Institute for FUTURES STUDIES

Sevilla, Jaypee

Age structure and productivity growth

Arbetsrapport/Institutet för Framtidsstudier; 2007:10
ISSN: 1652-120X
ISBN: 978-91-85619-12-2

Age structure and productivity growth

Jaypee Sevilla
Department of Population and International Health
Harvard School of Public Health
24 August, 2007

The author wishes to thank Bo Malmberg and the Institute for Future Studies for intellectual and financial support and encouragement.

I. Summary

Bland de mest centrala frågorna i gränsområdet mellan demografi och ekonomi är vilken påverkan storskaliga demografiska processer har på långsiktig ekonomisk utveckling. Den klassiska frågeställningen, som upptagit tänkare från Malthus fram till senare delen av 1900-talet, var om snabb befolkningstillväxt hotade ekonomisk tillväxt. Denna klassiska frågeställning har nu ersatts av mer sofistikerade frågeställningar där fokus på aggregerad befolkningstillväxt har ersatts av fokusering på specifika befolkningsgruppers tillväxt. Disaggregering av befolkningstillväxtens effekter på åldersgrupper har generellt accepterats som en avgörande förbättring jämfört med en klassiska frågeställningen eftersom människors ekonomiska roller och bidrag varierar över ålder: . de unga är nettokonsumenter och mottagare av humankapitalinvesteringar, mogna vuxna är nettoproducenter och sparare, och de gamla är (åtminstone i teorin eller i högre grad än mogna vuxna) nettokonsumenter. Därför blir de ekonomiska konsekvenserna av snabb tillväxt i befolkningsstorleken av de unga och de äldre en potentiell dämpning av tillväxttakten medan en snabb tillväxt i den aktiva vuxenbefolkningen kan stimulera tillväxten.

Den demografiska transitionen medför en trestegsprocess där en baby boom kohort rör sig genom befolkningens ålderspyramid. Denna kohorts livscykel skapar först ett stadium med snabb tillväxt i den unga befolkningen, därefter en period med snabba tillväxt i den aktiva vuxenbefolkningen och avslutas med ett stadium av snabb tillväxt i äldrebefolkningen. Den första och tredje perioden kan betraktas som ekonomiska utmaningar där man måste konfrontera frågan om hur man ska försörja en växande beroende befolkning. Däremot kan vi se det andra stadiet som en demografiska gåva eller avkastning eftersom den snabba tillväxten i aktiv befolkningen kan förstärka tillväxten i ekonomin.

Den traditionella mekanismen för den demografiska avkastningend inkluderar baby boomens ökning av arbetsutbudet, sparandet och humankapitalet. Emellertid tyckks man i forskningen ha förbisett den potentilla påverkan på den teknologiska utvecklingen, vilket är ovanligt eftersom alla standardredogörelser för ekonomisk tillväxt håller före att på lång sikt är teknisk utveckling den enda källan för förbättringar i levnadsstandar. Demografisk påverkan på teknologin kan emellertid mycket väl överskugga betydelen av allting annat.

Det finns tvåkonkurrerande hypoteser beträffande demografiska processer och teknisk utveckling. Den ena menar att snabbt växande vuxenbefolkningar stimulerar den tekniska utvecklingen medan den andra menar att det skulle bromsa teknikutvecklingen. Om vi analyserar makroekonomiska data från ländertvärsnitt under perioden 1970 till 2000 finner vi att baby boom kohorternas inträde i vuxenålder korrelerar med högre arbetsproduktivitet, även om man kontrollerar för kapitalbildning och tidigare produktivitet. Våra resultat stöder uppfattningen att den demografiska avkastningen även omfattar positiva effekter på den tekniska utvecklingen, vilket på lång sikt kan visa sig vara mycket viktigare än några de andra konsekvenserna av den demografiska avkastningen.

I. Summary

Among the most central questions at the intersection of demography and economics is the impact of large scale demographic processes on long-run economic performance. The classical version of this inquiry, occupying thinkers from Malthus towards those from the mid-to-late 20th century, had to do with whether rapid population growth threatened economic growth. This classical inquiry has been superseded by more sophisticated questioning in which the focus on growth rate of the aggregate population has been replaced by focus on the growth rates of age-specific population sub-groups. Disaggregating the effects of population growth by age-group is generally accepted to be a fundamental improvement over classical inquiry because people's economic roles and contributions vary by age: the young are net consumers and beneficiaries of human capital investments, adults are net producers and savers, and the old are (at least in theory or to a greater degree than adults) net consumers. Thus the economic consequences of rapid growth in the population size of the young and the elderly could potentially have a depressing impact on growth, while rapid growth in the population size of adults could stimulate growth.

The demographic transition brings with it a three stage process in which a baby boom cohort moves through the population's age pyramid. The life cycle of this cohort creates a first stage in which there is rapid growth in youth population, then a second stage in which there is rapid growth in the adult population, and finally a third stage in which there is rapid growth in the elderly population. The first and third stages can be thought of as the challenging stages since economies must confront the challenge of providing for large dependent populations. However, the second stage can be thought of as a demographic gift or dividend stage since growth in the productive adult population can potentially boost economic growth.

The traditional mechanisms for the demographic dividend include the impact of the boom cohort on labor supply, savings, and human capital. However, it seems to us that there has been no research on the potential impact of age structure on technological progress, which is unusual since all standard accounts of economic growth hold that in the long run, it is technological progress that is the sole source of improvement in living standards. Demographic impacts on technology could well dwarf the importance of everything else.

There are two competing hypotheses regarding demographic processes and technological progress. One holds that a rapidly growing adult population stimulates technological progress, while the other holds that it retards it. Analyzing cross-country macro data from developing countries for the period 1970 to 2000, we find that entry of the baby boom cohort into the adult stage is correlated with higher labor productivity, even after controlling for capital accumulation and past productivity. Our evidence supports the view that the demographic dividend includes positive impacts on technological progress, which may in the long-run prove more consequential than any other demographic dividend consequences.

II. Introduction

One of the most fundamental questions in the long history of thought in economics is the precise nature of the relationship between populations and development, in particular whether population growth was a threat or a facilitator of economic development. There have been, since the seventeenth century, two schools of thought that have recently been called the “pessimistic” and “optimistic” view.

The pessimistic view is perhaps the more resonant of these two views and received its most famous early statement from Malthus (1798)

“Taking the population of the world at any number, a thousand millions, for instance...the human species would increase in the ratio of 1, 2, 4, 8, 16, 32, 64, 128, 256, 516, etc. and subsistence as 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, etc. In two centuries and a quarter the population would be to the means of subsistence as 512 to 10; in three centuries as 4096 to 13, and in two thousand years the difference would be incalculable.”

Thus progress in food production is always threatened by population pressure. And although agricultural innovations and discoveries of new resources may cause improvements in standards of living, these can only be temporary. Rising prosperity sets in motion more rapid population growth, which drags living standards back to subsistence levels. Malthusian pessimism has persisted through the subsequent two centuries, and lives to this day. Some recent manifestations have been largely alarmist. A famous such example is Ehrlich (1968) which predicted that “The battle...is over. In the 1970s hundreds of millions of people are going to starve to death.”

The later half of the 20^{th} century has proved alarmist versions of pessimism to be wrong. At a global level, these have been periods of rapid population growth AND rapid economic growth. In the past few decades, world per capita incomes have increased by about 2/3rds and the world population has grown by over two billion (Bloom, Canning, and Sevilla 2003). Famines have occurred but Ehrlich’s “hundreds of millions” of people have not starved. Technological progress, in both agriculture and industry, has been more rapid than at any other time in human history. There have been equally dramatic social and institutional innovations, in the ways people work, the standard of their education and health, and the extent to which they participate in the political process. Rather than being constrained by fixed resources, the world sees the prices of raw materials in long-term decline; inflation (for the moment at least) quite low; and some parts of the economy becoming ‘dematerialized’ as the knowledge revolution kicks in.

While alarmist accounts seem largely and appropriately discredited, there remain more sober and carefully reasoned accounts of why large populations and high population growth pose challenges for development. One focuses on the possible effect of population growth in “diluting” a society’s material resources, which have to be spread out over more people. In the canonical Solow (1957) model of economic growth, which remains the foundation of the modern economics profession's view of the relationship between population growth and economic welfare, population growth lowers levels of per capita consumption because productive resources need to be spread out over a larger number of people, lowering each person’s stock of productive resources, and therefore that person’s product and well-being. Another strand focuses on the possible effect of population growth in “diluting” a society’s human capital. Larger population growth invariably occurs through growing numbers of dependent children that jeopardize society's and households' capacities to invest sufficiently in their nutrition, health, and education (Becker and Lewis 1973). In both cases of dilution of physical and human capital, economic growth is threatened, and the likelihood of poverty rises.

However while pessimism has centered around the idea that population "dilutes" either natural resources, physical capital, or human capital, a rival optimist view has focused on the potential positive impact that population growth might have on ideas, innovation, and technology. Optimism has an older and equally venerably lineage as pessimism. As early as 1682, William Petty argued that larger populations meant more innovation

"As for the Arts of Delight and Ornament, they are best promoted by the greatest number of emulators. And it is more likely that one ingenious curious man may rather be found among 4 million than 400 persons....And for the propagation and improvement of useful learning, the same may be said....(1682/1899, p. 474, quoted in Simon, 1981)"

More recently, optimist views have been expressed by Simon Kuznets (1967) and Julian Simon (1981), who argue that population increases serve to augment the stock of human ingenuity, allow economies of scale. Boserup (1981) argues that population growth creates pressures on resources, but thereby stimulate innovations to counteract these pressures. Thus innovation is borne of adversity.

Much empirical research that has tried to investigate the evidence for and against the pessimist and optimist views has found that there seems relatively little compelling evidence for either view (Bloom, Canning, and Sevilla 2003). While there is a raw empirical association between faster economic growth and slower growth in per capita income across countries, this association disappears once we control for country size, openness to trade, educational attainment, and the quality of civil and political institutions. By the mid-1990s, Kelley and Schmidt (1995) describe the evidence as follows:

"Possibly the most influential statistical finding that has shaped the "population debates" in recent decades is the failure, in more than a dozen studies using cross-country data, to unearth a statistically significant association between the growth rates of population and of per capita output."

Thus the data on cross-country experiences with population growth and economic growth provide no strong support for either pessimist or optimist views and has given rise to a third position, which might be called "population neutralism."

There seems to be lack of consistent empirical support for either of the grand but simple narratives relating population and growth. However, these narratives have perhaps been too simple, in that they focus only on the impact of population size and growth, and too little focus on what could be a critical demographic variable, and that is age structure. The most important population dynamics of the 20th century occurred through the demographic transition, which, while having an impact on population growth rates, also have an impact on age structure which have only recently received heightened attention.

The demographic transition consists of two stages: an initial decline in infant and child mortality followed by reductions in fertility. This transition became a distinct feature of populations all over the world, both rich and poor, after World War II. In the developing countries, the mortality reductions were spurred by developments in medicine and public health such as the use of antibiotics like penicillin, treatment for diseases like TB and diarrhea, the use of DDT for malaria control, and improved sanitation, hygiene, and nutrition. While these reduced mortality risks throughout the population, they were especially effective at reducing infant and child mortality.

The combination of falling mortality and steadily increasing fertility over a decade or more contributed to a spurt in population growth rates driven to a great extent by growth in the number of the young. This phenomenon was widely referred to as the population explosion and perceived to be a central obstacle to development. It was also this phenomenon that led to the resurgence of the population pessimism of Ehrlich and others, according to which population growth had a recurrent tendency to outstrip food supplies, and that balance between the two would only be achieved by widespread famine and starvation which brought them back into equilibrium, only to have the cycle repeat perhaps indefinitely.

This pessimistic scenario did not come to pass. Fertility declines from the 1960s onwards took the momentum out of population growth.

The lag between the declines in mortality and fertility created a historically larger than average cohort of children or baby boom: because of increased fertility and survival rates, it was larger than the ones that preceded it, and because of the subsequent fertility decline, it was also larger than the ones that followed. The coming into existence and aging of this cohort produced and continues to produce remarkable changes in the age structure of populations all over the world.

The movement of this cohort through the population age structure is potentially very important. Although the early part of the demographic transition is characterized by higher population growth, this stage lasts only as long as it takes for fertility rates to decline in response to mortality rates. This may last a generation. However the baby boom generation will live for perhaps as much as 70 to 80 years, thus far outliving the population growth that accompanied its creation. The impact of the cohort might therefore far outlast the impact of the population growth from earlier on in the transition.

The baby boom generation confronts the economy with challenges and opportunities corresponding to the different stages of its lifecycle. In its early stages, the economy faces the challenges of a high youth dependency. These include the challenges and expenses of feeding, clothing, housing, and of investing in the health and education of the young. Thus high youth dependency can result in lower human capital expenditures per child. This might occur for the following reasons. First, under some models of fertility determination, fertility may fail to respond optimally to declining mortality rates, making realized fertility higher than desired fertility. In the presence of credit constraints, this causes an unplanned reduction in household resources and human capital expenditures per child. Second, even when fertility is able to respond optimally to declining mortality rates, lower child mortality rates lower the cost of a surviving child. This can cause a substitution effect away from child quality towards child quantity. Third, models of endogenous fertility and human capital choices usually allow for multiple equilibria, one of which is characterized by low fertility and high child quality, and the other by high fertility and low child quality. Which equilibrium occurs depends on history and expectations. The demographic transition causes a general growth in youth dependency that can support the choice of the latter equilibrium.

This higher youth dependency can also reduce savings. The traditional mechanism is given by Coale and Hoover (1958) who hypothesize that higher youth dependency can depress savings and therefore economic growth since households must devote larger shares of household income and resources to children. Savings may also be reduced for a second reason, and that is because children are a source of retirement support. Thus if parents have more children, they may feel less need to save for retirement, and therefore save less. One must balance these, however, against some theoretical reasons whereby having more children might raise savings (Deaton and Paxson 2000): having more children may raise parental needs to save to provide bequests for their children and grandchildren, or to have resources that can be used to ensure good behavior among descendents (sometimes called the “strategic bequest” motive).

Fry and Mason (1982) have also argued that demographic effects on savings can interact with economic growth. Economic growth tends to make younger households wealthier than older households so that the behavior of younger households is more consequential for national aggregates than that of older households. Thus when economic growth is high, the savings behavior of younger households is what matters. If these younger households are saving less because they have more children, then national savings is more likely to fall as well.

However, when the baby boom cohort becomes adult, a second stage occurs in which this cohort can provide a boost to economic development through its impact on labor supply, savings, and human capital. This large working age cohort affects labor supply in two ways.

Firstly, there is an accounting effect. Labor force participation rates are highest during the ages of 15 and 64, so that a larger population share in this age group raises labor supply. Second is a behavioral effect. Since women in this cohort will have lower fertility rates, they will have fewer children and will be more likely to enter the labor force.

This cohort’s effect on savings can likewise be decomposed into an accounting and behavioral effect. Working age adults tend to save a higher proportion of their income than either the youth or the elderly. This is a prediction of both life cycle models of consumption and empirical study of the savings behavior of adults of different ages (Higgins, 1998; Higgins and Williamson, 1997; Kelley and Schmidt, 1996; Lee, Mason, and Miller, 2000; Leff, 1969; Mason, 1988; Webb and Zia, 1990). Thus a larger population share of adults mechanically increases savings. A behavioral response towards increased savings can occur for a few reasons. First, as households decrease in size due to lower fertility, then the traditional Coale and Hoover (1958) hypothesis implies that households can save larger fractions of their income. However, this may be counteracted by increased expenditures per child (Becker and Lewis 1973). Second, since these cohorts experience longer life expectancies, they need to save more to provide for a potentially longer retirement (Metzler 1992). Third, according to the Fry and Mason (1982) mechanism, if economic growth is high, then the increased savings of younger households is a strong driver of increased national savings.

Finally, there are effects on human capital. The baby boom generation has lower fertility, and therefore smaller households, which allows households to invest more intensively in each child, reflecting a movement from a demand for child quantity towards quality (Becker and Lewis 1973).

And when this cohort reaches old age, society is confronted with the need to provide for the health and pension needs of the elderly. The developed countries, whose baby boom generations are retiring, are already facing these challenges.

A final hypothesis—the central research question of this paper--has to do with the possible relationship between age structure and technological progress. While there have been pioneering contributions examining this issue, many of them have focused on the wealthy nations (Cutler, et. al. 1991, Malmberg et. al. 2005, Lindh and Malmberg 1999, Malmberg 1994), with only one studying the situation in developing countries (Kogel 2005). It is possible that while this hypothesis has received relatively less attention from researchers interested in age structure changes, this may be the most important with respect to long term economic development. Standard models of economic growth (see Romer 1996) all argue that sustained long-term growth in standards of living have only one source: productivity growth. If age structure changes have significant effects on productivity, these may in the very long run, outstrip all its other consequences in economic significance. For example, it is often argued that population aging and fertility reductions the world over will soon result in large old-age dependent populations supported by much smaller working age cohorts. This rise in the dependency ratio is often taken to mean that these smaller working cohorts will have to bear the very heavy burden of contributing their own income to provide old-age security. This may be counteracted partially by the fact that labor force participation rates, especially for women, are rising over time, so a given working age population size will, over time, represent more and more active workers on whom elderly populations can depend on for support. But more importantly if, as one hypothesis goes, technological progress is stimulated when labor is scarce, then the technological progress that accompanies the shrinking working age population could more than compensate for the increased dependency burden. Thus the direction in which changes in the size of working-age cohorts affects productivity is a central question.

Cutler, Poterba, Sheiner, and Summers (1991) review the arguments. According to one view, exemplified by Simon (1981) and Wattenberg (1987), large young cohorts increase the supply of creative thinkers and potential innovators. They also constitute a larger market of consumers that allows for—pace Adam Smith—greater division of labor, larger markets for capital goods, and greater opportunities for realizing economies of scale. These views echo the centuries' old view of Petty (1682) and the more recent view of Kuznets (1967) described earlier. The upshot of these arguments is that large adult cohorts will stimulate technological progress. An additional mechanism leverages the traditional demographic dividend hypothesis that adult-rich populations have higher savings rates with traditional endogenous growth model arguments (Romer 1996) whereby higher savings rates reduce interest rates which in turn stimulate investments and R and D expenditures, which in turn raise TFP. Yet another mechanism, suggested by Thomas Lindh in personal communication, might work through a cohort crowding effect whereby labor market congestion among larger young adult cohorts may sway young adults away from the labor market towards more schooling, resulting in a better educated population, which in turn is better able to generate innovation.

According to the opposing view, exemplified by Habakkuk (1962), innovations are more likely to emerge when labor is scarce and innovations are required to relax these constraints. It is when particular segments of the labor market are constrained that innovations are likely to come that save on labor requirements. Thus industrialization occurred faster in the US than in England because the profitability of US agriculture made American labor significantly more expensive than in England, stimulating industrial innovation to economize on its use. Habakkuk's view parallels that of Boserup (1981) who also argues that technological innovation is borne of adversity. The Habakkuk/Boserup view would lead us to suppose that an abundance of productive adults would dampen the stimulus to innovate, so that rapid growth in the adult population would be associated with slower technological progress. Thus we have two hypotheses, the first of which (Simon/Kuznets/Petty) implies that growth in the adult population should stimulate technological progress, and the second (Habakkuk/Boserup) says that it should slow it down.

There has been remarkably little work done on the question of age structure and technological progress. The exceptions to this are Romer (1990) and Cutler, Poterba, Sheiner, and Summers (1990) who both find evidence in the US and in the developed countries suggesting that the relationship is actually negative. That is, the argument put forward by Habakkuk/Boserup seems to be right. Labor productivity tends to grow fastest when adult cohort sizes shrink. In fact, Cutler et. al. find that the productivity growth caused by shrinking working age cohorts in the US is more than sufficient to negate the decline in living standards caused by the old-age dependency burden. If this result generalizes to the developing countries, the alarm with which demographers and economists react to the prospect of population aging and growing elderly dependency ratios is misplaced.

III. Regression specification

We use a modified Cobb-Douglas type production function similar to that used by Hall and Jones (1999):

$$\begin{aligned} &Y = AK^{\alpha}(HL)^{1-\alpha} \\ &0 < \alpha < 1 \\ &H = \exp[\rho E] \end{aligned}$$

where $A, K, L, H, E, \alpha, \rho$ are TFP, capital stock, labor stock, human capital, years of schooling, the Cobb-Douglas parameter and the Mincerian returns to schooling respectively. Dividing by L gives

$$\left(\frac{Y}{L}\right) = A\left(\frac{K}{L}\right)^{\alpha}(\exp[\rho E])^{1-\alpha}$$

We do not have data on capital stocks, but can re-express the production function in terms of investment flows by taking the usual dynamic equation for capital

$$\frac{dK}{dt} = I - \delta K$$

and assuming that depreciation is δ, and that in the long-run, the growth rate of the capital stock is given by *g*. This gives us

$$\frac{dK}{dt} = gK$$
$$I = (g + \delta)K$$
$$K = \frac{I}{(g + \delta)}$$

Plugging this steady state approximation into the capital per worker ratio gives

$$\frac{K}{L} = \frac{1}{(g + \delta)} \frac{I}{L}$$

and substituting this expression into the production function gives

$$\left(\frac{Y}{L}\right) = A\left(\frac{1}{g + \delta} \frac{I}{L}\right)^{\alpha} (\exp[\rho E])^{1-\alpha}$$

Taking logs and letting lower case letters refer to logs of variables per worker gives us

$$y = \ln A + \alpha\left(\ln \frac{1}{g + \delta} + i\right) + (1 - \alpha)\rho E$$

Allowing for country and period fixed effects and an error term gives

$$y_{ct} = \ln A_{ct} + \alpha i_{ct} + (1 - \alpha)\rho E_{ct} + \mu_c + v_t + \varepsilon_{ct}$$

where the $\ln\left(\frac{1}{g + \delta}\right)$ term is subsumed in the country fixed effect, countries are indexed by *c* and periods by *t*. Differencing out this fixed effect gives

$$y_{ct} - y_{ct-1} = \ln A_{ct} - \ln A_{ct-1} + \alpha(i_{ct} - i_{ct-1}) + (1 - \alpha)\rho(E_{ct} - E_{ct-1}) + (v_t - v_{t-1}) + (\varepsilon_{ct} - \varepsilon_{ct-1})$$

To model changes in TFP, we make the ad hoc assumption that:

$$\ln A_{ct} - \ln A_{ct-1} = \beta_0 \ln A_{ct-1} + \beta_1 (as_{ct} - as_{ct-1})$$
$$\ln A_{ct} - \ln A_{ct-1} = \beta_0 y_{ct-1} + \beta_1 (as_{ct} - as_{ct-1})$$

where the first equation allows changes in TFP to be a function of initial TFP and change in the age structure (which is the regression specification used by Kogel 2005), while the second equation follows simply by using y_{t-1} as a proxy for $\ln A_{t-1}$. Substituting the second equation into the difference equation gives:

$$y_{ct} - y_{ct-1} = \beta_0 y_{ct-1} + \beta_1 (as_{ct} - as_{ct-1}) + \alpha (i_{ct} - i_{ct-1}) + (1-\alpha)\rho (E_{ct} - E) + (v_t - v_{t-1}) + (\varepsilon_{ct} - \varepsilon_{ct-1})$$

Thus we can regress changes in log labor force productivity on lagged log productivity, change in age structure, change in logged investment per worker, and a constant representing the differenced period effect. A test of the reasonableness of the specification is the value of the parameter α which should equal the coefficient of capital in the Cobb-Douglas production function, usually thought to be around 1/3. This specification is similar to that used by Cutler et. al. (1990) (specifically their equation 18) with the exception that we use the change in logged investment per worker in our specification while they use the average investment rate I/Y over the period *t-1* to *t*.

Theory does not give us strong guidance as to the theoretically appropriate measure of age structure and so we use four different measures of age structure: population median age, the working-age share of the population, the size of the workforce, the size of the working-age population (aged 15-64).

IV. Data and analysis

We construct a panel dataset of economic and demographic variables observed for the developing countries during the period 1970 to 2000. We limit ourselves to the 66 developing countries with national populations of at least 1 million people in the year 2000 and complete data on the variables for the years 1970 to 2000. These countries are listed in Appendix 1. Our sources of data are the Penn World Tables version 6.2 (Heston, Summers, and Aten 2006) from which we obtain measures of output per worker (*rgdpwok*), investment per worker (which equals the product of the investment share of output variable *ki* multiplied by the output per worker variable *rgdpwok*), and the working population (which equals the population variable *pop* multiplied by the per capita output variable *rgdpch* divided by the output per worker variable *rgdpwok*), the World Population Prospects 2006 Revision dataset (United Nations Population Division 2006) from which we obtain population median ages and the proportion of the population of adult age, and the Cohen and Soto (2001) data on educational attainment from which we obtain the variable *ty1564* which measures total years of schooling among the population aged 15 to 64.

Our regression specification requires data from two time periods *t* and *t-1*, which we take to be the years 2000 and 1970 respectively. We do not use periods prior to 1970 because of the higher frequency of missing data for these periods. Summary statistics of the data are in Table 1, below:

Table 1. Summary statistics

Variable	Year	Obs	Mean	Std.Dev.	Min	Max
Output/worker	1970	66	8447	7225	922	26861
Output/worker	2000	66	11501	10492	1328	58750
Inv/worker	1970	66	131475	173110	2308	1017744
Inv/worker	2000	66	180352	327697	5063	2364501
Years school	1970	66	3.1	2.0	0.1	7.5
Years school	2000	66	5.9	2.6	1.0	12.3
Median age	1970	66	18.4	2.9	15.4	30.9
Median age	2000	66	21.9	5.0	15.2	34.7
WorkPop (000)	1970	66	15647	59201	252	423000
WorkPop (000)	2000	66	30460	106281	502	755338
Adult share	1970	66	0.53	0.04	0.47	0.65
Adult share	2000	66	0.58	0.06	0.48	0.72
AdultPop(000)	1970	66	19305	67693	318	464831
AdultPop(000)	2000	66	39539	130357	665	866450

Regressions results are contained in table 2. Each of the four columns uses a different age structure variable. The first column uses the median age, the second uses the adult share of the population, the third uses the working population, and the fourth uses the working-age population. Note that the age structure variable is statistically significant at the 1% level when the median age or adult population share is used. It is significant at the 5% when the working population is used, and significant at the 10% level when the adult population is used. Note also that the coefficient on the investment per worker variable is everywhere a little below 0.3, which is the level one would expect from a Cobb-Douglas production function.

Table 2.Regression results for Specification 1. Dependent variable is $y_{2000} - y_{1970}$

Dependent variable is $y_{2000} - y_{1970}$

	(1)	(2)	(3)	(4)
constant	1.796 (0.379)***	1.709 (0.4212)***	0.745 (0.387)*	0.777 (0.388)**
y_{1970}	-0.225 (0.046)***	-0.214 (0.051)***	-0.105 (0.048)**	-0.110 (0.048)**
$i_{2000} - i_{1970}$	0.224 (0.048)***	0.256 (0.050)***	0.268 (0.050)***	0.271 (0.051)***
$E_{2000} - E_{1970}$	0.075 (0.040)*	0.080 (0.044)*	0.134 (0.041)***	0.136 (0.041)***
$as^1{}_{2000} - as^1{}_{1970}$	0.054 (0.012)***			
$as^2{}_{2000} - as^2{}_{1970}$		3.040 (0.947)***		
$as^3{}_{2000} - as^3{}_{1970}$			2.60e-06 (9.29e-07)***	
$as^4{}_{2000} - as^4{}_{1970}$				1.83e-06 (6.97e-07)**
observations	66	66	66	66
Elasticity	20	32	0.6	0.5

Legend:

y is output per worker

i is investment per worker

E is years of schooling

as^1 is median age

as^2 is the adult share of the population

as^3 is the working population

as^4 is the working-age population

The last row of this table, labeled elasticity, shows the percentage change in the annual growth rate of labor productivity per percentage change in the age structure variable in the year 2000. It is readily seen that the elasticities of labor productivity with respect to median age and the adult share of the population are very large, while the “scale effects” of the size of the working population and working-age population are rather more modest. The results all broadly support the view that the entry of the baby boom cohort into the adult years has a positive impact on productivity. All of the age structure coefficients are positive, and the vast majority of them are statistically significant. This implies that none of our regressions support the finding of Cutler et. al. (1990) or the theoretical arguments of Habbakuk (1962) that scarcity of working age adults provokes technological innovation. Rather, our results support the general tenor of demographic dividend type arguments, which argue that emergence into adulthood of the baby boom cohort tend to have economic effects that are conducive to growth (Bloom, Canning, and Sevilla 2003). The results support the views of Simon (1981) and Wattenburg (1987) that larger adult cohorts are more productive ones.

V. Discussion

We find evidence of a correlation between the demographic dividend stage of the demographic transition with productivity. This suggests that further research on the technological consequences of demographic change would be fruitful. This new avenue of research could be especially useful since the empirical evidence for the impact of the demographic transition on macroeconomic variables, which mostly focuses on the relationship between age structure and savings, remains mixed. Some argue that age structure effects on savings are large: Leff (1969) found that the log of gross savings rates was inversely associated with population shares under 15 and older than 64, controlling for log per capita income and its growth over the previous five years. Bloom and Canning (1999) calculate that the demographic dividend accounts for about 1/3 of the rapid per capita income growth experienced by East Asia. Mason (2001) calculates that up to one-fourth of this growth is due to demography. Lee, Mason, and Miller (2001) perform simulations that imply that demography caused about half of a 20 percentage point increase in East Asian savings.

However, not everyone finds the evidence so compelling. For example, Schultz (2004) argues that a careful re-estimation of data from East Asia show that the association between age structure and savings is only one fourth that reported in Higgins and Williamson (1997), that careful specification eliminates any dependence of savings on age structure. Thus while the empirical work regarding age structure impacts on savings remains ambiguous, empirical work that tests the other two traditional mechanisms, the impact of age structure on human capital accumulation and labor supply, remains to our knowledge, non-existent.

Thus it remains credible to argue, as Schultz (2004) does, that the empirical case for a positive impact of the adult rich stage of the demographic transition remains to be made. It is our hope that our results stimulate interest in yet another mechanism whereby demographic change can have long-term beneficial consequences for economic well-being, through stimulating technological progress.

VI. References

Becker, G. and Lewis, H. 1973. On the interaction between quantity and quality of children. Journal of Political Economy 81:S279-88.

Bloom, D., and Canning, D. 1999. The health and wealth of nations. Science 287: 1207-9.

Bloom, D., Canning, D., and Sevilla, J. 2003. The demographic dividend: a new perspective on the economic consequences of population change. RAND: Santa Monica.

Boserup, E. 1981. Population and Technological Change: A Study of Long-Term Trends, Chicago: University of Chicago Press,

Coale, A., and Hoover, E. 1958. Population growth and economic development in low income countries: a case study of India’s Prospects. Princeton: Princeton University Press.

Cohen, D. and Soto, M. 2001. Growth and human capital: good data, good results. OECD Development Center Technical Paper 179.

Cutler, D., J. Poterba, L. Sheiner, and L. Summers. 1990. "An Aging Society: Opportunity or Challenge?" Brookings Papers on Economic Activity 1: 1-73.

Deaton, A., and Paxson, C. 2000. Growth, demographic structure, and national savings in Taiwan. in Chu and Lee (eds). Population and economic change in East Asia, supplement to Population and Development Review 26:141-73.

Easterlin, R. 1978. What will 1984 be like? Socioeconomic implications of recent twists in age structure. Demography 15(4): 397-432.

Ehrlich, P. 1968. The population bomb. New York: Ballantine.

Fry, M., and Mason, A. 1982. The variable rate-of-growth effect in the life-cycle saving model. Economic Inquiry, **20**, 426–441.

Gottschalk, P. 2001. What can we learn from the cohort size literature about the future demand for the graying baby boomers? Talk prepared for a Roundtable on the Demand for Older Workers Sponsored by the Retirement Research Consortium, The Brookings Institution.

Habakkuk, H. 1962. American and British technology in the Nineteenth Century. Cambridge University Press.

Hall, Robert E. and Charles I. Jones. 1999. “Why Do Some Countries Produce So Much More Output per Worker than Others?” Quarterly Journal of Economics 114:1, February, 1999, 83-116.

Heston, A., Summers, R., and Aten, B. 2006. Penn World Table version 6.2. Center for International Comparisions of Production, Income and Prices at the University of Pennsylvania.

Higgins, M. 1998. Demography, National Savings, and International Capital Flows. International Economic Review, Vol. 39, pp. 343–369.

Higgins, M., and Williamson, J. 1997. Age Dynamics in Asia and Dependence of Foreign Capital. Population and Development Review,Vol. 23, 1997, pp. 261–293.

International Labour Office. 1997. Economically Active Population, 1950-2010. Geneva.

Kelley, Allen C., and Robert M. Schmidt. 1995. “Aggregate Population and Economic Growth Correlations: The Role of the Components of Demographic Change.” Demography 32(4):543–55.

Kelley, A. and Schmidt, R. 1996. Savings, Dependency, and Development. Journal of Population Economics, Vol. 9, 1996, pp. 365–386.

Kogel, T. 2005. Youth dependency and total factor productivity. Journal of Development Economics 76: 147-73.

Kuznets, S. 1967. Population and economic growth. Proceedings of the American Philosophical Society, Vol. 111, 1967, pp. 170–193.

Lee, R., Mason, A. and Miller, T. 2000. Life Cycle Saving and Demographic Transition: The Case of Taiwan. Population and Development Review, Vol. 26 (Suppl.), pp. 194–222.

Lee, R., A. Mason, and T. Miller, 2001. . in Birdsall, Kelley, and Sindig (eds).

Leff, N. D. 1969. Dependency Rates and Savings Rates," American EconomicReview, Vol. 59, pp. 886–896.

Lindh, T. and Malmberg, B. 1999. Age structure effects and growth in the OECD, 1950-1990. Journal of Population Economics 12: 431-49.

Malmberg, B. 1994. Age structure effects on economic growth—Swedish Experience. Scandinavian Economic History Review 42: 279-95.

Malmberg, B., Lindh, T., and Halvarsson, M. 2005. Productivity consequences of workforce ageing—Stagnation or Horndal effect? Forthcoming in Population and Development Review.

Mason, A. 1998. "Saving, Economic Growth, and Demographic Change," Population and Development Review, 14 (1): 113–144.

Mason, A. 2001. Population and economic growth in East Asia. in Andrew Mason (ed) Population and economic growth in East Asia: challenges met, opportunities seized. Stanford, CA: Stanford University Press, pp. 1-30.

Romer, P. 1996. Advanced Macroeconomics. McGraw-Hill.

Schultz, T. 2004. Demographic determinants of savings: estimating and interpreting the aggregate association in Asia.

Simon, J. 1981. The ultimate resource. New Jersey: Princeton University Press.

Solow, R. 1956. A contribution to the theory of economic growth. Quarterly Journal of Economics 70 (1): 65-94.

United Nations. 1998. Demographic Indicators 1950-2050. New York.

United Nations Population Division. 2006. World Population Prospects 2006 Revision.

Wattenberg, B. 1987. The birth dearth. New York: Pharos Books.

Webb, S., and Zia, H. 1990. Lower Birth Rates = Higher Savings in LDCs. Finance and Development, Vol. 27, pp. 12–14.

Appendix 1. Countries in sample (n=66)

Algeria	Haiti	Paraguay
Argentina	Honduras	Peru
Benin	India	Philippines
Bolivia	Indonesia	Rep. of Korea (S. Kor.)
Brazil	Iran	Romania
Burkina Faso	Iraq	Senegal
Burundi	Ivory Coast	Sierra Leone
Cameroon	Jamaica	Singapore
Central African Republic	Jordan	South Africa
Chile	Kenya	Sudan
China	Madagascar	Syrian Arab Republic
Colombia	Malawi	Thailand
Costa Rica	Malaysia	Trinidad and Tobago
Cuba	Mali	Tunisia
Dominican Republic	Mauritius	Turkey
Ecuador	Mexico	Uganda
Egypt	Morocco	United Rep. of Tanzania
El Salvador	Mozambique	Uruguay
Ethiopia	Nepal	Venezuela
Gabon	Nicaragua	Zambia
Ghana	Niger	Zimbabwe
Guatemala	Nigeria	
	Panama	

Former Working Papers:

- **Arbetsrapport/Institutet för Framtidsstudier; 2000:1- 2005:5,** se www.framtidsstudier.se.

- **Arbetsrapport/Institutet för Framtidsstudier; 2005:7**
  Bäckman, Olof, *Welfare States, Social Structure and the Dynamics of Poverty Rates. A comparative study of 16 countries, 1980-2000.*
- **Arbetsrapport/Institutet för Framtidsstudier; 2005:8**
  Nilsson, Anders & Felipe Estrada, *Den ojämlika utsattheten. Utsatthet för brott bland fattiga och rika 1984-2001.*
- **Arbetsrapport/Institutet för Framtidsstudier; 2005:9**
  Esser, Ingrid, *Continued Work or Retirement? Preferred Exit-age in Western European countries?*
- **Arbetsrapport/Institutet för Framtidsstudier; 2005:10**
  Abramsson, Marianne, *Befolkningsfrågan i press och politik, 1994-2004.*
- **Arbetsrapport/Institutet för Framtidsstudier; 2005:11**
  Duvander, Ann-Zofie, Ferrarini, Tommy & Sara Thalberg, *Swedish parental leave and gender equality. Achievements and reform challenges in a European perspective.*
- **Arbetsrapport/Institutet för Framtidsstudier; 2005:12**
  Jans, Ann-Christin, *Family relations, children and interregional mobility, 1970 to 2000.*
- **Arbetsrapport/Institutet för Framtidsstudier; 2005:13**
  Ström, Sara, *Childbearing and psycho-social work life conditions in Sweden 1991-2000.*
- **Arbetsrapport/Institutet för Framtidsstudier; 2005:14**
  Lundberg, Urban, *A Leap in the Dark. From a Large Actor to a Large Approach: The Joint Committee of the Nordic Social Democratic Labour Movement and the Crisis of the Nordic Model.*
- **Arbetsrapport/Institutet för Framtidsstudier; 2005:15**
  Lindh, Thomas, Malmberg, Bo & Joakim Palme, *Generations at War or Sustainable Social Policy in Aging Societies?*
- **Arbetsrapport/Institutet för Framtidsstudier; 2005:16**
  Gentile, Michael, *Population Geography Perspectives on the Central Asian Republics.*
- **Arbetsrapport/Institutet för Framtidsstudier; 2005:17**
  Malmberg, Bo, Lindh, Thomas & Max Halvarsson, *Productivity consequences of workforce ageing - Stagnation or a Horndal effect?*
- **Arbetsrapport/Institutet för Framtidsstudier; 2005:18**
  Olofsson, Jonas, *Stability or change in the Swedish Labour Market Regime?*
- **Arbetsrapport/Institutet för Framtidsstudier; 2005:19**
  Hong, Ying & Diana Corman, *Women´s Return to Work after First Birth in Sweden during 1980-2000.*
- **Arbetsrapport/Institutet för Framtidsstudier; 2005:20**
  Lindh, Thomas & Bo Malmberg, *Demography and housing demand – What can we learn from residential construction data?*
- **Arbetsrapport/Institutet för Framtidsstudier; 2005:21**
  Amcoff, Jan, *Rural Population Growth in Sweden in the 1990s: Unexpected Reality of Spatial-Statistical Chimera*
- **Arbetsrapport/Institutet för Framtidsstudier; 2006:1**
  Alm, Susanne, *Drivkrafter bakom klassresan –kvantitativa data i fallstudiebelysning*
- **Arbetsrapport/Institutet för Framtidsstudier; 2006:2**
  Duvander, Ann-Zofie, *När är det dags för dagis? En studie om vid vilken ålder barn börjar förskola och föräldrars åsikt om detta*
- **Arbetsrapport/Institutet för Framtidsstudier; 2006:3**
  Johansson, Mats, *Inkomst och ojämlikhet i Sverige 1951-2002*
- **Arbetsrapport/Institutet för Framtidsstudier; 2006:4**
  Malmberg, Bo & Eva Andersson, *Health as a factor in regional economic development*
- **Arbetsrapport/Institutet för Framtidsstudier; 2006:5**
  Estrada, Felipe & Anders Nilsson, *Segregation och utsatthet för egendomsbrott. - Betydelsen av bostadsområdets resurser och individuella riskfaktorer*

- **Arbetsrapport/Institutet för Framtidsstudier; 2006:6**
  Amcoff, Jan & Erik Westholm, *Understanding rural change – demography as a key to the future*
- **Arbetsrapport/Institutet för Framtidsstudier; 2006:7**
  Lundqvist, Torbjörn, *The Sustainable Society in Swedish Politics – Renewal and Continuity*
- **Arbetsrapport/Institutet för Framtidsstudier; 2006:8**
  Lundqvist, Torbjörn, *Competition Policy and the Swedish Model*.
- **Arbetsrapport/Institutet för Framtidsstudier; 2006:9**
  de la Croix, David, Lindh, Thomas & Bo Malmberg, *Growth and Longevity from the Industrial Revolution to the Future of an Aging Society*.
- **Arbetsrapport/Institutet för Framtidsstudier; 2006:10**
  Kangas, Olli, Lundberg, Urban & Niels Ploug, *Three routes to a pension reform. Politics and institutions in reforming pensions in Denmark, Finland and Sweden.*
- **Arbetsrapport/Institutet för Framtidsstudier; 2006:11**
  Korpi, Martin, *Does Size of Local Labour Markets Affect Wage Inequality? A Rank-size Rule of Income Distribution*
- **Arbetsrapport/Institutet för Framtidsstudier; 2006:12**
  Lindbom, Anders, *The Swedish Conservative Party and the Welfare State. Institutional Change and Adapting Preferences.*
- **Arbetsrapport/Institutet för Framtidsstudier; 2006:13**
  Enström Öst, Cecilia, *Bostadsbidrag och trångboddhet. Har 1997 års bostadsbidragsreform förbättrat bostadssituationen för barnen?*
- **Arbetsrapport/Institutet för Framtidsstudier; 2007:1**
  Nahum, Ruth-Aïda, *Child Health and Family Income. Physical and Psychosocial Health.*
- **Arbetsrapport/Institutet för Framtidsstudier; 2007:2**
  Nahum, Ruth-Aïda, *Labour Supply Response to Spousal Sickness Absence.*
- **Arbetsrapport/Institutet för Framtidsstudier; 2007:3**
  Brännström, Lars, *Making their mark. Disentangling the Effects of Neighbourhood and School Environments on Educational Achievement.*
- **Arbetsrapport/Institutet för Framtidsstudier; 2007:4**
  Lindh, Thomas & Urban Lundberg, *Predicaments in the futures of aging democracies.*
- **Arbetsrapport/Institutet för Framtidsstudier; 2007:5**
  Ryan, Paul, *Has the youth labour market deteriorated in recent decades? Evidence from developed countries.*
- **Arbetsrapport/Institutet för Framtidsstudier; 2007:6**
  Baroni, Elisa, *Pension Systems and Pension Reform in an Aging Society. An Introduction to the Debate.*
- **Arbetsrapport/Institutet för Framtidsstudier; 2007:7**
  Amcoff, Jan, *Regionförstoring – idé, mätproblem och framtidsutsikter*
- **Arbetsrapport/Institutet för Framtidsstudier; 2007:8**
  Johansson, Mats & Katarina Katz, *Wage differences between women and men in Sweden – the impact of skill mismatch*
- **Arbetsrapport/Institutet för Framtidsstudier; 2007:9**
  Alm, Susanne, *Det effektiva samhället eller det goda livet? Svenska framtidsstudier om arbetsliv och fritid från 1970- till 1990-tal.*

ISSN: 1652-120X
ISBN: 978-91-85619-12-2