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Labor and consumption across the lifecycle ☆

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ABSTRACT

We propose new measures to summarize and compare age profiles of consumption and labor income. One measure is the lifetime support ratio or the ratio of effective lifetime labor to effective lifetime consumption. Two other measures measure the timing of work and consumption over the lifecycle. Using a highly stylized model we show how changes in these features of the lifecycle influence the standard of living that can be achieved. To illustrate the value of these measures we consider two practical applications. In the first we analyze the effect of increasing life expectancy on lifetime effective labor and consumption. We show that in longer life is leading to greater lifetime consumption but little response in lifetime labor supply. The exception to this generalization is in low income, high mortality countries where the gains in life expectancy are occurring at the working ages as well as the non-working ages. In the second application we consider whether the lifetime support ratio and the timing of consumption relative to labor income are influenced most by variation in life cycle patterns of work or lifecycle patterns of consumption. The answer depends on the level of development. In upper-middle income countries and high-income countries both are important. In these countries, then, effective policy should address both sides of the lifecycle – producing and consuming. In lower-income countries, however, only the age patterns of labor income appear to matter. Policies related to labor markets and labor force behavior appear to be critical under these circumstances.

Introduction

The lifecycle is a fundamental and important feature of every economy. Over extended periods at the beginning and end of life, individuals consume much more than they produce through their labor. During the middle years, they generate a surplus by producing much more through their labor than they consume. The lifecycle interacts with large, systematic changes in population age structure that occur over the demographic transition. In the early stages of the demographic transition, mortality declines from high levels producing population growth and, because mortality improvements are concentrated among infants and children, a very young population. During the next phase of the transition continued improvements in mortality and the onset of fertility decline lead to slower population growth and a shift in age structure into the ages where production through labor exceeds consumption. To varying degrees this has led to what is widely referred to as the *demographic dividend* (Bloom and Williamson, 1998; Mason, 2001, 2005; Bloom et al., 2002; Mason and Lee, 2007; Williamson, 2013).

At the end of the demographic transition, as it is playing out in many high-income countries, low fertility is leading to low population growth or population decline and rapidly aging societies. Rapid aging has two sources – mortality improvements concentrated at older ages and low fertility. The changes in population age structure at the end of the transition are a source of concern because they may undermine old-age support systems and retard economic growth (Cutler et al., 1990; National Research Council, 2012).

The conceptual foundations for understanding how population age structure interacts with the lifecycle to influence the economy have been established in several studies starting with the seminal work of Samuelson (Samuelson, 1958, 1976; Deardorff, 1976; Arthur and McNicoll, 1978; Lee, 1994a,b). Many empirical studies and simulation analyses have enhanced our understanding of the dynamics of population age structure's interaction with the economy (Kelley and Schmidt, 1995, 2001; Bloom and Canning, 2001,

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2003; Lee et al., 2003; Mason and Lee, 2007; Lee and Mason, 2010, 2011a,b; Mason et al., 2010).

Until recently the development of conceptual foundations has outpaced the availability of data to study the linkages between population and the macroeconomy. In recent years, however, members of an international research network, the National Transfer Account (NTA) network, have been constructing economic accounts that provide detailed estimates of economic flows by the age of individuals (Lee and Mason, 2011a,b). The analysis presented here relies on NTA data to quantify from an individual perspective how labor and consumption vary over the lifecycle and to analyze how variation in the economic lifecycle interacts with changing survival rates and population age distributions to influence standards of living. The broader goal of the paper is to understand how policies might influence the economic lifecycle to achieve better economic outcomes in a world where people are living much longer than in the past.

We propose new measures that can be used to summarize and compare age profiles of consumption and labor income. One measure is the lifetime support ratio or the ratio of effective lifetime labor to effective lifetime consumption. Two other measures are derived that measure the timing of work and consumption over the lifecycle. Using a highly stylized model we show how differences in these features of the lifecycle influence the standard of living that can be achieved.

To illustrate the value of these measures we consider two practical applications. In the first we analyze the effect of higher life expectancy on lifetime effective labor and consumption. Although a potentially valuable response to longer life is to work longer, we show that in practice longer life is leading to greater lifetime consumption but little response in lifetime labor supply. The exception to this generalization is in low income, high mortality countries where the gains in life expectancy are occurring at the working ages as well as the non-working ages.

In the second application we consider whether the lifetime support ratio and the timing of consumption relative to labor income are influenced most by variation in life cycle patterns of work or lifecycle patterns of consumption. The answer depends on the level of development. In upper-middle income countries and high-income countries both are important. In these countries, then, effective policy should address both sides of the lifecycle – producing and consuming. In lower-income countries, however, only the age patterns of labor income appear to matter. Policies related to labor markets and labor force behavior appear to be critical under these circumstances.

Theory

The goal of this section is to develop measures that can be used to evaluate how patterns of work and consumption over the lifecycle influence standards of living. The emphasis is on measuring the "experience" of a representative individual over his or her hypothetical life, rather than on population measures. With a simple set of data, we might know the representative individual begins working at age A, retires at age R, and dies at age D. Lifetime earnings of the individual will depend on the average earnings per years and the lifetime years of work, R–A. Lifetime consumption depends on average consumption per year and lifetime years of consumption, D. Average consumption over the lifetime relative to average earnings during the working years will depend on years of work relative to year of consumption, (R–A)/D. We call this the lifetime support ratio and it is a key summary measure, calculated in a much more refined way than in this simple case.

Even in this simple case, the consumption our hypothetical individual can realize also depends on the timing of work and consumption over the lifecycle, because shifting resources over the lifecycle involves a cost. If she consumes before she earns, on average, she must pay for the privilege. If she relies on credit to realize her desired consumption path, interest paid on debt reduces the resources available to pay for consumption, for example. On the other hand, if she consumes after she earns, on average, she will be compensated for delaying her gratification. Interest earned on the assets she holds allows her to consume more during her life relative to her lifetime earnings.

Individuals can reallocate resources across age in two ways: by relying on intergenerational transfers or by relying on assets, i.e., using lifecycle saving. The price for reallocating resources will generally be different for these reallocation mechanisms as pointed out by Samuelson (1958). The price for reallocating resources using lifecycle saving is the interest rate whereas the price for reallocating resources using intergenerational transfers is the rate of economic growth. In the analysis presented here we assume that there is a single price for reallocating resources, the interest rate.[1]

The analysis presented here differs from this simple case in ways that improve the realism of the analysis and capture important differences across countries with very different levels of development and demographic conditions. First, rather than assume a constant supply of labor during the work span, we allow for age-specific variation in labor force participation, hours worked, unemployment, and productivity. Second, rather than assume that people at each age consume at the same level, we use a detailed measure of consumption that varies by single year of age. Third, we use age specific survival rates rather than age at death to analyze the impact of changes in mortality.

Labor income

The average labor income of individuals at each age x in country j are influenced by two broad factors. First, the overall level of labor income of the country in which individuals live vary under the influence of country-specific features such as the quality of the education system, the capital intensity of the economy, the quality of government institutions and the financial sector, attitudes and practice towards gender and ethnic minorities, etc. Second, per capita labor income is affected by age due to a variety of factors, e.g., gains from experience, the influence of aging on cognitive and physical abilities, competing uses of time such as childbearing and childrearing, policies that influence work, e.g., child labor laws and retirement provisions, tastes about work and leisure, and a host of other factors.

These factors are incorporated into labor income, $y^l(x,j)$, using the following formulation:

$$y^l(x,j) = \bar{y}^l(j)\phi(x,j) \quad (1.1)$$

where $\bar{y}^l(j)$ is the level of labor income in country j and $\phi(x,j)$ is the age profile of labor income relative to the level of labor income. The level of labor income is measured as the average of per capita labor income at each age of prime-age adults, defined as persons age 30–49, in the base year. In other words, the relative age profile is calculated as the per capita labor income at age x divided by the average of per capita labor income at each age for the 30–49 age group.

Our interest here is in the age pattern of labor income and not its country-specific level. Hence, we analyze effective labor income relative to the labor income of prime age adults:

$$y^l(x)/\bar{y}^l = \phi(x) \quad (1.2)$$

[1] In a highly specialized case of golden rule growth the prices of reallocating resources through transfers and asset-based reallocations are the same. The interest rate is equal to the rate of growth of national income.

For the normalized profile of labor income, the level of labor income is 1.0 for all countries. This facilitates the comparison of age profiles across countries at very different levels of development. Notation has been simplified by dropping the country index *j*.

A simple intuitive way to interpret $\phi(x)$ is as the effective labor supplied at each age x. Those in the prime adult ages of 30–49 are counted, on average, as one effective worker while those at each age x are counted as more or less than one depending on their per capita labor income relative to the average for 30–49-year-olds. Effective labor at each is determined by the variation across age in labor force participation, unemployment, hours worked, and wages relative to the comparison group of those 30–49.

Summary measures and their analysis are based on a stylized model in which members of a synthetic cohort follow the cross-sectional path of labor income with two important elaborations. The first is that members of the cohort are subject to mortality. The effects of mortality are incorporated by analyzing the survival-weighted age profile of labor income, $s(x)\phi(x)$ where $s(x)$ is the probability of survival from birth to age x for both sexes combined in the base year, i.e., the year in which the age profile of labor income is estimated. The second elaboration is that economic growth or technological progress will lead to gains in the level of productivity, wages, and labor income over time. This is incorporated into the analysis assuming that labor income at each age shifts upward at the constant rate λ.

The cross-sectional profiles of unweighted and survival-weighted effective labor are illustrated using the simple average of the per capita age profiles available for 14 high-income countries (Fig. 1). Nothing about the unweighted per capita profile should come as a surprise. Effective labor begins to rise in the late teens and early twenties. The peak is reached at age 46, but note that effective labor at age 30 is only about 18 percent below the peak. Effective labor drops quite steeply in the later fifties and early sixties. By age 65, effective labor is lower than the peak value by 82%. After age 70 effective labor is negligible.

Survival weighting has a relatively modest impact on the effective labor profile for high-income countries because survival rates only begin to decline at high ages when the impact is not apparent in the figure because effective labor is so low. For lower-income countries effective labor is reduced by a more significant degree, however, reflecting the reduced likelihood of surviving at working ages.

If we consider a representative individual born in the base year, subject to the age profiles of effective labor and survival and experiencing economic growth at rate λ, survival-weighted effective labor at each age would be equal to $e^{\lambda x}s(x)\phi(x)$. The present value of lifetime survival-weighted effective labor for a representative individual, PVL, is given by:

$$\begin{aligned} \text{PVL} &= \int_0^{\omega} e^{-rx}e^{\lambda x}s(x)\phi(x)dx \\ &= \int_0^{\omega} e^{(\lambda-r)x}s(x)\phi(x)dx \end{aligned} \tag{1.3}$$

where r is the interest rate or discount rate.

As shown in the appendix, PVL can be approximated as a function of three summary measures of the per capita age profile of effective labor:

$$\ln \text{PVL} \simeq \ln \phi_0 - (r-\lambda)\mu_\phi + 0.5(r-\lambda)^2\sigma_\phi^2. \tag{1.4}$$

The first term on the right-hand-side is lifetime effective labor (the area shown in Fig. 1) calculated by:

$$\phi_0 = \sum_{x=0}^{\omega} s(x)\phi(x) \tag{1.5}$$

Given the other factors a one percentage point increase in lifetime effective labor produces a one percentage point increase in PVL.

The second and third factors measure the timing of effective labor over the lifecycle. The mean age of effective labor is calculated as:

$$\mu_\phi = \sum_{x=0}^{\omega} xs(x)\phi(x) \Big/ \sum_{x=0}^{\omega} s(x)\phi(x) \tag{1.6}$$

The variance of effective labor over the lifecycle is:

$$\sigma_\phi^2 = \left(\sum_{x=0}^{\omega} x^2 s(x)\phi(x) \Big/ \sum_{x=0}^{\omega} s(x)\phi(x)\right) - \mu_\phi^2 \tag{1.7}$$

Income earned later in life is advantaged because of the gains in productivity that occur throughout the life of our representative individual. Income earned later in life is disadvantaged, however, because of the opportunity costs of foregoing the use of income were it earned earlier in life. If the discount rate exceeds the rate of productivity growth, the more typical case, PVL is reduced by an increase in the average age at which labor income is earned, μ_ϕ.

The second measure of timing, the variance of effective labor, matters because of the non-linear nature of discounting and

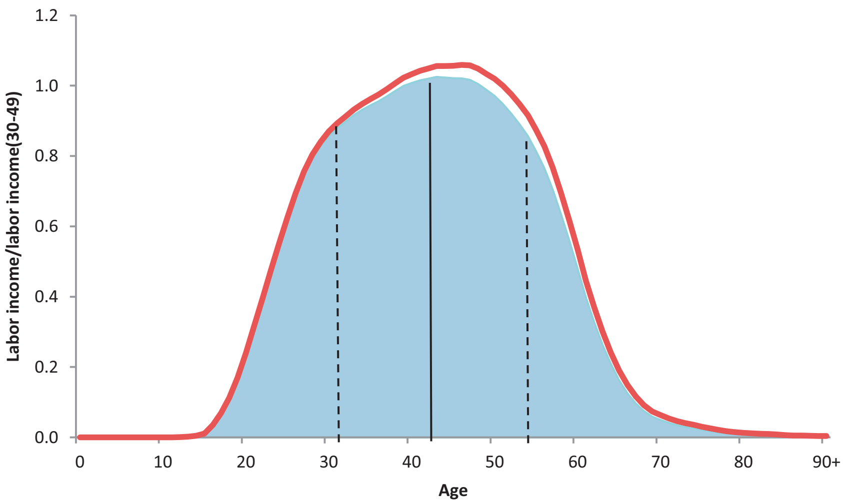

Fig. 1. Per capita effective labor by age, simple average of values for 14 high income countries. Calculated as per capita labor income divided by average per capita labor income of persons 30–49. Unweighted and survival-weighted values. The solid line marks the mean age of effective labor and dashed lines mark the mean age ± one standard deviation for survival weighted values.

growth. It is advantageous to have labor income spread out over many years of life rather than closely concentrated in the middle of life.

For the high income countries profile shown in Fig. 1, lifetime effective labor is 36.1 years. (Recall that this is the amount of lifetime labor measured in units of years of prime age labor income earned as measured by average labor income at ages 30–49. It will generally be less than lifetime years of labor force participation because it incorporates age variation in unemployment, hours worked, and wages or productivity.) This compares with life expectancy at birth in the high income countries averaging 79.8 years in the base year. Thus, effective lifetime years of labor amounted to 45% of life expectancy at birth. The mean age of effective labor is 42.6 years as marked by a solid line. The variance and standard deviation of the survival-weighted effective labor profile are 137.2 and 11.7, respectively. Sixty-four percent of the survival-weighted effective labor supplied over the lifetime of the synthetic cohort falls between 31 and 54 years of age, inclusive, approximately the mean age ± one standard deviation (shown by the dashed lines in Fig. 1).

Consumption

Effective consumption is treated in a fashion similar to labor income. Consumption at each age depends on the level of consumption, measured by the average of per capita consumption at each age in the 30–49 age interval, and a relative age profile of consumption equal to consumption at each age relative to mean consumption at prime ages. This approach is represented by:

$$c(x) = \bar{c}\gamma(x) \tag{1.8}$$

Given the relative consumption profile an increase in the level of consumption by x percent leads to an increase in consumption at every age by x percent.

The effects of survival and economic growth are incorporated into our model in the same fashion as for labor income. A representative individual is subject to the age profile of effective consumption and survival estimated for the base year. The age profile of consumption increases by a constant amount λ at each age, thereby maintaining the cross-sectional profile of consumption.[2]

The age profile $\gamma(x)$ can also be interpreted as an equivalence scale where adults 30–49 are assigned a value of one, on average, and those at each single year of age x are counted as more or less than one depending on their consumption relative to the average of the consumption values at each age for those 30–49. For a representative member of a cohort we will refer to these values as effective years of consumption.

The present value of lifetime survival-weighted effective years of consumption is given by:

$$\mathrm{PVC} = \int_0^{\omega} e^{(\lambda-r)x} s(x)\gamma(x)dx \tag{1.9}$$

where r is the interest rate or discount rate.

PVC can also be approximated as a function of three summary measures of the survival weighted consumption profile:

$$\ln \mathrm{PVC} \simeq \ln \gamma_0 - (r-\lambda)\mu_\gamma + 0.5(r-\lambda)^2\sigma^2_{\bar{\gamma}} \tag{1.10}$$

where γ_0 is lifetime survival-weighted effective years of consumption, μ_γ is the mean age and $\sigma^2_{\bar{\gamma}}$ the variance of effective consumption age profile. All terms are defined as shown above for the age profile of effective labor.

[2] It is natural to assume that the level of consumption grows at the same rate as labor income. In steady-state models of the economy, consumption and labor income must grow at the same rate. Here we are simply assuming that this is the case.

Per capita unweighted and survival-weighted effective consumption by age for the sample of 14 high-income countries is shown in Fig. 2.[3] Effective consumption increases from about 0.5 for young children and rises above 1 for late teens due to heavy spending on education. The profile is relatively flat throughout the adult years until around age 50 and then increases with age thereafter. The increase is particularly sharp at older ages due to consumption of health care and long-term care. The survival-weighted consumption profile declines at older ages because the proportion surviving is declining sharply.

For the high income countries as a whole, the number of years of effective consumption equals 80.5. This is slightly greater than life expectancy because consumption at older ages and in the late teens is greater than our unit of measure, consumption of a prime age adult. The mean age of consumption is age 44, about 1.5 years later than the mean age of effective labor. The variance of consumption (604) and standard deviation of consumption (24.6) are much greater than the values for effective labor. Sixty-two percent of effective consumption falls within one standard deviation of the mean age of consumption.

Labor income, consumption, and the balanced consumption level

The level of consumption (c^*) that the synthetic cohort can sustain over its synthetic lifetime depends on the present value of the number of years of effective consumption (PVC), the present value of the number of years of effective labor (PVL), and the present value of net transfers at age 0 (T). This dependence is embodied in the synthetic cohort's lifetime budget constraint:

$$c^*\mathrm{PVC} = \mathrm{PVL} + T \tag{1.11}$$

The level of consumption that can be realized is endogenously determined by PVC, PVL, and T.[4]

The existence of intergenerational transfers means that lifetime consumption is not fully constrained by lifetime labor income. Individuals can consume more than they produce through their labor, in present value terms, by relying on net public transfers, net inheritances, or net private transfers. Or altruistic individuals might choose to make net transfers to other generations and consume less over their lifetime, in present value terms, than they produce through their labor.

Here we consider a useful benchmark special case in which lifecycle labor income determines the level of lifetime consumption when the present value at birth of transfers made and received over the lifetime is zero. We will call this level of consumption, c^*, the level of balanced consumption. The term "balanced" is used because, by assumption, the intergenerational transfers received by the synthetic cohort, in present value terms, are equal to the intergenerational transfers made by the synthetic cohort. The level of balanced consumption fully absorbs changes in PVC or PVL rather than through adjustments in intergenerational transfers. Setting $T = 0$, the balanced consumption level is:

$$c^* = \int_0^{\omega} e^{(\lambda-r)x} s(x)\phi(x)dx \Big/ \int_0^{\omega} e^{(\lambda-r)x} s(x)\gamma(x)dx \tag{1.12}$$

[3] Important details about estimating the age profiles of consumption are provided below in the section on data.

[4] There is no reason in particular for the balanced level of consumption to equal $\bar{c}/\bar{y}^l$ in Eq. (1.8), which is influenced by population age structure, historical events that have influenced asset holdings by each age group, and intergenerational transfers among other factors.

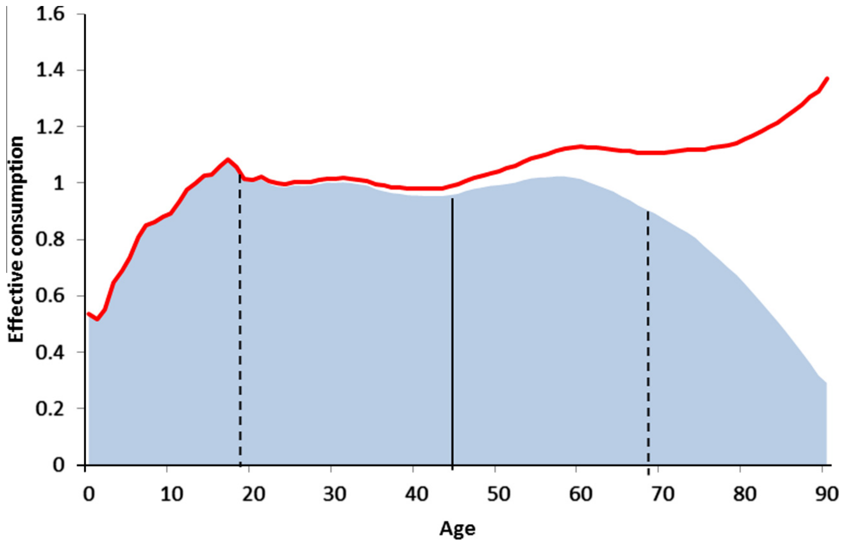

Fig. 2. Per capita effective consumption by age, simple average of values for 14 high income countries. Calculated as per capita consumption divided by average per capita consumption of persons 30–49. Unweighted and survival weighted values. The solid line marks the mean age of effective consumption and dashed lines mark the mean age ± one standard deviation for survival weighted values.

The balanced level of lifetime consumption is equal to the present value of effective years of labor divided by the present value of effective years of consumption. The balanced level of consumption can be approximated by:

$$\ln c^* \approx \ln\frac{\phi_0}{\gamma_0} + (r-\lambda)(\mu_\gamma - \mu_\phi) + 0.5(r-\lambda)^2(\sigma_\phi^2 - \sigma_\gamma^2) \qquad (1.13)$$

The first term on the right-hand-side is the lifetime years of survival-weighted effective labor relative to the lifetime years of survival-weighted consumption in the cross-section or for a synthetic cohort. We call this the lifetime support ratio. The balanced level of consumption is proportional to the lifetime support ratio. The effects of timing on the balanced level of consumption are captured by the second and third terms on the right-hand-side. The balanced level of consumption rises if the mean age of effective consumption increases relative to the mean age of effective labor or if the variance of effective labor increases relative to the variance of effective consumption.

Data

Estimates of the economic lifecycle are drawn from National Transfer Accounts (NTA) data. A comprehensive overview and detailed information about methods are reported in Lee and Mason (2011a,b) and on the NTA website: www.ntaccounts.org. Estimates are used for 8 low- and lower-middle-income countries (Cambodia, India, Indonesia, Kenya, Nigeria, the Philippines, Senegal, and Vietnam), 12 upper-middle-income countries (Argentina, Brazil, Chile, China, Colombia, Costa Rica, Jamaica, Mexico, Peru, South Africa, Thailand, and Uruguay) and 14 high-income countries/economies (Australia, Austria, Finland, France, Germany, Hungary, Italy, Japan, South Korea, Spain, Sweden, Taiwan, United Kingdom, and the United States).

Per capita labor income by age is the estimated value of all returns to labor effort including the value of goods and services produced by informal-sector workers and the imputed earnings of unpaid family workers. The labor income profiles are estimated from standard surveys of household income or labor force that report the labor income of individuals. The values are scaled (adjusted proportionately) to obtain consistency with estimates of aggregate labor income based on the UN System of National Accounts.

Per capita consumption by age is a comprehensive measure that includes all goods and services produced by both the private and public sectors. Public consumption includes public education and publicly funded health care, as well as collective public consumption. Public consumption is allocated based on administrative records on health and education spending, while other public consumption is allocated equally to each member of the population. Private consumption by age is based on household survey data with sharing rules used to allocate consumption to individual household members. The allocation of education and health within the household is based on regression analysis. Other household consumption is allocated using equivalence scales equal to 0.4 for young children, rising to 1.0 at age 20, and holding constant thereafter. Public and private consumption are also scaled to match aggregate values from the UN System of National Accounts. The empirical shape shown in Fig. 2 and estimates for other countries reflect many factors other than the sharing rules, such as the distribution of ages at which parents bear children, the association of fertility with parental income level, patterns of co-residence of the elderly with their adult children, other aspects of household headship rates by age, variations in household dependency rates over the family life cycle, the age distribution of receipt of in-kind public benefits, and so on.

The estimates were compiled by research teams in each country which participate in the National Transfer Account network. The members of those teams and their institutions are identified on the NTA website (www.ntaccounts.org).

Summary measure by income group

The lifecycle characteristics for each country are provided in the appendix tables at the end of the paper. Average values for lower income, upper-middle income, and higher income countries are presented in Tables 1 and 2. The average values for income groups are calculated as a simple average of the values for the countries falling into each of those groups.

Table 1 reports the effective years of lifetime labor and consumption and the lifetime support ratio. In lower income countries 31.5 years of effective labor is supplied over the lifetime which is

Table 1
Lifetime years of effective labor and effective consumption: values as a percentage of life expectancy at birth; lifetime support ratio (LSR) by income group.

Income group	Life expectancy at birth	Effective labor		Effective consumption		LSR
		Years	Percent	Years	Percent	
Lower income	63.0	31.5	50.0	56.4	89.5	0.559
Upper-middle income	72.9	35.0	48.1	67.1	92.2	0.522
High income	79.8	36.1	45.2	80.5	100.9	0.448

Note. Values are simple averages of country values.

Table 2
Measures of timing of labor income and consumption over the lifecycle, thirty-four countries by income group.

Income group	Mean age of life	Mean age		Variance		Standard deviation	
		Labor income	Consumption	Labor income	Consumption	Labor income	Consumption
Lower income	35.7	42.1	39.4	160.2	458.9	12.6	21.4
Upper-middle income	38.5	43.0	42.3	166.6	523.6	12.9	22.9
High income	40.6	42.6	44.0	137.2	598.5	11.7	24.5

precisely half of life expectancy. Lifetime labor increases to 35 years in upper-middle income countries and 36.1 years in high income countries. Note that the years of effective labor do not increase as much as life expectancy. In the high income countries, lifetime labor is only 45 percent of life expectancy.

Lifetime effective consumption also increases with income. The difference between lower income and higher income countries is 24 years as compared with the 5 year difference in lifetime effective labor. As a percentage of life expectancy at birth, effective consumption is greater in high income countries that in lower income countries. In high income countries the value exceeds 100 percent because consumption at some older ages and some late teen ages exceeds the consumption of prime age adults. In contrast, effective lifetime consumption in lower income countries is about 90% of life expectancy at birth reflecting low consumption among children and, in some countries, among the elderly.

The differences by income level in the lifetime support ratio (LSR) are very substantial. In lower income countries the representative individual has an effective labor supply of 0.56 years for every year of effective consumption. In upper-middle income countries, the LSR is about 5 percent lower at 0.52. In high income countries, however, the LSR is much lower at 0.45 – about 20 percent below the value for lower income countries.

All other things equal, the low LSR in high income countries implies that the level of lifetime consumption must be lower by 20 percent because people are living longer, consuming substantially more at young and old ages, but working only a little longer.

Next we turn to the timing of labor and consumption over the lifetime comparing income groups (Table 2). The mean age of labor income falls between 42 and 43 years of age with no apparent relationship to the level of development. In contrast the mean age of consumption rises sharply from 39.4 years for lower income countries to 44.0 years for high income countries. This leads to a reversal in the relative timing of consumption and labor income. In lower income countries, individuals consume at an earlier age than they earn. While in higher income countries, the reverse is true.

In all countries, effective labor is much more concentrated than consumption. Of course, this is a direct reflection of the fundamental feature of the lifecycle – extended periods at the beginning and end of life when consumption is substantially greater that labor income. The lifecycle is clearly more pronounced in the higher income countries. Labor income is concentrated in a narrower age span while consumption is less concentrated in higher income countries than in lower income or upper-middle income countries. The implications of this are drawn out more fully below.

Live longer, work longer?

Working longer is a potentially important behavioral response to living longer and policy options for encouraging later retirement are widely discussed (Gruber and Wise, 1999, 2001; OECD, 2006). Increases in the lifetime years of consumption could be offset by increases in the lifetime years of effective labor if workers delayed their retirement, were not disadvantaged by higher rates of unemployment, continued to work as many hours as their younger counterparts, and maintained their productivity.

One possible use of the calculations presented here is to assess the extent to which the work life must be extended in order to meet some particular goal, e.g., to maintain years worked relative to years lived, to maintain the lifetime support ratio, or to maintain the level of consumption relative to the level of labor income. Whether any of these alternatives is a reasonable goal is entirely unclear, but simple calculations suggest that labor supply responses are unlikely to be sufficient to offset the changes in age-specific survival rates and consumption patterns.

In lower income countries effective years worked is 50% of life expectancy at birth and the lifetime support ratio is 0.559 (Table 1). For high income countries effective lifetime labor would have to increase by almost four years from 36.1 years of work to 39.9 years of work to offset the difference in life expectancy. To offset the difference in years of effective consumption would require an even greater response. An LSR of 0.559 for high income countries would require 45.0 lifetime years of effective labor or an increase of about nine years from current levels. Note that this would require nine years of additional work at the productive level realized by 30–49 year olds not nine years of labor at the lower levels of productivity of those near retirement.

To maintain the level of consumption (relative to the level of labor income) would require even greater increases because delaying retirement would influence the timing of labor income. Both the mean age of labor income and the variance of labor income would increase as individuals extended their time in the workforce. Adding income later in life has a smaller impact on lifetime consumption than a proportional increase in labor income at all ages (see Eq. (1.13). Hence, an even greater increase in effective years of labor would be required in high income countries to realize the level of consumption (relative to the level of labor income) that we find in low income countries.

The data on effective years of labor by income groups suggests that responses in lifetime effective labor supply to longer life have been modest. This is a point we want to explore further in this sec-

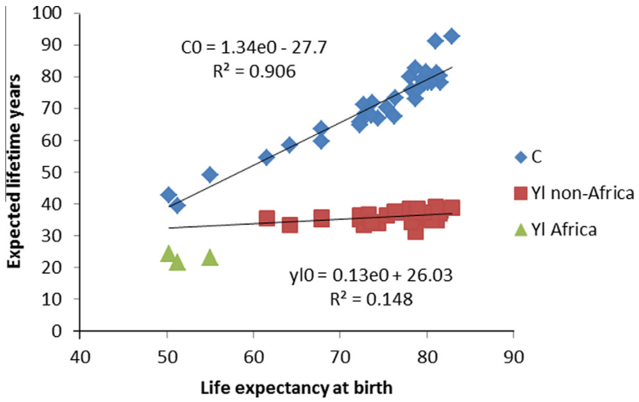

Fig. 3. Lifetime consumption and labor income and life expectancy at birth for NTA countries in a recent year. Consumption and labor income profiles are taken from the NTA database www.ntaccounts.org accessed March 15, 2013. Age-specific survival rates based on UN World Population Prospects 2011.

tion by looking at the impact of survival on both effective years of work and consumption.

In Fig. 3, lifetime years of effective labor and effective consumption are plotted against life expectancy at birth using estimates for the 34 countries for which data are available. For each a "trend line" is plotted showing how effective years of consumption and labor vary with life expectancy at birth. Effective years of consumption increases sharply with life expectancy – by 1.34 years for every additional year of life expectancy. Turning to effective labor we find a much weaker relationship. The African countries appear to be outliers with much lower effective lifetime labor than expected based solely on their life expectancy at birth. The low values of effective labor for these African countries reflect problems with unemployment of young workers, a problem that is widely acknowledged. Excluding those outliers an increase in life expectancy by one year leads to an increase in effective years of work of only 0.13 years – a very small response.

The combined effect of the large rise in the effective years of consumption combined with the tepid response in effective years of work is reflected in the relationship between LSR and life expectancy at birth shown in Fig. 4. Again the three African countries in the sample are outliers and are not included in the calculation of the trend line. An increase in one year of life leads to a decline in the LSR of 0.009 – roughly a 2 percent decline in the LSR for every additional year of life expectancy. Those living in countries with high life expectancy are not increasing their effective lifetime labor to match the higher lifetime consumption.

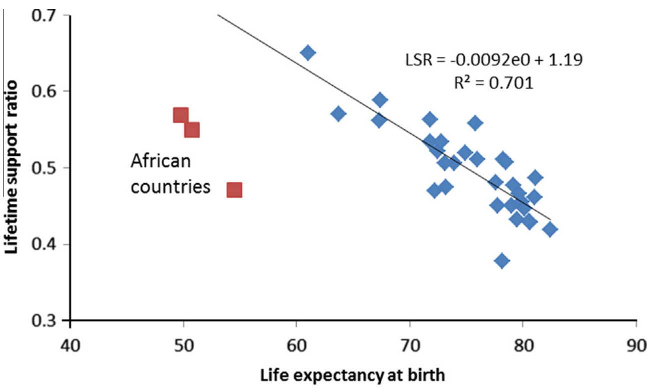

Fig. 4. Lifetime support ratio and life expectancy at birth, 34 countries for a recent year.

If people consumed the same amount at every age, an additional year of life would lead to an additional effective year of consumption, but we see an increase that is substantially greater than one. There are two possible explanations for this. The first is that the gains in consumption are occurring at ages where effective consumption is greater than average consumption. A likely candidate could be gains in years lived at old ages in countries where old-age consumption is relatively high. The second possible explanation is that the differences across countries reflect differences in the age profile of effective consumption. In some high income countries with high levels of life expectancy, consumption at older ages is much higher and so this will influence the effective years of consumption.

The absence of a rise in lifetime years of effective labor can be explained in a similar fashion. If gains in years lived are concentrated entirely at ages where labor income is very low, increases in life expectancy will not be accompanied by increases in years of effective labor. A second factor is the difference across countries in the age profile of effective labor. If people are not responding to the increase in effective years of consumption by working longer, that could account for the small response in effective lifetime labor.

The importance of these factors is explored using a simple decomposition analysis. The difference in the effective years of labor (or consumption) between two countries, ΔL, can be computed as:

$$\Delta L = \sum_{x=0}^{\omega} \Delta s(x)\phi(x) + \sum_{x=0}^{\omega} s(x)\Delta\phi(x) + \sum_{x=0}^{\omega} \Delta s(x)\Delta\phi(x) \qquad (1.14)$$

The first right-hand-side term is the portion explained by differences in survival, the second term is the amount explained by differences in the unweighted age profile, and the final term is the difference due to the interaction.

This is an unwieldy method for analyzing 34 countries and, hence, we have grouped the countries into five groups based on life expectancy at birth. The three African countries with life expectancy at birth under 60, four countries with e0 between 60 and 69, eight between 70 and 74, eleven between 75 and 79, and 8 with life expectancy at birth in excess of 80. For each of these groups we have calculated average age profiles of survival, effective labor, effective consumption, and the support ratio (Table 3).

The values for the five mortality groups are broadly consistent with the values presented in Figs. 3 and 4. Lifetime effective labor is very low in the high mortality Africa group, but otherwise large changes in life expectancy are associated with small changes in lifetime effective labor. Lifetime effective consumption, however, rises uniformly with life expectancy at birth. With the exception of Africa, the lifetime support ratio declines as life expectancy rises.

To analyze the role of changes in survival versus shifts in effective labor and consumption profiles we compare the adjacent country groups. First, consider the analysis of lifetime consumption (Fig. 5). The values are expressed relative to the increase in life expectancy between adjacent mortality groups. The first bar shows the components of change between the lowest mortality group with an e0 of 52.2 and the next highest mortality group with an e0 of 65.4. Effective years of consumption increased due to change in survival by slightly less than one year for every one year increase in life expectancy at birth. An additional 0.2 years increase can be attributed to the higher relative consumption profile in mortality group 2 as compared to mortality group 1.

As we move to successively higher levels of mortality the increase in effective lifetime consumption due to longer survival increases very gradually but is only slightly greater than 1 for the highest e0 comparison. Shifts in the consumption profile become increasingly prominent at higher levels of life expectancy. The

Table 3
Effective labor and consumption for countries classified by their life expectancy at birth.

Life expectancy		Number of countries	Lifetime effective		Lifetime support ratio
Range	Average		Labor	Consumption	
<60	52.2	3	23.02	43.74	0.53
60–69	65.4	4	34.90	59.05	0.59
70–74	73.2	8	34.96	68.20	0.51
75–79	78.2	11	36.26	76.03	0.48
80+	81.1	8	36.89	82.35	0.45

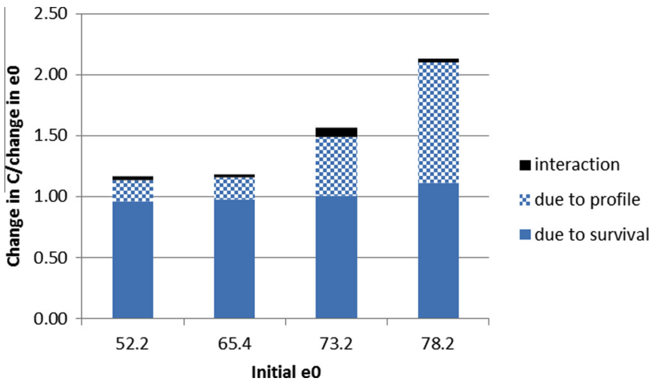

Fig. 5. Difference in effective years of consumption per additional year of expected life by source of change: due to increased survival, due to a shift in the per capita profile of effective consumption, and the interaction between the two. Difference calculated between adjacent groups of countries classified by their life expectancy at birth. Each bar analyzes the difference between adjacent mortality groups. The label is the average life expectancy in the country group with the lower life expectancy at birth. See Table 3 for additional information.

interactions are small and uninteresting. The key point is that effective consumption is rising because of shifts in the effective consumption profile. In the absence of this shift, effective years of consumption would be increasing about one year for every year of increase in life expectancy.

The decomposition analysis of effective lifetime labor is shown in Fig. 6. The effect of survival on effective lifetime labor is smaller and declines at higher levels of life expectancy. At the lowest mortality levels, each year of additional life expectancy increased effective years of labor by 0.6 years. This large impact of survival reflects the fact that survival to prime working ages in the three African countries is very low as compared with countries with life expectancy in the 60–69 range. Gains in life expectancy are producing more years at working ages and, hence, effective years of work not just more years at young and old ages. The large effect of survival is to some extent also a consequence of higher levels of effective labor at older ages in African countries.

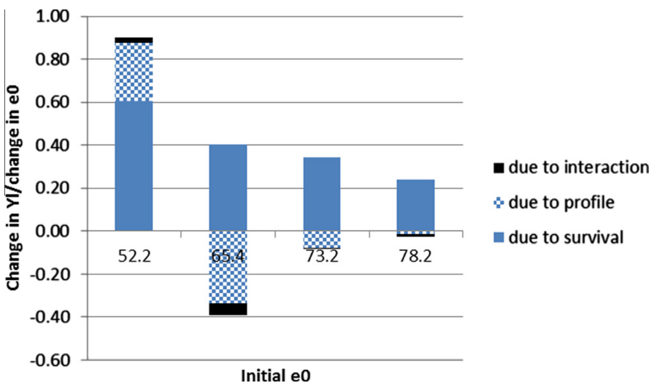

Fig. 6. Difference in effective years worked per additional year of expected life by source of change: due to increased survival, due to a shift in the per capita profile of effective labor, and the interaction between the two. Difference calculated between adjacent groups of countries classified by their life expectancy at birth. Each bar analyzes the difference between adjacent mortality groups. The label is the average life expectancy in the country group with the lower life expectancy at birth. See Table 3 for additional information.

The effect of gains in survival is much smaller at higher levels of life expectancy. At the highest level an additional year of life leads only to 0.2 additional years of work. This is a natural consequence of the pattern of survival change – the gains are increasingly concentrated at older ages where effective labor supply is low.

Shifts in the age profiles of effective labor present a mixed picture. Setting Africa aside, shifts in the effective labor age profiles reduce lifetime labor income as life expectancy increases. At higher levels of life expectancy people are working less although the difference between the two highest survival groups is negligible. The situation in the three African countries is distinctive. The effective labor profile in these countries is very low particularly at young ages. Hence, the lifetime supply of effective labor for the highest mortality country group is very low.

Given existing age patterns of work and consumption gains in life expectancy lead to an increase in effective years of consumption relative to effective years of labor and consequently a decline in the lifetime support ratio. This occurs because the years gained are concentrated more in the consuming ages than the working ages except at relatively low levels of life expectancy.

Changes in the age patterns of consumption or labor income could offset the effect of improved survival but this does not appear to be the case based on cross-national comparisons. Differences in age profiles of effective consumption are reinforcing the effect of survival so that effective years of consumption are very high in low mortality countries. The primary source of this change is spending on health and long-term care.

Differences in age profiles of effective labor are important in high mortality low income African countries reflecting a host of problems. Among countries at higher levels of life expectancy we see no evidence that people are increasing their supply of effective labor in response to their longer lives.

Is the support ratio influenced most by consumption or labor income?

The balanced level of consumption for a cohort varies directly with the lifetime support ratio. In the analysis in the preceding section we show how the LSR varies with life expectancy focusing on the differences between groups of countries which are at very different stages of the demographic transition and also at different levels of development.

Why the lifetime support ratio varies among countries is an important issue for countries that are experiencing rapid changes in population age structure. In many lower income countries the support ratio is rising yielding a demographic dividend as popula-

Table 4
Components of variation in lifetime support ratio.

		Percentage explained by		
		Labor income	Consumption	Interaction
High-mortality conditions				
All countries	100.0	37.2	39.6	23.2
High income	100.0	51.9	32.9	15.2
Upper-middle income	100.0	41.8	78.4	−20.2
Lower income	100.0	85.7	6.9	7.4
Across income groups	100.0	11.9	43.9	44.2
Low-mortality conditions				
All countries	100.0	40.7	41.6	17.8
High income	100.0	72.3	62.9	−35.2
Upper-middle income	100.0	50.4	81.3	−31.7
Lower income	100.0	87.5	9.7	2.8
Across income groups	100.0	16.2	36.4	47.4

tions become increasingly concentrated in the working ages. While in many more developed countries the support ratio is declining with potentially adverse consequences for economic growth. In all cases, raising the lifetime support ratio offers a potentially useful mechanism for realizing higher standards of living.

In order to simplify the analysis of this issue we focus exclusively on the profiles of effective labor and effective consumption rather than on survival. The reason for this approach, in addition to its simplicity, is that policies intended to influence the support ratio and the demographic dividend would surely focus on work and consumption patterns rather than on reducing survival rates so as to avoid a large dependent elderly population. Thus, in the analysis presented here we analyze lifetime support ratios holding survival rates constant while allowing the labor income and consumption profiles to vary across countries. The results could vary with the survival schedule chosen so we use two survival profiles in the analysis. Measures are calculated using the life table for Japan in 1949 and 2009 from the Human Mortality Database. In 1949, Japan had the lowest life expectancy of any OECD country and in 2009 it had the highest life expectancy in the world.

Which is more important as a determinant of the LSR, patterns of labor income or consumption? This question is answered using analysis of variance. The percentage variation in the lifetime support ratio across countries depends on the percentage variation in the amount of labor, the percentage variation in the amount of consumption, and the interaction between lifetime labor and lifetime consumption:

$$\mathrm{var}(\ln \phi_0/\gamma_0) = \mathrm{var}(\ln \phi_0) + \mathrm{var}(\ln \gamma_0) - 2\mathrm{cov}(\ln \phi_0, \ln \gamma_0) \qquad (1.15)$$

The components of variation calculated for the high- and low-mortality scenarios are reported in Table 4. First the analysis is applied to all countries combined showing that labor income and consumption explain the same amount of variation in the lifetime support ratio irrespective of the mortality assumption. Interaction between the consumption and labor-income profiles magnifies their effect because the covariance between them is negative. Countries with low lifetime labor income have high lifetime consumption.

A very different picture emerges when the analysis is applied separately for income groups. For high-income countries with low mortality, the most relevant mortality scenario for them, and upper-middle-income countries, lifetime levels of labor income and consumption are both important in explaining the lifetime support ratio. The interaction is negative, however. Within country income groups, countries with less lifetime effective years of work also have less lifetime effective years of consumption.

The situation is entirely different for lower-income countries. For them, lifetime consumption plays virtually no role in explaining why some have higher lifetime support ratios than others. Differences in the lifetime support ratio are almost entirely a consequence of differences in the years of lifetime effective labor.

This analysis applies only to the lifetime support ratio, but the balanced level of consumption also depends on the timing of effective labor and consumption. The decomposition analysis has been repeated to evaluate whether differences in the timing of consumption, or the timing of labor income, or both are responsible for timing differences that affect the balanced level of consumption. We will forego a technical discussion of the analysis, but the interested reader is referred to Mason and Lee (2012). We calculate the variance of the consumption effect and the labor effect and the covariance between the two, given possible values of r-λ. The results are similar to those shown in Table 4. For high- and upper-middle-income countries, the timing of consumption and labor income over the lifecycle are both important. For low-income countries, however, there is very little variation among countries in the timing of consumption. Almost all of the variation in timing stems from labor income – whether it is concentrated at younger or older ages.

This finding has important implications for understanding why demographic dividends are larger in some countries than in others. For lower-income countries, labor markets and policies that influence employment and labor productivity over the lifecycle play the key roles in determining the level of the LSR and the timing of labor income. Differences in consumption patterns do not play an important role.

As lower-income countries become richer and become upper-middle or high-income countries, a broader set of issues will surely become more relevant. Labor policies that influence employment and productivity over the entire lifecycle will continue to be important. Policies, e.g., the role of public transfers, which influence consumption over the entire lifecycle will also become critical. In this regard, of particular concern is spending on education for children and health and long-term care for the elderly.

Conclusions

Recent advances in measurement reveal differences in the lifecycle which are large and important for understanding the economic implications of changes in fertility, mortality, and population age structure. Understanding differences in the lifecycle can provide useful guidance to the kinds of policies that might help to achieve a larger demographic dividend or to mitigate adverse effects of population aging. The results presented here are a first step towards this goal. We have derived summary measures of the lifecycle, using a simple conceptual accounting framework to show how these measures can be used to understand the relationship of the lifecycle to standards of living.

Summary measures have been constructed for 34 countries which vary along many development and demographic dimensions. It is clear from these data that the lifecycle varies considerably around the world. The number of lifetime effective years worked is greater, on average, in rich countries than in poor countries, but only because survival rates at working ages are higher in rich countries. Lifetime effective years worked as a percentage of life expectancy is smaller in rich countries than in poor countries. The lifetime support ratio, lifetime effective years worked relative to lifetime effective years of consumption, is much smaller in high-income than in lower-income countries.

There are also differences in the timing of consumption over the lifecycle. The mean age of effective labor supply is unaffected by income level, but the mean age of effective consumption increases very substantially with income. As a result, in lower-income countries the mean age of effective consumption is less than the mean age of effective labor. In high-income countries the opposite is true – individuals are effectively working at a younger age than they are consuming.

The data have then been used in two practical applications. In the first application we show that the labor response to increased life expectancy has been negligible leading to a very substantial decline in the lifetime support ratio as mortality conditions improve. In the second application we show that in upper-middle income and high-income countries, the age patterns of work and consumption both play a very important role in determining the lifecycle situation of a country. But in lower-income countries, only age patterns of work appear to be important.

There are many ways that the research presented here could be improved or extended. One is that all of the estimates are based on cross-sectional data for a single year. Although following a cohort over its entire lifetime is not a realistic option, it is certainly possible to use repeated cross-sections to analyze how consumption and labor income are changing over time. Progress on constructing NTA time series estimates should make this possible in the near future. Using actual rather than real cohort data will certainly affect the results. The variance in labor income profiles has been declining in some countries as young people stay longer in school and older adults retire at a younger age. Changes in the consumption profile are also important in the cases for which we have data. In the United States, for example, spending on health care and long-term care has increased substantially over time. Synthetic cohort measures are also based on current survival rates which for a real cohort are changing over time. It is very important to keep in mind that synthetic cohort measures summarize detailed age profile data for a period.

A second issue is that measures of consumption and labor income are based exclusively on market-based economic flows. Many important flows, such as, familial care for children and the elderly occur outside of the market place. Valuing non-market time and determining who is producing it and who is benefitting from it will provide a much more complete picture of the economic lifecycle.

Appendix A. Appendix Tables

See Tables A.1. and A.2..

Appendix B. Mathematical Appendix

The present value of lifetime effective labor is:

$$\mathrm{PVL} = \int_0^{\omega} e^{(\lambda - r)x} s(x)\phi(x)dx \tag{1.16}$$

Where λ is the rate of growth of labor productivity, r is the discount rate,

$s(x)$ is the probability of surviving from birth to age x, and $\phi(x)$ is the age profile of effective labor (relative to mean labor income of persons 30–49). The maximum possible age is ω. The density of the survival weighted age profile of effective labor, $\delta(x)$, is defined by:

Table A.1.
Expected effective labor and effective consumption, lifetime years and as a percentage of life expectancy; lifetime support ratio; thirty-four countries by income group.

Country	Year	Life expectancy at birth	Effective labor		Effective consumption		Lifetime support ratio
			Years	Percent	Years	Percent	
Lower income							
Cambodia	2009	61.6	35.5	57.6	54.6	88.6	0.65
India	2004	64.2	33.4	51.9	58.5	91.0	0.57
Indonesia	2005	67.9	35.1	51.7	59.6	87.8	0.59
Kenya	1994	55.0	23.1	42.1	49.1	89.3	0.47
Nigeria	2004	50.3	24.3	48.3	42.7	84.8	0.57
Philippines	1999	67.8	35.7	52.6	63.6	93.7	0.56
Vietnam	2008	74.4	33.8	45.5	66.9	89.9	0.51
Upper-middle income							
Argentina	1997	75.4	36.5	48.4	70.3	93.2	0.52
Brazil	2002	72.3	35.0	48.4	65.6	90.7	0.53
Chile	1997	78.7	37.2	47.3	72.9	92.6	0.51
China	2002	72.8	33.4	46.0	71.3	98.0	0.47
Colombia	2008	73.0	35.7	49.0	68.6	93.9	0.52
Costa Rica	2004	79.0	38.4	48.6	75.6	95.7	0.51
Jamaica	2002	72.3	36.5	50.4	64.8	89.6	0.56
Mexico	2004	76.3	37.6	49.3	67.4	88.4	0.56
Peru	2007	73.3	36.7	50.1	68.8	94.0	0.53
South Africa	2005	51.2	21.7	42.3	39.4	77.0	0.55
Thailand	2004	73.6	34.3	46.6	67.8	92.1	0.51
Uruguay	2006	76.4	37.4	48.9	73.3	95.9	0.51
High income							
Australia	2004	81.6	37.9	46.5	78.0	95.6	0.49
Austria	2005	80.4	36.3	45.2	79.7	99.2	0.46
Finland	2004	79.5	35.6	44.8	79.1	99.5	0.45
France	2001	81.1	34.8	42.9	81.3	100.2	0.43
Germany	2003	80.0	35.1	43.9	81.3	101.7	0.43
Hungary	2005	73.7	34.1	46.3	71.9	97.6	0.47
Italy	2008	81.5	37.0	45.4	80.2	98.4	0.46
Japan	2004	82.9	38.7	46.7	92.5	111.6	0.42
Slovenia	2004	78.7	31.2	39.7	82.8	105.2	0.38
South Korea	2000	80.1	36.3	45.3	78.0	97.3	0.47
Spain	2000	80.6	34.9	43.3	78.1	96.9	0.45
Sweden	2003	81.0	39.1	48.3	91.1	112.5	0.43
Taiwan	1998	78.3	34.1	43.6	75.8	96.8	0.45
United Kingdom	2007	79.7	37.2	46.7	77.9	97.8	0.48
United States	2003	78.1	38.5	49.3	79.9	102.4	0.48

Table A.2.
Measures of timing of labor income and consumption over the lifecycle, thirty-four countries by income group.

Country	Year	Mean age of life	Mean age		Variance		Standard deviation	
			Labor income	Consumption	Labor income	Consumption	Labor income	Consumption
Lower income								
Cambodia	2009	35.4	37.6	39.9	173.1	443.4	13.2	21.1
India	2004	36.1	43.5	41.3	167.2	466.0	12.9	21.6
Indonesia	2005	36.3	43.4	38.4	190.2	444.5	13.8	21.1
Kenya	1994	33.8	40.3	37.6	129.4	459.6	11.4	21.4
Nigeria	2004	33.2	46.9	38.6	150.5	436.4	12.3	20.9
Philippines	1999	36.1	43.7	39.5	176.6	466.4	13.3	21.6
Vietnam	2008	39.1	39.0	40.9	134.6	495.7	11.6	22.3
Upper-middle income								
Argentina	1997	39.1	42.3	41.7	158.6	546.5	12.6	23.4
Brazil	2002	38.7	43.5	43.1	175.7	530.2	13.3	23.0
Chile	1997	40.4	43.4	44.4	171.7	559.7	13.1	23.7
China	2002	38.0	41.5	40.5	154.6	502.4	12.4	22.4
Colombia	2008	38.8	43.6	43.4	175.6	532.9	13.3	23.1
Costa Rica	2004	40.6	43.8	45.3	177.6	554.6	13.3	23.5
Jamaica	2002	38.6	42.1	42.3	182.9	513.1	13.5	22.7
Mexico	2004	39.7	43.8	43.0	187.8	515.7	13.7	22.7
Peru	2007	38.9	43.1	43.2	181.1	537.6	13.5	23.2
South Africa	2005	31.1	42.4	36.4	122.5	411.0	11.1	20.3
Thailand	2004	38.6	42.0	41.2	152.1	524.6	12.3	22.9
Uruguay	2006	39.5	44.1	42.7	158.9	555.1	12.6	23.6
High income								
Australia	2004	41.4	41.2	44.7	152.1	583.5	12.3	24.2
Austria	2005	40.8	41.6	44.0	137.4	580.0	11.7	24.1
Finland	2004	40.5	42.7	44.2	132.1	617.1	11.5	24.8
France	2001	41.3	42.5	43.3	120.1	597.3	11.0	24.4
Germany	2003	40.6	42.6	45.7	122.8	581.6	11.1	24.1
Hungary	2005	37.9	42.6	41.7	121.4	529.7	11.0	23.0
Italy	2008	41.3	43.7	44.0	138.4	597.4	11.8	24.4
Japan	2004	42.1	45.2	47.1	145.3	670.6	12.1	25.9
Slovenia	2004	40.0	40.6	41.6	106.6	617.2	10.3	24.8
South Korea	2000	40.7	42.1	41.8	156.5	552.8	12.5	23.5
Spain	2000	40.9	42.8	43.3	129.6	585.4	11.4	24.2
Sweden	2003	41.0	44.0	45.2	145.7	696.8	12.1	26.4
Taiwan	1998	40.1	41.0	41.1	138.5	584.1	11.8	24.2
United Kingdom	2007	40.5	41.4	44.8	149.2	585.6	12.2	24.2
United States	2003	40.2	45.3	46.8	162.0	599.0	12.7	24.5

$$\delta(x) = s(x)\phi(x) / \int_0^{\omega} s(x)\phi(x)dx \tag{1.17}$$

The present value of lifetime effective labor can be rewritten as:

$$\begin{aligned} \text{PVL} &= \int_0^{\omega} s(x)\phi(x)dx \int_0^{\omega} e^{(\lambda-r)x}\delta(x)dx \\ \ln \text{PVL} &= \ln \int_0^{\omega} s(x)\phi(x)dx + \ln \int_0^{\omega} e^{(\lambda-r)x}\delta(x)dx \end{aligned} \tag{1.18}$$

The second term on the right-hand side, known as the cumulant-generating function, can be approximated as a linear combination of moments of the effective labor age distribution.[5] Thus, an approximation of the natural log of the lifetime effective labor is given by:

$$\begin{aligned} \ln \text{PVL} &\simeq \ln \phi_0 - (r-\lambda)\mu_\phi + 0.5(r-\lambda)^2\sigma_\phi^2 \\ \phi_0 &= \int_0^{\omega} s(x)\phi(x)dx \\ \mu_\phi &= \int_0^{\omega} x\delta(x)dx \\ \sigma_\phi^2 &= \int_0^{\omega} x^2\delta(x)dx - \mu_\phi^2 \end{aligned} \tag{1.19}$$

where ϕ_0 is the lifetime effective labor, μ_ϕ is the mean age of effective lifetime labor, and σ_ϕ^2 is the variance (across age) of effective lifetime labor. The natural log of the effective consumer years can be approximated in exactly the same manner.

The accuracy of the approximation will depend on features of the age profile and the magnitudes of higher moments. We have investigated this issue quite extensively and find that that the approximation for the support ratio is very precise even though the approximation is much less reliable for either the effective number of consumer or workers.

[5] See Weisstein, Eric W. "Moment-Generating Function." From *MathWorld*–A Wolfram Web Resource. http://mathworld.wolfram.com/Moment-GeneratingFunction.html.

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