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How old is too old?

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Introduction

Around the world, fertility is falling or is already low. Forty two percent of the world's people live in countries where fertility is less than two births per woman, the level necessary to avoid population decline (United Nations, 2011). Average fertility is 1.5 births per woman in Europe and 1.4 births per woman in Japan. In China, more than 500 million people live in provinces where fertility is 1.3 births per woman or less. With fertility this low, population aging will be rapid and population growth will give way to population decline. These developments are viewed with alarm in many countries. In 2009, 51 countries worldwide viewed their fertility as too low (United Nations 2011).

This is a remarkable reversal from decades of high fertility, rapid population growth, high youth dependency, and widespread concerns about the economic and environmental consequences. Should we be alarmed about low fertility, population decline, and population aging? Have we reached the point that governments should be encouraging their citizens to bear more children to balance the dramatic increase in the number of elderly that is coming?

Identifying an optimal population policy is likely impossible for several reasons. First, children yield direct satisfaction and impose costs on parents that are difficult or impossible to measure. Second, the environmental consequences of continuing population growth are exceedingly complex and difficult to value or weigh against other costs and benefits of low fertility. Third, assessing differences in fertility involves the difficult or impossible task of comparing the welfare of alternative future populations consisting of different individuals.

The goal of our research is more modest, but nonetheless important. We examine how low fertility and population aging will influence the material standard of living using a refined measure of per capita consumption. The analysis emphasizes two important aspects of the impact of population change on the economy. The first is the change in intergenerational transfers due to changes in population age structure. As populations age the rise in public and private transfers to the elderly eventually undermines standards of living. A second factor, however, favors lower fertility and an older population than indicated solely by looking at intergenerational transfers. As fertility declines and population growth slows the capital costs of each new generation is reduced.

Previously data have not been available that would allow a comprehensive assessment of these effects. Researchers from over 40 countries participating in an international research network, the National Transfer Accounts network, have constructed economic accounts that provide comprehensive estimates of the flows of resources by age. These data document the values of goods and service produced and consumed at each age and the intergenerational flows across age achieved by relying on public and private transfers and assets. National Transfer Accounts are constructed in a manner that is consistent with the UN System of National Accounts to facilitate analyzing the macroeconomic implications of population change.

Whether fertility is too low and a population is too old depends on important features of the economic lifecycle that vary from country to country. If the elderly consume at high per capita levels relative to children and younger adults, then higher fertility and a younger population is advantageous. If the elderly continue to be productively employed contributing more to national output, then lower fertility and an older population is advantageous.

The analysis presented here extends a complementary study in which we calculate the consumption maximizing TFR and age structure for individual countries given current conditions in each country –

their age-specific survival schedule and their estimated age profile of consumption and labor income. In this paper, we allow for changes in the age profiles of consumption and labor income in response to population age structure using a simple approach. We also extend the analysis to consider how changes in life expectancy influence the total fertility rate and corresponding age structure that maximize per capita consumption.

Using NTA estimates we show that, given observed patterns of consumption and labor income, a total fertility rate of 1.7 provides a useful benchmark for evaluating whether fertility is too low. Raising fertility that is already above this level is unlikely to produce an increase in the material standard of living and should not be a source of concern on economic grounds. There is no apparent reason why governments should consider pro-natalist policies with fertility near this level or higher. Fertility below this level is likely to produce some sacrifice in the material standard of living. We estimate, for example, that a decline in fertility to 1.5 births per woman would eventually lead to a decline in per capita consumption by xx% and a decline to 1.3 births per woman to a decline in per capita consumption by yy%. With a TFR of 1.7, the average age of the population would be about 45. By comparison the average US resident is 38 years of age and in the absence of further changes in fertility and mortality would eventually rise to 41 years of age. A TFR of 1.7 would eventually lead to population decline by 0.x percent per year.

The benchmark fertility rate depends on life expectancy at birth. The benchmark fertility rate of 1.7 is consistent with current life expectancy in high income countries of around 80. Life expectancy continues to increase, however, and this will lead to older populations. The benchmark fertility rate will rise as this occurs because the increase in the number of older persons must be balanced by an increase in the number of children and working-age adults if deterioration in standards of living is to be avoided. At a life expectancy of 90, which the UN projects will be reached for high income countries in the year xxxx, the benchmark TFR will rise to 2.2 births per woman, slightly above replacement level.

It seems possible that changes in consumption and work patterns not seen in the data will offset some of the economic effects of population aging. People may work more in their sixties and seventies than they do today. Many Western countries have seen some increase in labor force participation at older ages in recent years and pension reform may further encourage this trend. It is also possible that efforts to rein in health care spending at older ages will help to reduce the costs of aging populations. We expect to present some calculations here about some of these policy options and how they influence the fertility rate that maximizes material standards of living.

Basic concepts

The Demography of Aging

Population age structure is determined primarily by fertility and mortality rates with migration playing a secondary role. The relationship between fertility and population aging is emphasized in this study for two reasons. The first is that fertility has such an important determinant of age structure. The second is that concerns about population aging influence decisions to adopt pro-natalist policies. No one to our knowledge proposes curtailing gains in mortality as a means of achieving a younger population. We do consider, however, how improvements in life expectancy over the coming decades influence our conclusions.

One approach to analyzing demographic effects is to rely on population projections. This is preferred for considering the complex dynamics of population change. The interest here, however, is to assess whether observed levels of fertility will result in a population that is older than preferred from an economic perspective.

Addressing this issue is facilitated by an important feature of a population closed to migration, with fixed age specific birth and death rates. Over time the population would reach a steady state equilibrium in which the total population and all groups grow at the same rate n, the *intrinsic* population growth rate. The proportions of the population at each age also would converge to equilibrium values with a mean population age which we will call the intrinsic age of the population.

Fertility is summarized by the total fertility rate (TFR), the number of births women would have over their reproductive span given current age-specific birth rates. Mortality is summarized by life expectancy at birth which is the average number of years individuals could expect to live were they subject to current age-specific death rates.

Given mortality conditions, the TFR has a one-to-one relationship to the intrinsic rate of population growth and the intrinsic age of the population. A decline in the TFR unambiguously leads to slower population growth and an older population. The effect of changes in life expectancy at birth on population age structure is more complex. When life expectancy is very low, gains in mortality are concentrated at young ages and often produce a younger population and much faster population growth due to heavy concentrations of people in the reproductive years. When life expectancy is high, gains in mortality are concentrated at older ages and produce an older population and more modest growth in population.

Demographic variables used in the analysis are defined and descriptive statistics are presented in Table 1 below.

Economic lifecycle and aging economies

Changes in population age structure have important implications for the economy, in large part, because of the economic interdependency across age groups – children depending on their parents or the elderly on working-age taxpayers, for example. These patterns of economic dependency mirror the economic lifecycle with feature common to all contemporary societies. At the beginning and the end of life people consume more than they produce through their labor. Sandwiched between these two groups are adults who produce more through their labor than they consume.

The economic lifecycle is summarized by per capita labor income and consumption, explained in more detail in the Data section below, is shown for three countries (India, the US, and Germany) in Figure 1. The age patterns are broadly similar for the three countries. Labor income drops quite sharply in India at age 60 because of mandatory retirement. Labor income at old ages is much lower in Germany than in the US, but consumption rises very sharply at older ages in the US due to spending on health and long-term care for the elderly. At young ages spending on education in the US and Germany is much more important than in India.

Figure 1 about here.

The influence of population aging on the age structures of aggregate consumption and labor income can be seen in Figure 2. The US and Germany have much greater consumption at old ages than India. The average age of consumption (Ac) (see Table 1 for details) are 42 and 45.5 in the US and Germany, respectively, as compared with 32 in India. India's population is 10 years younger than the US population and 15 years younger than Germany's. The average age of labor income (Ayl) is not very sensitive to population aging. The mean age of labor income is 39.6 in India, 44.0 in the US, and only 42.7 in Germany.

Comparing the mean ages of consumption and labor income quantifies the direction and extent of the intergenerational flow of resources in the economy. In India, resources are being shifted strongly downward, in the US moderately downward, and in Germany the flow is upward from younger workers to older consumers. The reversal in the direction of intergenerational flows is a general feature of population aging and, as will be shown, is central to assessing the economic implications of population age structure.

The impact of population aging on the means ages of consumption and labor income is in part a mechanistic effect. Consumers and workers are older because people or older. But labor income is concentrated in a relatively small segment of the population. Changes in the number of children and elderly have little or no effect on the average age of labor income because children and the elderly have little or no labor income. In contrast, the mechanical effect of population aging on the average age of consumption is much greater because consumption is an important activity at all ages.

The mean ages of consumption and labor income may also be affected by the population aging because of changes in the per capita age profiles of consumption and labor income. This possibility has been addressed in a number of studies. Preston presents evidence that population aging would increase the political power of the elderly which might increase their consumption by raising in-kind public transfers, e.g., health care, or public pensions. Or their political power might allow the elderly to increase their leisure and reduce labor income at older ages. As an alternative, it is possible that population aging would reduce per capita transfers to the elderly because the non-elderly are unwilling to raise their taxes.

Another important possibility is that the average age of consumption will be influenced by changes in spending on children that occur as fertility declines. The importance of quantity-quality tradeoff was first noted by Becker and has been explored by many economists since. To the extent that it is important spending on children will decline by less than expected from the pure mechanical effects of population aging. Hence, the mean age of consumption would rise by less than the mean age of the population.

Changes in the economic lifecycle must influence the economic flows that allow children and the elderly to consume more than they produce through their labor. Intergenerational transfers are used, for example, to support children living in families, students attending public schools, the elderly living with their adult children and relying on publicly funded pensions and health care systems. The gaps between consumption and labor income can also be funded by relying on assets (or capital). Young people can support consumption in excess of their labor income by accumulating debt repaid later in life. Old people can rely on assets accumulated during their working years including funded pensions, personal saving, and owner-occupied dwellings.

Transfer economy and the support ratio

Assessments of population age structure often emphasize the dependency ratio or a related measure, the support ratio. The support ratio is defined as the effective number of workers (L) divided by the effective number of consumers (N) where the effective number of workers is calculated by weighting the population at each age by labor income at each age relative to labor income of those aged 30-49. The effective number of consumers is calculated as the population at each age weighted by consumption at each age relative to consumption by those aged 30-49. As fertility declines from high levels the support ratio increases due to the drop in child dependency. Eventually, however, the support ratio reaches a maximum and then begins to decline due to the increase in old age dependency.

Is the population age structure that maximizes the support ratio the one that maximizes per capita consumption? Except under very special circumstances, the answer is no. But it is useful to consider this special case because it is a key component of a more general answer to issue.

Samuelson (1958) first proposed a highly stylized model of the economy as a means of thinking about the role of intergenerational transfers and lifecycle needs.[1] In high model labor is the only source of production and income. There is no capital (or durable goods) and, hence, no saving. Under these conditions, all that is produced by workers each period is consumed in that period, as expressed in the cross-sectional budget constraint in the base year:

$$\bar{c}N = \bar{y}L \tag{0.1}$$

Total consumption, consumption per equivalent consumer ($\bar{c}$) times the number of equivalent consumers (*N*), must equal total labor income, labor income per equivalent worker ($\bar{y}$) times the number of equivalent workers (*L*). Labor income per equivalent worker is exogenously determined in the model and, along with the support ratio (L/N) determines the level of consumption at any point in time. Rearranging terms, consumption per equivalent consumer is equal to:

$$\bar{c} = \bar{y}_l \, L/N\,. \tag{0.2}$$

By inspection, consumption reaches a maximum with the support ratio is at its highest level. The effect of a change in the population growth rate on the level of consumption is given by:

$$\frac{\partial}{\partial n}\ln\bar{c} \;= \frac{\partial}{\partial n}\ln SR = A_C - A_{yl} \tag{0.3}$$

a result first derived by Arthur and McNicol (1978). If effective consumers are older than effective producers, a younger population achieved through higher fertility and more rapid population growth is advantageous because it shifts the population age structure towards younger ages where producers more heavily concentrated than consumers. If the average age of consumption is 3 years greater than the average age of labor income, the case for Germany in Figure 1 for example, raising the population growth rate by one percentage point (or 0.01) would increase lifetime consumption by .01 times 3, or by 3%. (Note that that this illustrative calculation is an approximation because the mean ages of consumption and labor income will change as population growth increases.)

The first order condition for consumption-maximizing population growth is that the mean ages of consumption and labor income are equal, $A_C = A_{yl}$. The second order condition is met because the

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[1] Samuelson did not include children in his model. He did consider reliance on credit and rejects this as a possible solution to the lifecycle problem. We do not consider credit here.

variance of the consumption profile is always greater than the variance in the labor income profile due to the periods of dependency at the beginning and end of life.

Given life expectancy at birth, there is a one-to-one correspondence between the consumption-maximizing values of the population growth rate, the mean age of the population, and the TFR.

In the simple transfer economy there are no credit markets or interest rates, but the transfer system yields an implicit rate of return that satisfies the lifecycle budget constraint,

$$PV_y = PV_c \tag{0.4}$$

By comparing the lifecycle budget constraint to the cross-sectional budget constraint it is clear that that interest rate that satisfies the lifecycle constraint is $n+\lambda$, called the biological rate of interest by Samuelson. Aggregate consumption and the present value of lifetime consumption are identical. The population growth rate that maximizes per capita consumption also maximizes the present value of lifetime consumption.

The value of this analysis is that it shows the circumstances under which the support ratio is an accurate indicator of the effects of age structure on standards of living. In economies without capital and complete reliance on transfers to deal with lifecycle issues, an increase in the support ratio leads to an increase in the level of consumption. The maximum consumption is achieved when the maximum support ratio is realized. And that is the age structure at which the average age of the effective consumer is the same as the average age of the effective worker.

Capital

Incorporating capital into the model is essential because saving and capital provide an alternative mechanism for meeting old-age needs. If the elderly relied fully on accumulated assets to support their old-age needs, net transfers to the elderly would be zero. They would impose no dependency burden at all. Samuelson (1975) first addressed these ideas theoretically in what is known as his Serendipity Theorem. He proposed what he called the goldenest golden rule as the saving rate and population growth rate that allowed the highest level of consumption that could be achieved for all generations. Arthur and McNicoll (1978) show that, conditional on golden rule capital, the highest level of consumption that can be achieved occurs when:

$$A_{yl} = A_c - \frac{K_{gr}}{C} \tag{0.5}$$

where K_{gr} is golden-rule level of capital and C is the corresponding value of aggregate consumption. In an economy that is maintaining capital at the golden rule level, standards of living are favored by populations where the average age of effective consumers is substantially greater than effective producers. This occurs when populations are substantially older than in the simple case of the pure transfer economy.

The difficulty with the golden rule standard is that countries do not have the golden rule level of capital and there is no reason to expect that they will achieve that level of capital in the future. As an alternative, we consider the case of a country in which K/Y, the capital-output ratio, is fixed at the observed level. An attractive feature of this approach is its consistency with an important feature of almost all advanced economies – stability of the ratio of capital to consumption.

If K/Y is exogenous then the first order condition for maximizing consumption per effective consumer is very similar to the first order condition for the golden rule:

$$A_{yl} = A_c - \frac{K}{C}. \quad (0.6)$$

In both cases, K/C is endogenous (technical appendix to come) and as empirical matter, the observed K/C that maps to the observed K/Y is less than the golden-rule case.

Data

Analysis is carried out relying on National Transfer Accounts (NTA), a new set of economic accounts which document economic flows to and from ages in a manner consistent with the UN System of National Accounts. Research teams in 32 to 36 countries on six continents have successfully constructed accounts. The theoretical foundations of the accounts build on Lee(1994; 1994) with the most comprehensive treatment in Lee and Mason (2011). Full documentation of methods has recently been published by the United Nations (United Nations Department of Economic and Social Affairs: Population Division 2013). The key NTA series used in this analysis are consumption and labor income by single years of age. The data can be downloaded from the NTA website – www.ntaccounts.org. We also make extensive use of demographic data on population, fertility, and survival. We rely primarily on World Population Prospects 2012 (United Nations Population Division 2011) for these data.

NTA estimates are constructed using household surveys, administrative data from government agencies, and UN System of National Accounts data. Consumption is a comprehensive measure that includes both public and private consumption. The age profiles of public education and health consumption are estimated separately while per capita consumption of other public goods and services is assumed to be identical for all ages (public pension transfers are income and not consumption). The age profiles of private health and education are also estimated separately. Other private consumption is estimated using household survey data and equivalence scales that rise from 0.4 for children who are 5 or younger to 1.0 for those who are twenty or older. Labor income is a comprehensive measure that includes earnings, benefits, and an estimate of value of labor of self-employed workers including unpaid family workers. The resulting profiles reflect age specific variation in labor force participation, hours worked, unemployment rates, and productivity.

Estimates are available for Africa (Ethiopia, Ghana, Kenya, Mozambique, Nigeria, Senegal, and South Africa), Asia (Cambodia, China, India, Indonesia, Japan, the Philippines, South Korea, Taiwan, Thailand, and Vietnam), Europe (Austria, Finland, France, Germany, Hungary, Italy, Slovenia, Spain, Sweden, Turkey, and the United Kingdom), Latin America and the Caribbean (Argentina, Brazil, Chile, Colombia, Costa Rica, Jamaica, Mexico, Peru, and Uruguay), Australia, Canada and the United States.

The method and source of calculated variables is identified in Table 1.

Table 1. Key variables, summary statistics, methods of calculation, and sources.			
Variable	Range (mean)	Method of calculation	Source of data
Total fertility rate (TFR)	1.1 to 5.6 (2.2)	$\sum_{x=15}^{49} f(x)$ where *f(x)* is births per year per woman age x.	WPP
Life expectancy at birth		$\sum_{0}^{\omega} L(x)$ where *L(x)* is person years lived at each age x given current age-specific death rates.	WPP
Intrinsic growth rate (n)	.026 to -.023 (-.0025)	$\ln\left((1/SR) l_{\mu} TFR\right)/\mu$ where SR is the sex ratio at birth l_{μ} is the probability of surviving to the mean age of childbearing (μ) is calculated using WPP data.	WPP
Intrinsic mean age of population (A)	23.6 to 54.6 (41.3)	$\sum_{x=0}^{\omega}(x+0.5)e^{-nx}l(x) \Big/ \sum_{x=0}^{\omega} e^{-nx}l(x)$	WPP
Intrinsic mean age of consumption (A_C)	28.0 to 56.9 (44.5)	$\sum_{x=0}^{\omega}(x+0.5)e^{-nx}l(x)c(x) \Big/ \sum_{x=0}^{\omega} e^{-nx}l(x)c(x)$ where c(x) is per capita consumption of persons of age x	WPP , NTA
Intrinsic mean age of consumption (A_y)	35.2 to 47.4 (42.8)	$\sum_{x=0}^{\omega}(x+0.5)e^{-nx}l(x)y(x) \Big/ \sum_{x=0}^{\omega} e^{-nx}l(x)y(x)$ where y(x) is per capita labor income of persons of age x	WPP , NTA
Notes: WPP is World Population Prospects 2012 Revision; NTA is National Transfer Accounts (www.ntaccounts.org) accessed July 10, 2013.			

Results

The key issue for assessing the economic implications of population aging is how the mean ages of consumption and labor income are influenced by mean age of the population.

In the end this is an empirical issue that is addressed in a very simple way by analyzing how the mean ages of consumption and labor income vary with the mean ages of population in the countries for which estimates are available (Figure 3).

Population aging has a very modest impact on the age of the effective labor force. The intrinsic mean age of labor income rises by only 1/6 of a year for every year of increase in the intrinsic mean age of the population. In contrast, population aging has a strong impact on the age of effective consumers. The intrinsic mean age of consumption rises by about nine-tenths of a year for every year increase in the intrinsic mean age of the population.

At a population age of about 40, the predicted intrinsic mean ages of consumption and labor income are equal. This marks the age at which the support ratio would reach its peak. There are country differences at play here, but for the observation closest to the intersection (Uruguay) the mean ages of consumption and labor income are nearly identical. For every country older than 40, the mean age of consumption exceeds the mean age of labor income. And for every country younger than 40, the mean age of labor income exceeds the mean age of consumption.

The intrinsic age that maximizes consumption per effective consumer, however, is several years older than the age that maximizes the support ratio. The dashed line in Figure 3 marks Ac – K/C and the intersection with the Ay line marks the population age, close to 45, that yields that maximum consumption per effective consumer. This is a simple illustration because K/C will not be constant. The analysis to correct has been completed and it will be incorporated into the paper shortly.

The age 45 benchmark does not unambiguously separate countries that are too old from countries that are not. All countries that are older than 46 are too old and no country age 43 is too old. Some countries with an intrinsic age between 43 to 46 are mixed with some being too old and some not. This heterogeneity arises primarily because of two countries, China and Thailand. They have low fertility and their intrinsic population ages are greater than the United Kingdom, for example, but their effective consumers are younger and their effective workers are older than in the UK.

The TFR that corresponds to an intrinsic population age of 45 depends on mortality conditions. Life expectancy in more developed countries is currently estimated at 78. The average for Southern Europe is 81 and for Japan, the highest in the world, 84. Taking life expectancy at age 80, the benchmark TFR is about 1.7 births per woman. A fertility rate at this level produces population decline of approximately 0.6 percent per annum.

Increases in life expectancy will lead to a corresponding increase in benchmark TFR as the increase in the number of elderly must be balanced by an increase in the number of children and prime-age adults. Given a life expectancy of 85 benchmark TFR rises to 1.95 and with a life expectancy of 90 the consumption-maximizing TFR reaches 2.2 births per woman.

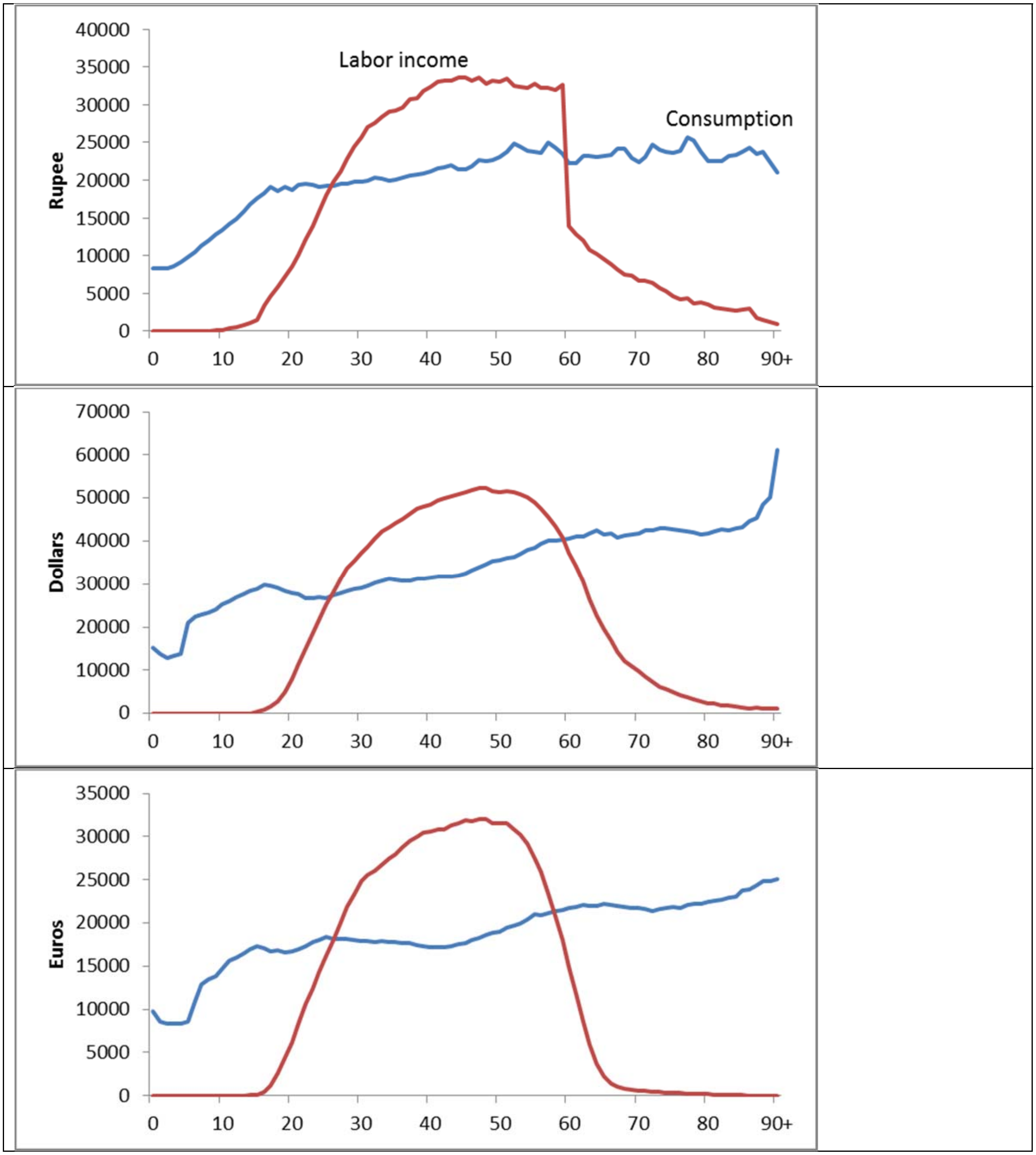


Figure 1. Per capita consumption and labor income by age, India 2004 (upper panel), United States 2003 (middle panel), and Germany 2004 (lower panel). Source: www.ntaccounts.org accessed June 27, 2013.

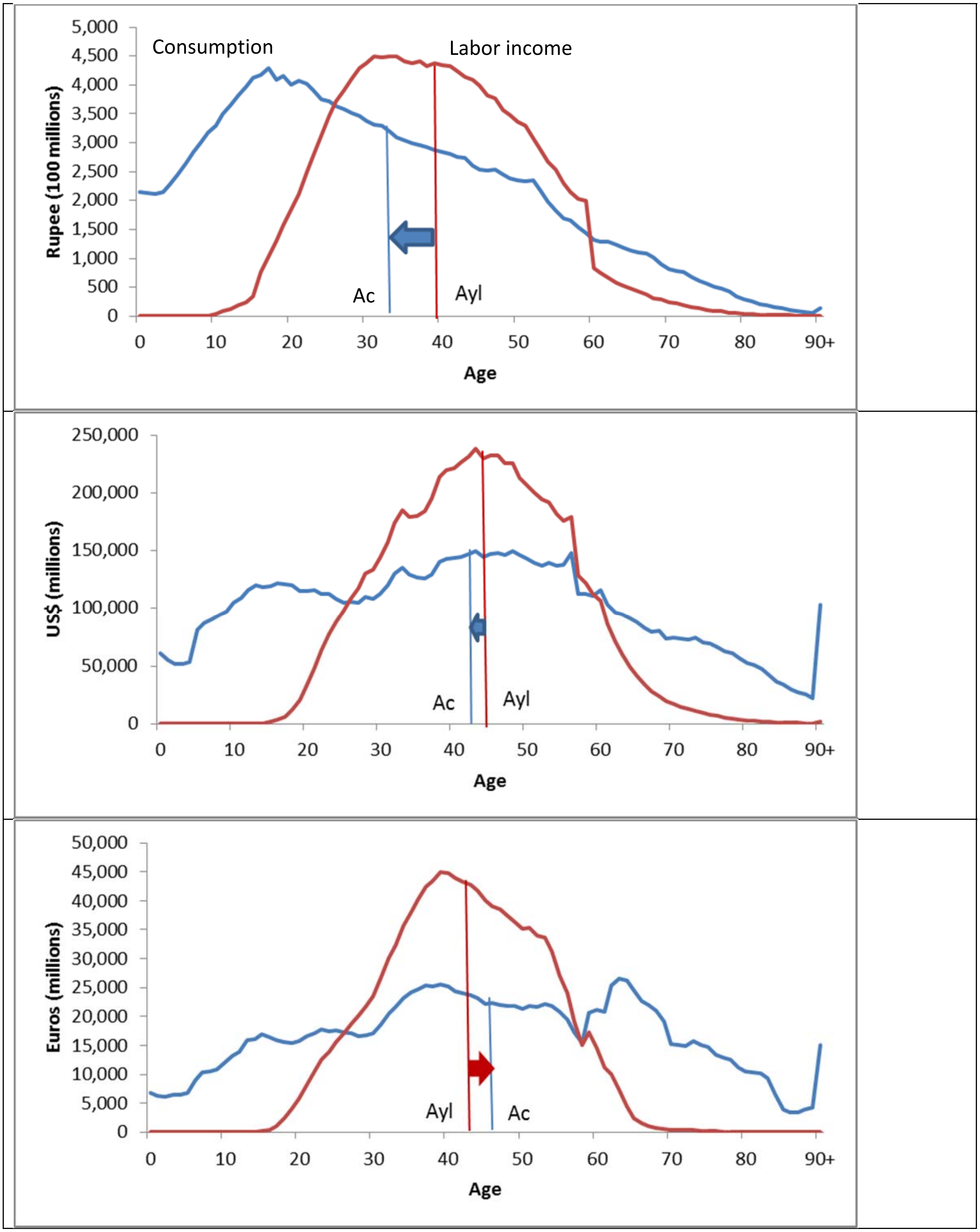
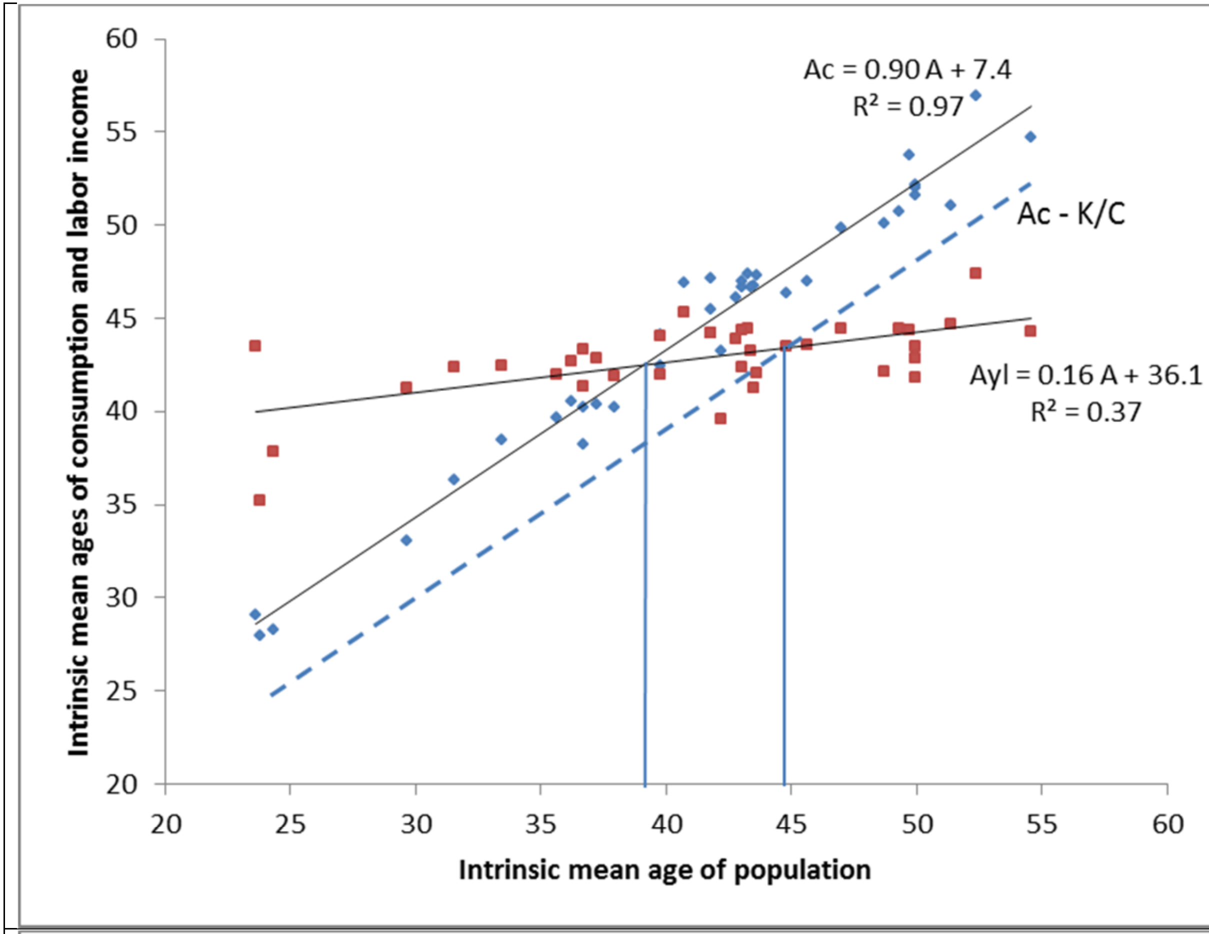


Figure 2. Consumption and labor income by age for India 2004 (upper panel), United States 2003 (middle panel), and Germany 2004 (lower panel). Mean ages of consumption (Ac) and labor income (Ay).



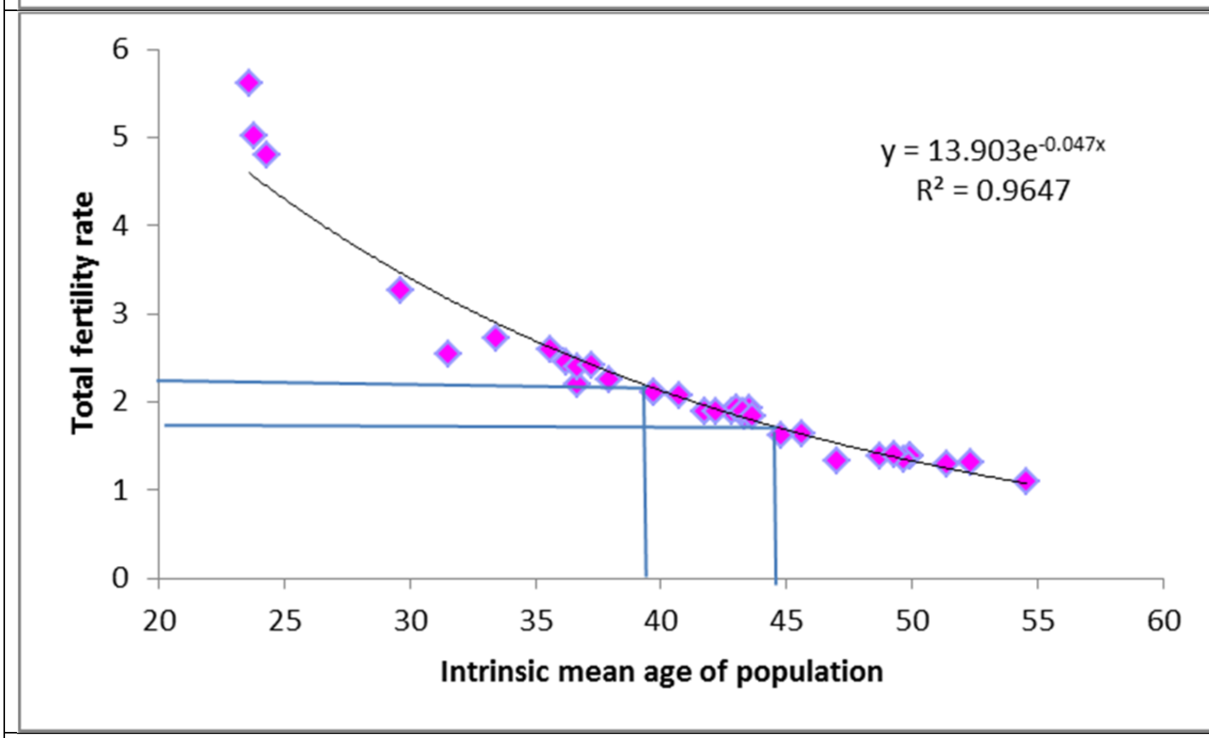
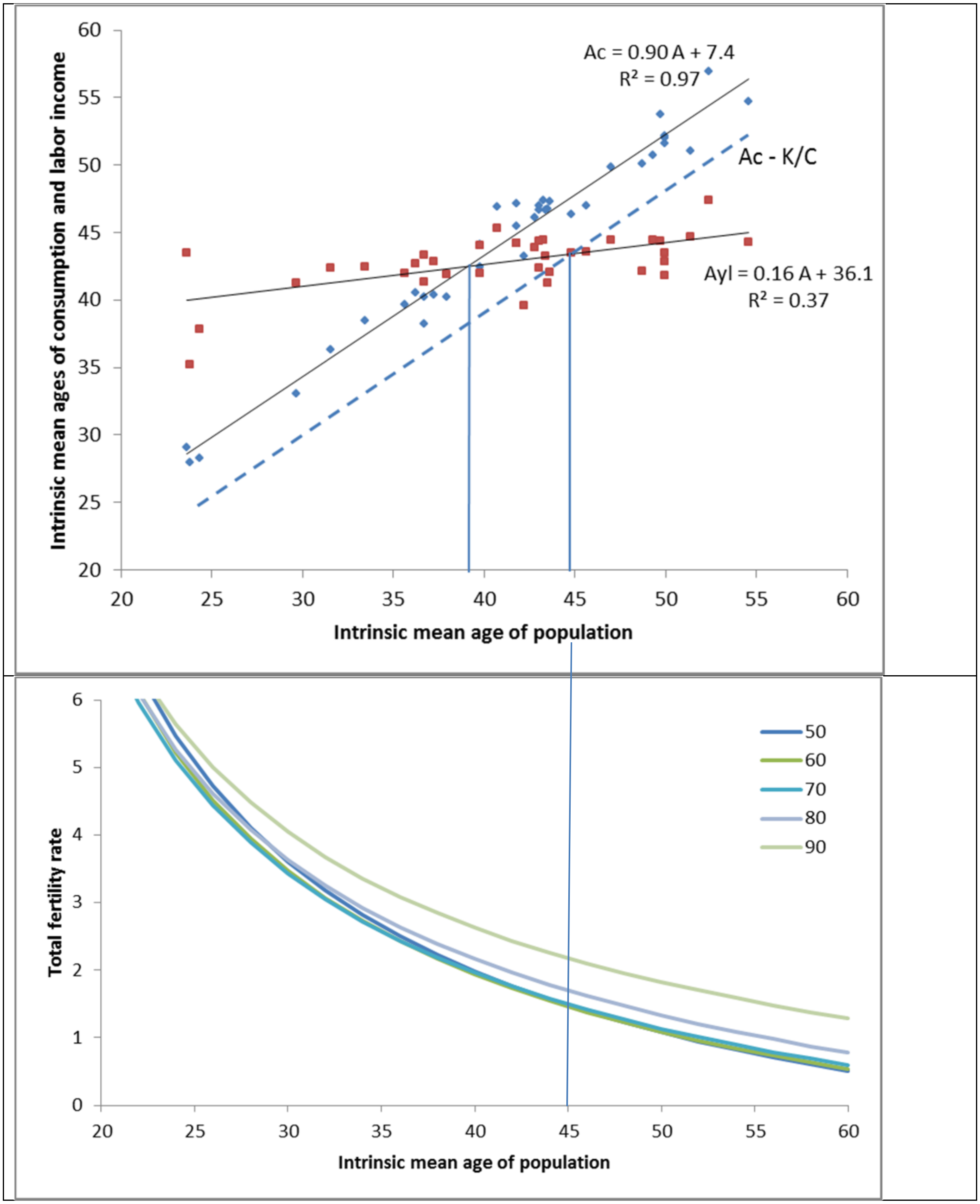


Figure 3. This determines the relationship between intrinsic age and TFR using the cross-sectional data. An alternative approach is to use the isoquants (see below). I suppose we could put the observed point

on the same graph with the isoquants. We also could break the graphs up into multiple graphs. I don't think we are approaching the limit on graphs.

The dashed line incorporates the gains from reduced capital costs that arise given a K/C of 4. The mean population ages for the two intersections are 38.1 years and 44.5 years. The corresponding TFRs are 2.2 and 1.7.


Ac = 0.90 A + 7.4
R² = 0.97
Ac - K/C
Ayl = 0.16 A + 36.1
R² = 0.37
Intrinsic mean ages of consumption and labor income
Intrinsic mean age of population
Total fertility rate
Intrinsic mean age of population
50
60
70
80
90

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