

**Economic Development and the Demographic Transition: The  
Role of Cumulative Causality**

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## **Abstract**

The links between demographic change and economic growth are viewed as an interacting system with feedback in both directions. This framework implies that even relatively small exogenous shocks can ultimately have a powerful effect on income if the endogenous linkages between population structure, capital accumulation, and income are sufficiently strong. For example, public health measures that increase life expectancy can lead to an increase in saving and education rates, thereby setting off economic growth. Rising incomes can lead to a reduction in fertility that may trigger a virtuous spiral of falling dependency ratios, greater investment in education, and further economic growth. This virtuous spiral, linking increasing life expectancy, rising incomes, and falling fertility, must eventually come to an end. But it can, in the interim, account for long periods of sustained improvement in living standards in developing countries, especially in the presence of a policy environment that is favorable to enjoying a 'demographic gift'.

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## 1. Introduction

In recent years, studies of economic growth have underemphasized the impact of population issues. Giving demographic variables a prominent place in a framework that treats economic and social development as a complex system considerably strengthens our understanding of economic growth.

There is now strong evidence that demographic change has a major impact on the course of economic growth. Rising life expectancy tends to increase savings and education rates, boosting investment in physical and human capital. However, the mortality decline is not spread evenly across the population. Initially, it is concentrated among infants and young children, creating a ‘baby boom’. Subsequently, fertility rates fall through increased use of contraception, creating a large cohort of young people that steadily works its way through the age distribution.

When this cohort enters the labor force, it produces a period of 40–50 years in which there is a relatively high ratio of workers to dependents, thus creating a potential boost to income per capita. Eventually, this effect disappears as the cohort ages, but it can have a notable significance while it lasts. In 1965–1990, for instance, the working-age population of East Asia grew nearly ten times faster than the dependent population, a substantial factor in creating the East Asian ‘miracle’.

However, the equally strong evidence that fertility and mortality rates follow income levels must also be considered. In other words, causality runs in both directions, from the economy to demography, and from demography to the economy. The interaction is a dynamic process, with each side affecting the other.

History relates that the relationship between demography and economic growth is not necessarily constant over time. For example, the negative impact of income levels on fertility has become stronger between 1870 and 1988. This suggests that developments in contraceptive technology do not reduce fertility directly, but allow women to achieve lower fertility more easily, as incomes rise and desired fertility falls.

Equally, the effect of economic growth on mortality rates appears to have weakened. Mortality rates still do fall with income, but they have also fallen throughout the world regardless of

income. It has been argued that recent falls in mortality are due mainly to health care technology, with economic growth a somewhat less important factor.

The Malthusian model saw population pressure as having an essentially dampening effect on economic growth. However, changes in health technology and contraception have made it easier for population change to have a positive exogenous effect on economic growth, noticeable during the baby-boom cohort's working lives when the ratio of workers to total population is high. Once growth is under way, an endogenous multiplier effect may develop, with positive feedback between economic growth and demographic change. This can allow substantial gains to be achieved in a short period, with an economy switching rapidly from an undeveloped to a developed state.

Historically, the demographic transition in Europe took around 200 years. Steady improvements in health were matched by slowly rising living standards and falling fertility. The same process in East Asia spans around 50 years from the end of the Second World War to the present time. The economic 'miracle' in East Asia can be understood only when viewed in association with its rapid fertility decline. These two processes went hand in hand.

Conversely, there is the possibility of being held down by a poverty trap, in which high mortality rates and high fertility keep incomes persistently low. Sub-Saharan Africa has recorded impressive increases in life expectancy over the past 50 years, though from a very low base, and it still lags behind developing countries in other regions. While life expectancy has improved, fertility remains high and incomes stagnate. As long as income levels and female education remain so limited in Africa, it is hard to see fertility falling; the problem is high desired levels of fertility, not a lack of contraception. The high fertility, on the other hand, creates a very high youth-dependency rate, giving low levels of workers per capita, low savings rates, and low school enrolment rates.

The view presented here is that economic growth is a system with many different entry points. Technological advance, demographic change, or capital accumulation can all give economic growth an important initial impetus. Western Europe, for instance, provides an example where income growth triggered a demographic transition. In East Asia, however, it seems that advances in public health may have triggered a demographic shift that, in turn, generated the dramatic economic growth of the latter half of the 20th century.

Section 2 begins with an overview of the traditional role demography has played in studies of economic growth. In section 3, we lay out and explore the ‘new demography’ which suggests that demographic variables may be much more important than traditionally has been found. Section 4 discusses the size, speed, and causes of the demographic transition in developing countries. In section 5, we examine the feedback between demographic change and economic development, and the issues of cumulative causality and poverty traps. In section 6, we discuss the policy implications of our analysis.

## 2. The Role of Population in Economic Growth

Approaches to understanding economic growth have varied widely, dating back at least as far as Adam Smith. For many years population pressure was seen as a key, if not *the* key, force determining income levels. Thomas Malthus (1798) conjectured that population growth, if unchecked, would be geometric, due to our inability to limit the number of our offspring. In a world with fixed resources for growing food, and slow (arithmetic) technical progress, food production would quickly be swamped by population pressure. The available diet would then fall below the subsistence level, until population growth was halted by a high death rate.

This model implies that income growth cannot be sustainably achieved. While technological advances, or the discovery of new resources, will increase per capita income temporarily, this will trigger rapid population growth, forcing income levels back down to subsistence levels. This bleak outlook led economics to be labeled ‘the dismal science’.

For many years this view seemed a reasonably good description of how the world actually worked. The introduction of high-yielding technologies in agriculture, such as irrigation in China, and of ‘new’ crops, such as the potato in Ireland, accompanied vast increases in population, with little or no increase in living standards. Up to 1700, income gaps between countries were fairly small, and even by 1820 the ‘advanced’ European countries enjoyed real income levels only about double those found in Africa, Asia and Latin America (Maddison 1995).

The phenomenal sustained economic growth of many countries over the past three centuries cannot be explained by the Malthusian model. We now live in a world where growth in living standards is so commonplace as to be the norm. In the industrialized countries, population pressure is not seen as a barrier to growth; indeed the opposite is true, the threat is seen as the problem of a low birth rate and too few workers relative to the number of retirees.

If the Malthusian trap is not operating at present in developed countries, the situation is less clear in the developing world, where some argue that increases in population density will depress income per capita in the long run. In addition, population pressure and economic growth may lead to the depletion of natural resources, creating environmental pressures that act to increase poverty. This ‘population pessimist’ school of thought continues to uphold the Malthusian

premise that population increases reduce economic well being (Coale and Hoover 1958; Ehrlich 1968).

An alternative view is that a higher level of population actually increases income per capita. The pressure of increasing population may inspire the invention or adoption of more efficient technologies (Boserup 1981; Simon 1981). Increasing returns to scale, and increases in the stock of scientific knowledge with a growing number of geniuses (assumed to be a constant proportion of the population), are two other mechanisms through which increases in the size of the population may have a beneficial effect on incomes (Kuznets 1967; Simon 1981).

A middle ground, which has come to be known as ‘population neutralism’, asserts that population growth rates do not matter. This theory arises from the neoclassical growth model (Solow 1957), which attempts to explain the historically unprecedented economic growth seen since the industrial revolution. The key assumptions in the simple Solow model are that population behavior is determined outside the model, and that all factors of production are reproducible. It follows that technological progress and savings can raise income levels in the long run, as any increase in income generated has no feedback into population growth. The absence of a fixed factor means that the level of population has no effect – countries with higher populations simply need to accumulate more capital.

The Solow model shifts the focus away from population size and concentrates instead on the rate at which the population is growing. Population growth *does* depress income levels, as existing capital is shared among a greater number of workers. However, this effect is only temporary: as the population stabilizes, capital adjusts to the new population level.

These effects have been examined empirically in dozens of studies over the past half century (Bloom and Freeman 1986; Coale 1986; Kelley 1988, 1995). Some of these studies focus simply on cross-country and time-series correlations between population growth and economic growth. Others use multiple regression analysis to estimate the correlation between these variables, holding constant the effects of other factors that might influence economic growth. Although the empirical specifications vary quite widely, most of the studies done over the past 15 years report a similar finding: that population growth has a small and statistically insignificant effect on the rate of economic growth.

This empirical result has had a considerable influence on policy-makers in developing countries and on the international development community. It has also helped steer the modern literature on economic development away from serious consideration of demographic factors as a major factor in economic growth. We believe that it is now time to challenge population neutralism and to create a more carefully nuanced theory. This theory relies on moving beyond the growth of the population as a whole, and placing an increased emphasis on the age structure of the population.

### 3. The New Demography and Economic Growth

The importance of the age structure of a population can be seen in various ways. Perhaps the simplest is to consider separately the effects of fertility and mortality on economic growth, and then to compare these with the effect of population growth as a whole. The population growth rate is equal to the crude birth rate minus the crude death rate, plus net immigration. In what follows we ignore the effect of international migration; while migration is important in a small number of countries, for most countries it is not a significant factor.

Bloom and Freeman (1988), Barlow (1994), Brander and Dowrick (1994), and Kelley and Schmidt (1995) find that while the overall population growth rate has little effect, the birth rate and death rate entered separately into growth regressions do have effects on economic growth. Countries with low death rates and low birth rates tend to do well in terms of economic growth, while those with high death rates and high birth rates do badly. However, both types of countries could have similar population growth, so emphasizing this as a factor could mask important changes. It is also quite possible that population growth arising from increases in the birth rate may have a quite different effect on the economy than that arising from decreases in the death rate.

In practice, theorists tend to treat birth and death rates separately when they are thinking about population pressure. Most focus on reductions in fertility as the way to decrease population growth, with few arguing that the answer is to raise the death rate. However, during the Irish famine of 1845–1850 economists did advise against famine relief on Malthusian grounds. They argued that famine relief would simply prolong the agony, as deaths were needed in order to allow survivors' incomes to rise to subsistence levels. Even in the Solow model, a high death rate has the same beneficial influence on income as a low fertility rate. Jonathan Swift (1729) satirized these views a century before the Irish famine, proposing that infants should be eaten at 1 year old, relieving population pressures, increasing the ratio of working-age people, and providing a valuable resource for the population.

There is some evidence to support the view that high death rates lead to an income boost. Herlihy (1997) and Hirshleifer (1987) argue that the plague of 1348–1350 in Europe reduced the

population by over 25 per cent, but caused an improvement in living standards due to a relative increase of resources, particularly land. However, it should be equally obvious that this view does not hold true in current circumstances. There are few people arguing that the AIDS crisis now facing many developing countries will lead to a rise in living standards (Bloom and Mahal 1997).

The basis of Malthusian pessimism has proved weak on two grounds. We have the emergence of low birth rates, and also exponential (rather than arithmetic) growth in productivity through technical progress. The fundamental structure of production has changed: technological progress has led to an emphasis on industry and services, reducing the importance of agriculture. Traditionally, it is in agriculture that the problem of fixed resources looms largest, though even here the 'Green Revolution' led to substantial improvements in productivity, while biotechnology promises much for the future. In the 1970s there was a great deal of worry about fixed natural resources of raw materials at the global level, though this problem now seems less urgent. The main argument for the Malthusian story today is in concerns about irreversible damage to the environment through global warming and depletion of the rain forest.

The importance of age structure can be seen still more clearly when the different impacts of the birth of a baby and the survival of a 30-year-old worker are considered. Each adds one to the population, but will have very different economic effects. We explore three mechanisms: (i) a labor market effect; (ii) an effect on savings and capital accumulation; and (iii) an effect on educational enrolment and human capital.

#### *Labor market effect*

The labor market effect looks at how populations with different age structures have more or fewer people available to work. Having a greater number of workers in the prime working-age group relative to dependents (the young and the old) raises inputs into production per capita, and so raises income per capita. A reduction in the number of young or old should lead to a proportional improvement in income per capita. An increase in the numbers of workers, meanwhile, is likely to dilute the amount of capital available per worker and lead to less than proportional gains, at least in the short term.

Exploring this area empirically presents some difficulties. Births, of course, increase the number of youth dependents (for a period at least), and it is possible to measure whether these depress

income per capita. The effects of death rates, however, are more difficult to ascertain – is the person dying young, of working age, or elderly? A more direct way of looking at labor market effects has been adopted by Kelley and Schmidt (1995, 1999), Sheehey (1996), Bloom and Williamson (1997, 1998), Williamson (1997), and Bloom *et al.* (1999). This uses the dependency ratio directly, rather than birth and death rates separately. It then compares the effect of the growth rate of working-age population against that of the total population. From this approach, significant age-structure effects on economic growth have been demonstrated.

It is important to realize that these changes cannot simply be explained by the ‘accounting effect’, whereby economic growth results purely from the growth in the number of workers. If income per worker were steady, there would be a one-for-one effect of increasing workers per capita. Bloom and Williamson (1998) find a much larger effect on growth from reductions in the dependency ratio over a 25-year period than is suggested by the accounting effect, while Bloom *et al.* (1999) show that this effect persists even if we exclude the reverse causality from economic growth to the age structure.

The accounting effect appears to be joined by a strong behavioral element, though the mechanisms by which this is achieved are unclear. One possibility is that reduction in dependency ratios may free home-carers to enter the formal labor market. As people shift from unpaid work in the home to paid work in the formal labor market, measured income will rise. Note, however, that this is more of a measurement issue than a substantive increase in welfare.

Changes in the age structure of the population may also reflect changes in the ages at which people are dying, which in turn is an indicator of their health. By including age-structure effects, therefore, we are also including a proxy for the overall health of workers. Strauss and Thomas (1998) have shown that healthier workers are more productive, so as death rates fall, not only do we have more workers, we also have more productive workers.

#### *Savings and capital accumulation effect*

The savings and capital accumulation effect is the second mechanism through which age structure has an impact on economic growth. The East Asian example is instructive, with its exceptionally high rates of physical and human capital accumulation seen as a major factor behind its economic success (Krugman 1994; Young 1994, 1995). If this is so, the question remains as to why East

Asian savings and education rates were so much higher than in other developing countries. In fact, while savings rates in East Asia were remarkably high, education levels in Latin America are comparable with those in East Asia, and sub-Saharan Africa has made substantial progress in education despite its low income level.

Firstly, it is important to remember that higher savings do not necessarily translate into higher local investment. With completely open international capital markets, only worldwide demographic factors should have an impact on worldwide investment, with investment always flowing to where it can find highest returns. Markets are far from perfect, however, and there is strong evidence that national savings and national investment are roughly equal.

Given that savings facilitate local investment, the life-cycle hypothesis argues that age will have an impact on savings rates. This assertion is modestly backed by data from household surveys (Paxson 1996; Deaton and Paxson 1997), which show peak savings rates among people of around 45 years of age. There is also a dip in savings rates for people in their early thirties, which may be due to the consumption needs of people with young families, as suggested by Coale and Hoover (1958).

However, even very old people save a significant proportion of their income. This contradicts the simple life-cycle model, in which people save when young, and consume their savings when old. The old may be saving to leave bequests to their children, or because the age of their death is uncertain and they are protecting themselves against using all their savings before they die. The variations in savings rates are therefore not large, and by themselves cannot account for large swings in savings rates. Deaton and Paxson (1998) find that if the amount people save at a specific age is assumed to remain constant, then changes in the age structure can account for only a small proportion of Taiwan's very large rise in the savings rate over the past 30 years.

The relationship between age structure and aggregate savings is quite interesting (Leff 1969; Mason 1981, 1987; Webb and Zia 1990; Kelley and Schmidt 1996; Higgins and Williamson 1997; Higgins 1998). This takes account of changes in the distribution of income between generations, as well as shifts in the population's age structure. Higher income for age groups that have higher savings rates will increase aggregate savings, for example. In this way, researchers can show significant age-structure effects, particularly when they take account of expected economic growth, which tends to raise the lifetime expected income of the young relative to the

older generation. While these age-structure effects on aggregate savings agree with our intuition from the life-cycle model of savings, in practice the results of cross-country savings studies are fragile and should be treated with caution.

In recent work, Mason (1998) has proposed a different demographic mechanism for explaining the increase in savings rates in East Asia – a very rapid increase in life expectancy. If the retirement age is constant, this creates a greater need for retirement income and may lead to higher savings rates at all ages for those in work. A simulation model of this effect for the Taiwanese economy, calibrated using plausible parameter values, explains most of the rapid increase in observed saving. Importantly, this is a temporary effect, which will last for only one generation. The sudden increase in life expectancy makes the young save at high rates, while there are no old to spend their savings. In the future, aggregate savings return to equilibrium, as the young save and (according to this model) the old spend their savings. Aggregate savings in East Asia are therefore likely to become much more like those seen in Western Europe and North America today.

One caveat to this approach is that it assumes the retirement age is fixed. A reasonable argument could be made that higher life expectancy should lead people to work for longer, postponing their retirement. If this happens, there is no need for savings rates for workers to rise. However, empirically there is a tendency for life expectancy to rise over time, while average retirement ages tend to fall. It seems unlikely, therefore, that demand for higher retirement savings is being met by a longer working life. In addition, Kalemli-Ozcan *et al.* (1998) show that, in theory, the optimal response to longer life expectancy, particularly when it is rising from low levels, may be to retire earlier. They argue that when life expectancy is low, death rates are high, and it is optimal not to plan for a retirement one has a small chance of reaching. People in low life-expectancy countries may simply work indefinitely and not take retirement. As life expectancy rises, however, the prospect of reaching old age becomes more likely and planning for retirement at a future, perhaps fixed, date becomes sensible.

The story that savings rates are mainly driven by life expectancy and by the need for retirement income is plausible, and is likely to be an important part of the wider picture. It needs to be tested against alternative explanations, however. For example, reductions in fertility and increased labor mobility may increase savings rates, as people are unable to rely on their family to supply old-age security. Non-demographic explanations may be important, too. For instance, the development of

financial markets and regulations aimed at protecting depositors may be needed in order to encourage people to save. Further studies are clearly needed in order to understand the importance of the role of age structure for investment, and to identify different mechanisms more precisely.

#### *Effect on educational enrolment and human capital*

Finally we turn to the third possible mechanism: the effect of demographic changes on education. A high youth-dependency ratio may reduce parents' ability to finance educational investments. There is some microeconomic evidence showing a negative effect of family size on school enrolment rates and educational attainment (Knodel *et al.* 1990; Rosenzweig 1990; Knodel and Wongsith 1991; Hanushek 1992). Cheng and Nwachukwu (1997), meanwhile, attempt to find a causal link from education to fertility in Taiwan, but instead find evidence that the causality runs the other way, from fertility to education rates. However, the evidence is not universally in favor of this hypothesis (Kelley 1996) and, despite its plausibility, it should be treated as a conjecture rather than an established fact.

Longer life expectancy may also affect rates of return to education, a possibility examined by Meltzer (1995) and Kalemli-Ozcan *et al.* (1998). The value of education depends on future earnings gains – gains which can be realized only if a person lives long enough. Psacharopolos (1994) finds that estimated rates of return to education are broadly similar across countries. However, these estimates are calculated under the assumption that people are infinitely long-lived (Mincer 1974). Kalemli-Ozcan *et al.* (1998) show that having a finite lifetime, with uncertain time of death, can have a significant impact on the rate of return to education. Meltzer (1995) calibrates a model, using empirical age-specific mortality profiles to estimate the effect of mortality on the rate of return, and argues that enrolment rates are sensitive to the rate of return. Behrman *et al.* (1999) find that life expectancy is a robust predictor of school enrolment rates in a cross-country study. While it is clear that mortality rates will affect the rate of return to education, the magnitude of this effect on school enrolment rates needs further study.

Taken together, these three mechanisms suggest that reductions in the death rate, particularly the death rate of adults, have a significant positive effect on economic growth. Reductions can increase the labor force per capita, generate higher levels of savings for retirement, and increase returns to education. Eventually, a low death rate leads to a higher proportion of old-age

dependents, but this need not be a drain on income per capita if old people live off their accumulated capital; even less so if they continue to save. In fact, the presence of an old generation living off their capital increases the wages of young workers, whose productivity rises due to the high level of capital intensity. Of course, this rosy picture may be reversed in a pay-as-you-go pension system where the old live off transfer payments from the young and do represent a burden on those working (Bloom and Williamson 1997).

On the other hand high rates of population growth, due to high fertility or low infant mortality, may depress the growth of income per capita, increasing the number of people to be fed, clothed, and housed, in the short run at least, while adding little to the productive capabilities of the economy. In an agricultural setting children can work from a young age and may represent a net income gain for parents (Caldwell 1982). This may help explain the high rate of desired fertility in Africa. However, in more urban settings children usually represent a net cost to their parents.

While the new demography focuses on age structure, there have also been developments concerning the older question of the effect of population density and resource constraints versus economies of scale. Most studies find little effect of population density on long-run economic growth; the success of countries with low population density such as the USA and Australia is matched by successes in some high-density countries such as Japan, and particularly Singapore and Hong Kong.

While population density does not seem very significant averaged over all countries, Bloom and Sachs (1998) and Gallup and Sachs (1999) find that high population density does appear to promote economic growth in coastal regions, while it impedes growth in inland areas. Coastal regions (those near the sea or navigable rivers) have greater access to trade routes and can relieve resource constraints quite cheaply by exchange with other countries. They then exploit the scale economies that come from specialization, without the impediment of local resource constraints. For example, Singapore is so densely populated that it needs to import not only food but also fresh water, but this has not imposed any real resource constraint on its growth.

This result can be compared to what we know about the income advantages enjoyed in cities relative to rural areas. Cities essentially enjoy the benefits of specialization while acquiring raw materials through trade. Since trade is cheaper by sea or river, large cities tend to be located on

coasts or rivers, or near raw materials with high transport costs. Countries appear able to benefit from the same advantages when their location is favorable and they are open to trade.

While coastal countries may find high population density beneficial, inland areas may face the Malthusian problem: they may find trade more costly, and rely more heavily on local resources. This may limit their ability to enjoy economies of scale and specialization, both through their lack of access to markets and through the limits the local resource constraints impose on population levels. Globally, too, the situation may be more Malthusian. Whether economic growth will be weakened by such local congestion effects in isolated economies, and by global pressure on natural resources and raw materials through higher population, is still an open question.

Interestingly, there is evidence that an abundance of resources can actually impede growth. When natural resources other than land are studied, there is evidence that countries with greater natural resource abundance per capita do worse in terms of economic growth (Sachs and Warner 1995). While greater natural resource abundance clearly raises *potential* wealth, in practice it may reduce average income by generating rent-seeking activities, activities that may benefit the individual but add nothing to total output. People may attempt to benefit from the royalties on the natural resource, rather than undertake productive employment; more time is devoted to fighting over the division of the pie than to creating the pie. Natural resource abundance may also lead to high exports of raw materials, promoting exchange-rate overvaluation, thereby reducing competitiveness in the labor-intensive manufacturing sectors which often lead the process of economic growth.

## 4. The Size and Speed of the Demographic Transition

The size of the impact of demographic change on income depends on two factors. Firstly, the total impact is likely to be larger than the demographic changes that occur. Secondly, the impact will be greater the greater the degree of sensitivity of economic outcomes to demographic change. The claim that demographic factors exert a large influence on economic performance requires both these factors to be present.

There *has* been enormous change in the demographic structure throughout the world over the past 50 years. Figure 1 shows life expectancy in Africa, Latin America, south-central Asia, and East Asia between 1950 and 1995. Life expectancy has increased rapidly in all regions, although this process has happened particularly quickly in East Asia and Latin America. Life expectancy has also risen substantially in Africa, though from a much lower base.

Figure 2 shows total fertility rates in the same regions over the same period. Fertility rates have come down most sharply in East Asia and Latin America, with evidence of the start of a decline in south-central Asia. However, fertility rates remain high in Africa.

The consequences of these changes on age distribution are shown in Figure 3, which shows the ratio of working-age (15–64) to dependent population (both young, 0–14, and old, 65 and over) over the period. In developing countries dependents are primarily the young, with a significant number of old people only now beginning to appear in East Asia. It can be seen that increases in life expectancy, which come mainly from reductions in child and infant mortality, tend initially to increase the dependency ratio. The population as a whole is increasing, but the number of young people is increasing more rapidly. However, if fertility rates fall, the number of the young being born eventually declines, creating a ‘baby-boom’ generation where the population contains a cohort of exceptionally large size.

As this baby-boom generation enters the labor market, we see an increase in the ratio of workers to non-workers, which continues for around 45 years. They then leave the labor market and enter retirement. This demographic pattern lies behind the enormous growth in East Asia in the ratio of workers to dependents, from around 1.3 in 1965 to 2.1 by 1995. No other region has seen anything comparable, although Latin America and south-central Asia are clearly experiencing the start of this process. It is possible that the reduction in fertility in East Asia was purely

exogenous, causing age-structure and labor-market effects which, in turn, created rapid growth. However, it is more likely that the causality runs both ways, with the rapid fall in fertility a partial consequence of rapid economic growth. Fertility and mortality are more likely to be linked to the level of income than the growth rate; however, over a 30-year period differences in growth rates between countries lead to large differences in income levels.

To explore this situation in more detail, we first look at mortality. Fogel (1993) has argued that the declines in European mortality during the industrial revolution followed economic growth. However, the 20th century experience seems quite different. Preston (1975, 1980) attributes only a very small portion of the decline in death rates observed around the world between 1930 and 1970 to economic growth. Exogenous factors, such as advances in health care, are seen as being much more important. This debate is by no means settled. Pritchett and Summers (1996), working with data from 1960 for developing countries, find a significant effect on infant mortality from both income and education. They argue that this is a causal relationship, although they find that overall life expectancy appears to evolve exogenously. Wang and Jamison (1997), meanwhile, find an independent effect for female education levels, in addition to the overall impact of education and income. They emphasize the changing nature of the relationship between the factors affecting infant mortality over time. More work is clearly needed, in particular to understand the direction of causation within the system.

Our own analysis uses data spanning the period 1870–1988 for a cross-section of countries. The data on real GDP levels are from Maddison (1995), while the data on population, vital statistics and age structure are from Mitchell (1992, 1993, 1995). A problem with looking at crude death rates is that it is difficult to disentangle the effects of falling mortality rate at each age from the effects of a changing population age structure. While it would be possible to overcome this problem by using age-specific death rates, these data are generally unavailable. However, data are available for infant mortality rates (up to age 1). Figure 4 plots infant mortality rates against GDP per capita for three periods, again pooling data from each period. During the period 1870–1910, infant mortality rates are high and decline only slightly with rising incomes. Between 1911 and 1950, there is a sharp steepening of the relationship as infant mortality rates fall in high-income countries. After 1950, infant mortality rates appear to be low for all countries, with dependence on income level for the lower-income countries. These results again point to the importance of

improvements in public health, of the kind that initially had an impact on richer countries but have eventually become widespread.

Our statistical analysis follows the model of Jamison *et al.* (1996, 1997) in trying to establish how the relationship between income and mortality changes over time. Our analysis, however, uses data spanning a much longer time frame. One important factor in interpreting Figure 4 is that the number of countries in the data set increases over time, so when looking at differences between time periods there may be variation induced by changing the set of countries under consideration. This problem can be overcome by using a fixed-effects framework to allow for country-specific differences in mortality rates.

Table 1 shows the results of regression analysis using log infant mortality as the dependent variable, with the independent variables being decade dummies and log income per capita interacted with the decade dummies. This model assumes the relationship is constant within each decade, but changes between decades; it amounts to pooling observations from different years within a decade. Testing the three specifications suggests that a random-effects model is most appropriate (an  $F$  test decisively rejects OLS against fixed effects, but the Hausman test of random effects against fixed effects gives a chi-square value of 0.76 with 5 degrees of freedom, which is not significant). The regression results indicate that a significant negative relationship between income levels and infant mortality occurs only after 1900, and that the slope of the relationship has become steeper since then.

It should be noted that the regression analysis in Table 1 uses the logarithms of the variables, while the graph in Figure 4 plots levels of the variables. While a logarithmic specification appears to fit the data better, plotting the data in levels emphasizes how large the absolute differences are in infant mortality between developed and developing countries. The relationship between income and infant mortality shown in Figure 4 appears to flatten out in the period 1950–1988, while the regression results in Table 1 indicate an increasing sensitivity of infant mortality to income over time. This means that while infant mortality rates are becoming closer in levels (and are approaching zero in richer countries), the ratio of infant mortality rates in poor countries to that in rich countries is increasing.

The most important point about Figure 4 and Table 1 is the decline in infant mortality rates over time, which is apparently independent of the effect of rising incomes. The results suggest that

infant mortality in poor countries is now 10–30 times lower than in countries at comparable levels of income in 1870. This points towards both an exogenous shift and an endogenous component in the determination of mortality rates. One story that might fit the data is the discovery of new techniques that are applied first in developed countries and then diffuse slowly to developing countries.

There appears to be an upward movement of the intercept over time in the infant mortality regressions in Table 1, which may give the misleading impression that infant mortality is increasing in very poor countries. However, what is really happening is that the relationship is becoming steeper over the actual range of incomes we observe. It is easy to show that the results imply rising infant mortality over time only in countries with annual incomes less than 1 cent per year (in 1985 US dollars at purchasing-power parity). It follows that even in very poor countries, which are well above this threshold, there has been a tendency for infant mortality rates to fall over time.

To compare the magnitudes of the income effect with the exogenous change taking place over time, we can calculate the change in income that would have been required to generate a reduction in infant mortality of the same magnitude as the exogenous shift in the relationship in infant mortality between 1870 and 1980. Using the relationship between income and infant mortality in 1980, we can calculate that the downward shift in the curve between 1870 and 1980 has had roughly the same effect as that obtained by increasing income by a factor of 50. This is just about the limit of the range of income levels we see today between the richest countries in the World (USA, Sweden, Switzerland) and the poorest (Mozambique, Chad).

Turning to births, there has been debate on the relative importance in determining fertility of family planning programs versus economic development. Gertler and Molyneaux (1994), Schultz (1994) and Pritchett (1994) show that desired fertility, as determined by economic forces such as education levels and wage rates of women, plays a significant role in a fixed-effects framework, while family planning activity appears less important. If these results are correct, fertility decline may be an endogenous factor, following economic growth rather than causing it – although as we have shown, it still has the potential to play its part in an important multiplier effect.

Figure 5 shows the relationship between fertility rates (births per thousand women aged 15–45) and GDP per capita in the three time periods. While income levels seem to have little effect on

fertility in the 19th century, there is a strong negative relationship between fertility and income after 1910. However, the lack of a clear relationship in the data before 1910 may well be because the range of incomes across countries in this time period was fairly small. Table 2 shows regression results using log fertility rates as the dependent variable. Due to a smaller data set, the explanatory variables in this regression are dummy variables for 20-year periods, and these dummies interacted with log income per capita. Again, statistical analysis finds random effects to be the preferred model (we can once again decisively reject OLS against fixed effects, but a Hausman test of random effects against fixed effects gives a chi-square value of 0.95 with 3 degrees of freedom, which is not significant). Fertility appears not to have had a significant relationship with income before 1890, but there is a significant negative association thereafter. While there appear to be movements in the intercept, these do not follow a regular pattern. Surprisingly, there is no clear evidence of technological progress in birth control having an exogenous impact on fertility rates. There is no downward trend in the relationship over time; in particular the introduction of significant new birth control methods in the 1970s and 1980s are not reflected in reductions in the fertility level.

These suggestive results should be qualified in two important ways. A more comprehensive study would require the inclusion of further explanatory variables such as education levels, particularly for females, and the availability of contraception. The regressions are intended mainly to demonstrate the existence of feedback from income levels to fertility and mortality: they are not intended to imply that we believe that only income matters in determining fertility. In addition, it would be desirable to find an instrument for income levels, in order to ensure the robustness of the results to the presence of reverse causation. Bloom *et al.* (1999) adopt an instrumental variables approach in order to do this, using only data from after the Second World War, but find similar results to those presented here.

Bearing these caveats in mind, these empirical results suggest that the relationship between fertility, mortality and income levels has changed over the past 130 years. A possible cause for these changes has been technological developments in both health care and contraceptive methods. Such changes will tend to reduce mortality and allow actual fertility to more closely approximate desired fertility. Such technological effects are not likely to impact on all countries equally. Rich countries may be alone in being able to afford the improvements offered by health technology, while desired fertility may vary across countries. It follows that technological advances can change the slope, as well as the intercept, of our relationships.

It would be a simpler story if demographic change was exogenous, and had an economic impact; or if economic development was exogenous, and determined demographic change. But the truth appears to be that each affects the other. The relationship between economic development and the demographic shift can be understood only as a process, in which causality runs in both directions.

## 5. Models of the Demographic Transition and Economic Development

The richest countries of the world have around 50 times the income per capita of the poorest, in terms of purchasing-power parity. Even ignoring the very poorest countries (for example Chad and Mozambique, whose problems have been compounded by civil war), rich countries have about 20 times the income levels of the poorer developing countries. A central question is why such a large gap exists. Two types of answer are possible. One argues that countries are fundamentally different and these differences account for their different economic performance. For example, Gallup and Sachs (1999) emphasize the role of geography in economic growth. The second argues that countries are really quite similar, but that economic development involves positive feedback: countries that do well tend to make further gains, creating wide gaps in outcomes across countries, from very small differences in initial conditions.

The neoclassical Solow model assumes diminishing returns to capital, and so predicts relatively small differences in income levels for countries with different savings rates. Rich countries may have higher levels of capital per worker, but diminishing returns imply that this has only a small impact on income levels. It is difficult for the model to generate the vast differences in real income levels we observe across the world.

Endogenous growth theory is a response to this problem. If the elasticity of output with respect to capital is 1, so that a 1 per cent increase in capital stock leads to a 1 per cent increase in output, capital accumulation becomes a very powerful force in the growth process. With no diminishing returns to capital, economies need not slow down as they get richer, and growth can continue indefinitely. Klenow and Rodriguez-Clare (1997) and Prescott (1998) argue that, based on microeconomic evidence exploring the returns on physical capital and education, the elasticity of output with respect to aggregate capital is estimated as 0.5. If this is true, we lack an explanation of the wide differences in income levels across countries.

An alternative approach to explaining the wide income differences is to argue that there may be cumulative causality between income growth, mortality decline, and declines in fertility. To understand this process we require a model in which demographic factors can affect economic growth, and income levels can have an impact on demographic variables. In many ways this is a return to the basic approach used by Malthus, who had a theory of production and technological progress, and a theory of fertility and mortality. It is the interaction of these mechanisms that makes the Malthusian model so rich.

Modern models go beyond Malthus by describing how fertility can fall as well as rise with income. Barro and Becker (1989), for instance, argue that as wages increase, time has a rising opportunity cost – child rearing is time-intensive, and they are therefore able to introduce the negative effects of income on fertility into a standard neoclassical growth model. This model then generates multiple equilibria, with country income able to settle at a higher or a lower level. Becker *et al.* (1990) argue that, as income growth depresses fertility, there is more human capital per child. If the returns from education are large enough, this in turn leads to further gains in income. This model has a poverty trap at low income levels, where there are large numbers of children, a lack of education, and a relatively low value for time. However, escape from this trap may lead to a phase of endogenous growth, based on ever-increasing levels of income and education.

What is needed is an exogenous stimulus to start this exogenous process, and reductions in mortality offer one such mechanism. Ehrlich and Lui (1991) argue that lower child mortality may lead to lower fertility (if the number of surviving children desired by families is constant). In their model, this leads in turn to higher levels of education per surviving child, as education is no longer ‘wasted’ on children who die before entering the labor market, which can set off a virtuous spiral of rising income and education. In practice, a decline in infant mortality is likely to lead to an increase in the youth-dependency ratio in the short run, until fertility behavior adjusts. However, in the longer run the reduction in fertility may be more than one-for-one, as the decline in infant mortality also reduces uncertainty about the number of surviving children, allowing even more resources per child to be made available for education.

Quah (1997) supports the idea of a development trap, with growth occurring only after a critical level of income. He shows that there are two distinct groups of countries, the poor and the rich, with very few countries in the middle-income range. Many ideas have been put forward as to why

these two groups, and the multiple equilibria they imply, should exist (Azariadis 1996). Most depend on the notion that endogenous growth is possible, but it is difficult to get started on such a path at low income levels. For example, the multiple equilibria in models presented by Becker *et al.* (1990) and Ehrlich and Lui (1991) arise from an interaction between fertility and education in models where there are no decreasing returns from education. The endogenous growth phase essentially relies on increasing returns. Strulik (1997) also produces multiple equilibria in a model with endogenous population growth and learning-by-doing, essentially using learning-by-doing to produce dynamic increasing returns to scale, once growth is under way.

It is argued here that demography plays an important part in understanding the process of economic growth. However, the interaction between demography and economic growth must be approached within a system framework, in which each variable affects the others. To an extent this is a trivial observation: there is little dispute that these forces do interact. At a deeper level, however, the system approach changes the way we must view causality within the system, but only if the links between variables are sufficiently strong.

Figure 6 sets out a schematic diagram that shows our view. We believe that demography influences output directly through its effects on labor supply, and indirectly through its effect on capital accumulation. On the other hand, income levels and the capital stock have effects on fertility and mortality. The links at the bottom of the graph, showing the effects of capital accumulation on income and the effects of income on further capital accumulation through savings, are the links that have been most extensively examined by economists.

This schematic could be extended to include other forces. For example, political scientists might see the political process as both a cause and a consequence of economic development, and add a box labeled 'politics' with arrows connecting it to all the other variables. However, for the moment we have taken politics and other factors as exogenous to the system, and focused on the interaction between capital accumulation, economic growth, and demographic change.

The system approach throws new light on the wide dispersion in income levels that lies at the center of the growth debate. Any changes to the exogenous factors in the model will have repercussions for all the endogenous variables. For example, a family planning program may slow down the rate of population growth. This will have an impact on income per capita directly, through its effects on the dependency ratio and the labor force. The ratio of working-age to non-

working-age populations will rise in the short run, while, in the longer run the lower population may lead to a higher capital–labor ratio. It will also have an indirect impact on income through capital accumulation, perhaps increasing investment in education per child, as there are fewer children. Family planning in the form of contraception distribution programs may itself be endogenous and related to income and education levels: contraception is most required where the demand for children is waning, and this occurs at higher levels of income education and development.

In order to elaborate the simple models set out here, it will be necessary to decompose population growth into birth rates and death rates. As incomes rise, both death rates and birth rates tend to decline. However, there may be a threshold effect whereby as mortality falls, a reasonably high income level is required before fertility is affected. There is also evidence that in the initial stages of a demographic transition, rising incomes actually increase fertility, while also reducing child mortality. Taken together, these effects create a take-off problem, deepening the low-level poverty trap. As in the studies of Nelson (1956) and Leibenstein (1978), escape from this Malthusian world is possible only if income levels are pushed slightly above subsistence levels due to some exogenous factor. Then fertility begins to decline, positive feedbacks are felt, and endogenous growth can start.

A focus on the system approach also highlights the problem of trying to attribute economic growth to ‘causes’ that are themselves endogenous. For example, Young (1994, 1995) attributes almost all of East Asia’s growth to capital accumulation, but this begs the question why capital accumulation was so high. Higgins and Williamson (1997) argue that the entire rise in savings in East Asia may be due to the demographic shift, but this begs the question why these countries underwent the transition in this period. Factors can be important whether endogenous or exogenous. Even if the demographic shift was completely endogenous, it would still have provided positive feedback and could still be an important part of understanding the East Asian ‘miracle’. Endogeneity is often seen as a purely technical problem that makes the estimation of each separate effect more complex. However, it also has a conceptual dimension, forcing us to think of the process as a whole rather than looking at each causal link in isolation.

If our view of the East Asian miracle as a period of endogenous growth is correct, there may in fact be no ultimate causes, only a process. Once the interactions in Figure 6 become very strong, the final outcome in terms of the endogenous variables may not depend on the exogenous

variables in a unique way. We may need to understand growth as a process of cumulative causation rather than a mapping from causes to effects.

The model also serves to highlight a possible difference between the recent economic success of East Asia and the original industrial revolution in the UK. It may be that the relatively slow population growth rate in the UK during the industrial revolution was essentially due to a slow but steady increase in income levels over a period of 200 years, as suggested by Crafts (1998). However, improvements in medical technology, our understanding of public health, and advances in contraceptive technology may mean that, in the 20th century, the feedback from income level to demography is much stronger. The transition from a low-income economy to a high-income economy could now involve a jump between steady states, a jump that may take only one generation.

## 6. Policy Implications

There are three distinct areas in which the models for the ‘new demographics’, which emphasize age-structure effects rather than total population, have potential policy applications.

### *Economic policy*

The first is rooted in the realization that demographic changes have only a *potential* economic impact. The benefits of the ‘demographic dividend’ require that desired changes in labor supply, savings, and educational attainment actually come about in practice. Any adverse effect of population pressure can be mitigated through the smooth functioning of markets and the price mechanism. Appropriate economic policies are therefore essential.

The baby-boom generation will certainly increase the size of the workforce, but this will provide higher output only if these people find productive work. If the labor market fails to absorb the large cohort, then the potential gains will probably be wasted. Equally, increases in life expectancy will lead people to save more, but only if they have sufficient trust in a well regulated and efficient financial sector. These savings must then be invested in a way that benefits the economy. Again, demand for education is likely to increase, as people demand schooling for their children and consider returning to education themselves. But this demand may require public intervention, particularly at the primary and secondary school levels, as poor families lack the funds to finance educational investments and have difficulty borrowing.

Table 3 shows fairly standard growth regressions, explaining growth in per capita income over the period 1965–1990 for a cross-section of countries, including demographic factors. Initial demographic factors, measured at the beginning of the period, are taken to be exogenous. However, all population growth rates measured over the period are assumed to be endogenous. We instrument these in the regression with log of the fertility rate and the youth-dependency rate in 1965, and the lagged growth rates (between 1960 and 1965) of working-age and total population. Since demographic change is instrumented with variables measured before the period of growth begins, we can argue that these instruments are immune from reverse causality. There are several problems with treating ‘prior’ variables as exogenous. The first is that economic growth rates may be correlated over time so that countries with high growth rates in the period 1965–1990 also had high growth rates over the period 1960–1965. If this is the case, even if

causality runs entirely from economic growth to demography, our instruments will have a spurious correlation with growth in the period we are trying to explain. However, in practice there is very little persistence in economic growth rates over time, and essentially zero correlation between current growth rates and lagged growth rates (Easterly *et al.* 1993). The second problem is that, if economic growth is expected, it can have an effect on fertility behaviour and demographic change even before it occurs, so that the arrow of causality may run backwards in time. While we cannot rule this effect out, it seems unlikely in practice that uncertain predictions of future rates of economic growth have a large effect on current decisions. If we accept these arguments, our instruments control for reverse causality and give estimates of the effect of population growth on economic growth.

We find that total population growth entered on its own does not have a statistically significant effect on economic growth. However, adding the growth of working-age population, and the total population growth rate, gives a significant improvement in the fit. The effects of working-age growth and total population growth appear to be equal and opposite; it seems to be the differential growth rate that matters. This is reported in column 3 of Table 1. In this specification we also find that growth is higher, the higher the initial ratio of workers per capita. This implies that the steady-state level of income per capita is higher if the ratio of workers per capita is higher.

When we include demographic factors in growth regressions, as in column three of Table 3, the education variable (log of average years of secondary schooling) tends to become statistically insignificant. We interpret this as meaning not that education does not matter, but rather that education may be driven by the demographic factors (life expectancy and school enrolment are highly correlated), so that demographic change is working partly through its effect on enrolment rates. If demographic change explains school enrolment, education levels do not have an independent explanatory role in regression analysis. It could be that the real problem is that our education data are very poor, measuring quantity rather than quality (Behrman and Birdsall 1983), or that the relationship between education and growth is more complex (Birdsall and Londono 1997).

Table 4 reports growth regressions in which we include policy variables both on their own and interacted with the differential growth rate of working-age and overall population. We use institutional quality and openness to trade as policy variables, although ideally we would like to have included separate indicators for the efficiency of the labor market, the financial market, and

the education system. Even using our simple proxies, however, we see that good policy (as expressed by high-quality institutions and openness to trade) leads to higher growth, and the impact of demographic change is greater when institutions are better. It is, of course, always important to get policies right, but it may be more so when the baby boom is occurring.

One caveat to these results is that it is difficult to estimate the interaction of demographic change with multiple policies. In columns one and two of Table 4, when we interact with openness of the economy and institutions separately, we find significant effects. However, when we interact with both policies at the same time, in column three, neither is significant. While the demographic dividend is greater when good policies are in place, cross-country data are not rich enough to tell us which policies are most important. Note, however, that adding interactions between policies and initial income level gives some evidence that policies matter more in poor countries, but the interaction between policies and demographic change remains significant.

The interaction effects estimated are not only statistically significant, they are large in magnitude. In countries with the worst policies (zero openness and institutions), no significant effect of changes in the age structure is seen. In countries with the best policies, we find very large effects. For example, the interaction between demographic change and policies translates into a 2 percentage-point gap between economic growth in East Asia relative to Latin America over the period, due to the faster demographic transition and better economic policies in East Asia. This is a substantial part of the observed growth differential of just over 5 percentage points a year.

In many cases, when we add the interaction effects between policy and demography, the coefficients on the original level terms representing policy and demography become statistically insignificant, and often change sign. This does not mean that there are no demographic or policy effects. For example, the effect of an increase in the rate of demographic change (measured as the differential growth of the working-age to total population) is the coefficient on the demography variable *plus* the coefficient on the interaction term multiplied by the level of the relevant policy variable. In general, this will be positive even if the coefficient on the level term is zero. In fact, the ‘average’ effect of demographic change, that is, the effect in a country with average levels of the policy variables, is exactly what is calculated in Table 3 when we do not allow policy interactions. In countries with the very worst policies (giving policy values of zero on our measures) we do not find any effect of demography in our specifications, but this should not be especially surprising.

### *Health policy*

The second implication of the new demographics is for health policy. Better health and increased life expectancy clearly have a direct impact on human welfare. However, if life expectancy promotes economic growth, public health measures may have an indirect impact on welfare by encouraging economic growth. The results in Tables 3 and 4 show that life expectancy to has a significant impact on economic growth. This is one of the most robust results in the growth literature. While there is a problem that life expectancy may merely be acting as a proxy for the overall level of human development, it may be that health policy should be given a greater priority; it may have a double dividend, increasing welfare directly and also promoting long-run economic growth. It is obvious that the AIDS epidemic represents an enormous human tragedy for the people of sub-Saharan Africa, as is the recent decline in life expectancy for the population of Russia. The economic bad news, however, may be only beginning to be felt.

### *Population policy*

Finally, these results have important implications for population policy, by which is usually meant family planning through the control of fertility. One view is that there is a trade-off between the number of children and economic growth, with fewer children leading to greater growth. However, we do not wish to imply that people would be better off with fewer children, as it is essential not to confuse economic growth with human welfare.

One issue is how (and whether) policy-makers should calculate a trade-off between potential children and the well being of those already born. We can side-step this difficult philosophical question if we follow Becker and Barro (1989) and assume that parents are altruistic towards their children. Parents already calculate a trade-off between having more children, and having fewer but providing them with a higher standard of living and education. If they have knowledge of, and access to, family planning, the number of children born will reflect this trade-off. It is therefore unclear what more policy-makers can do. This leads to the view that the correct aim for family planning policy is to inform parents of the trade-offs involved and to provide methods of making actual fertility match desired fertility. Reducing births below the desired level might increase income growth, but would reduce welfare.

The argument for going further is based on situations where there are externalities to the number of children born. For example, if an extra child in one family reduced the welfare of children in another, perhaps through pressure on scarce public resources, it is possible to make both families better off if birth numbers are restricted. In this case, each family is in a situation known as the 'prisoners' dilemma', first formulated by mathematician Albert W. Tucker in the 1950s (Axelrod 1984). The dilemma is that each family is best off if the other does not have a child, and worst off if the other family has a child and they do not. Between these two poles, they are slightly worse off if both have children and slightly better off if neither does. However, the situation is different when examined globally, with all families better off overall if the number of children is limited. The latter is a cooperative strategy, and it may be possible for policy-makers to influence more families to choose it for the mutual good.

Macroeconomic analysis is not well placed to decide whether externalities exist, or whether benefits of fewer children accrue only to families making that decision. Detailed microeconomic studies at the family level are needed to find the private trade-off between child quantity and quality, and to compare that to the macroeconomic effects. Only if there is a clear social, rather than private, trade-off can we justify societal intervention to influence the fertility decisions taken by individuals.

## 7. Conclusions

Why are income levels so different across the world? Why do the differences show no sign of narrowing? These are fundamental questions. Endogenous growth models in economics have tended to answer them by arguing from the existence of very high returns to capital, and a process of cumulative causation whereby countries that invest more (in physical capital, human capital, and research and development) grow much more quickly than others.

There is another possibility, however. The interaction of economic growth with population dynamics can create a poverty trap. There may be two clubs, one with low income and high population growth rates, the other with high income and low population growth rates. Transition between these clubs may be rare, but when it occurs it may happen very quickly due to the positive feedbacks between growth and demographic change, and be seen as a growth 'miracle'.

This model depends on the interactions between income levels, demographic changes, and capital accumulation being sufficiently strong. Evidence is emerging that these links may be fairly strong, but a great deal more empirical research is required. In addition, the overall behavior of the system can only be understood as a whole. This requires an integration of demographic studies of the effect of income and education levels on fertility and mortality, with economic studies of the effect of demographic variables on capital intensity, labor force participation rates, savings rates, and school enrolment rates.

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