (1830-2000): All values from 1830-1950 are at the decadal frequency. Values for 1830-1940 from M. The 1950-1990 values, at the quinquennial frequency, are from KF2. The 2000 figure comes from *HDR 2001*.

Infant mortality rates (1840-2000): The 1840-1940 values, at decadal frequency, are from M. The 1950-2000 values are at the quinquennial frequency. The 1950-1985 values are from KF2. The 1990, 1995 and 2000 values come from various issues of *WDR* and *HDR*.

Life tables information are available for: 1900, 1910, 1920, 1924, 1930, 1935, 1940, 1945, 1950, 1955, 1960, 1963, 1964, 1970, 1975, 1980 and 1984.

Canada:

Population (1, 1000, 1500, 1600, 1700, 1800, 1810-2000): Values for 1, 1000, 1500 and 1700 are from Mn01. The 1600 and 1800 figures come from MJ. All figures from 1810-2000 are at the decadal frequency. The 1810-1840 figures come from MJ. The 1850-2000 values come from BDT.

Per capita income (1820, 1850, 1870-2000): The 1820 and 1850 values are from Mn95. All figures, 1870-2000, are at the decadal frequency. All values come from BDT.

Age at labor force entry (1880-2000): The figures are at the decadal frequency. All values are from BDT.

Life expectation (1920-2000): All even year figures are at the decadal frequency. The 1920-1990 figures are from KF1, P. The 2000 figure is from *HDR 2001*. The 1965, 1975 and 1985 values are from KF2.

Conditional life expectation (1930-1990): The 1930-1960 values are at the decadal. The 1930-1965 values are from KF1. The 1970-1985 values, at the quinquennial frequency, are from KF2. The 1990 value comes from the internet site of Statistics Canada.

Total fertility rates (1900-2000): The figures from 1900-1950 are at the decadal frequency. They are calculated from M. The 1950-1990 figures are at the quinquennial frequency are from KF2. The 2000 figure is from *HDR 2001*.

Infant mortality rates (1900-2000): The 1900, 1910 and 1920 values are from M. The 1930 and 1940 values are from KF1. The 1950-2000 values are at the quinquennial frequency. The 1950-1985 values are from KF2. The 1990, 1995 and 2000 values come from various issues of *WDR* and *HDR*.

Life tables information are available for: 1921, 1931, 1941, 1951, 1956, 1960, 1961, 1963, 1964, 1965, 1970, 1975, 1980, 1985 and 1990.

Denmark:

Population (1, 1000, 1500, 1600, 1700, 1800, 1810-2000): Values for 1, 1000, 1500 and 1700 are from Mn01. The 1600 and 1800 figures are from MJ. The rest, at the decadal frequency, are from M.

Per capita income (1500, 1600, 1700 1820, 1850, 1870-2000): Values for 1500, 1600 and 1700 are from Mn01. The 1820 and 1850 values are from Mn95. All figures, 1870-2000, are at the decadal frequency, and all are from BDT.

Age at labor force entry (1850-2000): All figures are at the decadal frequency. The 1850-2000 figures are from BDT.

Life expectation (1840-2000): All even figures are at the decadal frequency. The 1840-1990 figures are from KF1, KF2, P. The 1955, 1965, 1975 and 1985 values are from KF2. The 2000 figure is from *HDR 2001*.

Conditional life expectation (1950-1985): The 1950, 1960 and 1965 values come from KF1. The 1970-1985 values, at the quinquennial frequency come from KF2.

Total fertility rates (1800-2000): The 1800-1950 figures are at the decadal frequency, and are calculated from M. The 1955-1990 values are at the quinquennial frequency, and are from KF2. The 2000 figure is from *HDR 2001*.

Infant mortality rates (1840-2000): The 1840-1940 values are at the decadal frequency and are from M. The 1950-2000 values are at the quinquennial frequency. The 1950-1985 values are from KF2. The 1990, 1995 and 2000 values come from various issues of *WDR* and *HDR*.

Life tables information are available for: 1921, 1930, 1940, 1951, 1953, 1954, 1957, 1960, 1962, 1963, 1964, 1968, 1970, 1973, 1975, 1978, 1980, 1982 and 1985.

Finland:

Population (1, 1000, 1500, 1600, 1700, 1800, 1810-2000): Values for 1, 1000, 1500 and 1700 are from Mn01. The 1600 and 1800 figures are from MJ. The rest, at the decadal frequency, are from M.

Per capita income (1500, 1600, 1700, 1820, 1850, 1870-2000): Values for 1500, 1600 and 1700 are from Mn01. The 1820, 1850 and 1870 figures are from Mn95. All figures, 1880-2000, are at the decadal frequency, and all are from BDT.

Age at labor force entry (1850-2000): All figures are at the decadal frequency. The 1850-2000 figures are from BDT.

Life expectation (1850-2000): All figures are at the decadal frequency. The 1850-1990 figures are from KF1, KF2, P. The 2000 figure is from *HDR 2001*.

Conditional life expectation (1760-1985): The 1760-1960 values are at the decadal frequency. The 1965-1985 values are at the quinquennial frequency. All values are from Kannisto, Nieminen and Turpeinen (1999).

Total fertility rates (1750-2000): The 1750-1940 (at the decadal frequency) are calculated from M. The 1950-1990 values are at the quinquennial frequency, and are from KF2. The 2000 figure is from *HDR 2001*.

Infant mortality rates (1850-2000): The 1850-1940 values, at the decadal frequency, except for 1930, are from M. The 1930 value is from KF1. The 1950-2000 values are at the quinquennial frequency. The 1950-1985 values are from KF2. The 1990, 1995 and 2000 values come from various issues of *WDR* and *HDR*.

Life tables information are available for: 1930, 1951, 1954, 1957, 1960, 1963, 1964, 1965, 1970, 1975, 1980 and 1985.

France:

Population (1, 1000, 1500, 1600, 1700, 1800, 1810-2000): Values for 1, 1000, 1500 and 1700 are from Mn01. The 1600 and 1800 figures are from MJ. The rest, at the decadal frequency, are from M.

Per capita income (1500, 1600, 1700, 1820, 1850, 1870-2000): Values for 1500, 1600 and 1700 are from Mn01. The values for 1820, 1850, 1870-1890 (decadal) are from Mn95. All figures, 1900-2000, are at the decadal frequency, and all are from BDT.

Age at labor force entry (1850-2000): All figures are at the decadal frequency. The 1850-2000 figures are from BDT.

Life expectation (1740, 1820-2000): The 1740 value comes from Mn01. All even years from 1820-2000 are at the decadal frequency. The 1890-1990 figures are from KF2, P. The 1885, 1895, 1905, 1925, 1935, 1945 values are from KF1. The 2000 figure is from *HDR 2001*.

Conditional life expectation (1850-1985): The 1850-1960 values are at the decadal frequency, and are from KF1. The 1970-1985 values, at the quinquennial frequency, are from KF2.

Total fertility rates (1800-2000): The 1800-1940 figures, at the decadal frequency, are calculated from M. The 1950-1990 values are at the quinquennial frequency, and are from KF2. The 2000 figure is from *HDR 2001*.

Infant mortality rates (1740, 1820-2000): The 1740 and 1820 values are from Mn01. The 1820-1940 values, at the decadal frequency, are from M, except for 1820. The 1950-2000 values are at the quinquennial frequency. The 1950-1985 values are from KF2. The 1990, 1995 and 2000 values come from various issues of *WDR* and *HDR*.

Life tables information are available for: 1851, 1861, 1866, 1871, 1872, 1876, 1881, 1886, 1891, 1896, 1901, 1906, 1911, 1921, 1926, 1931, 1936, 1946, 1951, 1954, 1956, 1960, 1961, 1964, 1965, 1968, 1970, 1975, 1980 and 1985.

Germany:

Population (1, 1000, 1500, 1600, 1700, 1800, 1810-2000): Values for 1, 1000, 1500 and 1700 are from Mn01. The 1600 and 1800 figures are from MJ. The rest, at the decadal frequency, are from M.

Per capita income (1500, 1600, 1700, 1820, 1850, 1870-2000): Values for 1500, 1600 and 1700 are from Mn01. The 1820, 1850 and 1870 figures are from Mn95. All figures, 1880-2000, are at the decadal frequency, and all are from BDT.

Age at labor force entry (1850-2000): All figures are at the decadal frequency. The 1850-2000 figures are from BDT.

Life expectation (1820,1900, 1950-2000): The 1820 and 1900 values are from Mn01. All figures 1950-2000 are at the decadal frequency. The 1950-1990 figures are from KF1, P. The 1965, 1975 and 1985 values are from KF2. The 2000 figure is from *HDR 2001*.

Conditional life expectation (1960-1985): All values are at the quinquennial frequency. The 1960 and 1965 values are from KF1. The 1970-1985 values are from KF2.

Total fertility rates (1820-2000): The 1820-1940 figures, at the decadal frequency, are calculated from M. The 1950-1990 values are at the quinquennial frequency, and are from KF2. The 2000 figure is from *HDR 2001*.

Infant mortality rates (1840-2000): The 1840-1940 values are at the decadal frequency, and are from M. The 1950-2000 values are at the quinquennial frequency. The 1950-1985 values are from KF2. The 1990, 1995 and 2000 values come from various issues of *WDR* and *HDR*.

Life tables information are available for: 1960, 1961, 1962, 1963, 1964, 1965, 1970, 1975, 1980 and 1985.

Greece:

Population (1, 1000, 1500, 1600, 1700, 1800, 1810-2000): Values for 1, 1000, 1500 and 1700 are from Mn01. The 1600 and 1800 figures are from MJ. The rest, at the decadal frequency, are from M.

Per capita income (1910-2000): All figures are at the decadal frequency, and all are from BDT.

Age at labor force entry (1910-2000): All figures are at the decadal frequency. The 1910-2000 figures are from BDT.

Life expectation (1930, 1950-2000): All even year figures after 1930 are at the decadal frequency. The 1930, 1950-1990 figures are from KF1, P. The 1965, 1975 and 1985 values are from KF2. The 2000 figure is from *HDR 2001*.

Conditional life expectation (1950-1985): The 1950 and 1960 values are from KF1. The 1970-1985 values, at the quinquennial frequency, are from KF2.

Total fertility rates (1860-2000): The 1860-1940 values are at the decadal frequency and are from M. The 1950-1990 values are at the quinquennial frequency, and are from KF2. The 2000 figure is from *HDR 2001*.

Infant mortality rates (1920-2000): The 1920, 1930 and 1940 values are from M. The 1950-2000 values are at the quinquennial frequency. The 1950-1985 values are from KF2. The 1990, 1995 and 2000 values come from various issues of *WDR* and *HDR*.

Life tables information are available for: 1928, 1950, 1960, 1963, 1964, 1965, 1970, 1975, 1980 and 1985.

Ireland:

Population (1600, 1800, 1810-2000): The first two figures are from MJ. The rest, at the decadal frequency, are from M.

Per capita income (1820, 1870-2000): The values for 1820, 1870-1940 (decadal) are from Mn95. All figures, 1950-2000, are at the decadal frequency, and all are from BDT.

Age at labor force entry (1870-2000): All figures are at the decadal frequency. The 1870-2000 figures are from BDT.

Life expectation (1900-2000): All even year figures are at the decadal frequency. The 1900-1990 figures are from KF1, P. The 1965, 1975 and 1985 values are from KF2. The 2000 figure is from *HDR 2001*.

Conditional life expectation (1925-1985): The 1925-1945 values at the decadal frequency are from KF1. The 1950-1985 values, except for the missing 1965 value, are at the quinquennial frequency. The 1950-1960 values are from KF1, and the 1965-1985 values are from KF2.

Total fertility rates (1860-2000): The 1860-1940 values are at the decadal frequency and are from M. The 1950-1990 values are at the quinquennial frequency, and are from KF2. The 2000 figure is from *HDR 2001*.

Infant mortality rates (1870-2000): The 1870-1920 values are at the decadal frequency, and are from M. The 1925-1945 values, at the decadal frequency, are from KF1. The 1950-2000 values are at the quinquennial frequency. The 1950-1985 values are from KF2. The 1990, 1995 and 2000 values come from various issues of *WDR* and *HDR*.

Life tables information are available for: 1926, 1936, 1946, 1951, 1956, 1961, 1971, 1975, 1981 and 1986.

Italy:

Population (1, 1000, 1500, 1600, 1700, 1800, 1810-2000): Values for 1, 1000, 1500 and 1700 are from Mn01. The 1600 and 1800 figures are from MJ. The rest, at the decadal frequency, are from M.

Per capita income (1500, 1600, 1700, 1820, 1860–2000): Values for 1500, 1600 and 1700 are from Mn01. The 1820 value comes from Mn95. All figures, 1860-2000, are at the decadal frequency, and all are from BDT.

Age at labor force entry (1870-2000): All figures 1870-2000 are at the decadal frequency. The 1870-2000 figures are from BDT.

Life expectation (1820, 1880-2000): All even year figures are at the decadal frequency. The 1820 figure is from Mn01. The 1880-1990 figures are from KF1, P. The 1955, 1965, 1975 and 1985 values are from KF2. The 2000 figure is from *HDR 2001*.

Conditional life expectation (1930-1985): The 1930, 1935, 1950, 1960 and 1965 values are from KF1. The 1970-1985 values, at the quinquennial frequency are from KF2.

Total fertility rates (1850, 1875, 1900-2000): The values for years 1850, 1875, 1900, 1911, 1920, 1930, and 1940 are calculated from M. The 1935 value is calculated from KF1. The 1950-1990 values are at the quinquennial frequency, and are from KF2. The 2000 figure is from *HDR 2001*.

Infant mortality rates (1860-2000): The 1860-1920 values are at the decadal frequency, and are from M. The 1930 and 1935 values are from KF1. The 1950-2000 values are at the quinquennial frequency. The 1950-1985 values are from KF2. The 1990, 1995 and 2000 values come from various issues of *WDR* and *HDR*.

Life tables information are available for: 1881, 1891, 1901, 1910, 1921, 1931, 1936, 1951, 1960, 1961, 1964, 1970, 1975, 1978, 1980 and 1983.

Japan:

Population (1, 1000, 1500, 1600, 1700, 1800, 1810-2000): Values for 1, 1000, 1500 and 1700 are from Mn01. The 1600 and 1800 figures are from MJ. The rest, at the decadal frequency, are from M.

Per capita income (1, 1000, 1500, 1600, 1700, 1820, 1870, 1890-2000): Values for 1, 1000, 1500, 1600 and 1700 are from Mn01. The 1820, 1870 and 1890 values are from Mn95. All figures, 1900-2000, are at the decadal frequency, and all are from BDT.

Age at labor force entry (1900-2000): All figures 1900-2000 are at the decadal frequency. The 1900-2000 figures are from BDT.

Life expectation (1820, 1900-2000): The 1820 value comes from Mn01. All figures 1900-2000 are at the decadal frequency. The 1900-1990 figures are from KF1, P. The 1955, 1965 and 1975 values are from KF2. The 2000 figure is from *HDR 2001*.

Conditional life expectation (1940-2000): The 1940, 1950, 1955, 1960, 1965 values are from KF1. The 1970, 1980 values are from KF2. The 2000 figure is from the internet.

Total fertility rates (1870-2000): From 1870 to 1940 the figures are at the decadal frequency, and are calculated from M. The 1950-1990 values are at the quinquennial frequency, and are from KF. The 2000 figure is from *HDR 2001*.

Infant mortality rates (1820, 1830, 1900-2000): The 1820 and 1830 values are from Mn01. The 1900, 1910, 1920 and 1930 values are from M. The 1940 value is from KF1. The 1950-2000 values are at the quinquennial frequency. The 1950-1985 values are from KF2. The 1990, 1995 and 2000 values come from various issues of *WDR* and *HDR*.

Life tables information are available for: 1899, 1908, 1940, 1951, 1954, 1957, 1960, 1963, 1964, 1970 and 1980.

Korea:

Population (1, 1000, 1500, 1600, 1700, 1800, 1810-2000): Values for 1, 1000, 1500 and 1700 are from Mn01. The 1600 and 1800 figures are from MJ. The rest, at the decadal frequency, are from M.

Per capita income (1900-2000): The 1900-1930 figures, at the decadal frequency, are from Mn95. All figures, 1940-2000, are at the decadal frequency, and all are from BDT.

Age at labor force entry (1910-2000): All figures are at the decadal frequency, and all are from BDT.

Life expectation (1950-2000): The even year values (decadal) prior to 1990 are from KF2. The 1985 value also comes from KF2. The 2000 figure is from *HDR 2001*.

Conditional life expectation values are unavailable for Korea.

Total fertility rates (1950-2000): The 1950-1990 values are at the quinquennial frequency, and are from KF2. The 2000 figure is from *HDR 2001*.

Infant mortality rates (1950-2000): The 1950-2000 values are at the quinquennial frequency. The 1950-1985 values are from KF2. The 1990, 1995 and 2000 values come from various issues of *WDR* and *HDR*.

Life tables information are available for: 1960 and 1978.

Netherlands:

Population (1, 1000, 1500, 1600, 1700, 1800, 1810-2000): Values for 1, 1000, 1500 and 1700 are from Mn01. The 1600 and 1800 figures are from MJ. The rest, at the decadal frequency, are from M.

Per capita income (1500, 1600, 1700, 1820, 1850, 1870-2000): Values for 1500, 1600 and 1700 are from Mn01. The 1820, 1850, 1870-1890 (decadal) values are from Mn95. All figures, 1900-2000, are at the decadal frequency, and all are from BDT.

Age at labor force entry (1840-2000): All figures are at the decadal frequency. The 1840-2000 figures are from BDT.

Life expectation (1820-2000): All figures are at the decadal frequency, except for 1830. The 1820-1990 figures are from KF1, KF2, P. The 2000 figure is from *HDR 2001*.

Conditional life expectation (1900-1985): All values are at the quinquennial frequency. The 1900-1965 values are from KF1. The 1970-1985 values are from KF2.

Total fertility rates (1840-2000): The 1840-1890 values are decadal and are from M. The 1900-1990 values are quinquennial. The 1905, 1915, 1920, 1930, 1935 and 1945 values are calculated from KF1, the others from 1900-1945 are from M. The 1950-1990 values are at the quinquennial frequency, and are from KF2. The 2000 figure is from *HDR 2001*.

Infant mortality rates (1840-2000): The 1840-1890 values are at the decadal frequency, and are from M. The 1900-2000 values are all at the quinquennial frequency. The 1900-1945 values are from KF1. The 1950-1985 values are from KF2. The 1990, 1995 and 2000 values come from various issues of *WDR* and *HDR*.

Life tables information are available for: 1901, 1905, 1910, 1915, 1920, 1925, 1930, 1931, 1935, 1940, 1945, 1950, 1955, 1960, 1963, 1964, 1965, 1970, 1975, 1977, 1980, 1985 and 1989.

New Zealand:

Population (1850-2000): All figures are at the decadal frequency and are from M.

Per capita income (1870-2000): The 1870 value comes from Mn95. All figures, 1880-2000, are at the decadal frequency, and all are from BDT.

Age at labor force entry (1870-2000): All figures are at the decadal frequency. The 1870-2000 figures are from BDT.

Life expectation (1880-2000): All figures are at the decadal frequency. The 1880-1990 figures are from KF1, KF2, P. The 2000 figure is from *HDR 2001*.

Conditional life expectation (1950-1985): The values are at the quinquennial frequency. The 1950-1965 values are from KF1. The 1970-1985 values are from KF2.

Total fertility rates (1860-2000): From 1860 to 1940 the figures are at the decadal frequency, and are calculated from M. The 1950-1990 values are at the quinquennial frequency, and are from KF2. The 2000 figure is from *HDR 2001*.

Infant mortality rates (1860-2000): The 1860-1940 values are at the decadal frequency, and are from M. The 1950-2000 values are at the quinquennial frequency. The 1950-1985 values are from KF2. The 1990, 1995 and 2000 values come from various issues of *WDR* and *HDR*.

Life tables information are available for: 1951, 1954, 1957, 1961, 1964, 1965, 1970, 1975, 1980, 1981, 1982 and 1985.

Norway:

Population (1, 1000, 1500, 1600, 1700, 1800, 1810-2000): Values for 1, 1000, 1500 and 1700 are from Mn01. The 1600 and 1800 figures are from MJ. The rest, at the decadal frequency, are from M.

Per capita income (1500, 1600, 1700, 1820, 1850, 1860, 1870-2000): Values for 1500, 1600 and 1700 are from Mn01. The 1820, 1850 and 1870 values come from Mn95. All figures, 1860 and 1880-2000, at the decadal frequency, are from BDT.

Age at labor force entry (1850-2000): All figures are at the decadal frequency. The 1850-2000 figures are from BDT.

Life expectation (1880-2000): From 1900 all figures are at the decadal frequency, excluding 1940. The 1880-1990 figures are from KF1, KF2, P, excluding 1890. The 2000 figure is from *HDR 2001*.

Conditional life expectation (1950-1985): The values are at the quinquennial frequency. The 1950-1965 values are from KF1. The 1970-1985 values are from KF2.

Total fertility rates (1750-2000): From 1750 to 1940 the figures are at the decadal frequency, and are calculated from M. The 1950-1990 values are at the quinquennial frequency, and are from KF2. The 2000 figure is from *HDR 2001*.

Infant mortality rates (1840-2000): The 1840-1940 values are at the decadal frequency, and are from M. The 1950-2000 values are at the quinquennial frequency. The 1950-1985 values are from KF2. The 1990, 1995 and 2000 values come from various issues of *WDR* and *HDR*.

Life tables information are available for: 1910, 1920, 1930, 1946, 1951, 1954, 1957, 1960, 1963, 1964, 1968, 1970, 1975, 1980 and 1985.

Portugal:

Population (1, 1000, 1500, 1600, 1700, 1800, 1810-2000): Values for 1, 1000, 1500 and 1700 are from Mn01. The 1600 and 1800 figures are from MJ. The rest, at the decadal frequency, are from M.

Per capita income (1500, 1600, 1700, 1820, 1850, 1870, 1890-2000): Values for 1500, 1600, 1700 and 1820 are from Mn01. The 1850, 1870 and 1890-1940 (decadal) values are from Mn95. All figures, 1950-2000, are at the decadal frequency, and all are from BDT.

Age at labor force entry (1850-2000): All figures are at the decadal frequency. The 1850-2000 figures are from BDT.

Life expectation (1920-2000): All figures are at the decadal frequency. The 1920-1990 figures are from KF1, KF2, P. The 2000 figure is from *HDR 2001*.

Conditional life expectation (1950-1985): The values are at the quinquennial frequency. The 1950-1965 values are from KF1. The 1970-1985 values are from KF2.

Total fertility rates (1890-2000): From 1890 to 1940 the figures are at the decadal frequency, and are calculated from M. The 1950-1990 values are at the quinquennial frequency, and are from KF2. The 2000 figure is from *HDR 2001*.

Infant mortality rates (1890-2000): The 1890-1940 values are from M, at the decadal frequency. The 1950-2000 values are at the quinquennial frequency. The 1950-1985 values are from KF2. The 1990, 1995 and 2000 values come from various issues of *WDR* and *HDR*.

Life tables information are available for: 1920, 1930, 1940, 1951, 1954, 1957, 1960, 1963, 1964, 1965, 1970, 1975, 1980 and 1985.

Spain:

Population (1, 1000, 1500, 1600, 1700, 1800, 1810-2000): Values for 1, 1000, 1500 and 1700 are from Mn01. The 1600 and 1800 figures are from MJ. The rest, at the decadal frequency, are from M.

Per capita income (1500, 1600, 1700, 1820, 1850, 1870, 1890-2000): Values for 1500, 1600 and 1700 are from Mn01. The 1820, 1850, 1870, 1890 and 1900 values are from Mn95. All figures, 1910-2000, are at the decadal frequency, and all are from BDT.

Age at labor force entry (1870-2000): All figures are at the decadal frequency. The 1870-2000 figures are from BDT.

Life expectation (1820, 1900-2000): The 1820 value comes from Mn01. All figures 1900-2000 are at the decadal frequency. The 1920-1990 figures are from KF1, KF2, P. The 2000 figure is from *HDR 2001*.

Conditional life expectation (1950-1985): The 1950, 1960 and 1965 values are from KF1. The 1970-1985 values, at the quinquennial frequency, are from KF2.

Total fertility rates (1860-2000): From 1860 to 1940 the figures are at the decadal frequency, and are calculated from M. The 1950-1990 values are at the quinquennial frequency, and are from KF2. The 2000 figure is from *HDR 2001*.

Infant mortality rates (1860-2000): The 1860-1940 values are at the decadal frequency, and are from M. The 1950-2000 values are at the quinquennial frequency. The 1950-1985 values are from KF2. The 1990, 1995 and 2000 values come from various issues of *WDR* and *HDR*.

Life tables information are available for: 1930, 1940, 1950, 1960, 1962, 1963, 1975, 1980 and 1983.

Sweden:

Population (1, 1000, 1500, 1600, 1700, 1800, 1810-2000): Values for 1, 1000, 1500 and 1700 are from Mn01. The 1600 and 1800 figures are from MJ. The rest, at the decadal frequency, are from M.

Per capita income (1500, 1600, 1700, 1820, 1850-2000): Values for 1500, 1600 and 1700 are from Mn01. The 1820 and 1850 values come from Mn95. All figures, 1860-2000, are at the decadal frequency, and all are from BDT.

Age at labor force entry (1850-2000): All figures are at the decadal frequency. The 1850-2000 figures are from BDT.

Life expectation (1780-2000): All figures 1780-1990 are at the quinquennial frequency. The 1780-1960 figures are from KF1. The 1965-1990 values are from KF2. The 2000 figure is from *HDR 2001*.

Conditional life expectation (1780-1985): All values are at the quinquennial frequency. The 1780-1965 values are from KF1. The 1970-1985 values are from KF2.

Total fertility rates (1750-2000): The values from 1750-1990 are at the quinquennial frequency. The values for 1750-1775 are from M. The values for the years 1780-1795, and the odd years 1905-1945 are calculated from KF1. The even years from 1800 to 1940 are calculated from M. The 1950-1990 values are at the quinquennial frequency, and are from KF. The 2000 figure is from *HDR 2001*.

Infant mortality rates (1750-2000): The 1750-1770 values at the decadal frequency are from M. All values from 1780-2000 are at the quinquennial frequency. The 1780-1945 values are from KF1. The 1950-1985 values are from KF2. The 1990, 1995 and 2000 values come from various issues of *WDR* and *HDR*.

Life tables information are available for: 1860, 1865, 1870, 1875, 1880, 1885, 1890, 1895, 1900, 1905, 1910, 1911, 1915, 1920, 1925, 1930, 1935, 1940, 1945, 1950, 1951, 1955, 1960, 1964, 1965, 1970, 1975, 1980 and 1985.

Switzerland:

Population (1, 1000, 1500, 1600, 1700, 1800, 1810-2000): Values for 1, 1000, 1500 and 1700 are from Mn01. The 1600 and 1800 figures are from MJ. The rest, at the decadal frequency, are from M.

Per capita income (1500, 1600, 1700, 1820 1870, 1890-2000): Values for 1500, 1600, 1700 and

1820 are from Mn01. The 1870, 1890 and 1900 values come from Mn95. All figures, 1910-2000, are at the decadal frequency, and all are from BDT.

Age at labor force entry (1870-2000): All figures are at the decadal frequency. The 1870-2000 figures are from BDT.

Life expectation (1930-2000): All figures are at the decadal frequency. The 1930-1990 figures are from KF1, KF2, P. The 2000 figure is from *HDR 2001*.

Conditional life expectation (1950-1985): All figures are at the quinquennial frequency. The 1950-1965 values are from KF1. The 1970-1985 values are from KF2.

Total fertility rates (1870-2000): From 1870 to 1940 the figures are at the decadal frequency, and are calculated from M. The 1950-1990 values are at the quinquennial frequency, and are from KF. The 2000 figure is from *HDR 2001*.

Infant mortality rates (1870-2000): The 1870-1940 values are at the decadal frequency, and are from M. The 1950-2000 values are at the quinquennial frequency. The 1950-1985 values are from KF2. The 1990, 1995 and 2000 values come from various issues of *WDR* and *HDR*.

Life tables information are available for: 1930, 1941, 1951, 1954, 1957, 1960, 1962, 1963, 1964, 1970, 1975, 1980 and 1986.

United Kingdom:

Population (1, 1000, 1500, 1600, 1700, 1800, 1810-2000): Values for 1, 1000, 1500 and 1700 are from Mn01. The 1600 and 1800 figures are from MJ. The rest, at the decadal frequency, are from M.

Per capita income (1500, 1600, 1700, 1820-2000): Values for 1500, 1600 and 1700 are from Mn01. The 1820 value comes from Mn95. All figures, 1830-2000, are at the decadal frequency, and all are from BDT.

Age at labor force entry (1830-2000): All figures are at the decadal frequency. The 1830-2000 figures are from BDT.

Life expectation (1360, 1560, 1620, 1720, 1800, 1820, 1850-2000): The 1360, 1560, 1620, 1720, 1800 and 1820 values are from Mn01. All figures 1850-2000 are at the decadal frequency. The 1930-1990 figures are from KF1, KF2, P. The 2000 figure is from *HDR 2001*.

Conditional life expectation (1860-2000): The 1860-1940 values are at the decadal frequency. The 1945-1985 values are at the quinquennial frequency. The 1860-1965 values are from KF1. The 1970-1985 values are from KF2. The 2000 figure comes from the internet.

Total fertility rates (1600-2000): The 1600, 1640, 1680, 1720, 1760, 1800 1830 values are from

WS. The values from 1840-1940 are at the decadal frequency, and are calculated from M. The 1950-1990 values are at the quinquennial frequency, and are from KF. The 2000 figure is from *HDR 2001*.

Infant mortality rates (1360, 1620, 1720, 1800, 1840-2000): The 1360, 1620, 1720 and 1800 values are from Mn01. The 1840 and 1850 values are from M. The 1860-1940 values are at the decadal frequency. The 1860-1940 values are from KF1. The 1950-2000 values are at the quinquennial frequency. The 1950-1985 values are from KF2. The 1990, 1995 and 2000 values come from various issues of *WDR* and *HDR*.

Life tables information are available for: 1861, 1871, 1881, 1891, 1901, 1911, 1921, 1931, 1940, 1941, 1946, 1951, 1956, 1960, 1961, 1963, 1964, 1970, 1975, 1979, 1983 and 1985.

USA:

Population (1600, 1800, 1810-2000): The first two figures are from MJ. The rest, at the decadal frequency, are from M.

Per capita income (1500, 1600, 1700, 1790-2000): Values for 1500, 1600 and 1700 are from Mn01. All figures, 1790-2000, are at the decadal frequency, and all are from BDT.

Age at labor force entry (1840-2000): All figures are at the decadal frequency. The 1840-1880 figures are from BMTT. The 1880-2000 figures are from BDT.

Life expectation (1820, 1850-2000): The 1820 value comes from Mn01. All figures 1850-2000 are at the decadal frequency, and are from various issues of the *Statistical Abstract of the United States* and *Historical Statistics of the United States: Colonial Times to 1970*.

Conditional life expectation (1850-2000): All figures are at the decadal frequency. The 1850-1970 values from the *Historical Statistics of the United States: Colonial Times to 1970*. The 1980, 1990 and 2000 values come from various issues of the *Statistical Abstract of the United States*.

Total fertility rates (1800-2000): All 1800-1900 figures are at the decadal frequency, from 1900-1990 the values are at the quinquennial frequency, and are from various issues of the *Statistical Abstract of the United States* and *Historical Statistics of the United States: Colonial Times to 1970*.

Infant mortality rates (1850-2000): The 1850-1950 values are at the decadal frequency. The 1950-2000 values are at the quinquennial frequency. The 1850-1970 values are from *Historical Statistics of the United States: Colonial Times to 1970*. The 1980, 1985, 1990, 1995 and 2000 values come from various issues of *The Statistical Abstract of the United States*.

Life tables information are available for: 1900, 1910, 1920, 1930, 1935, 1940, 1945, 1950, 1955, 1960, 1962, 1963, 1964, 1970, 1975, 1980, 1985 and 1990. The 1990 value comes from the *Statistical*

Abstract of the United States.

Latin America (Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, Trinidad & Tobago, Uruguay, Venezuela):

Population (1, 1000, 1500, 1600, 1700, 1800-2000): Values for 1, 1000, 1500 and 1700 are from Mn01. The 1600 and 1800 figures are from MJ. The figures from 1810 to 2000 are from M. The values from 1800-2000 are at the decadal frequency.

Per capita income (1, 1000, 1500, 1600, 1700, 1820, 1870, 1890-2000): Values for 1, 1000, 1500, 1600, 1700, 1820 and 1870 are from Mn01. The 1890 and 1900 values come from Mn95. All figures, 1910-2000, are at the decadal frequency, and all are from BDT. These are labor force weighted averages. Not all countries are represented throughout. For those countries that are missing some observations, I list the year of their first appearance in the weighted average: Argentina (1895), Bolivia (1888), Brazil (1872), Chile (1895), Colombia (1917), Costa Rica (1892), Dominican Republic (1935), Ecuador (1950), El Salvador (1930), Guatemala (1921), Guyana (1946), Haiti (1950), Honduras (1930), Jamaica (1953), Mexico (1895), Nicaragua (1950), Panama (1950), Paraguay (1940), Peru (1910), Puerto Rico (1960), Trinidad & Tobago (1960), Uruguay (1940) and Venezuela (1940).

Age at labor force entry (1890-2000): All figures are at the decadal frequency, and all are from BDT. These are labor force weighted averages. Not all countries are represented throughout. For those countries that are missing some observations, I list the year of their first appearance in the weighted average. Argentina (1910), Bolivia (1950), Brazil (1950), Chile (1900), Colombia (1920), Costa Rica (1910), Dominican Republic (1950), Ecuador (1950), El Salvador (1930), Guatemala (1930), Guyana (1911), Haiti (1950), Honduras (1930), Jamaica (1921), Mexico (1895), Nicaragua (1950), Panama (1950), Paraguay (1940), Peru (1910), Puerto Rico (1950), Trinidad & Tobago (1930), Uruguay (1900) and Venezuela (1940).

Life expectation (1820, 1900-2000): The 1820 and 1900 values come from Mn01. The 1950-1990 figures are at the decadal frequency, and all are from KF. The 2000 figure comes from *HDR 2001*. These are labor force weighted averages. For those countries with missing observations, I list the first year of their appearance in the weighted average: Argentina (1950), Bolivia (1950), Brazil (1950), Chile (1909), Colombia (1950), Costa Rica (1950), Dominican Republic (1950), Ecuador (1950), El Salvador (1950), Guatemala (1950), Haiti (1950), Honduras (1950), Jamaica (1951), Mexico (1950), Nicaragua (1950), Panama (1950), Paraguay (1950), Peru (1950), Puerto Rico (1950), Trinidad &

Tobago (1950), Uruguay (1950), and Venezuela (1950).

Conditional life expectation (1910-1990): All values are at the decadal frequency. All values come from KF1 and KF2. These are labor force weighted averages. Not all of the countries are represented throughout. For those countries that are missing observations, I list the year of their first appearance in the weighted average. Argentina (1960), Bolivia (1970), Brazil (1980), Colombia (1960), Costa Rica (1960), Dominican Republic (1960), Ecuador (1960), El Salvador (1950), Guatemala (1960), Guyana (1990), Haiti (1970), Honduras (1960), Jamaica (1950), Mexico (1960), Panama (1960), Paraguay (1970), Peru (1960), Puerto Rico (1960), Trinidad and Tobago (1950), Venezuela (1960).

Total fertility rates (1900-2000): The figures are at the decadal frequency, and all are from KF. The 2000 figure is from *HDR 2001.* These are labor force weighted averages. Not all countries are represented throughout. For those countries that are missing some observations, I list the year of their first appearance in the weighted average: Argentina (1910), Bolivia (1950), Brazil (1950) Chile (1900), Colombia (1920), Costa Rica (1910), Dominican Republic (1950), Ecuador (1950), El Salvador (1930), Guatemala (1930), Guyana (1911), Haiti (1950), Honduras (1930), Jamaica (1921), Mexico (1900), Nicaragua (1950), Panama (1950), Paraguay (1950), Peru (1950), Puerto Rico (1950), Trinidad & Tobago (1930), Uruguay (1920), Venezuela (1920).

Infant mortality rates (1900-2000): The 1900-1940 values are at the decadal frequency. The values are weighted averages of Argentina, Chile and Mexico, and come from M. The 1950-2000 values are at the quinquennial frequency. The 1950-1985 values are from KF2. The 1990, 1995 and 2000 values come from various issues of *WDR* and *HDR;* these are labor force weighted averages. Not all countries are represented throughout. For those countries that are missing some observations, I list the year of their first appearance in the weighted average. Argeninta (1910), Bolivia (1950), Brazil (1950) Chile (1900), Colombia (1920), Costa Rica (1910), Dominican Republic (1950), Ecuador (1950), El Salvador (1930), Guatemala (1930), Guyana (1910), Haiti (1950), Honduras (1930), Jamaica (1921), Mexico (1900), Nicaragua (1950), Panama (1950), Paraguay (1950), Peru (1940), Puerto Rico (1950), Trinidad & Tobago (1930), Uruguay (1920), Venezuela (1920).

Life table values exist for the following countries and following years: Argentina (1961,1963,1968,1970,1973,1978), Bolivia (1973, 1978), Brazil (1975), Chile (1909, 1920, 1930, 1940, 1950, 1954, 1959, 1960, 1962, 1964, 1970, 1980 and 1982), Colombia (1960, 1964, 1973 and 1984), Costa Rica (1960, 1963, 1964, 1973, 1980 and 1984), Dominican Republic (1960, 1965, 1974 and 1980), Ecuador (1958, 1968, 1973 and 1978), El Salvador (1950, 1971, 1980 and 1982), Guatemala (1961, 1964, 1980 and 1985), Guyana (1985), Haiti (1970), Honduras (1960, 1963, 1964, 1965, 1983 and 1988), Jamaica (1951, 1956, 1970 and 1977), Mexico (1960, 1962, 1964, 1970, 1973 and 1980), Panama (1960, 1962, 1964, 1970, 1980 and 1989), Paraguay (1972, 1979 and 1987), Peru (1961, 1973 and 1978), Puerto Rico (1960, 1963, 1964, 1965, 1970 and 1985), Trinidad and Tobago (1954, 1955, 1957, 1960, 1963, 1970, 1975 and 1980), Uruguay (1975), and Venezuela (1960, 1963, 1964, 1970 and 1985).

Eastern Europe (Albania, Armenia, Azerbaijan, Belarus, Bulgaria, Cyprus, Czechoslovakia, East Germany, Estonia, Georgia, Hungary, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Poland, Romania, Soviet Union/Russia, Slovak Republic, Tajikistan, Turkmenistan, Ukraine, Uzbekistan, Yugoslavia)

Population (1, 1000, 1400, 1500, 1600, 1700, 1800-2000): Values for 1, 1000, 1500 and 1700 are from Mn01. The 1400, 1600 and 1800 figures are from MJ. The figures from 1810 to 2000 are from M. The values from 1800-2000 are at the decadal frequency.

Per capita income (1, 1000, 1500, 1600, 1700, 1820, 1870, 1890-2000): Values for 1, 1000, 1500, 1600, 1700, 1820 and 1870 are from Mn01. The 1890 and 1900 values come from Mn95. All figures, 1890-2000, are at the decadal frequency, and all are from BDT. These are labor force weighted averages. Not all countries are represented throughout. For those countries that are missing some observations, I list the year of their first appearance in the weighted average. Albania (1990), Armenia (1990), Azerbaijan (1990), Belarus (1990), Bulgaria (1930), Czechoslovakia (1920), East Germany (1950), Estonia (1990), Georgia (1990), Hungary (1890), Kazakhstan (1990), Kyrgyzstan (1990), Latvia (1990), Lithuania (1990), Moldova (1990), Poland (1930), Romania (1930), Soviet Union (1900), Slovak Republic (1990), Tajikistan (1990), Turkmenistan (1990), Ukraine (1990), Uzbekistan (1990), Yugoslavia (1920).

Age at labor force entry (1870-2000): All figures are at the decadal frequency, and all are from BDT. These are labor force weighted averages. Not all countries are represented throughout. For those countries that are missing some observations, I list the year of their first appearance in the weighted average. Albania (1990), Armenia (1990), Azerbaijan (1990), Belarus (1990), Bulgaria (1890), Czechoslovakia (1920), East Germany (1950), Estonia (1990), Georgia (1990), Hungary (1870), Kazakhstan (1990), Kyrgyzstan (1990), Latvia (1990), Lithuania (1990), Moldova (1990), Poland (1920), Romania (1900), Soviet Union (1900), Slovak Republic (1990), Tajikistan (1990), Turkmenistan (1990), Ukraine (1990), Uzbekistan (1990), Yugoslavia (1920).

Life expectation (1820, 1900, 1930, 1950-2000): The 1820 and 1900 values are for Russia and come from Mn01. The 1930, 1950-1990 figures are at the decadal frequency, and all are from KF. The 2000 figure comes from *HDR 2001*. These are labor force weighted averages. Not all countries are represented throughout. For those countries that are missing some observations, I list the year of their first appearance in the weighted average. Albania (1990), Armenia (1990), Azerbaijan (1990), Belarus (1990), Bulgaria (1950), Czechoslovakia (1930), East Germany (1950), Estonia (1990), Georgia (1990), Hungary (1951), Kazakhstan (1990), Kyrgyzstan (1990), Latvia (1990), Lithuania (1990), Moldova (1990), Poland (1950), Romania (1950), Soviet Union (1950), Slovak Republic (1990), Tajikistan (1990), Turkmenistan (1990), Ukraine (1990), Uzbekistan (1990), Yugoslavia (1950).

Conditional life expectation (1930,1950-1990): The 1950-1990 values are at the decadal frequency. These are labor force weighted averages. All values come from KF1 and KF2. Not all countries are represented throughout. For those countries that are missing some observations, I list the year of their first appearance in the weighted average. Albania (1990), Armenia (1990), Azerbaijan (1990), Belarus (1990), Bulgaria (1950), East Germany (1950), Estonia (1990), Georgia (1990), Hungary (1950), Kazakhstan (1990), Kyrgyzstan (1990), Latvia (1990), Lithuania (1990), Moldova (1990), Poland (1960), Romania (1960), Soviet Union (1960), Slovak Republic (1990), Tajikistan (1990), Turkmenistan (1990), Ukraine (1990), Uzbekistan (1990), Yugoslavia (1950). The following countries had no observations: Albania, Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Slovak Republic, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan.

Total fertility rates (1870-2000): The values are at the decadal frequency. The 1870-1950 values are weighted averages and come from M. The 1950-1990 values are from weighted averages from KF2. The 2000 value is the weighted average from *HDR 2001*. All countries data are from 1950-2000 with the exception of: Bulgaria (1890), Czechoslovakia (1920), Hungary (1880), Poland (1920), Romania (1900), Russia (1900), Yugoslavia (1920).

Infant mortality rates (1870-2000): The values are at the decadal frequency. The 1870-1940 values, at the decadal frequency, are weighted averages and come from M. The 1950-2000 values are at the quinquennial frequency. The 1950-1985 values are from KF2. The 1990, 1995 and 2000 values come from various issues of *WDR* and *HDR;* these are labor force weighted averages. Not all countries are represented throughout. For those countries that are missing some observations, I list the year of their first appearance in the weighted average. Albania (1990), Armenia (1990), Azerbaijan (1990), Belarus (1990), Bulgaria (1890), Czechoslovakia (1920), East Germany (1950), Estonia (1990), Georgia (1990), Hungary (1880), Kazakhstan (1990), Kyrgyzstan (1990), Latvia (1990), Lithuania (1990), Moldova (1990), Poland (1920), Romania (1900), Soviet Union (1900), Slovak Republic (1990), Tajikistan (1990), Turkmenistan (1990), Ukraine (1990), Uzbekistan (1990), Yugoslavia (1930).

Life tables are available for the following countries and years: Bulgaria (1951, 1954, 1957, 1960, 1963, 1964, 1965, 1970, 1975, 1980 and 1985), Cyprus (1951, 1954, 1957, 1960, 1977, 1980 and 1985), Czechoslavakia (1930, 1934, 1951, 1954, 1957, 1960, 1962, 1963, 1964, 1970, 1975, 1980 and 1985), East Germany (1952, 1954, 1957, 1960, 1962, 1963, 1964, 1970, 1975, 1980 and 1985), Hungary (1951, 1954, 1957, 1960, 1963, 1964, 1965, 1970, 1975, 1980 and 1985), Poland (1955, 1960, 1962, 1964, 1966, 1970, 1975, 1980, 1983 and 1985), Romania (1960, 1963, 1964 and 1965), USSR (1959, 1979 and 1987), and Yugoslavia (1951, 1954, 1957, 1961, 1964, 1970, 1975, 1980 and 1985).

China:

Population (1, 1000, 1400, 1500, 1600, 1640, 1680, 1700, 1800-2000): Values for 1, 1000, 1500, 1700 are from Mn01. All figures from 1800 onward are at the decadal periodicity. Values 1400, 1600, 1640, 1680 and 1800-1980 from are from MJ. The final 2 values are from *Time Almanac 1999*.

Per capita income (1, 1000, 1500, 1600, 1700, 1820, 1870, 1890-2000): Values for 1, 1000, 1500, 1600 and 1700 are from Mn01. The 1820, 1870, 1890-1910 and 1940 values come from Mn95. All figures, 1930, 1950-2000 (decadal), and all are from BDT.

Age at labor force entry (1930, 1950-2000): All figures are at the decadal frequency, and all are from BDT.

Life expectation (1900, 1930, 1950-2000): The 1900 value comes from Mn01. The 1930-1990 figures are at the decadal frequency, with the exception of 1940, and all are from KF1, KF2, P. The 2000 figure comes from *HDR 2001*.

Conditional life expectation (1950, 1970, 1980): The first value comes from KF1, and the latter values come from KF2.

Total fertility rates (1950-2000): The 1950-1990 figures are at the decadal frequency, and all are from KF. The 2000 figure comes from *HDR 2001*.

Infant mortality rates (1950-2000): The 1950-2000 values are at the quinquennial frequency. The 1950-1985 values are from KF2. The 1990, 1995 and 2000 values come from various issues of *WDR* and *HDR*.

Life table information are available for: 1953, 1974 and 1981.

Rest of Asia without China and India (Bangladesh, Cambodia, Fiji, Hong Kong, Indonesia, Iran, Iraq, Israel, Jordan, Kuwait, Laos, Malaysia, Myanmar, Nepal, Oman, Pakistan, Papua New Guinea, Philippines, Saudi Arabia, Singapore, Sri Lanka, Syria,

Taiwan, Thailand, Turkey, United Arab Emirates, Vietnam, Yemen):

Population (1, 1000, 1500, 1600, 1700, 1800-2000): Values for 1, 1000, 1500 and 1700 are from Mn01. The 1600 and 1800 figures are from MJ. The figures from 1810 to 2000 are from M. The values from 1800-2000 are at the decadal frequency.

Per capita income (1, 1000, 1500, 1600, 1700, 1820, 1870, 1910, 1940-2000): Values for 1, 1000, 1500, 1600, 1700, 1820, 1870 and 1910 are from Mn01. All figures 1940-2000 are at the decadal frequency, and all are from BDT. These are labor force weighted averages. Not all countries are represented throughout. For those countries that are missing some observations, I list the year of their first appearance in the weighted average. Bangladesh (1970), Cambodia (1980), Fiji (1960), Hong Kong (1950), Indonesia (1950), Iran (1960), Iraq (1950), Israel (1950), Jordan (1960), Kuwait (1980), Laos (1980), Malaysia (1960), Myanmar (1940), Nepal (1960), Oman, (1970), Pakistan (1950), Papua New Guinea (1960), Philippines (1940), Saudi Arabia (1960), Singapore (1950), Sri Lanka (1950), Syria (1950), Taiwan (1920), Thailand (1940), Turkey (1940), United Arab Emirates (1980), Vietnam (1970), Yemen (1970).

Age at labor force entry (1880-2000): All figures are at the decadal frequency, and all are from BDT. These are labor force weighted averages. Not all countries are represented throughout. For those countries that are missing some observations, I list the year of their first appearance in the weighted average. Bangladesh (1970), Cambodia (1970), Fiji (1960), Hong Kong (1950), Indonesia (1950), Iran (1950), Iraq (1950), Israel (1950), Jordan (1950), Kuwait (1950), Laos (1970), Malaysia (1950), Myanmar (1880), Nepal (1960), Oman, (1970), Pakistan (1950), Papua New Guinea (1960), Philippines (1940), Saudi Arabia (1960), Singapore (1950), Sri Lanka (1920), Syria (1950), Taiwan (1920), Thailand (1940), Turkey (1940), United Arab Emirates (1970), Vietnam (1970), Yemen (1970).

Life expectation (1820, 1900, 1950-2000): The 1820 and 1900 values come from Mn01. The 1950-1990 figures are at the decadal frequency, and all are from KF. The 2000 figure comes from *HDR 2001*. These are labor force weighted averages. Not all countries are represented throughout. For those countries that are missing some observations, I list the year of their first appearance in the weighted average. Bangladesh (1965), Cambodia (1960), Fiji (1960), Hong Kong (1950), Indonesia (1950), Iran (1950), Iraq (1950), Israel (1950), Jordan (1950), Kuwait (1950), Laos (1960), Malaysia (1950), Myanmar (1950), Nepal (1960), Oman, (1960), Pakistan (1950), Papua New Guinea (1960), Philippines (1950), Saudi Arabia (1960), Singapore (1950), Sri Lanka (1950), Syria (1950), Taiwan (1920), Thailand (1950), Turkey (1950), United Arab Emirates (1960), Vietnam (1960), Yemen

(1960).

Conditional life expectation (1920-1990): These are at the decadal frequency and are weighted by the labor force. All values come from KF1 and KF2. Not all countries are represented throughout. For those countries that are missing some observations, I list the year of their first appearance in the weighted average. Bangladesh (1970), Cyprus (1950), Fiji (1960), Hong Kong (1960), Indonesia (1960), Iran (1960), Iraq (1970), Israel (1950), Kuwait (1970), Malaysia (1970), Nepal (1980), Pakistan (1960), Philippines (1960), Singapore (1960), Thailand (1960), Turkey (1960).

Total fertility rates (1920-2000): The values are at the decadal frequency. The 1920-1940 values are from KF and are weighted averages; and the values 1950-1990 are weighted averages from KF2. The 2000 value is the weighted average of *HDR 2001.* Bangladesh (1965), Fiji (1956), Hong Kong (1950), Indonesia (1950), Iran (1950), Iraq (1950), Israel (1950), Jordan (1950), Kuwait (1950), Malaysia (1950), Myanmar (1950), Nepal (1960), Pakistan (1950), Philippines (1940), Singapore (1950), Sri Lanka (1920), Syria (1950), Taiwan (1920), Thailand (1950), Turkey (1950),

Infant mortality rates (1950-2000): The values are at the decadal frequency. The 1950-1980 values are from KF2. The 1990 and 2000 values come from various issues of *WDR* and *HDR;* these are labor force weighted averages. Not all countries are represented throughout. For those countries that are missing some observations, I list the year of their first appearance in the weighted average. Bangladesh (1965), Cambodia (1960), Fiji (1956), Hong Kong (1950), Indonesia (1950), Iran (1950), Iraq (1950), Israel (1950), Jordan (1950), Kuwait (1950), Laos (1960), Malaysia (1950), Myanmar (1950), Nepal (1960), Oman, (1960), Pakistan (1950), Papua New Guinea (1960), Philippines (1940), Saudi Arabia (1960), Singapore (1950), Sri Lanka (1920), Syria (1950), Taiwan (1920), Thailand (1950), Turkey (1950), United Arab Emirates (1960), Vietnam (1960), Yemen (1960).

Life tables are available for the following countries and years: Bangladesh (1981), Fiji (1956, 1963, 1964, 1975, 1980 and 1986), Hong Kong (1961, 1964, 1970, 1976, 1980, 1985, 1986, 1987 and 1988), Indonesia (1961, 1966 and 1976), Iran (1956 and 1975), Iraq (1974), Israel (1951, 1954, 1957, 1960, 1963, 1964, 1970, 1973, 1975, 1980 and 1985), Kuwait (1970 and 1980), Malaysia (1970, 1975, 1980 and 1985), Nepal (1977), Pakistan (1961, 1963 and 1976), Philippines (1960, 1964, 1970 and 1975), Singapore (1957, 1962, 1970, 1975, 1980, 1985 and 1987), Sri Lanka (1971 and 1979), Syria (1977), Taiwan (1920, 1930, 1936, 1956, 1960, 1962, 1963, 1964, 1965, 1970, 1975, 1980, 1982, 1985 and 1988), Thailand (1960, 1975 and 1985), Turkey (1960, 1967 and 1975.

India:

Population (1, 1000, 1400, 1500, 1600, 1640, 1680, 1700, 1760-2000): Values for 1, 1000, 1500 and

1700 are from Mn01. All values from 1400, 1640, 1680, 1760-1920 (1800-1920 at decadal frequency) are from MJ. The 1930-2000 values are at the decadal frequency from Kremer.

Per capita income (1, 1000, 1500, 1600, 1700, 1820, 1850, 1870, 1890, 1900-2000): Values for 1, 1000, 1500, 1600 and 1700 are from Mn01. The 1820, 1850, 1870, 1890 and 1940 values are from Mn95. All figures, 1900-1930 and 1950-2000, are at the decadal frequency, and all are from BDT.

Age at labor force entry (1900-2000): All figures are at the decadal frequency, except for the missing value in 1940, and all are from BDT.

Life expectation (1820, 1900-2000): The 1820 and 1900 values come from Mn01. 1910, 1920, 1930 figures come from Kalemli-Ozcan. The 1950-1990 figures are at the decadal frequency, and all are KF2. The 2000 figure comes from *HDR 2001*.

Conditional life expectation (1960): The value comes from KF1.

Total fertility rates (1910-2000): All figures are at the decadal frequency, and for years 1910-1940 are from M, and 1950-1990 are from KF. The 2000 figure comes from *HDR 2001*.

Infant mortality rates (1910-2000): The 1910-1940 values are at the decadal frequency, and are from M. The 1950-2000 values are at the quinquennial frequency. The 1950-1985 values are from KF2. The 1990, 1995 and 2000 values come from various issues of *WDR* and *HDR*.

Life tables information are available for: 1955, 1961, 1965, 1969, 1977 and 1980.

Africa (Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Congo, Cote de Ivoire, Egypt, Ethiopia, Gabon, The Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, Somalia, South Africa, Sudan, Tanzania, Togo, Tunisia, Uganda, Zaire, Zambia, Zimbabwe):

Population (1, 1000, 1500, 1600, 1700, 1800-2000): Values for 1, 1000, 1500 and 1700 are from Mn01. The 1600 and 1800 figures are from MJ. The remaining figures are at the decadal frequency are from the *Time Almanac 1999*.

Per capita income (1, 1000, 1500, 1600, 1700, 1820, 1870, 1910, 1950-2000): Values for 1, 1000, 1500, 1600, 1700, 1820, 1870 and 1910 are from Mn01. The figures 1950-2000 are at the decadal frequency and come from BDT. Not all countries are represented throughout. For those countries that are missing some observations, I list the year of their first appearance in the weighted average. Algeria (1950), Angola (1960), Benin (1960), Botswana (1960), Burkina Faso (1960), Burundi (1960), Cameroon (1960), Central African Republic (1960), Chad (1960), Congo (1960), Cote de

Ivoire (1960), Egypt (1920), Ethiopia (1950), Gabon (1960), The Gambia (1960), Ghana (1960), Guinea (1960), Guinea-Bissau (1960), Kenya (1960), Lesotho (1960), Liberia (1960), Libya (1960), Madagascar (1960), Malawi (1960), Mali (1960), Mauritania (1960), Mauritius (1960), Morocco (1950), Mozambique (1960), Namibia (1960), Niger (1960), Nigeria (1950), Rwanda (1960), Senegal (1970), Sierra Leone (1960), Somalia (1960), South Africa (1950), Sudan (1970), Tanzania (1960), Togo (1960), Tunisia (1960), Uganda (1960), Zambia (1950), Zimbabwe (1950).

Age at labor force entry (1910-2000): All figures are at the decadal frequency, and all are from BDT. They are constructed from the labor force weighted averages of age. Not all countries are represented throughout. For those countries that are missing some observations, I list the year of their first appearance in the weighted average. Algeria (1950), Angola (1950), Benin (1950), Botswana (1950), Burkina Faso (1960), Burundi (1960), Cameroon (1950), Central African Republic (1950), Chad (1950), Congo (1950), Cote de Ivoire (1950), Egypt (1920), Ethiopia (1950), Gabon (1950), The Gambia (1950), Ghana (1950), Guinea (1960), Guinea-Bissau (1960), Kenya (1950), Lesotho (1960), Liberia (1950), Libya (1960), Madagascar (1950), Malawi (1950), Mali (1950), Mauritania (1950), Mauritius (1950), Morocco (1950), Mozmbique (1940), Namibia (1950), Niger (1950), Nigeria (1950), Rwanda (1950), Senegal (1950), Sierra Leone (1950), Somalia (1950), South Africa (1910), Sudan (1950), Tanzania (1950), Togo (1950), Tunisia (1950), Uganda (1950), Zaire (1950), Zambia (1950), Zimbabwe (1950).

Life expectation (120, 1820, 1900, 1950-2000): The values for 120, 1820 and 1900 are from Mn01. All figures 1950-2000 are at the decadal frequency. All except 2000 are from KF. The 2000 value comes from *WDR 2000/2001.* They are constructed from the labor force weighted averages of age. Not all countries are represented throughout. For those countries that are missing some observations, I list the year of their first appearance in the weighted average. Algeria (1950), Angola (1950), Benin (1560), Botswana (1950), Burkina Faso (1960), Burundi (1950), Cameroon (1950), Central African Republic (1950), Chad (1950), Congo (1950), Cote de Ivoire (1950), Egypt (1950), Ethiopia (1950), Gabon (1950), The Gambia (1950), Ghana (1960), Guinea (1950), Guinea-Bissau (1950), Kenya (1950), Lesotho (1950), Liberia (1950), Libya (1950), Madagascar (1950), Malawi (1950), Mali (1950), Mauritania (1950), Mauritius (1950), Morocco (1950), Mozambique (1950), Namibia (1950), Niger (1950), Nigeria (1950), Rwanda (1950), Senegal (1950), Sierra Leone (1950), Somalia (1950), South Africa (1950), Sudan (1950), Tanzania (1950), Togo (1950), Tunisia (1950), Uganda (1950), Zambia (1950), Zimbabwe (1950).

Total fertility rates (1920-2000): All figures are at the decadal frequency. All are from KF except 1990 and 2000 from *WDR* various years. Not all countries are represented throughout. For those countries that are missing some observations, I list the year of their first appearance in the weighted average. Algeria (1950), Angola (1950), Benin (1950), Botswana (1950), Burkina Faso (1960), Burundi (1950), Cameroon (1950), Central African Republic (1950), Chad (1950), Congo (1950), Cote de Ivoire (1950), Egypt (1920), Ethiopia (1950), Gabon (1950), The Gambia (1950), Ghana (1950), Guinea (1950), Guinea-Bissau (1950), Kenya (1950), Lesotho (1950), Liberia (1950), Libya (1950), Madagascar (1950), Malawi (1950), Mali (1950), Mauritania (1960), Mauritius (1950), Morocco (1950), Mozambique (1950), Namibia (1950), Niger (1950), Nigeria (1950), Rwanda (1950), Senegal (1950), Sierra Leone (1950), Somalia (1950), South Africa (1950), Sudan (1950), Tanzania (1950), Togo (1950), Tunisia (1950), Uganda (1950), Zaire (1950), Zambia (1950), Zimbabwe (1950).

Conditional life expectation (1960-1990): These are at the decadal frequency and labor force weighted. All data comes from KF and KF2. Not all countries are represented throughout. For those countries that are missing some observations, I list the year of their first appearance in the weighted average. Algeria (1980), Botswana (1970), Burundi (1970), Cameroon (1970), Egypt (1980), Gambia (1970), Ghana (1970), Kenya (1970), Lesotho (1970), Liberia (1970), Morocco (1970), Nigeria (1990), Senegal (1970), Sierra Leone (1970), South Africa (1970), Sri Lanka (1970), Tanzania (1970), Tunisia (1970), Uganda (1970).

Infant mortality rates (120, 1910-2000): The 120 value is for Roman Egypt and comes from Mn01. The values 1920-2000 are at the decadal frequency. The 1950-1980 values are from KF2. The 1990 and 2000 values come from various issues of *WDR* and *HDR*. These are labor force weighted averages. Not all countries are represented throughout. For those countries that are missing some observations, I list the year of their first appearance in the weighted average. Algeria (1950), Angola (1950), Benin (1950), Botswana (1950), Burkina Faso (1960), Burundi (1950), Cameroon (1950), Central African Republic (1950), Chad (1950), Congo (1950), Cote de Ivoire (1950), Egypt (1920), Ethiopia (1950), Gabon(1950), The Gambia (1950), Ghana (1950), Guinea (1950), Guinea-Bissau (1950), Kenya (1950), Lesotho(1950), Liberia (1950), Libya (1950), Madagascar (1950), Malawi (1950), Mali (1950), Mauritania (1950), Mauritius (1950), Morocco (1950), Mozambique (1950), Namibia (1950), Niger (1950), Nigeria (1950), Rwanda (1950), Senegal (1950), Sierra Leone (1950), Somalia (1950), South Africa (1910), Sudan (1950), Tanzania (1950), Togo (1950), Tunisia (1950), Uganda (1950), Zaire (1950), Zambia (1950), Zimbabwe (1950).

Life tables exist for the following countries and following years: Algeria (1977,1980,1981,1982), Botswana (1967, 1981), Burundi (1970), Cameroon (1974), Egypt (1977), The Gambia (1970), Ghana

(1970), Kenya (1974), Lesotho (1971), Liberia (1971), Mauritius (1955, 1960, 1963, 1964, 1965, 1970, 1972, 1980 and 1983), Morocco (1972), Nigeria (1987), Senegal (1970), Sierra Leone (1974), South Africa (1970 and 1985), Tanzania (1974), Togo (1961), Tunisia (1969 and 1981), and Uganda (1969).

H. GOODNESS OF FIT: STACKED REGRESSIONS

In this appendix I present the results of a stacked regression analysis. Here I take the synthetic variables, X and Y for all of the seven different variables, population, income per capita, age at entry into the labor force, total fertility rates, infant mortality, life expectation at birth and conditional life expectation at entry into the labor force, and stack them. I then stacked these observations into a single synthetic time series of normalized actual values and normalized solution values.

$$Y = \begin{bmatrix} Y^1 \\ \vdots \\ Y^7 \end{bmatrix}$$

$$X = \begin{bmatrix} X^1 \\ \vdots \\ X^7 \end{bmatrix}$$

By subtracting each series by the solution mean and dividing by the standard deviation of the solution series, I give an observation on any variable equal weight to any other randomly chosen observation. Thus population and per capita incomes that are measured in millions and dollars get no additional weight relative to infant mortality, compared to total fertility rates because of their size. I then regressed Y on X as before. These are reported in Tables A1 through A3 below. The final row of each of these tables presents the results of a quartic in time for each series, and hence 28 different quartic parameters. In all three cases the model which allows for a logistic infant mortality function, m and all refinements of this model are comparable to the TIME model.

Table A1: Goodness of fit: all variables (standard error)

	$\delta = .5345$	base	spillover $\varepsilon = .1$ $\varphi = .25$	m	$m,\, \psi = .1$	$m,\, \psi = .1$ clife	$m,\, \psi = .1$ clife, $\Upsilon = .4$
β	-3.2407	.6435	.7405	.9475	.9491	1.0587	1.0754
	(.3681)	(.0243)	(.0239)	(.0167)	(.0167)	(.0073)	(.0081)
α	7.4440	.4558	.3403	.3693	.3749	-.2784	-.3422
	(.4259)	(.0466)	(.0443)	(.0398)	(.0398)	(.0174)	(.0192)
$\overline{R}^2$	.0216	.1689	.2174	.4814	.4824	.8590	.8364
N	3458	3458	3458	3458	3458	3458	3458
$\beta = 1$	132.71	215.84	118.06	9.86	9.27	64.81	86.86
Prob	.0000	.0000	.0000	.0017	.0024	.0000	.0000
TIME $\overline{R}^2$	.8556	.8556	.8556	.8556	.8556	.8556	.8556

Table A2: Goodness of fit: all variables, rich sample (standard error)

	$\delta = .5345$	base	spillover $\varepsilon = .1$ $\varphi = .25$	m	m, $\psi = .1$	m, $\psi = .1$ clife	m, $\psi = .1$ clife, $\Upsilon = .4$
β	-3.5616	.7009	1.0633	1.0336	1.0343	1.1182	1.1188
	(.5120)	(.0555)	(.0500)	(.0457)	(.0457)	(.0206)	(.0210)
α	7.0010	.3763	.3122	.3857	.3890	-.2851	-.3005
	(.4932)	(.0514)	(.0463)	(.0444)	(.0444)	(.0200)	(.0205)
$\overline{R}^2$	.0160	.0516	.1345	.1495	.1497	.5041	.4933
N	2909	2909	2909	2909	2909	2909	2909
$\beta = 1$	79.37	29.01	1.61	0.54	0.56	33.03	31.92
Prob	.0000	.0000	.2052	.4619	.4530	.0000	.0000
TIME $\overline{R}^2$	.6523	.6523	.6523	.6523	.6523	.6523	.6523

Table A3: Goodness of fit: all variables, poor sample (standard error)

	$\delta = .5345$	base	spillover $\varepsilon = .1$ $\varphi = .25$	m	m, $\psi = .1$	m, $\psi = .1$ clife	m, $\psi = .1$ clife, $\Upsilon = .4$
β	-47.2651	.7297	1.2936	1.2013	1.2008	.9929	1.0492
	(7.4181)	(.1681)	(.0920)	(.0746)	(.0732)	(.0425)	(.0489)
α	31.3893	1.0653	.3165	.1894	.1949	-.0594	-.1921
	(6.9576)	(.1576)	(.0863)	(.0705)	(.0691)	(.0402)	(.0462)
R^2	.0674	.0315	.2640	.3203	.3286	.4981	.4559
N	549	549	549	549	549	549	549
$\beta = 1$	42.33	2.59	10.17	7.28	7.53	0.03	1.01
Prob	.0000	.1083	.0015	.0072	.0063	.8668	.3145
TIME $\overline{R}^2$	.5759	.5759	.5759	.5759	.5759	.5759	.5759

I. YOUNG ADULT MORTALITY SHOCKS

The following graph presents the values of the young adult mortality shocks, ξ, relative to the deterministic portion of the mortality function, in each region, (Δ) rich region, and ($\bigcirc$) poor region, for the spillover model. The base model relative mortality shocks are similar and for brevity are not reported. Prior to 1 A.D. the unexpected young adult mortality shock is essentially less than 5 percent in absolute value of the deterministic portion. After 1 A.D. the relative shock remains small until the 1800 - 2000 period. The relative unexpected rich young adult mortality shock is fairly large during this period, approaching 100 percent in absolute value, and in 2000 in the spillover model it is 5.2 times bigger. However in 2000 this occurs because the value of $\xi = .028$ and the deterministic portion is roughly $\delta = .005$. I do not report the 2000 value for the rich region in order to present more of the variation in other years. The large unexpected negative value for ξ in both the base model and the spillover model for the 1800 - 2000 period indicates that fertility fell with quite a lag.