DEMOGRAPHIC DESTINIES

Interviews with Presidents of the Population Association of America

Interview with David Lam
PAA President in 2011

This series of interviews with Past PAA Presidents was initiated by Anders Lunde (PAA Historian, 1973 to 1982)
And continued by Jean van der Tak (PAA Historian, 1982 to 1994)
And then by John R. Weeks (PAA Historian, 1994 to present)
With the collaboration of the following members of the PAA History Committee:
David Heer (2004 to 2007), Paul Demeny (2004 to 2012), Dennis Hodgson (2004 to present), Deborah McFarlane (2004 to 2018), Karen Hardee (2010 to present), Emily Merchant (2016 to present), and Win Brown (2018 to present)

DAVID LAM

PAA President in 2011 (No. 74)

WE DO NOT YET HAVE AN INTERVIEW WITH DR. LAM

STAY TUNED!

Demography (2011) 48:1231–1262
DOI 10.1007/s13524-011-0070-z

How the World Survived the Population Bomb: Lessons From 50 Years of Extraordinary Demographic History

David Lam

Published online: 18 October 2011

Abstract The world population will reach 7 billion in late 2011, a demographic milestone that is causing renewed attention to the challenges caused by population growth. This article looks at the last 50 years of demographic change, one of the most extraordinary periods in demographic history. During this period, world population grew at rates that have never been seen before and will almost surely never be seen again. There were many concerns about the potential impact of rapid population growth in the 1960s, including mass starvation in countries such as India, depletion of nonrenewable resources, and increased poverty in low-income countries. The actual experience was very different. World food production increased faster than world population in every decade since the 1960s, resource prices fell during most of the period, and poverty declined significantly in much of the developing world. The article considers the economic and demographic explanations for the surprising successes of this important period in demographic history. It also looks at regions that have been less successful, especially Africa, and at the lessons for dealing with the important challenges that still remain.

Keywords Population growth · Demographic transition · Poverty · Resources · Food

Introduction

The world's population is projected to reach 7 billion in late 2011 (United Nations Population Division 2011). This important demographic milestone is motivating renewed interest in the challenges posed by population growth. It was only 12 years

Electronic supplementary material The online version of this article (doi:10.1007/s13524-011-0070-z) contains supplementary material, which is available to authorized users.

D. Lam (✉)
Department of Economics and Population Studies Center, University of Michigan,
426 Thompson Street, Ann Arbor, MI 48106, USA
e-mail: davidl@umich.edu

ago, in 1999, that there was similar attention to world population reaching 6 billion. With a population of 7 billion, and another billion projected in less than 15 years, the world faces daunting challenges, including global warming, a recent rapid increase in food prices, and more than 1 billion people living in extreme poverty.[1] As we think about the challenges facing the world as these billions of people are added, it is instructive to look back at the last 50 years of world population growth. In this article, I argue that the last 50 years represent one of the most extraordinary periods of demographic history the world has ever seen. Looking at what happened to food production, resource scarcity, and poverty during this exceptional period can provide us with valuable lessons about our capacity for dealing with the many difficult challenges yet to come.

In the 1960s, as today, there were optimists and pessimists among those looking at the challenges of population growth. Indeed, there have been optimists and pessimists about population and the economy since at least the time of Thomas Malthus. Malthus's (1803/1960) "Essay on the Principle of Population," which argued that economic growth tends to be choked off by the population growth that results from rising incomes, was a challenge to the optimistic utopianism of writers like William Godwin (1793/1798).[2] William Stanley Jevons (1866), another important early economist, predicted in 1866 that England's economic growth was unsustainable because England was running out of coal. The debate between pessimists and optimists looking at population and resources has gone on for hundreds of years and will surely continue for hundreds more. The debate may have reached a peak in the 1960s, with plenty of things for pessimists to worry about.

In this article, I will consider what the world looked like in the 1960s as researchers and policy makers considered the demographic challenges ahead. My characterization will be much more broad than deep, incorporating data on a wide range of economic and demographic outcomes. I will touch on several issues, any one of which would be impossible to do justice to in a article of this length. My goal is to look at the big picture of the last 50 years of economic and demographic change, recognizing that this inevitably allows only a superficial look at many complex issues.

Concerns About Population in the 1960s

In 1960, the world's population reached 3 billion. This received considerable attention at the time, including a January 1960 cover story in *Time Magazine* under the banner "That Population Explosion" (*Time Magazine* 1960). Even more important than the population of 3 billion was the unprecedented rate of population growth. The increase from 2 billion to 3 billion took about 35 years,[3] whereas the increase from 1 billion to 2 billion took about 125 years and the addition of the first

[1] These trends will be documented and discussed in more detail later in the article.

[2] For a history of the debate between Malthus and Godwin, see Petersen (1971).

[3] McEvedy and Jones (1978) estimated that world population reached 2 billion in 1925, roughly consistent with other estimates compiled by the U.S. Census Bureau (2011) and the United Nations Population Division (1999).

billion took from the beginning of the human race until about 1800. The annual growth rate of world population reached 2.2% in 1962 (U.S. Census Bureau 2010). This may have been the first time in human history that the world's population grew at 2% per year, since, as discussed later, 2% growth requires an unusual set of demographic conditions. It is easy to see why there was concern about population pressures and what they might mean for our future.

Concern about population growth was widespread in academic circles and the media in the 1960s. The University of Michigan's Population Studies Center was founded in 1961. Many other U.S. population centers were also founded in the 1960s, a reflection of the interest in population among the foundations that funded the centers and among the researchers that created them (Caldwell and Caldwell 1986; Donaldson 1990). Numerous books and articles expressed concern about the dangers posed by rapid population growth. These concerns are typified by Paul Ehrlich's 1968 book *The Population Bomb*. The words on the cover of the paperback edition, "Population control or race to oblivion" (Ehrlich 1968), give a sense of the book's alarmist tone. Many other books and articles sounded the alarm about population growth, although *The Population Bomb* continues to be the best-known book on population from the period.[4]

How Unusual Was the Demography of the 1960s?

Was the demographic experience of the 1960s unusual enough to deserve the attention it received? One way to look at this is to examine doubling times of world population. World population increased from 3 billion to 6 billion between 1960 and 1999, a doubling time of 39 years. The previous doubling time—the time it took the world to grow from 1.5 billion to 3 billion—was about 70 years.[5] The doubling before that took about 150 years, the one before that about 500 years, and the doubling before that about 1200 years (see Fig. A1 in Online Resource 1). The sequence of doubling times from AD 1 to 1999, then, is something like 1,200 years, 500 years, 150 years, 70 years, and 39 years. My undergraduate students are good at "what is the next number in this sequence?" problems, so I have them guess the next doubling time—the time from 1999, when the world had 6 billion people, until the world population reaches 12 billion. Given the choice of 20, 30, 40, 60, or 100 years, most students choose 20 or 30 years, with almost none choosing 60 or 100. The correct answer is almost surely more than 100 years, as will be discussed later in the article. Those who have worked on population projections might even prefer an answer like more than 500 years or perhaps even "forever," since it's very plausible that the world will never reach a population of 12 billion.

How can we say that world population won't double in the next 100 years, given the doubling from 1960 to 1999 and given uncertainty about future fertility and mortality? Figure 1 shows the U.N. Population Division's population projections to 2100 using

[4] Other frequently cited books that raised concerns about population growth include *Famine 1975!* (Paddock and Paddock 1967) and the Club of Rome's *Limits to Growth* (Meadows 1972).

[5] The doubling times in this paragraph are rough estimates based on the U.S. Census Bureau's (2011) compilation of a number of historical estimates of world population.

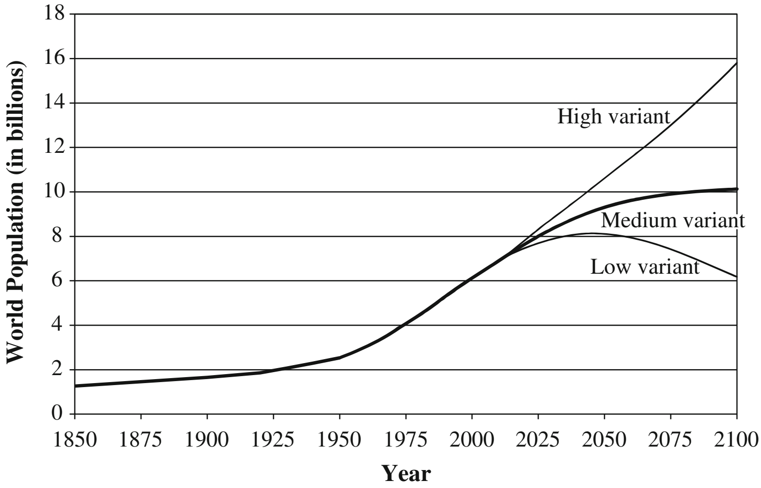

Fig. 1 Estimates of world population, 1850 to 2010, and U.N. high, medium, and low projections to 2100

their high-, medium-, and low-variant projections.[6] According to the medium-variant projection, world population will reach 9.3 billion in 2050. That's another 2.3 billion people, a sobering increase. But it is an increase of 33% in the next 39 years, far from the 100% increase that occurred between 1960 and 1999. The U.N. medium-variant projection reaches 10 billion in 2083 and 10.1 billion in 2100. The addition of 3 billion people in 72 years can be compared to the addition of 3 billion in just 39 years between 1960 and 1999. Using the high-variant projection, which assumes slower fertility decline, world population will reach 10.6 billion in 2050 and 12 billion in 2065. Using the low-variant projection, which assumes faster fertility decline, world population reaches a maximum of 8.1 billion in 2046, then falls to 6.2 billion by 2100. None of these scenarios predicts a doubling in anything close to 39 years.

Other projections have reached similar conclusions. Lutz et al. (1997, 2001, 2004), using models of probabilistic population projections, have argued for some time that the world population growth rate will approach zero by 2100. Their median forecast predicts that world population will peak in 2070 at a level of 9 billion people, with an 85% chance that the world will reach population stability by 2100. While it is difficult to make precise forecasts of world population, a great deal of information can be garnered from analyzing the current age distributions in different countries and recent trends in fertility and mortality (Bongaarts and Bulatao 2000). It is virtually certain that world population will never again double in 40 years, making the 1960–2000 experience absolutely unique in human history.

To understand why world population will not double again by 2100 or even by 2200, it is useful to look at population growth rates. Population growth was very slow before the industrial revolution, although there may have been short periods with annual growth rates above 1% (Lee 2003). Figure 2 shows annual growth rates

[6] The main source of population estimates and projections in this article is the 2010 Revision of World Population Prospects (United Nations Population Division 2011). Details about the assumptions in the low-, medium-, and high-variant projections are available at the United Nations Population Division (2011) website.

and projections from various sources from 1900 to 2100. The growth rate probably reached 1% around 1925. Better estimates are available starting in 1950 and show the growth rate rising in the 1950s. Census Bureau estimates show a dramatic drop in 1959, the result of increased mortality and decreased fertility in China's Great Famine. According to the Census Bureau, the peak annual growth rate for the world was 2.2% in 1963, implying a doubling in 32 years if this rate stayed constant. Interpolations from the U.N.'s five-year estimates imply a peak annual growth rate of 2.03% in 1968. The big picture is that population growth rates reached just over 2% per year in the 1960s and have fallen rapidly since.

The 2011 growth rate is estimated at 1.1%. If this rate stayed constant, world population would double in 60 years. But there is little doubt that the growth rate will continue to fall. The growth rate is as high as it is only because of population momentum, with many women at childbearing ages because of earlier population growth. Figure 2 shows growth rates to 2100 for the U.N.'s high-, medium-, and low-variant projections. The 2050 medium-variant growth rate is 0.38%, implying a doubling time of about 175 years. The 2100 medium-variant growth rate is 0.05%, implying a doubling time of 1,400 years. Although these projections, especially when taken to 2100, must be interpreted with caution, it is clear that the world population growth rate is falling rapidly. These growth rates demonstrate why the world population is unlikely to reach 12 billion in the foreseeable future or even the unforeseeable future.

Why Was the Demography of the 1960s so Unusual?

Clearly, the last 50 years represent an exceptional period in demographic history. The 2% growth rates of the 1960s really were a population explosion by historical

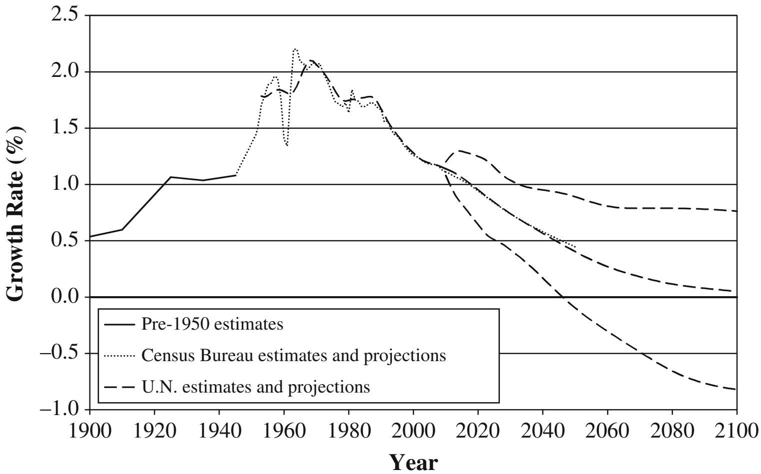

Fig. 2 Annual growth rate of world population, 1900 to 2100. The estimates before 1950 are rough estimates based on the U.S. Census Bureau's (2011) compilation of historical estimates. Estimates from 1950–2010 are taken from the U.S. Census Bureau (2010) and the United Nations Population Division (2011). Projections beyond 2010 are from the United Nations Population Division (2011)

standards, almost surely never seen before and never to be seen again. To understand the consequences of these growth rates, we first need to understand why they happened. This is best done with a quick tour through the demographic transition, which is fundamental to understanding what we've been through.[7]

It is beyond the scope of this article to discuss the demographic transition in detail, but a few points are important for an understanding of what caused the exceptional demographic history of the last 50 years. The demographic transition begins from a regime with high birth and death rates that are roughly equal, implying little or no population growth. The transition starts with a decline in death rates, resulting in a period of population growth. This is followed with some lag by a decline in birth rates, reducing the population growth rate. The transition ends with a new equilibrium characterized by low birth and death rates that are once again roughly equal, returning to low or zero population growth. This stylized description provides quite an accurate picture of the recent demographic history of most developing countries.

Figure 3 shows the case of Southeast Asia, a fairly typical pattern that demonstrates a number of key points (data are from U.N Population Division 2011). Southeast Asia had the highest population growth rate in the world in the 1950s, the result of rapid mortality decline that was already well underway. The crude death rate (CDR) in the 1950s was 23 per 1,000, well below the crude birth rate (CBR) of 45 per 1,000. It is important to keep in mind that these are simply births and deaths as a proportion of the total population and are very sensitive to the large changes in age structure that take place during the demographic transition. The rate of natural increase—the difference between the CBR and the CDR—was about 20 per 1,000, or 2% per year, in Southeast Asia in the early 1950s, reaching a peak of 2.5% in the 1960s. Rapid declines in the birth rate caused the growth rate to fall to 1.2% in 2010, a rate that is as high as it is only because of the continuing large numbers of women at childbearing ages. Reaching a gap between birth and death rates of 25 per 1,000 requires the unusual conditions that occur during that fairly brief period in which the death rate has fallen but the birth rate is still high. We see that this gap existed for only about a decade in Southeast Asia—roughly the 1960s—and is very unlikely to return.

One reason we won't see population growth of 2.5% again in Southeast Asia is that the CDR is already below 10 per 1,000, with little room to fall further. In fact, CDRs are leveling off or rising in most countries that are well advanced through the demographic transition. This is not because of a leveling off in life expectancy but is the result of population aging. Life expectancy actually increased by 8 years in Southeast Asia between 1985 and 2010, but the aging of the population meant there was only a slight decline in the CDR.

The demographic transition since 1950 for Latin America looks very similar to Southeast Asia in terms of magnitudes and timing, evidence of the similar demographic change across the developing world in the last 60 years.[8] South Asia

[7] I use *demographic transition* to refer to empirical patterns in birth rates, death rates, and population growth rates, as in Lee (2003). For a discussion of the demographic transition as a theory of demographic change, see Kirk (1996).

[8] The demographic transition for other regions and the world as a whole since 1950 are presented in Figs. A2 and A3 in Online Resource 1.

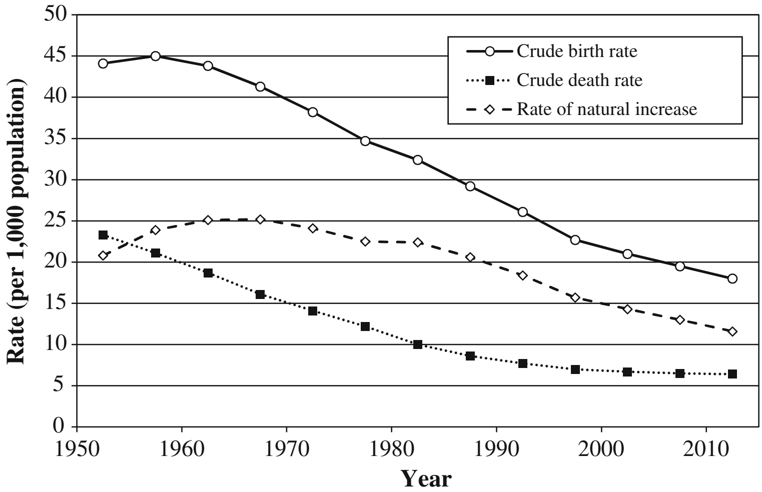

Fig. 3 Demographic transition, Southeast Asia. Data are from United Nations Population Division (2011)

is also quite similar, although its population growth peaked in the 1980s rather than the 1960s. Sub-Saharan Africa exhibits some important differences, however, with a later and slower fertility decline. In the 1950s, sub-Saharan Africa had a CBR of 48 per 1,000 and a CDR of 26 per 1,000, generating a natural increase of 2.2% per year. The CBR had declined to only 46 by the early 1980s, while the CDR had fallen to 17, generating the highest annual growth rates observed for any region—just under 3%. Sub-Saharan Africa has nonetheless experienced declines in fertility and a resulting decline in the population growth rate since the 1980s, with a current CBR around 36 and a CDR around 13, for an annual rate of natural increase of 2.4%.

The demographic transition for the world looks similar to that of Southeast Asia. The CDR was already well below the CBR in 1950. The gap between them increased to cause the 2% growth rate of the 1960s, and then narrowed to cause growth rates to fall. Trends in the CDR help explain why the world is unlikely to ever again see population growth rates of 2% per year. The current world CDR is about 8 per 1,000, permitting little room for further decline, with a leveling and an eventual increase projected as a result of population aging. The current world CBR is about 19 per 1,000. Reaching 2% annual growth, given current death rates, would require a CBR of 30 per 1,000, a rate last seen in the early 1970s.

Dramatic changes in age structure are an intrinsic feature of the demographic transition (Lee 2003) and are a key component of demographic change in the last 50 years. The rapid growth resulting from declines in infant and child mortality caused very young age structures in developing countries in the 1960s and 1970s. In 1975, the proportion of the population under age 15 was 40% in Brazil, 43% in Thailand, and 50% in Kenya, creating enormous pressure on schools. Declining fertility eventually caused declines in cohort size, reductions in the size of the school-aged population (Lam and Marteleto 2008a), and the "demographic dividend" of a population concentrated in working ages (Bloom et al. 2003). The current concentration of women at childbearing ages creates continued population growth even in countries with near-replacement fertility. Rapid growth of the elderly

population is already emerging as a challenge in many developing countries (Kinsella and Velkoff 2001).

What we learn from looking at the demographic transition from 1950 to 2010 is that the period of rapid population growth was relatively short and is quickly coming to an end. A doubling of world population in 40 years has never happened before and will almost surely never happen again. The concern that population was growing at unprecedented rates in the 1960s was unquestionably correct. However, the rate had already reached a peak by the mid-1960s, shortly before the publication of *The Population Bomb*, and was already beginning a rapid decline.

Three Big Concerns of the 1960s

Observers in the 1960s worried about a number of potential challenges created by rapid population growth. In this section, I focus on three of the most important areas of concern. First, and perhaps the biggest concern, was that we would not be able to feed everyone, especially in the poorest and fastest growing countries. Second, we were worried about depletion of many critical, nonrenewable resources. Third, we were concerned that levels of poverty, already high in Asia, Africa, and Latin America, would increase. In the subsequent sections, I address each of these three issues, drawing on data from a number of sources. As we will see, the big lesson is that the world survived the challenges of the population bomb amazingly well.

Food Production

Concerns that the population will grow faster than food production have been fundamental to the population debate since Malthus, who argued that while populations tend to increase geometrically (or, we would say, exponentially), food production increases only linearly. Because of this, these arguments suggest, population growth will eventually lead to starvation and will thus be checked by increased mortality (Lee 1997). Many pessimistic statements were made about the world's ability to feed the rapidly growing population in the 1960s. One famous quote from Paul Ehrlich in *The Population Bomb* reads, "The world, especially the developing world, is rapidly running out of food . . . . In fact, the battle to feed humanity is already lost, in the sense that we will not be able to prevent large-scale famines in the next decade or so" (Ehrlich 1968:36).

Figure 4 presents indices of population and food production from 1961 to 2009 for the world using the U.N. Food and Agriculture Organization's (FAO) food production index, with 1961, the first year of the index, set to 100 (FAO 2011).[9] Looking first at the period from 1961 to 1980, we see that the world did quite well in food production in the 1960s and 1970s. World population increased by 44% but food production increased by 59% from 1961 to 1980, resulting in per capita food production being 10% higher in 1980 than it was in 1961. I mention the 1961–1980

[9] The food production data are based on the production index for food from the FAOSTAT online database (FAO 2011), converted to a base of 1961=100. As of June 2011, the index covered the period 1961 to 2009. The population estimates are from the United Nations Population Division (2011).

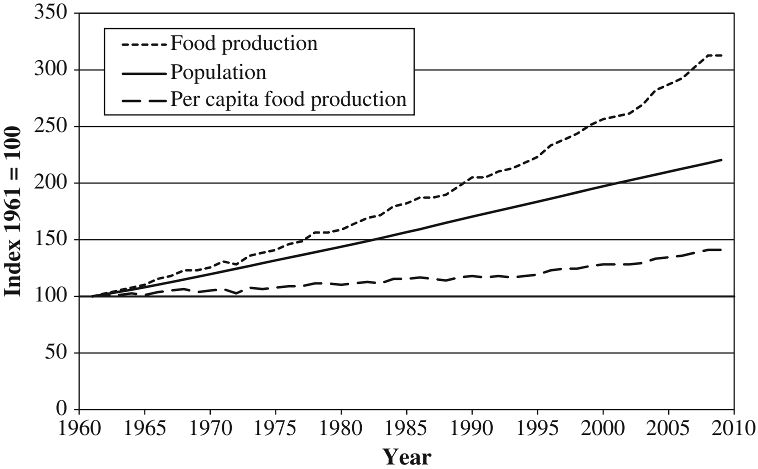

Fig. 4 World food production, 1961 to 2009. Data are from FAO (2011)

period first because concerns about food production continued to be voiced during this period, including some pessimistic predictions for the 1980s. Lester Brown argued in a 1981 *Science* article, "As the 1980s begin, the growth in world production is losing momentum and its excess over population growth is narrowing" (Brown 1981:1001). However, Fig. 4 shows no evidence of such a slowdown in the 1980s, and the growth of world food production continued to be impressive in the following decades. Food production in 2009 was 3.1 times its 1961 level, while population was 2.2 times its 1961 level, implying that that per capita food production increased 41% between 1961 and 2009.

These numbers are for the world as a whole. It might be argued that the real concern in the 1960s was with particular countries or regions. India was the focus of a great deal of concern in the 1960s and was a particular focus in Ehrlich's *The Population Bomb*. He quoted the agricultural economist Louis Bean, who said, "My examination of the trend of India's grain production over the last 18 years leads me to the conclusion that the present 1967–1968 production . . . is at a maximum level" (Ehrlich 1968:41). This was one of the reasons Ehrlich and others predicted mass starvation in India in the 1980s.

Figure 5 shows food production and population for India. Looking at the 1960s, we see that the pessimistic predictions for India had some basis. India's food production was fairly flat through the mid-1960s, with per capita production falling by 7% between 1961 and 1967. Around that time, Green Revolution hybrid seeds were first used, leading to large increases in yields in the late 1960s (discussed in more detail later in the article). Food production grew impressively in the 1970s and 1980s, and by 1990 was 2.3 times its 1961 level. India's population also grew rapidly during this period, reaching growth rates of 2.3% per year in the 1970s. Its 1990 population was 1.9 times the 1961 level. As a result, per capita food production declined in the 1960s, remained roughly flat in the 1970s, and then rose in the 1980s. Per capita food production in 1990 was 20% higher than its 1961 level.

There were concerns in the late 1980s that the impressive gains of the Green Revolution had played themselves out. In *The Population Explosion*, a 1990 sequel

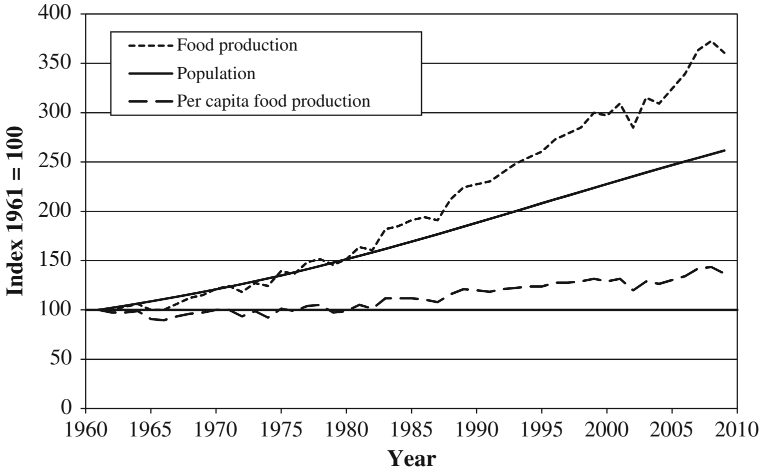

Fig. 5 Food production in India, 1961 to 2009. Data are from FAO (2011)

to *The Population Bomb*, Paul Ehrlich and his wife Anne Ehrlich made the following pessimistic forecast about Indian food production: "Since 1983, India's rising grain production has lost momentum . . . . the country appears to be facing a catastrophic problem in the 1990s" (Ehrlich and Ehrlich 1990:70). But as seen in Fig. 5, Indian food production continued to increase in the 1990s, growing at an average rate of 2.3% per year.[10] In 2009, Indian food production was 3.6 times its 1961 level, while population was 2.6 times its 1961 level. The net result is that per capita food production in 2009 was 37% above its 1961 level.

Looking at Fig. 5, it is important to note that there were bad years as well as good years. For example, 2002 saw a sharp decline in food production. One of the lessons of a 50-year record like this is not to focus too much on 1 or 2 years. The overall record of food production in India is one of impressive increases in output, far from the pessimistic predictions.

At the regional level, sub-Saharan Africa has lagged behind the rest of the developing world in both economic growth and fertility decline. Sub-Saharan Africa's record for food production is actually quite impressive, however. As shown in Fig. 6, its total food production in 2009 was 3.4 times the 1961 level, a larger increase than for the world as a whole during the same period. Africa's problem is that population increased even faster, with 3.6 times more people in 2009 than there were in 1961. Although per capita food production fell by about 7% since 1961, the African situation is far from being a total disaster. Food production has grown faster than population since about 1995, although the modest increase in per capita food production since then has not occurred fast enough to offset the declines of the 1970s and 1980s.

Before discussing other outcomes, it is worth noting the famous statement that "it's difficult to make predictions, especially about the future"—an observation that has been attributed to many people, among them Yogi Berra and Neils Bohr, and is

[10] The results shown here are for total food production, but the trend for grains is very similar. The FAO's cereals index grew at an average rate of 2.2% per year in the 1990s (FAO 2011).

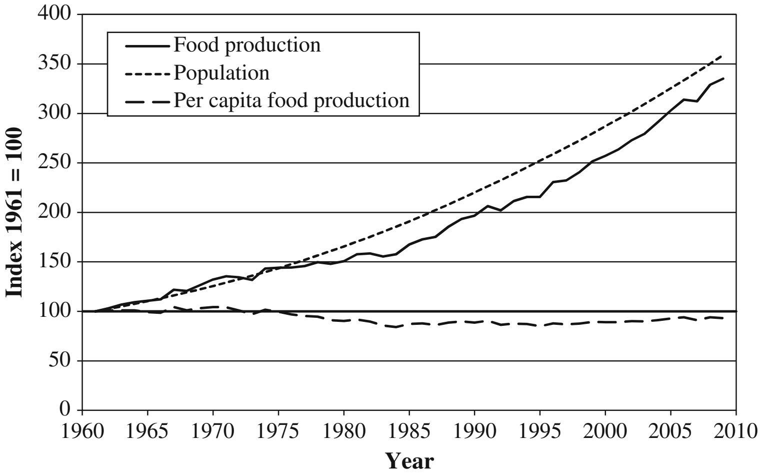

Fig. 6 Food production in sub-Saharan Africa, 1961 to 2009. Data are from FAO (2011)

relevant to this article. A corollary is that it is easy to look back and find inaccurate predictions, especially from 40 to 50 years ago. We can all be glad that we didn't make any predictions for others to look back and scrutinize. But, as we'll see in the next section, some people's predictions were a lot better than others'.

Resource Depletion

I now turn to the concern that rapid population growth would cause depletion of essential nonrenewable resources. To economists, the best place to look for evidence of increasing resource scarcity is in resource prices. Non-economists don't always agree with this view, but to economists, it's hard to develop a model in which a resource that is about to be depleted has a price that is declining, especially a resource owned by private individuals or governments. So in this section I will look at what's happened to resource prices during the last 50 years.

In discussing population and resource prices, it is useful to bring up Julian Simon. Simon, who died in 1998, regularly attended the annual meetings of the Population Association of America (PAA) when I started attending in the early 1980s. He was a gadfly, always taking provocative positions, and he had a substantial impact on the population-resource debate. His 1981 book, *The Ultimate Resource*, was filled with graphs of things like the price of coal and copper over time. The overall pattern was of falling prices, although with lots of short-term volatility. The cover of the paperback, second edition of *The Ultimate Resource* says "Every trend in material welfare has been improving—and promises to do so, indefinitely" (Simon 1996). You can't get much more optimistic than that. Simon is certainly the poster child for optimism about the world's ability to survive the population bomb. The "ultimate resource" of the book's title is human ingenuity, which Simon argued is never in short supply and always generates solutions to the pressures created by population growth.

The Ultimate Resource included predictions that were in many ways more audacious than the predictions Ehrlich and Brown made about food shortages.

Simon offered to bet that the price of any mineral would decline in the future (Simon 1981:27). Ehrlich and some Stanford colleagues famously took Simon up on his bet, choosing five metals—chromium, nickel, copper, tin, and tungsten—and the future date of 1990 (Tierney 1990). It was essentially a futures contract in which Simon bet that the amount of the five metals that could be purchased for $1,000 in 1980 would cost less than $1,000 in 1990, adjusting for inflation. They began with $200 worth of each metal. The inflation-adjusted price of each metal declined between 1980 and 1990. The amount of tungsten one could buy for $200 in 1980 cost $86 in 1990, adjusted for inflation. The amount of tin, copper, nickel, and chromium that could be bought for $200 in 1980 fell to $56, $163, $193, and $120, respectively. The total cost of the five metals fell from $1,000 to $618, a 38% decline. Ehrlich wrote Simon a check for the difference. It's worth remembering that world population increased by 28% during these 10 years, an addition of 830 million people.[11]

The big picture of commodity prices is a bit more complicated than this 10-year bet implies. Figure 7 tracks the real price of these five metals from 1960 to 2010, setting 1980 values at 100 (data are from Kelly and Matos 2010). The "average cost" is the inflation-adjusted cost of the $1,000 worth of metals in the Ehrlich-Simon bet, indexed to 1980 = 100. Prices rose in the 1960s and 1970s (the average almost doubled), perhaps the reason the Ehrlich team picked them. Prices fell in the 1980s (except for a spike around 1989), and fell still further in the 1990s. The bundle purchased for $1,000 in 1980 cost only $415 in 2000 (in 1980 prices). We also see a lot of volatility: these are traded in commodity markets with lots of speculation and short-term price movements. Figure 7 also shows the recent increase in commodity prices. Simon would have lost $200 if the bet had ended in 2007 (prices were about 20% higher than 1980), although evidence of the volatility is that he would have won $200 if the bet had ended in 2009 (prices were about 20% lower than 1980). The big picture is that these important nonrenewable resources cost about the same today as they did 50 years ago, despite the addition of 4 billion people.

Expanding the analysis from these five metals, Fig. 8 shows indexes for three broad sets of commodities: food, non-energy, and energy, taken from the World Bank Global Economic Monitor Commodity Indices (World Bank 2011). Much attention has been devoted to the spike in food prices in 2008 and 2010, and the general increase that began around 2005. It is striking, however, that food prices are about the same as they were in 1960. They were much higher in 1974, a result of the OPEC oil embargo. Food prices in 2000 were roughly half of their 1960 level, an important fact to put the recent increases in perspective. An index of all non-energy commodities, of which food is one component, looks very similar to the food price index. Energy prices are dominated by the rise of OPEC in the 1970s, followed by price declines in the 1980s, then large increases in recent years. Energy prices are so dominated by OPEC's market manipulations, however, that they provide little information about actual resource scarcity.

The big picture in commodity prices has something for both pessimists and optimists. For pessimists, there is the fact that non-energy prices more than doubled since 2000. For optimists, we have the fairly amazing fact that while world population doubled from 1960 to 2000, the price of non-energy commodities fell

[11] Ehrlich's perspective on this bet can be found in Ehrlich and Ehrlich (1996).

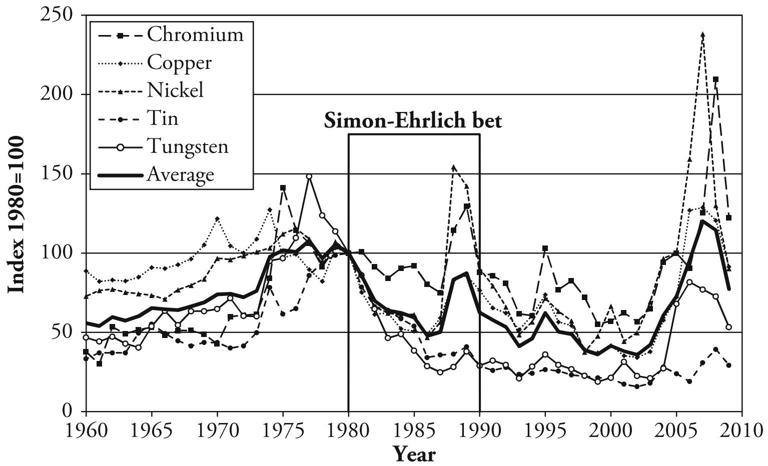

Fig. 7 Real prices of metals, 1960 to 2010. Data are from Kelly and Matos (2010)

almost 50%. These two facts roughly offset each other, with the price of non-energy commodities in 2009 almost exactly at its 1960 level.

Poverty

I now turn to the concern that rapid population growth would lead to increased poverty in low-income countries. The World Bank has invested considerable resources in trying to make consistent estimates of poverty across countries and across time, going back to 1981 (Chen and Ravallion 2010). Angus Deaton's 2010 presidential address to the American Economic Association (Deaton 2010) is a cautionary tale about comparisons of poverty across countries and about the World Bank's poverty line, but it leaves some room for believing that the World Bank's estimates of trends in poverty represent real trends.

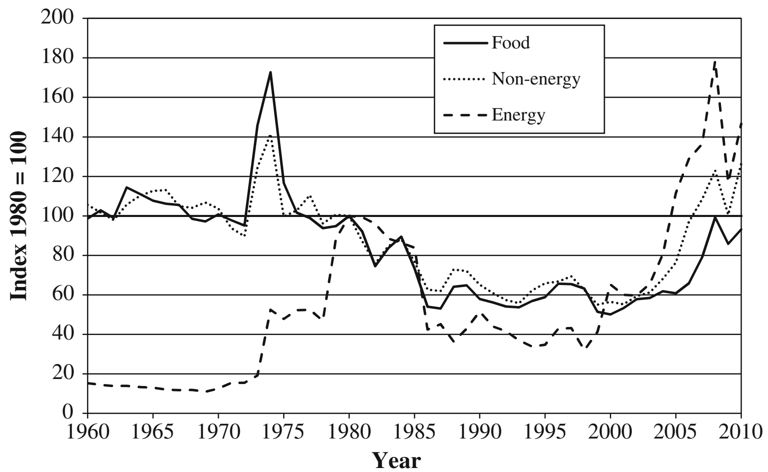

Fig. 8 World Bank index of real commodity prices, 1960 to 2010. Data are from World Bank (2011)

Figure 9 shows the World Bank's estimates of poverty from 1981 to 2005 for all low- and middle-income countries and for separate regions (Chen and Ravallion 2010). Using a poverty line of household per capita consumption of $1.25 per day, the World Bank estimates that the percentage of the population in poverty in low- and middle-income countries fell from 52% in 1981 to 25% in 2005. Based on a poverty line of $2.00 per day, there was a decline from 69% to 47% (see Fig. A4 in Online Resource 1). Large declines in poverty in China play a major role in the aggregate picture. If we leave out China, the poverty rate for all low- and middle-income countries fell from 40% to 28% (see Fig. A4).

The success in reducing poverty varies greatly by region, as seen in Fig. 9. The pattern for East Asia is dominated by the experience of China and shows a remarkable decline in poverty from 78% to 17% based on the $1.25 poverty line. Estimates for China separately show a decline from 84% in 1981 to 16% in 2005 (Chen and Ravallion 2010). Latin America had much lower poverty in 1981, at a little over 10%, and has had modest declines since then. Poverty in South Asia, dominated by the experience of India, declined from 59% to 40%. Estimates for India separately (not shown) indicate a decline from 60% to 42%. Sub-Saharan Africa has been less successful in reducing poverty, with a slight decline from 53% in 1981 to 51% in 2005.

Given the rapid population growth during this period, we might wonder whether the declines in poverty rates were large enough to cause a decline in the absolute number in poverty. For all countries at the $1.25 poverty line, the answer is yes. The absolute number in poverty is estimated to have declined from 1.9 billion in 1981 to 1.4 billion in 2005 (see Fig. A5 in Online Resource 1). Based on the $2.00 per day poverty line, the number increased until 1999 and then declined to about the same level in 2005 as it was in 1981. The large decrease in poverty in China once again has a big impact on the numbers. If we leave out China, the absolute number in poverty at the $1.25 poverty line increased from 1.1 billion in 1981 to 1.2 billion in

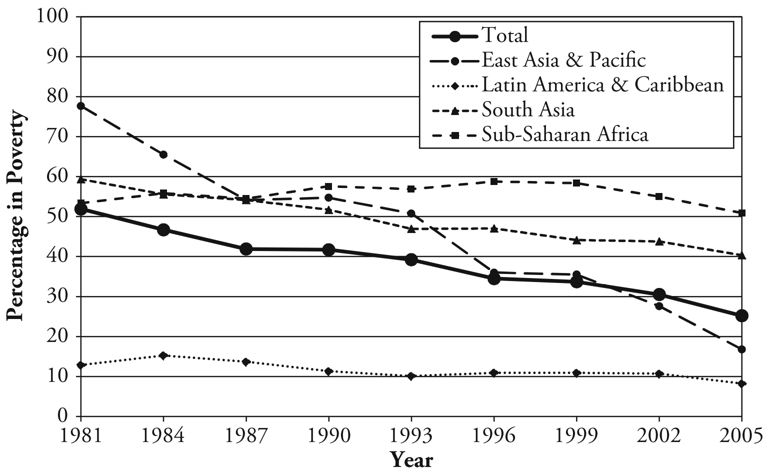

Fig. 9 World Bank estimates of percentage in poverty for all low- and middle-income countries and by region, poverty line per capita household consumption less than $1.25 per day, 2005 U.S. dollars. Data are from Chen and Ravallion (2010)

2005, although the recent trend is downward. Given the relatively constant poverty rate and rapid population growth in sub-Saharan Africa, the number living below the $1.25 per day poverty line in the region is estimated to have increased from 214 million in 1981 to 391 million in 2005.

How Did We Survive?

In the previous sections, I have tried to make the case that the world really did have a population explosion, that we are well through the worst of it, and that we have made it through in remarkably good shape, with increased per capita food production, declines in commodity prices during the period of most rapid growth, and declining rates of poverty. As I've noted, not every indicator is positive, and at the end of the article I will return to some of the challenges that remain. Still, it is surely worth marveling at the fact that we did not experience mass starvation given a doubling of world population in 39 years. So how did we do it? Obviously, many factors were involved. At the risk of greatly oversimplifying a complex period of rapid economic and social change, I will highlight six factors, three of which I have labeled economic and three of which I have labeled demographic. A common theme throughout this section is the adaptations made by individuals, firms, and policy makers in response to the pressures created by rapid population growth. Arguably the biggest mistake made by the pessimists of the 1960s was in underestimating the impact of these adaptations.

Economic Factors

I will begin by discussing the three economic factors, which I have identified as (1) market responses, (2) innovation, and (3) globalization. These are far from cleanly separable, but each captures some important economic forces that deserve credit for understanding how we survived the population bomb.

Market Responses

By market responses I mean things like the fact that when food prices go up, farmers grow more food. We have already seen evidence of market responses in the preceding discussion. The fall in the prices of the five metals in the Simon-Ehrlich bet is explained by factors such as cartels falling apart because of market pressures and producers switching to alternative materials. While the magic of the market may not seem all that magical in the current economic crisis, we should not lose sight of the powerful positive force the market can be. Economic agents all over the world, from small farmers to seed producers to clothing manufacturers to parents sending children to school, have responded to economic incentives created by population growth. In some cases, there have been dramatic changes in incentives, with exactly the results that economists would predict.

Consider the case of food production in Vietnam. Total food production in Vietnam in 2009 was 5.5 times its 1960 level (see Fig. A6 in Online Resource 1). Vietnam's population increased 2.6 times during the same period, implying that per

capita food production in 2009 was more than double its 1960 level. While many factors were involved in this success story, one of the most important is the market liberalization reforms that took place between 1981 and 1989. The well-known Doi Moi reforms began in 1986, but reforms that decollectivized farms and gave farmers more incentive to increase output began in 1981 (Che et al. 2006; Pingali and Xuan 1992). These reforms helped stimulate a huge increase in food production, with output more than doubling between 1990 and 2010. Vietnam went from one of the world's largest rice importers to the second largest rice exporter in the world (FAO 2011).[12]

Market reforms have also played a critical role in China, India, and many other countries. GDP has been growing at rates of 10% per year in China and 6%–7% per year in India, growth that has led to substantial declines in poverty. When we see growth rates of food output or GDP of 7% and 10% per year, it becomes clear how countries like Vietnam, China, and India outraced the Malthusian devil in recent decades. The point is not that population growth does not create challenges for economic development, but that these challenges can be overcome when forces like market liberalization lead to this kind of rapid economic growth.

Innovation

It's a bit arbitrary to separate innovation from market responses, since innovation is one of the most important kinds of market response. But I want to distinguish between what economists would call movements along a production possibility frontier—choosing among known technologies as prices change—and outward shifts of that frontier—developing new technologies that produce more from a given quantity of inputs. Food production is certainly one area where innovation has played a major role. Gale Johnson (2000:2) put it this way in his presidential address to the American Economic Association: "What made it possible for the world to escape from . . . the Malthusian trap? The answer is simple: the creation of knowledge."

There is no better poster child for innovation in agriculture than Norman Borlaug, the American agronomist often called the "father of the Green Revolution" and winner of the 1970 Nobel Peace Prize. Borlaug developed new varieties of wheat in Mexico in the 1940s, 1950s, and 1960s, taking them to India and Pakistan beginning in 1965.[13] The results of the hybrid varieties developed by Borlaug and others were spectacular. As Bongaarts (1996) pointed out, increased yields are by far the most important factor explaining increased food production, with increased cropland and crop frequency playing much smaller roles. FAO data can be used to analyze agricultural productivity per hectare of land since 1961 (FAO 2011). For the world as a whole, rice yields were 2.2 times higher and wheat yields were 2.8 times higher

[12] The latest milled rice exports by country from the FAOSTAT online database trade statistics are for 2008.

[13] For a history of Borlaug's life, see Hesser (2006). For overviews of the Green Revolution technologies, see Beddington (2010), Brown (1970), Cohen (1995), Dyson (1996), Evenson and Gollin (2003), and Glaeser (1987).

in 2009 than in 1961 (see Fig. A7 in Online Resource 1). In India, rice yields made impressive increases, although not quite as fast as the rest of the world. Wheat yields, however, increased even faster in India than in the rest of the world, with yields increasing 60% between 1967 and 1972, the early years of Borlaug's high-yield wheat, and more than tripling between 1961 and 2009.

Data on yields provide evidence for pessimists as well, however. Yields have leveled off since 1990, and especially since 2000. And the Green Revolution has certainly had its critics. The high-yield hybrid seeds require intensive use of fertilizers and irrigation, raising concerns about environmental consequences such as soil degradation, aquifer depletion, and chemical pollution (Cohen 1995; Evenson and Gollin 2003). Recent problems in food production and rising food prices have been the focus of influential articles in publications such as *The Economist* (2011) and the *New York Times* (Gillis 2011). Many factors affect current food prices, some of them with disturbing implications for the future. There have been major crop failures in recent years in several countries, possibly related to global warming (Beddington 2010). Increased demand for meat in fast-growing countries like China is also playing a role, as is the diversion of 30% of the U.S. corn crop into ethanol for automobiles (Beddington 2010; *The Economist* 2011).

Looking back, we can see that impending famine in India, Pakistan, and other countries was a legitimate concern in the mid-1960s. It is understandable that the dramatic increases in crop yields following the introduction of Green Revolution varieties around 1967 seemed almost miraculous at the time, producing recognition such as Borlaug's 1970 Nobel Peace Prize. It's important to recognize that these new varieties and the technology that accompanied them did not just appear overnight. They were the result of decades of research supported by major funding from the Rockefeller Foundation, the U.S. government, and other organizations (Evenson and Gollin 2003; Hesser 2006). The lesson from the great success in food production in the last 50 years is not that we should be complacent and assume that current pressures on food supply will take care of themselves, but rather that we need to recognize the challenges and invest in the research and sound public policy necessary to meet those challenges.

There have also been many other innovations in the last 50 years: computers, cell phones, the Internet, and more efficient ways of producing almost everything. Although some of these innovations were the result of good luck, many of them were a response to population growth and actual or anticipated resource pressures. The idea that population growth would induce technological change has been suggested by, among others, Boserup (1981) and Simon (1986). Lee (1988) presents a formal model synthesizing this "Boserup" effect with standard Malthusian diminishing returns, and Kremer (1993) found empirical evidence that larger populations lead to faster technological change using historical population data. Many of the innovations of the last 50 years, including Green Revolution innovations in agriculture, are arguably examples of population-induced technological progress. These innovations are also part of the market response. There is a lot of money to be made in selling high-yield variety seeds and a lot of money to be made by farmers in growing them. Although the many technological advances of the last 50 years do not guarantee that we will come up with equally successful innovations in the future, they are certainly a reason for optimism.

Globalization

The third economic factor I want to highlight is globalization: the increased economic integration of countries through international flows of goods and capital. Globalization has many critics, but there is no question that it has led to increased efficiency in production and distribution.[14] World Bank data on exports and imports show that exports as a percentage of GDP more than doubled between 1960 and 2008 in high-income countries, rising from 12% to 29%, declining recently with the global recession (see Fig. A8 in Online Resource 1).[15] The increase was even larger in low- and middle-income countries, where exports as a percentage of GDP more than tripled between 1970 and 2008, from 10% to 33%. This is a big change from the protectionist policies many of these countries had in the 1960s. Increased trade is linked to increased fragmentation of production (Jones et al. 2005). A single product may now use components from all over the world. This has lowered the costs of products while also shifting jobs to places like India and China, a key factor driving poverty reduction in those countries. While not all countries have benefited from globalization, some of the big winners have been the very countries we were most concerned about in the 1960s.

India is in many ways the embodiment of all of the economic factors I have discussed. In the 1960s, it was the focus of many of the concerns about the potential for disastrous consequences from rapid population growth, including mass starvation. As we have seen, the actual experience was very different, with food production growing faster than the population and with rapid economic growth leading to significant declines in poverty. India was one of the primary beneficiaries of innovation in the form of Green Revolution agriculture and the development of computers and the Internet as a vehicle for economic growth in international provision of services. It is also an excellent example of the success of market reforms in producing rapid and sustained economic growth. Finally, India has benefited greatly from globalization, with its call centers and software industry being some of the best-known examples of globalization in the service sector.

Demographic Factors

Demographic change has also played a key role in explaining how the world survived the population bomb. I focus on three demographic factors: (1) urbanization, (2) fertility decline, and (3) investment in children. Although investment in children is closely linked to fertility decline, I will discuss it as a factor in its own right because of its fundamental importance.

Urbanization

The world in 2011 is much more urban than it was 50 years ago. The 4 billion people that have been added to the world since 1960 have mainly been absorbed in

[14] For a broad discussion of the debate regarding globalization, see Bhagwati (2007) and Stiglitz (2002).

[15] Data on exports of goods and services as percentage of GDP are taken from World Development Indicators in the World Bank's online World DataBank (World Bank 2011). Data on imports for these large aggregates of countries look almost identical.

urban areas. Figure 10 shows U.N. projections of urban and rural populations to 2150.[16] The medium-variant estimate for the total population, as noted earlier, reaches 9.3 billion in 2050. The urban population is projected to reach 6.4 billion, or 69% of the total. The rural population was overtaken by the urban population around 2009, and is projected to decline after 2020. Of the 4 billion more people in the world in 2011 compared with 1960, 65% are in towns and cities.

The population explosion, then, has mainly been absorbed in cities and towns, not in rural areas. This is partly because rural areas grew to become urban. But it's also because of rapid rural-urban migration, a response by individuals to the economic and educational opportunities in cities and the decreased need for rural labor as a result of increased agricultural yields. Urbanization is one of the challenges of population growth, but it is also one of the important ways that the world was able to absorb a doubling in 40 years without mass starvation or increased poverty. Why did putting people in cities help us survive the population bomb? Economist Edward Glaeser's (2011) recent book, *The Triumph of the City*, argues that cities are one of our greatest inventions, allowing us to make and trade things more efficiently and to interact with others to develop new ideas. Similar points are made in the National Research Council's overview of urbanization in developing countries (Panel on Urban Development, National Research Council 2003). Cities have been fundamental to economic progress in the last 50 years, and most low-income countries would do well to encourage rather than discourage increased urbanization.

Fertility Decline

Fertility decline was obviously fundamental to surviving the population bomb, since it is the reason world population growth has declined rapidly since the 1960s. Figure 11 shows U.N. estimates of the total fertility rate (TFR) for the world and major developing regions. The decline in the world TFR is quite remarkable, falling from 5.0 births per woman during her lifetime in the early 1950s to 2.5 births in 2010. This is a decline of 50%. If, as my late colleague Ronald Freedman liked to do (Freedman and Blanc 1992), we make the benchmark not zero but replacement fertility of 2.1, the decline is 85% of the decline necessary to reach replacement fertility.

Looking at the TFR for different regions in Fig. 11, East Asia, led by China, had the largest declines, falling to below replacement fertility by the 1990s. Latin America and Southeast Asia had declines almost as fast, both having a TFR in 2010 of around 2.3. The TFR in South-Central Asia, dominated by India, fell to 2.8 by 2010. Africa has had a later and slower decline, with a TFR around 5 in 2010. The period from 1960 to 2010 was surely the fastest fertility decline the world will ever see. With the important exception of Africa, women in developing countries moved from having around six births during their lifetime to having closer to two births. This fertility decline alone would make the last 50 years one of the most exceptional periods in demographic history, even in the absence of the historically unprecedented population growth.

[16] These combine the proportions rural and urban in the most recent U.N. urbanization projections (United Nations Population Division 2009) with the 2010 population projections (United Nations Population Division 2011).

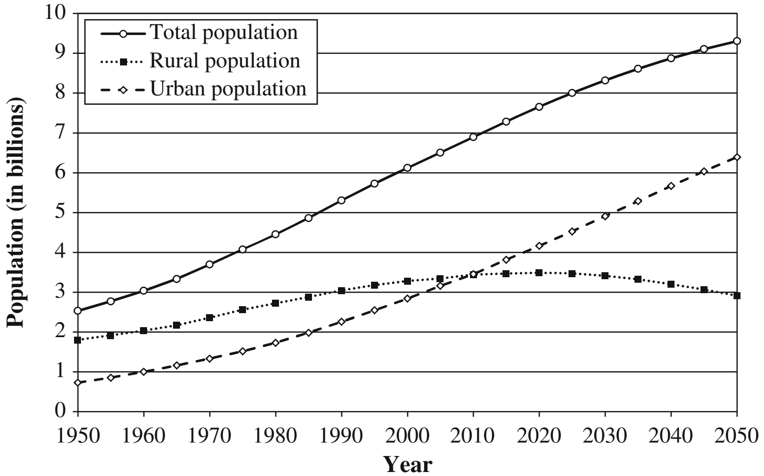

Fig. 10 Estimated and projected urban and rural population in billions, world, 1950–2050. Data are from United Nations Population Division (2009, 2011)

Why Did Fertility Fall so Rapidly?

How do we explain this rapid fertility decline? Many distinguished researchers have contributed to answering the question, and there is no single answer or clear consensus. One of the most important factors is surely the rapid declines in infant and child mortality that were the main cause of the population explosion. As Karen Mason (1997) argued in her 1997 PAA presidential address, mortality decline is fundamental in understanding fertility decline. The fertility response to falling infant mortality was surprisingly fast, taking place in most countries within one generation. In this sense, the cause of the population explosion also helped bring about its end.

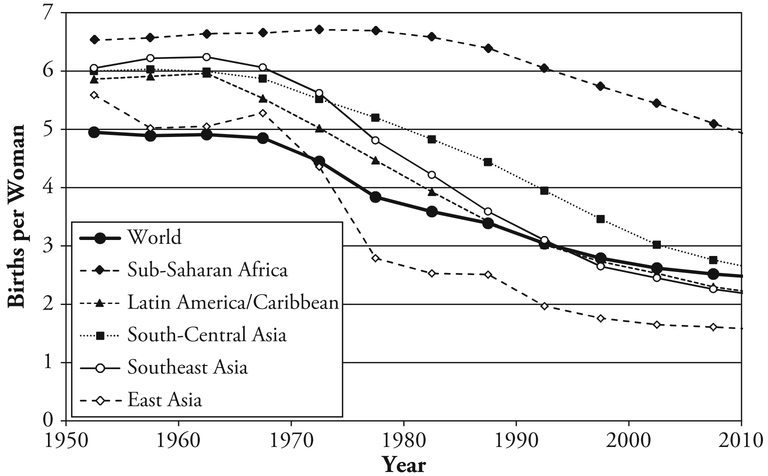

Fig. 11 Total fertility rate for world and regions, 1950–2010. Data are from United Nations Population Division (2011)

Declining infant mortality caused populations to grow, but it also helped drive the fertility reductions that brought growth rates back down.

Although mortality decline is fundamental in understanding the fertility decline of the last 50 years, it is certainly not the whole story. Many would argue that access to contraceptives and family planning programs was essential for women to achieve a goal of smaller families. Others, especially economists, would focus on determinants of the demand for children, including income, wages, and the education and employment opportunities of women.

One approach to the question of what caused the fertility decline is to look at whether it resulted from a decline in women's desired fertility or from women's improved ability to achieve their desired family size. The latter emphasizes the role of increased access to contraceptives, while the former emphasizes the role of change in the demand for children. One way of looking at the issue is Lant Pritchett's (1994a) comparison of total fertility rates with various measures of wanted or desired fertility.[17] Pritchett's paper used World Fertility Surveys and Demographic and Health Surveys (DHS) from the 1970s and 1980s. We now have much more data covering a longer period of time.[18]

Table 1 shows the TFR along with the "wanted total fertility rate" developed by Bongaarts (1990), using 185 DHS surveys for 74 countries (Demographic and Health Surveys 2011), a much larger set of surveys than Pritchett used. The wanted fertility measure counts only births of women who say they want another birth, with an adjustment for incomplete childbearing. Note that it is not a question about "ideal family size," and it is not based on *ex post* statements about children being wanted. It assumes only that women who want more children must have wanted all their previous children. Column 1 shows the means for both variables, with the mean TFR almost exactly 1 birth higher than the mean wanted TFR. In other words, on average, about one birth in the TFR for each country is due to unwanted fertility. The regression coefficients in column 1 are almost identical to Pritchett's earlier results (as is the scatterplot, shown in Fig. A9 in Online Resource 1). Pritchett's interpretation was that while there is unwanted fertility in virtually every country, the variation in the TFR across countries is almost entirely explained by variation in wanted fertility. The regression coefficient implies that a one-birth increase in wanted fertility leads to a 0.98 increase in the TFR. The R^2 implies that 83% of cross-country variation in the TFR is explained by cross-country variation in wanted fertility. In other words, while unwanted fertility exists almost everywhere, there is little evidence that some countries have higher fertility because they have a larger gap between actual fertility and wanted fertility.

When Pritchett wrote his paper, only a few countries had more than one DHS, so it wasn't possible to look systematically at the relationship between changes in wanted fertility and changes in actual fertility. With the wealth of DHS data in the last 20 years, we can look more directly at changes in fertility. The means and regression coefficients based on annual changes are in column 2 of Table 1 (the

[17] Pritchett's paper generated considerable debate. See, for example, Bongaarts (1994), Casterline and El-Zeini (2007), Knowles et al. (1994), and Pritchett (1994b).

[18] This section has benefited from helpful discussions with John Casterline, who also provided his estimates of the fertility measures used here.

Table 1 Ordinary Least Squares (OLS) regressions of total fertility rate (TFR) on Bongaarts's wanted TFR using Demographic and Health Surveys

	Level (1)	Annual Change (2)
TFR, Mean (SD)	4.45	−0.060
	(1.49)	(0.076)
Wanted TFR, Mean (SD)	3.47	−0.038
	(1.39)	(0.063)
Number of Observations	185	111
Number of Countries	74	48
OLS Intercept (SE)	1.067	−0.028
	(0.122)	(0.006)
OLS Slope Coefficient (SE)	0.976	0.829
	(0.033)	(0.085)
R^2	.830	.466
Predicted Mean	3.39	−0.031
Predicted Mean/Actual Mean	0.76	0.53

scatterplot is shown in Fig. A10 in Online Resource 1). The first thing to note is that while wanted fertility declined by an average of 0.038 births per year, the TFR declined by 0.060 births per year. Clearly, changes in wanted fertility cannot explain all of the change in the TFR. The regression coefficient implies that a one-birth decline in wanted fertility is associated with a 0.83 decline in actual fertility. This is reasonably close to 1, providing support for Pritchett's argument that changes in wanted fertility drive fertility decline. But many countries experienced fertility declines that were considerably larger than their declines in wanted fertility. Given the mean annual decline in wanted fertility of 0.038 and the regression coefficient of 0.829, the predicted decline in the mean TFR is 0.031, 53% of the actual decline.[19]

The analysis of changes in fertility gives a considerably different picture than we saw in the cross-sectional relationship between wanted fertility and actual fertility. Declines in wanted fertility explain 53% of the mean decline in TFR. The remaining 47% of the decline occurs without any change in wanted fertility, implying that women are now better able to reach their fertility targets. This could be due to improved family planning services, although a closer match between wanted fertility and actual fertility could occur without any change in access to family planning. It could indicate that women are better able to use the services that were previously available, perhaps because of increased education. It could also occur if women feel more strongly about their stated fertility objectives in more recent surveys, an indication of how difficult it is to disentangle fertility desires from the ability to meet those desires.

[19] Or, equivalently, the intercept of −0.028 means that 47% (0.028 / 0.060) of the decline in the TFR would have occurred in the absence of any decline in wanted fertility. Using the Casterline and El-Zeini (2007) measure of wanted fertility to decompose fertility change into a wanted and unwanted component for 44 countries, Casterline (2010) found that the median estimate is that 46% of the decline is due to a decline in wanted fertility, a result roughly consistent with the results in Table 1.

While economists have emphasized demand-side determinants of fertility decline, with considerable supporting evidence, it is certainly consistent with economic models of fertility that women would take advantage of being better able to control their fertility. Joshi and Schultz (2007) showed that the Matlab family planning program not only reduced fertility in Bangladesh but also improved the lives of women and their children up to 20 years later. In Brazil, on the other hand, family planning programs seem to be a very minor factor explaining that country's rapid fertility decline (Lam and Duryea 1999; Martine 1996; Potter et al. 2002). There is obviously no one explanation for the incredible fertility decline of the last 50 years. In terms of understanding the enormous economic progress of the last 50 years, one key dimension of the fertility decline is that it has gone hand in hand with increased investments in children.

Investment in Children

I have listed investment in children as a third demographic factor explaining how we survived the population bomb. This is arguably just as much economic as demographic, and it is inextricably linked to fertility decline. It is so fundamental, however, that it merits discussion in its own right. In documenting the accomplishments of the last 50 years, I might well have included increases in education. To give just two examples, Fig. 12 shows the percentage of each cohort with primary schooling in Brazil and Thailand, using 2000 census data (via IPUMS-International; Minnesota Population Center 2011). Each cohort is plotted against the year it was age 10, roughly matching the years it was in primary school. In Thailand, the percentage of males with primary schooling rose from 18% in 1950 to 95% in 1990 (the 1980 birth cohort, the last cohort with complete schooling data in the 2000 census). Female schooling increased even more, starting at a primary completion rate of 7% in 1950 and catching up to the 95% rate of males by 1990. During the 1960s,

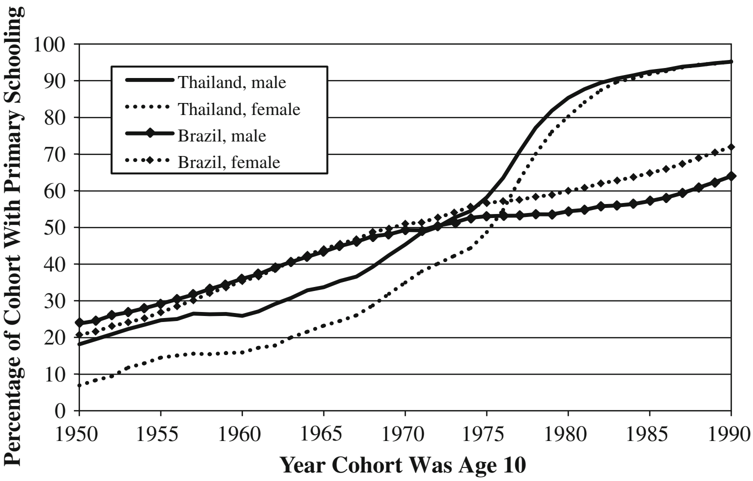

Fig. 12 Percentage of cohort with primary schooling, by year cohort was age 10, Thailand and Brazil. Three-year moving averages based on 2000 census data accessed via IPUMS-International (Minnesota Population Center 2011)

the population aged 7–14 was growing as fast as 4.5% per year, doubling between 1950 and 1970.

Brazil's education performance was not as good as Thailand's, but it was still impressive. The percentage of males completing primary school rose from 20% in 1950 to 64% in 1990. Female schooling increased even more and surpassed male schooling in the 1960s, with more than 70% of girls completing primary school in 1990. During much of this period, the school-aged population grew at a rate of 3%–4% per year. The population aged 7–14 almost doubled between 1960 and 1990, a period in which the proportion of girls finishing primary school more than doubled.

We find similar patterns all over the world. Even in Kenya, a country with disappointing economic performance and slow fertility decline, the percentage of girls finishing primary school increased from 9% in 1950 to 71% in 1990, eliminating the gender gap. This is especially impressive considering that half of Kenya's population was under 15 in the 1970s. This is one of the most remarkable accomplishments of the last 50 years—providing more and more schooling at a time when the number of children was growing at historically unprecedented rates. It is also important to point out that these increases in schooling, especially for women, are likely to produce further declines in fertility and increased investment in children in the future, given the considerable evidence that better-educated women have lower fertility and invest more in children's health and education (Lam and Duryea 1999; Schultz 1993).

Why Did Schooling Increase so Rapidly?

We don't have a Norman Borlaug of education to point to in explaining how schooling increased so much during a period in which school-age populations were growing by 3%–4% per year. Many actors get the credit: governments building schools and hiring teachers, parents sacrificing to send their kids to school, and young people doing their homework and staying in school. Market incentives also play an important role, since the returns to schooling in both earnings and employment have been very high in most countries.

Evidence from South Africa illustrates the determination of young people and their families to become educated. I've been involved in the Cape Area Panel Study (CAPS), an NICHD-funded longitudinal study of young people in South Africa conducted in collaboration with researchers at the University of Cape Town (Lam et al. 2008). Although South Africa's young people face many challenges, an important finding in CAPS is the persistence of young people in trying to finish secondary school. As an illustration, we find high enrollment rates among black (African) respondents aged 18 and older who have not yet finished secondary school. In 2005, 67% of black 19-year-olds, 45% of 20-year-olds, and 30% of 21-year-olds who had not completed grade 12 were still enrolled in secondary school (see Fig. A11 in Online Resource 1). This is not an entirely positive picture. Results from CAPS demonstrate the problems with the high rates of grade repetition that delay completion of secondary school (Lam et al. 2011), including the problems caused by having 21-year-olds in the same grade as 16-year-olds (Lam et al. 2009). But the good news is that young people show incredible persistence in trying to complete secondary school. As further evidence, 60% of our 18-year-old female respondents

with a child were enrolled in secondary school. Our results suggest that these young people are doing the right thing: finishing secondary school substantially increases earnings and the probability of finding a job (Lam et al. 2010a,b). South African youth clearly understand these incentives and respond by staying in school.

One reason schooling increased so much during a period of rapid growth in the school-age population is declining family size. As Letícia Marteleto and I have shown, many countries in recent decades experienced declines in the family size of school-aged children simultaneously with increases in the size of the school-aged population (Lam and Marteleto 2008a). Family size fell because of declining fertility, while cohort size grew because of population momentum—that is, the growing numbers of women of childbearing age due to earlier population growth. It is the link between declining family size and increased schooling that I believe is fundamental.

The Transition From Quantity to Quality

Declining fertility and increased investments in children go hand in hand. A key point I want to emphasize is that the shift from couples having large families and making small investments in their children to having small families and making large investments in their children is one of the fundamental dimensions of economic development. This is one of the most dramatic changes of the last 50 years, and it is essential in understanding how we survived the population bomb. Economists think of this as trading quantity of children for quality of children, drawing on the pioneering theoretical work of Gary Becker (Becker and Lewis 1973) and Robert Willis (1973).

Several factors influence this shift. Declining infant mortality makes it rational to invest heavily in a small number of children. Rising incomes lead couples to increase their demand for "high-quality" children with good health, lots of schooling, and high consumption, a goal achieved by having fewer children. Suzanne Duryea and I have argued that increased education gives parents greater ability to produce well-endowed children, inducing a switch from quantity to quality, an argument for which we found strong empirical support in Brazil (Lam and Duryea 1999).

A quantity-quality model assumes that fertility and children's education are outcomes of the same decision process, making it impossible to interpret one as causing the other. With that important caveat, it is interesting to look at the relationship between family size and children's schooling during the demographic transition in Brazil. In Fig. 13, I use census data for Brazil to look at the relationship between the schooling of 16- to 17-year-olds and the number of children ever born to their mothers. I focus on 16- to 17-year-olds because they are old enough to exhibit considerable variation in schooling but young enough to be living with the mothers, allowing us to have data on their mother's fertility. The vertical axis is years of schooling of 16- to 17-year-olds. The horizontal axis is the number of children born to their mother—the family size experienced by the child. The figure shows a significant negative relationship between schooling and family size. Looking at the 1960 census, children whose mother had two children had 4 years of schooling, while children whose mother had nine children had 2 years of schooling. The negative relationship between family size and children's schooling is

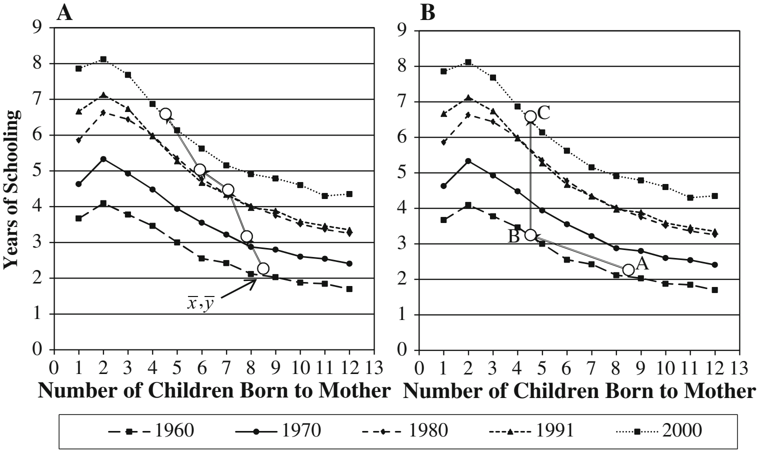

Fig. 13 Years of schooling of 16- to 17-year-olds, Brazil, 1960–2000. Estimates based on census data for each year accessed via IPUMS-International (Minnesota Population Center 2011)

fairly similar across years, with the slope becoming somewhat more negative over time. Increased schooling in Brazil clearly involves more than just reductions in family size, however. For example, children with 10 siblings in 2000 had more schooling than children with 1 sibling in 1960.

It is instructive to look at mean family size and mean schooling in every year, shown by the $\bar{x}$, $\bar{y}$ dots in Panel A of Fig. 13. The dot for 1960 shows that mean family size was 8.5 and mean schooling was 2.3 years.[20] Looking at the combination of mean family size and mean schooling for each year, the movement up and to the left shows that family size decreased and schooling increased over time. Schooling of 16- to 17-year-olds increased by 4.3 years between 1960 and 2000, while their family size fell by four children. Brazil has moved from large families in which children received little schooling to small families in which children receive considerably more schooling.

Increased schooling is not simply due to couples having smaller families, however. We can compare movements along the curves, indicating that children in smaller families get more schooling, with upward shifts of the curves, indicating that children of a given family size get more schooling over time. This approach is shown in Panel B of Fig. 13. If we take the curve for 1960 and move everyone to the 2000 mean family size of 4.5 (moving from Point A to Point B), schooling increases by about 1 year, about 25% of the overall 1960–2000 increase. When we then shift up to the 2000 curve (moving from Point B to Point C) schooling increases by 3.3 years, about 75% of the 1960–2000 increase. So a simple decomposition is that smaller family size accounts for about 25% of increased schooling between 1960 and 2000, with the remaining 75% due to a host of factors affecting both schooling supply and schooling demand.

[20] If it seems odd that mean family size was 8.5 at a time when the TFR was about 6, the explanation is provided in Sam Preston's classic paper on family size of women and family size of children (Preston 1976). As Leticia Marteleto and I have shown, a good rule of thumb is that the mean family size for school-age children is about 40% larger than the TFR around the same time (Lam and Marteleto 2008b).

The increase of 4.3 years of schooling for 16- to 17-year-olds in Brazil between 1960 and 2000 is a substantial increase, especially in light of the rapid growth of the school-aged population during this period. Schooling growth in many other countries was even more impressive, with a general pattern in the developing world of today's young people being much better educated than their parents. This improvement in education helps explain the economic progress of the last 50 years and is another reason for optimism about the decades to come.

Have We Really Survived?

In the preceding sections, I provided evidence of a number of positive—in many ways remarkably positive—developments during the last 50 years. Many of these can be viewed as direct responses to the pressures and incentives created by declining mortality and rapid population growth. There are many less-positive trends that I have not discussed, however, including environmental problems such as climate change. Although it is impossible to do justice to the many complex environmental challenges we currently face, I will briefly touch on a few issues.

Global Warming and Pollution

Looking at one piece of evidence on global warming—mean global annual temperature—recent temperatures are 2 degrees Fahrenheit above their 1880–1920 level, with about a 1-degree increase since 1980 (Fig. A12 in Online Resource 1).[21] It is beyond the scope of this article, to discuss global warming in detail, but two points deserve emphasis. First, it is no surprise to economists that some things have worked out better than others as world population has increased. In domains with ownership of resources and well-functioning markets, as with food and most other commodities, market pressures and price signals induce increased supply, behavioral change, and innovation extremely well. In domains without markets and resource ownership, problems are much more likely. With a few exceptions, there is no cost to polluting the air or oceans—no market mechanism to make polluters bear the costs of the externalities they impose on their neighbors or the world. This was a key conclusion of the 1986 National Research Council Working Group on Population Growth and Economic Development: population growth is more likely to create environmental damage when externalities are important (National Research Council 1986). As the report pointed out, the problem is not population growth *per se*, but the fact that environmental resources are common property. The challenge is to find solutions that address the problem of externalities.

Second, there are some environmental success stories. Sulfur dioxide emissions, the major cause of acid rain, increased from 1900 until about 1970 in the United States (data based on Smith et al. (2011) are shown in Fig. A13 in Online Resource 1). Emissions decreased sharply starting around 1970 because of better technology, use of lower-sulfur coal, and regulation. The 1990 Clean Air Act created the Acid

[21] These data are from the U.S. National Aeronautics and Space Administration's Goddard Institute for Space Studies (NASA 2011).

Rain Program, a very successful market-based cap-and-trade system. The result is that U.S. sulfur dioxide emissions in 2005 were less than half their 1970 level and were below the 1910 level. Another success story is the massive reductions in chlorofluorocarbons (CFCs)—a leading cause of the hole in the ozone layer—resulting from the 1987 Montreal Protocol (Guus et al. 2007). These examples must, of course, be weighed against the many environmental problems with which we have not achieved similar successes. But they do suggest that environmental problems do not always get worse and that there are frameworks for solutions in the presence of adequate commitment.

Are Consumption Levels Sustainable?

Rising incomes in countries like China and India have increased the demand for food, automobiles, air conditioning, and the kinds of consumption that have contributed to the high commodity prices and environmental challenges we currently face. With more than 2 billion people in China and India alone, and with consumption levels in these countries sure to increase in the future, many are understandably worried about whether the world's level of consumption is sustainable. There is no question that these are difficult challenges and that we will need the creativity of many future Norman Borlaugs to meet them. I do not want to minimize the magnitude of those challenges. But I do want to emphasize how amazing it is that in 2011 we are worried about the problems resulting from such rapid increases in consumption in India and China. Imagine someone writing in 1961 that in 50 years we would be worrying about how fast per capita consumption is growing in India and China, rather than worrying about mass starvation in those countries.

Conclusions

There is much to worry about in the coming decades. Between 2011 and 2050, the world will add 2 billion people, the equivalent of two more Indias. Evidence of flattening crop yields, increasing food prices, and climate change provides plenty of cause for concern. But the lesson of the last 50 years is that the world survived challenges that were in many ways much more daunting. Instead of adding 2 billion people in 39 years, we added 3 billion people in 39 years. Rather than the 30% increase that's projected between 2011 and 2050, we increased by 100% between 1960 and 1999. The world is projected to reach 10 billion people by 2083. The challenge of adding 3 billion people in 72 years seems somewhat less challenging when we keep in mind that we added 3 billion people in 39 years between 1960 and 1999, an increase of 100% rather than the 43% from the next 3 billion.

We have seen that during the last 50 years of historically unprecedented population growth, we experienced substantial increases in food production per capita, declines in resource prices during the period of most rapid growth, and decreases in poverty rates in developing countries. School-age populations grew faster than they will ever grow again, yet we saw the largest increases in schooling we'll ever see. Given all this, I remain in the camp of the optimists. I'm sure that by

the time of the 2050 PAA annual meeting, the world will still face important challenges, but I also expect that it will have improved in many ways, including lower poverty rates, higher levels of education, and plenty of food to go around. I'm optimistic not because the problems posed by continued population growth are simple or because they will take care of themselves, but rather because the last 50 years have demonstrated our capacity to recognize the challenges and to tackle them with hard work and creativity. I'm confident that the members of PAA will continue to make important contributions to these efforts by collecting the data necessary to track demographic and social change, by rigorously analyzing those data, and by having lively debates about what the results mean.

Acknowledgments This is a revised version of the presidential address presented at the annual meeting of the Population Association of America on April 1, 2011, in Washington, D.C. The article draws on previous work, including Lam (2005), Lam and Duryea (1999), and Lam and Marteleto (2008a). Excellent research assistance was provided by Kendra Goostrey and Laura Zimmermann. Valuable comments were provided by many of my colleagues at the University of Michigan and by two anonymous reviewers. Financial support for the research that is presented here was provided by the Eunice Kennedy Shriver National Institute of Child Health and Human Development, the William and Flora Hewlett Foundation, and the Andrew W. Mellon Foundation.

References

Becker, G. S., & Lewis, H. G. (1973). Interaction between quantity and quality of children. *Journal of Political Economy, 81,* S279–S288.

Beddington, J. (2010). Food security: Contributions from science to a new and greener revolution. *Philosophical Transactions of the Royal Society B: Biological Sciences, 365,* 61–71.

Bhagwati, J. (2007). *In defense of globalization* (2nd ed.). New York: Oxford University Press.

Bloom, D., Canning, D., & Sevilla, J. (2003). *The demographic dividend: A new perspective on the economic consequences of population change*. Santa Monica, CA: RAND.

Bongaarts, J. (1990). The measurement of wanted fertility. *Population and Development Review, 16,* 487–506.

Bongaarts, J. (1994). The impact of population policies: Comment. *Population and Development Review, 20,* 616–620.

Bongaarts, J. (1996). Population pressure and the food supply system in the developing world. *Population and Development Review, 22,* 483–503.

Bongaarts, J., & Bulatao, R. (Eds.). (2000). *Beyond six billion: Forecasting the world's population*. Washington, DC: Panel on Population Projections, Committee on Population, Commission on Behavioral and Social Sciences and Education, National Research Council.

Boserup, E. (1981). *Population and technological change: A study of long-term trends*. Chicago, IL: University of Chicago.

Brown, L. R. (1970). *Seeds of change: The Green Revolution and development in the 1970's*. New York: Praeger Publishers.

Brown, L. R. (1981). World population growth, soil erosion, and food security. *Science, 214,* 995–1002.

Caldwell, J., & Caldwell, P. (1986). *Limiting population growth and the Ford Foundation contribution*. London, UK: F. Pinter.

Casterline, J. (2010). *Wanted fertility, unwanted fertility, and fertility decline: A fresh assessment*. Paper presented at 2010 meeting of Population Association of America, Dallas, TX.

Casterline, J., & El-Zeini, L. (2007). The estimation of unwanted fertility. *Demography, 44,* 729–745.

Che, T. N., Kompas, T., & Vousden, N. (2006). Market reform, incentives and economic development in Vietnamese rice production. *Comparative Economic Studies, 48,* 277–301.

Chen, S. H., & Ravallion, M. (2010). The developing world is poorer than we thought, but no less successful in the fight against poverty. *Quarterly Journal of Economics, 125,* 1577–1625.

Cohen, J. E. (1995). *How many people can the Earth support*. New York: W.W. Norton.

Deaton, A. (2010). Price indexes, inequality, and the measurement of world poverty. *American Economic Review, 100,* 5–34.
Demographic and Health Surveys. (2011). Data sets for individual countries. Retrieved from http://www.measuredhs.com
Donaldson, P. (1990). *Nature against us: The United States and the world population crisis, 1965–1980*. Chapel Hill: University of North Carolina Press.
Dyson, T. (1996). *Population and food: Global trends and future prospects*. London, UK, and New York: Routledge.
The Economist. (2011, Feb. 24). The future of food. Retrieved from http://www.economist.com/node/18229412
Ehrlich, P. R. (1968). *The population bomb*. New York: Ballantine Books.
Ehrlich, P. R., & Ehrlich, A. H. (1990). *The population explosion*. New York: Simon & Schuster.
Ehrlich, P. R., & Ehrlich, A. H. (1996). *Betrayal of science and reason: How anti-environmental rhetoric threatens our future*. Washington, DC: Island Press.
Evenson, R. E., & Gollin, D. (2003). Assessing the impact of the Green Revolution, 1960 to 2000. *Science, 300,* 758–762.
Food and Agriculture Organization (FAO). (2011). *FAOSTAT* online database. Retrieved from http://faostat.fao.org
Freedman, R., & Blanc, A. K. (1992). Fertility transition: An update. *International Family Planning Perspectives, 18,* 44–50.
Gillis, J. (2011, June 4). A warming planet struggles to feed itself. *The New York Times,* p. A1.
Glaeser, B. (1987). *The Green Revolution revisited: Critique and alternatives*. London, UK: Allen & Unwin.
Glaeser, E. (2011). *Triumph of the city: How our greatest invention makes us richer, smarter, greener, healthier, and happier*. New York: Penguin Press.
Godwin, W. (1793/1798). *Enquiry concerning political justice, and its influence on morals and happiness* (3rd edition corrected, two volumes). London, UK: printed for G. G. and J. Robinson.
Guus, J., Velders, M., Andersen, S. O., Daniel, J. S., Fahey, D. W., & McFarland, M. (2007). The importance of the Montreal Protocol in protecting climate. *Proceedings of the National Academy of Science, 104,* 4814–4819.
Hesser, L. F. (2006). *The man who fed the world: Nobel Peace Prize laureate Norman Borlaug and his battle to end world hunger: An authorized biography*. Dallas, TX: Durban House Publishing Company, Inc.
Jevons, W. S. (1866). *The coal question*. London, UK: Macmillan and Co.
Johnson, D. G. (2000). Population, food, and knowledge. *American Economic Review, 90,* 1–14.
Jones, R., Kierzkowski, H., & Lurong, C. (2005). What does evidence tell us about fragmentation and outsourcing? *International Review of Economics & Finance, 14,* 305–316.
Joshi, S., & Schultz, T. P. (2007). *Family planning as an investment in development: Evaluation of a program's consequences in Matlab, Bangladesh* (Discussion Paper No. 951). New Haven, CT: Yale University Economic Growth Center.
Kelly, T. D., & Matos, G. R. (2010). *Historical statistics for mineral and material commodities in the United States, Version 2010* [Data file]. Retrieved from http://minerals.usgs.gov/ds/2005/140/
Kinsella, K., & Velkoff, V. (2001). *An aging world: 2001* (U.S. Census Bureau Series P95/01-1). Washington, DC: U.S. Government Printing Office.
Kirk, D. (1996). Demographic transition theory. *Population Studies, 50,* 361–387.
Knowles, J. C., Akin, J. S., & Guilkey, D. K. (1994). The impact of population policies: Comment. *Population and Development Review, 20,* 611–615.
Kremer, M. (1993). Population growth and technological change: One million B.C. to 1990. *Quarterly Journal of Economics, 108,* 681–716.
Lam, D. (2005). How the world survived the population bomb: An economic perspective. In S. Asefa (Ed.), *The economics of sustainable development* (pp. 99–132). Kalamazoo, MI: W.E. Upjohn Institute for Employment Research.
Lam, D., Ardington, C., Branson, N., Case, A., Leibbrandt, M., Menendez, A., . . . Sparks, M. (2008, October). *The Cape Area Panel Study: Overview and technical documentation of Waves 1-2-3-4*. Cape Town, South Africa: The University of Cape Town.
Lam, D., Ardington, C., & Leibbrandt, M. (2011). Schooling as a lottery: Radical differences in school advancement in urban South Africa. *Journal of Development Economics, 95,* 121–136.
Lam, D., Branson, N., Leibbrandt, M., & Goostrey, K. (2010a, April). *Credit constraints and the racial gap in post-secondary education in South Africa*. Paper presented at annual meeting of Population Association of America, Dallas, TX.

Lam, D., & Duryea, S. (1999). Effects of schooling on fertility, labor supply, and investments in children, with evidence from Brazil. *Journal of Human Resources, 34,* 160–192.
Lam, D., Leibbrandt, M., & Mlatsheni, C. (2010b, April/May). *Human capital, job search, and unemployment among young people in South Africa*. Paper presented at 2010 meeting of Population Association of America, Dallas, TX.
Lam, D., & Marteleto, L. (2008a). Stages of the demographic transition from a child's perspective: Family size, cohort size, and children's resources. *Population and Development Review, 34,* 225–252.
Lam, D., & Marteleto, L. (2008b, April). *Family size of women and children during the demographic transition*. Paper presented at the annual meeting of the Population Association of America, New Orleans, LA.
Lam, D., Marteleto, L., & Ranchhod, V. (2009, April/May). *Schooling and sexual behavior in South Africa: The role of peer effects*. Paper presented at the annual meeting of the Population Association of America, Detroit, MI.
Lee, R. D. (1988). Induced population growth and induced technological progress: Their interaction in the accelerating stage. *Mathematical Population Studies: An International Journal of Mathematical Demography, 1,* 265–288.
Lee, R. D. (1997). Population dynamics: Equilibrium, disequilibrium, and consequences of fluctuations. In M. R. Rosenzweig, & O. Stark (Eds.), *Handbook of population and family economics* (pp. 1063–1115). Amsterdam, The Netherlands: Elsevier.
Lee, R. D. (2003). The demographic transition: Three centuries of fundamental change. *Journal of Economic Perspectives, 17,* 167–190.
Lutz, W., Sanderson, W., & Scherbov, S. (1997). Doubling of world population unlikely. *Nature, 387,* 803–805.
Lutz, W., Sanderson, W., & Scherbov, S. (2001). The end of world population growth. *Nature, 412,* 543–545.
Lutz, W., Sanderson, W. C., & Scherbov, S. (2004). *The end of world population growth in the 21st century: New challenges for human capital formation and sustainable development*. London, UK, and Sterling, VA: Earthscan.
Malthus, T. R. (1803/1960). *An essay on population*. London, UK, and New York: Dent; Dutton.
Martine, G. (1996). Brazil's fertility decline, 1965–95: A fresh look at key factors. *Population and Development Review, 22,* 47–75.
Mason, K. O. (1997). Explaining fertility transitions. *Demography, 34,* 443–454.
McEvedy, C., & Jones, R. (1978). *Atlas of world population history.* New York: Penguin Books.
Meadows, D. H. (1972). *The limits to growth: A report for the Club of Rome's project on the predicament of mankind*. New York: Universe Books.
Minnesota Population Center. (2011). *Integrated Public Use Microdata Series, International: Version 6.1* [Machine-readable database]. Minneapolis: University of Minnesota. Retrieved from https://international.ipums.org/international/index.shtml
National Aeronautics and Space Administration (NASA). (2011). GISS Surface Temperature Analysis, Global mean monthly temperature data. Retrieved from http://data.giss.nasa.gov/gistemp/tabledata/GLB.Ts+dSST.txt
National Research Council. (1986). *Population growth and economic development: Policy questions*. Washington, DC: National Academy Press.
Paddock, W., & Paddock, P. (1967). *Famine, 1975! America's decision: Who will survive*. Boston, MA: Little, Brown.
Panel on Urban Development, National Research Council. (2003). In M. R. Montgomery, R. Stren, R. Cohen, & H. E. Reed (Eds.), *Cities transformed: Demographic change and its implications in the developing world*. Washington, DC: National Academies Press.
Petersen, W. (1971). The Malthus-Godwin Debate, then and now. *Demography, 8,* 13–26.
Pingali, P. L., & Xuan, V. T. (1992). Vietnam: Decollectivization and rice productivity growth. *Economic Development and Cultural Change, 40,* 697–718.
Potter, J., Schmertmann, C., & Cavenaghi, S. (2002). Fertility and development: Evidence from Brazil. *Demography, 39,* 739–761.
Preston, S. H. (1976). Family sizes of children and family sizes of women. *Demography, 13,* 105–114.
Pritchett, L. H. (1994a). Desired fertility and the impact of population policies. *Population and Development Review, 20,* 1–55.
Pritchett, L. H. (1994b). The impact of population policies: Reply. *Population and Development Review, 20,* 621–630.

Schultz, T. P. (1993). Returns to women's education. In M. A. Hill & E. M. King (Eds.), *Women's education in developing countries*. New York: Oxford University Press for The World Bank.

Simon, J. (1981). *The ultimate resource*. Princeton, NJ: Princeton University Press.

Simon, J. (1986). *Theory of population and economic growth*. Oxford, UK: Blackwell.

Simon, J. (1996). *The ultimate resource* (2nd ed.). Princeton, NJ: Princeton University Press.

Smith, S. J., van Aardenne, J., Klimont, Z., Andres, R. J., Volke, A., & Delgado Arias, S. (2011). Anthropogenic sulfur dioxide emissions: 1850–2005. *Atmospheric Chemistry and Physics, 11,* 1101–1116.

Stiglitz, J. E. (2002). *Globalization and its discontents*. New York: W. W. Norton.

Tierney, J. (1990, Dec. 2). Betting the planet. *New York Times Magazine*. Retrieved from http://www.nytimes.com/1990/12/02/magazine/betting-on-the-planet.html

Time Magazine. (1960, Jan. 11). Population: The numbers game.

United Nations Population Division. (1999). *The world at six billion*. Retrieved from http://www.un.org/esa/population/publications/sixbillion/

United Nations Population Division. (2009). *World urbanization prospects: The 2009 revision* [Database]. Retrieved from http://esa.un.org/unpd/wup/index.htm

United Nations Population Division. (2011). *World population prospects: The 2010 revision* [Database]. Retrieved from http://esa.un.org/unpd/wpp/index.htm

U.S. Census Bureau. (2010). *Total midyear population for the world: 1950–2050* [Data updated Dec. 20, 2010]. Retrieved from http://www.census.gov/population/international/data/idb/worldpoptotal.php

U.S. Census Bureau. (2011). *Historical estimates of world population*. Retrieved from http://www.census.gov/population/international/data/idb/worldhis.php

Willis, R. J. (1973). New approach to economic theory of fertility behavior. *Journal of Political Economy, 81,* S14–S64.

World Bank. (2011). *World DataBank* [Database]. Retrieved from http://databank.worldbank.org/ddp/home.do