Economic and Demographic Change: A Synthesis of Models, Findings, and Perspectives

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Puzzles, Controversy, and the Problem

Puzzles and Controversy[2]

No empirical finding has been more important to conditioning the "population debate" than the widely-obtained statistical result showing a general lack of correlation between the growth rates of population and per capita output. Documented in more than two dozen studies, such a (lack of) statistical regularity flies in the face of strongly held beliefs by those who expect rapid population growth to deter the pace of economic progress. The correlations have therefore become a point of contention. On the one hand, most analysts[3] agree that simple correlations between population and economic growth are difficult to interpret, plagued as they are by failure to adequately account for reverse causation between demographic and economic change, complicated timing relationships associated with the Demographic Transition, excessive reliance on cross-national data, sensitivity to the selection of countries, complexity of economic-demographic linkages that are poorly modeled, spurious correlation, econometric pitfalls, and data of dubious quality. On the other hand, the virtual absence of a systematic relationship in the face of such strongly held priors has quite literally kept the population debate alive. Ronald Lee's early summary evaluation of dozens of studies in this literature is instructive:

> ... these cross-national studies have not provided what we might hope for: a rough and stylized depiction of the consequences of rapid population growth: unless, indeed, the absence of significant results is itself the result. (1983, p. 54)

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[2] This section draws upon Kelley and Schmidt (1994).

[3] For example, "...these statistical correlations provide little *prima facie* information about the size or nature of the net impact of population growth on economic development" (Kelley 1988, p. 1701). In a similar vein, see National Research Council (1986, p. 7) and Blancet (1991, p. 4).

The importance of this finding is exemplified by the evolution of the two major United Nations reports (1953, 1973) on population. The first, in 1953, was eclectic in assessing the relative importance of the various positive and negative impacts of population growth. In contrast, the second, in 1973, came down (in the text) as somewhat anti-natalist; yet this tone was strongly qualified (in the executive summary) by a single study: Simon Kuznets' empirical results that failed to uncover a negative relationship between the pace of population growth and economic development. Kuznets' impeccable research could not be ignored; the UN report's major conclusions had to be qualified.

Confirmation of Kuznets' findings in many studies by numerous researchers of differing perspectives has provided force to the "revisionist" position that emphasizes a methodology that provides for a balanced and relatively complete assessment of the economic impacts of demographic change--one that accounts for long- as well as short-run impacts of, as well as economic/social/political feedbacks in response to, demographic change. This perspective obtained analytical interpretation and empirical buttressing through an extensive review of the economic-demographic literature in the 1986 National Academy of Sciences report, Population Growth and Economic Development: Policy Questions. With this report, and several appearing around the same time, the population debate appeared to turn the corner.[4] The strong anti-natalist arguments of the 1970s were reassessed as alarmist overstatements of the negative consequences of rapid population growth. Depending on one's persuasion, the NAS Report represented either a backlash or a balanced rendering that put the debate back on solid footing.[5]

Ironically, while on the one hand the simple empirical correlations between population growth and economic development constituted a major force in causing a reassessment of the impacts of population growth, on the other hand the appearance of "new" correlations in several recent studies could well cause the pendulum to swing back toward a more cautious (alarmist?)

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[4] McNicoll (1984), Srinivasan (1988), World Bank (1984).

[5] An alternative interpretation is that the alarmist renderings in the 1970s were mainly by non-economists. This is supported, for example, by a careful reading of the 1971 National Academy of Sciences report, Rapid Population Growth: Consequences and Policy Implications, often cited as the major scholarly justification for the alarmist view. In fact, this impression results mainly from the short, crisply-written executive summary, which is unfaithful to the evidence and argumentation of important scholarly contributions to the study, mainly, but not exclusively, written by the economists. Unfortunately, the executive summary is unauthored, and it was not vetted with most of the participants in the NAS study. An evolution of swings in thinking on population matters, as depicted in several major reports, is provided in Kelley (1991).

interpretation.[6] These studies appear to reveal a negative association between population and economic growth based on international cross-country data for the early 1980s. Even though the authors of these studies are generally guarded with respect to the strength or importance of this finding, the intriguing question arises: Has the impact of population growth changed?

The Problem: A First Pass

Could it be that the negative consequences of rapid population growth associated with diminishing returns to capital and the environment are emerging as relatively more important forces than, say, the positive impacts of scale, induced innovation/technical change, and/or attenuating feedbacks? Or, is it possible that the 1980s--a period encompassing significant structural adjustments, world recession, wars, and droughts--constitute an "exceptional" decade for untangling these economic-demographic interactions? Are these recent statistical correlations robust, or are they the result of necessarily arbitrary research decisions that are not yet fully assessed--decisions relating to choice of statistical procedures, data sets, time periods, countries included, modeling structures, functional forms, and the like? In short, is a negative population- and economic-growth correlation emerging? If so, why; and so what?

The Argument. A central message of the present study is that neither the results of the recent studies pertaining to the experience of the 1980s, nor those similar to them over the last two decades, should carry excessive weight in assessing the net consequences of demographic change on economic growth. While we believe this message is compelling, we predict it will be selectively heard, crowded out in the minds of those who would like to accept or reject the recent (as well as the past) empirical findings.

Accordingly, it is important that the recent studies be carefully evaluated--at a minimum, in terms of their econometric and empirical muster; and, to the extent that they appear to be yielding new findings, that the robustness and meaning of such findings be uncovered. Timing is important. After all, it was Kuznets' single empirical finding showing a lack of association of population and economic growth in the early 1970's that profoundly conditioned the population debate for more than a decade.

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[6] These studies include Barlow (1992), Blanchet (1991), Bloom and Freeman (1988), Brander and Dowrick (1994), and United Nations (1988).

Veracity and Meaning of Recent Studies. What can we make of the recent empirical studies of population- and economic-growth connections? We addressed this question in considerable detail in a World Bank study (Kelley and Schmidt 1994), where the five key studies were replicated and assessed, and some new modeling variants were explored.[7] Generally, the recent evidence is consistent with an impact of population growth on per capita output growth that:

(1) is not statistically significant in the 1960s and 1970s (a finding consistent with a wide literature);
(2) is negative, statistically significant, and large in the 1980s; and
(3) varies with the level of economic development in the 1980s (it is negative in the LDCs and positive for many DCs).

In extending these studies, and considering some new variants, we also found that:

(4) population density exerts a consistently significant (positive) impact across all decades;
(5) population size exerts a positive impact in some periods; and
(6) the "net" impact of demography over the decade of the 1980s was negative.

Whether this new finding represents an aberration or a confirmation of an emerging trend is a key question. Providing an explanation will require detailed econometric and demographic modeling. The present study will offer some clues relevant to such modeling.

The Problem: A Second Pass

A beginning is provided in two recent studies that highlight the dynamics of demographic change. In particular, since the economic-growth impacts of a new birth vary over a lifetime (the impact is initially negative during the child-rearing years, then positive during the labor force years, and finally [possibly] negative during retirement), modeling of demography must account for the patterns of birth and death rate changes over time. In one such study, Kelley and Schmidt (1995; hereafter KS) confirm that some of the early "no-correlation" findings can plausibly be related to these offsetting effects. This interpretation gains additional support from Bloom and Williamson (1998; hereafter BW), and also by Radelet, Sachs and Lee (1997; hereafter RSL),

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[7] The assessments included three data sets (Summers and Heston 1988, United Nations, World Bank), five country selections, five country groupings, eight periods, and five estimation procedures.

which emphasize the same timing issues and show that demographic change at a given point in time can have positive, negative, or neutral impacts on economic growth depending, in part, on the timing of the components of (positive) labor force versus (negative) dependent population growth.

All of these studies draw upon an analytic framework that is commonly denoted as “convergence” or “technology-gap” models. These are handy paradigms since they permit an examination of both long- and shorter-run (or transition) impacts of demography. Unfortunately, there is wide variance in the choice of variables (and estimation techniques) in the empirical implementation of these models; moreover, the incorporation of demography has been spotty, so that generalizations, at this point, must be cautious. While the KS and the BW studies have pointed the way in dynamic modeling, much work remains.

This justifies the primary objectives of the present paper, which takes stock of the various ways demography has been incorporated into convergence-type models, and which extends these analyses in several ways by: (1) incorporating and comparing alternative demographic specifications; (2) extending the time period of analysis to the mid 1990s; and (3) assessing the impacts of demography in early and later periods. This will permit us to assess, in a preliminary way, the role of demography on economic growth, at least in the popular convergence-type models.

Modus Operandi

Our methodology will be to append various demographic specifications to a “core” convergence-type model (Barro 1997), using a common data set, data aggregation, statistical procedure, and country selection. Each of the results will then be subjected to robustness tests. The selection of the demographic specifications draws upon studies by Barro, KS, BW, and others. In addition, we extend two of the modeling formulations to expose economic-demographic linkages in more detail. We end up with eight models that command considerable support. To these we apply the historical experience of the period 1960-1995 in order to assess the quantitative importance of the various components of demography, and the net impacts of demography in alternative modeling variants.

Since at this stage the present paper represents an exploratory study, we can provide at most a qualified judgment that declines in both mortality and in fertility have notably increased the rate of economic growth. Declines in each component contributed around .32 points to changes in per capita output growth over the period 1960-1995. This figure corresponds to 21% of 1.50%, the average annual growth of per capita output, or, alternatively, 22% of the combined impacts of changes in non-demographic influences on Y/N_{gr}. A combination of all components of demographic change roughly doubles this sizeable impact.[8] Apparently the positive impacts of population density, size, and labor force growth are more than offset by the costs of rearing children and maintaining an enlarged youth-dependency age structure. The emphasized “qualified” caveat relates to robustness tests we have performed, the results of which are discussed below.

Theory and Modeling

Three approaches dominate the extensive literature on economic-demographic modeling: simple correlations, production functions, and convergence patterns.

Simple Correlations

Simple-correlations studies hypothesize that per capita output growth is influenced by various dimensions of demography:

$$Y/N_{gr} = f(D), \tag{1}$$

where D is usually taken to be contemporaneous population growth (Y/N_{gr}), sometimes age structure (youth and aged dependency, working-ages), births and/or deaths (e.g., crude birth or death rates, life expectancy, and/or total fertility), migration, and occasionally size (N) and/or density (e.g., N/Land).

Several early studies focused on unconditioned correlations between per capita output and population growth for various country samples and periods of time. Most authors recognized the limitations of such simplistic modeling. Nevertheless, given the exceptional <u>strength</u> of the posited negative impacts of population growth on development voiced in many circles, the frequent failure to uncover any notable empirical relationship added a qualifying empirical dimension to the population debates. In the 1980s, however, the debates changed toward a more balanced and complete reckoning of population's many impacts; diminished alarmism based on somewhat narrow and usually short-run renderings was attenuated, and with it the popularity of the simple correlations studies. Such models were, after all, of limited use since they failed to expose the many channels, as well as the dynamics, through which demography affects the economy. Specifically, the correlations that found little or no impact of population growth did <u>not</u> demonstrate the absence of a

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[8] For expositional simplicity, we use "mortality" to refer to life expectancy or CDR and "fertility" to refer to all other demographic variables in the models (TFR, CBR and its lags, population and working-age growth rates, age structure, size, and density).

role for demography; indeed, demographic impacts may well have been important, but simply offsetting. Fortunately, about this time, data were increasingly available for broadening empirical inquiries to account for a wider array of linkages.

Production Functions

Production-function studies are based on estimating variants of a model:

$$Y = g(K, L, H, R, T), \qquad (2)$$

where output (Y) is produced by the stocks of various factors: physical capital (K), labor (L), human capital (H: education and health), resources (R: land, minerals, and environment), and technology (T). Because data on these stocks are difficult to compile, and in an effort to attenuate possible problems of reverse causality, this equation is usually transformed into growth-rate terms in which attention is focused on more easily observable factor flows such as the growth of physical capital (e.g., net investment = gross investment less depreciation). Demographic processes are then linked to the growth of the factor inputs.

These models, however, face formidable difficulties in empirical implementation: estimates of capital depreciation, resource depletion, and human capital growth are difficult to compile; and technology and scale, considered central to economic growth, are exceptionally elusive to assess. It has therefore become necessary to impose constraining assumptions that result in simpler renderings than desired. For example, potentially important demographic linkages through scale, diminishing returns, and technical change are sometimes combined into a single “residual” which obscures many of the most important linkages between demography and the economy.[9] Thus, although aggregate production functions represent promising analytical frameworks, their empirical renderings have been limited in scope.

Convergence Patterns

Convergence-patterns studies, rooted in neoclassical growth-theory,[10] explore the relationships between economic growth and the level of economic development. They focus on the pace at which countries move from their current level of labor

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[9] See Brander and Dowrick (1994) and others they cite in this tradition.

[10] Ramsey (1928), Solow (1956), Cass (1965), and Koopmans (1965). This section benefits from the presentation of RSL (1997, pp. 4-6); see also Barro (1997), and Barro and Lee (1993).

productivity (Y/L) to their long-run, or steady-state equilibrium level of labor productivity [$(Y/L)^*$].[11]

Formally, the usual variant of this model can be written:

$$Y/L_{gr} = c\ [\ln(Y/L)^* - \ln(Y/L)].^{12} \qquad (3)$$

Here the rate of labor productivity growth (Y/L_{gr}) is proportional to the gap between the logs of the long-run, steady-state $(Y/L)^*$ and the current (Y/L) level of labor productivity. The greater this gap, the greater are the gaps of physical capital, human capital, and technical efficiency from their long-run levels. Large gaps allow for "catching up" through (physical and human) capital accumulation, and technology creation and diffusion across, and within countries.

Under restrictive assumptions,[13] this model predicts "unconditional convergence" by all countries to the same long-run level of labor productivity. Were $(Y/L)^*$ the same for all countries, low-income countries would have larger gaps and equation (3) predicts them to grow faster as a result. In fact, however, <u>positive</u> rather than negative correlations are observed between the level and growth rate of labor productivity. The model has, as a result, been modified.

Specifically, models now hypothesize "conditional convergence" where long-run labor productivity differs across countries depending on country-specific characteristics:

$$\ln(Y/L)^* = a + bZ. \qquad (4)$$

The actual specification of the determinants of long-run labor productivity (the Z's) varies notably, but the basic model, which combines equations (3) and (4), is the same across scores of empirical studies.

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[11] Most empirical studies highlight per capita rather than per-laborer output. In neoclassical modeling this distinction is sidestepped by the assumption that L = aN, where a is usually unity. Theoretically, short of invoking this assumption, the labor-productivity formulation is preferred; and it can be easily transformed into per capita terms, as shown below.

[12] By way of comparison, consider the formulation for continuous growth of Y/L at a constant rate, r, between time periods 0 and T:

$$Y/L_T = Y/L_0\ e^{rT}$$

Taking logs, and solving for r,

$$r = [\ln(Y/L_T) - \ln(Y/L_0)]/T.$$

This formulation is analogous to that in the convergence model where r corresponds to Y/Lgr; Y/L to Y/L^*; Y/L to Y/L; and (1/T) to c.

[13] These assumptions include, for example, perfect factor mobility; identical attitudes toward work, saving and property; identical resource endowments; and identical economic and governmental structures.

$$Y/L_{gr} = a' + b'Z - c\ln(Y/L);^{14} \qquad (5)$$

where $a' = ac$ and $b' = bc$.

What types of Z variables are, and should be, included as determinants of long-run labor productivities? Illustrative are two recent studies. The first, by Radelet, Sachs, and Lee (1997, RSL), highlights two categories of determinants: economic structure variables (e.g., natural resource and human capital stocks, access to ports, location in tropics, whether landlocked, extent of coastline, etc.), and economic/political policies (e.g., openness to trade, quality of institutions, etc.). The second, by Barro (1997), highlights inflation, size of government, form of political system, terms of trade, human capital, and demography (fertility). (Papers by other authors would expand this list several fold.[15])

A revealing feature of the convergence-patterns models can be gleaned by considering variables omitted by Barro and RSL. In both papers the authors emphasize variables that determine long-run, or "potential" $(Y/L)^*$ labor productivity, and downplay variables that bring about the "adjustment" or "transition" to long-run equilibrium. An example of one such omitted variable is investment shares.[16] Putting aside the problem of endogeneity, investment can be viewed as an adjustment variable. The gap between current and long-run labor force productivity largely dictates the return to investment. Investment will flow to those countries with highest returns. Rather than investment accounting for growth *per se*, it can be argued that the "structural" features of countries that impede or facilitate

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[14] Most empirical implementations differ from the theoretical formulation in two important ways. First, the theory models instantaneous growth rates while studies employ 5-, 10-, 25-year, or even longer periods. In theory, all variables in equation (5) are measured at exact instant t. In implementation, measurement of Y/Lgr is over the period while Y/L is at the beginning of the period. The theory dictates (1) that the estimated intercept and convergence parameters are functions of the true convergence parameter, c, and the length of the estimation period; and (2) that the Z vector be calculated as period averages (see RSL, 1997, pp. 4-6 for the mathematical details). In practice, studies use beginning-of-period values, lagged values, period averages, and/or period changes for the Z variables, often without convincing rationale. We prefer to use period average or change. In an instance where endogeneity might be an issue, we employ the beginning-of-period value as an instrument.

Second, most studies couch equation (5) in per capita (Y/N) rather than in per worker (Y/L) terms. The nature of the translation from labor productivity to per capita is examined below.

[15] For a survey, see Pritchett (1998), Easterly et al. (1998), and Fagerberg (1994).

[16] Barro and Lee (1993) included investment shares in an earlier model.

investment should be highlighted in the modeling of Z (e.g., measures of the risk of expropriation, restrictive licensing, political conditions, etc.). Such features modify long-run potential labor productivity because they impede or encourage investment.

We hasten to observe that there are many defendable perspectives on variable choice, and that much is yet to be learned about the appropriate configuration of “core variables” to be included in such modeling.[17]

Demography

Incorporating demography into convergence-patterns models has been spotty and *ad hoc*.[18] Demographic variables that qualify are those that affect $(Y/L)^*$, and those that condition the transition to $(Y/L)^*$. The nature of these two types of demographic variables can be illustrated by examining the studies of: (1) Barro (1997) and Kelley and Schmidt (1994), which highlight long-run impacts of demography but include a role for transitions; (2) Kelley and Schmidt (1995) which examine both long-run and transition impacts; and (3) Bloom and Williamson (1998), which capture transition-impacts solely, or primarily.

Barro's Demography

Barro (1997) focuses on a single demographic variable, the Total Fertility Rate (TFR).[19] This variable captures both the adverse capital-shallowing impact of more rapid population growth, and the resource costs of raising children versus producing other goods and services. By its very nature the TFR exerts its impacts mainly on long-run labor productivity $(Y/L)^*$ versus the short-run transitions en route to equilibrium. After all, the TFR is an hypothetical construct that represents what the fertility rate “would be if” the current age-specific

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[17] Levin and Renelt (1992) find that investment rates constitute the most robust variable in such studies. Pritchett (1998) leans toward production-function type variables, with an emphasis on econometric properties (e.g., their variation across time and space). Sala-i-Martin (1997) is somewhat eclectic, based on his research with around two million growth regressions.

[18] In a review of more than two dozen studies, Fagerberg (1994) finds that demography is omitted one-third of the time. Where Ngr is included, its estimated effect is equally split between being significantly negative, and insignificant. More detailed (and appropriate) specifications of demography are sparse.

[19] He also includes life-expectancy at birth (e0), but mainly as a measure of health, although he recognizes that this variable has demographic interpretations as well.

fertility rates were maintained over a long period of time.[20]

Kelley/Schmidt's Early Demography

In their early modeling, KS (1994) highlight three dimensions of demography: population growth, size, and density.

Population Growth. To conform with an extensive empirical literature, KS initially examine the impact of population growth, whose “net” effects on per capita output growth are postulated to be ambiguous. Only in the simplest of growth-theoretic frameworks is there an unequivocal quantitative prediction: i.e., population growth affects the level but not the growth of per capita output in the long run.[21] More complex variants that allow for embodied technical change, embellishments for human capital and factor augmentation, population-induced feedbacks, and scale always produce ambiguous assessments.[22]

To this simple demographic specification in N_{gr}, KS provide an “augmented” model that includes size and density.

Size and Density. Curiously, even though studies in the economic-demographic tradition have long harkened the importance of population size and density, these influences have been strikingly missing in empirical analyses of growth in recent decades. This is due in part to the finding that resource scarcity (land, natural resources) appears to have played a relatively small role in accounting for growth; to the popularity of neoclassical economics that focuses on physical and human capital; and to the discovery that technological change has largely dominated economic progress. In effect, technology has

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[20] In some earlier renderings, Barro and Lee (1993) experiment with alternative demographic specifications, including total population growth and the youth-dependency ratio.

[21] Solow (1956), Phelps (1968). In these models technical change is exogenous, and savings rates are exogenous to population growth. The capital-shallowing effect of an increase in population growth eventually drives down the long-run level of capital per worker enough so that it can be sustained by the (fixed) ratio of savings to output.

[22] Formally, if the production function exhibits constant returns to scale, and if one assumes that labor is a constant proportion of population, then O/L depends on the availability of complementary factors and technology. An increase in population growth will reduce the growth of average productivity through diminishing returns--a “resource-shallowing” effect--if such a population increase does not also affect the growth of complementary factors and/or technology. If population growth diminishes the growth of the other factors and/or technology, labor productivity growth is reduced by even more; if it stimulates the growth of other factors and/or technology (a “resource-augmenting” effect), labor productivity growth is increased or decreased, depending on the relative importance of the negative resource-diluting versus the positive resource-augmenting effects.

in many countries relaxed the constraints of fixed resources against which increasing population sizes press, thereby attenuating the adverse impacts of diminishing returns. Still, many studies in agricultural economics, as well as dozens in economic theory, have emphasized the advantages of size, scale, and density.

Building on KS (1994), the present paper resurrects the size and density variables as a part of the empirical story accounting for economic progress. While our findings are exploratory, they serve to add breadth to the analysis. In the following subsections we therefore review some of the arguments and empirical studies that relate population size and density to output growth. We will conclude that both recent theory and empirical work justify the inclusion of scale and density in empirical studies of growth, but with specifications that are sufficiently flexible to allow for a variety of outcomes.

Economies of Scale.[23] Scale effects are exceptionally elusive to specify and evaluate. At the narrowest level, they refer to within-firm variations in productivity when all factors change proportionately. With few exceptions, such economies are usually exhausted by firms of moderate size. At a broader level, scale economies emanate from indivisibilities in lumpy investments, including roads, communications, research and development, and markets. These can be important, especially in agriculture (Boserup 1981). In a still broader framework, scale economies derive from increased specialization and diversification between firms (Stigler 1961). While some of these size benefits can be obtained in other ways (e.g., through international trade and/or the linking of regional centers with transport and communications), still, these investments are themselves likely to be more viable with larger populations (Glover and Simon 1975).

A review of the limited empirical literature relating to scale and density leaves one with the assessment that both factors are relevant to growth, but that the magnitude of the impacts varies notably from place to place, and over time. For some developed countries (e.g., the US) where resources have been abundant, institutions strong, and densities relatively sparse, expanding population size has generally been viewed as a positive influence on long-run growth (Abramovitz 1956, Denison 1962).

However, these underlying conditions do not generally prevail in the Third World. First, population sizes are already sufficiently large in many areas to garner most scale economies in manufacturing. Indeed, the distribution and density of population may be relatively more important here (Henderson 1987;

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[23] This section draws upon Kelley (1988).

James 1987; National Research Council 1986). Second, scale effects are usually associated with high capital/labor ratios, a production format at variance with prevailing factor proportions. Third, city sizes are approaching (or in some cases, exceeding) those where additional scale efficiencies from size are available.

It is in agriculture where the positive benefits of population size are most discussed. Higher population densities can decrease per unit costs and increase the efficiency of transportation, irrigation, extension services, markets, and communications. These favorable impacts may be substantial, but they vary from place to place.[24] On the one hand, Asian land densities were likely sufficiently dense decades ago to garner most positive size effects. On the other hand, much of Africa is sparsely settled, and in places some infrastructure investments may not be economical for years to come. Additionally, even in areas where densities are not limiting, institutions often are. Constraining land ownership patterns, poorly developed markets, and imprudent government policies diminish the economic viability of investments and technology. It is not unlikely that differing institutional conditions most differentiate the putative favorable historical experience with scale effects in some developed countries from the apparently less favorable experiences in many Third World nations in the present.

<u>Endogenous Growth</u>. Most theoretical models of technological change in the endogenous-growth literature arrive at a striking conclusion: the pace of technological change is directly related to population size. This is because the fruits of R&D are assumed to be available to all without cost, and there are no constraints on adoption. In effect, there is an R&D industry producing a nonrival stock of knowledge. Holding constant the share of resources used for research, an increase in population size advances technological change without limit.[25] Partly in response to this prediction, a few analysts have recently been developing models that highlight firm-specific innovation and invention processes to include limitations and costs on even the use of nonrival technology. This can give rise to an outcome where population size has little or no impact on the pace of innovation in the long run, although it can have a favorable

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[24] Simon (1975), Glover and Simon (1975), Boserup (1981), Pingali and Binswanger (1987), Hayami and Ruttan (1987).

[25] There are numerous studies in this tradition, including those of Arrow (1962), Grossman and Helpman (1991), Lucas (1988), and Romer (1986, 1990). Citations are greatly expanded in Backus et al. (1992), and Dinopoulos and Thompson (1998). These arguments apply mainly to world and not to national populations, although if there are nation-specific impediments to diffusion, country-specific population sizes may matter as well.

impact during the “transition” to the long run.[26]

Evidence. Apart from the historical literature for developed countries, where scale is sometimes held to be positive and important, there are surprisingly few empirical studies that apply to the Third World. The pioneering work is by Chenery and Syrquin (1975). Based on the experience of 101 countries across the income spectrum and over the period 1950-1970, they find that the structure of the development process reveals strong and pervasive scale effects (measured by population size), although these effects vary by stage of development. Basically, small countries develop a modern productive industrial structure more slowly, and later; and large countries have higher levels of accumulation and (presumably) higher rates of technical change.[27]

Taken together, several recent studies also support the relevance of positive scale effects, although the results are not uniform. Backus *et al.* (1992) show that the growth of manufacturing output per worker is strongly related to both scale and measures of intra-industry trade. They fail to unearth scale effects at the economy-wide level (measured by the growth GDP per capita), a result confirmed by Dinopoulos and Thompson (1998). However, these latter results can be discounted since they represent simple, unconditioned correlations.[28] Also at the aggregate level, and based on a range of historical data and simulations, Kremer (1993) concludes that larger initial populations have tended to have faster technical change and population growth. Finally, at the firm level, it is clear that R&D is positively related to firm size (Cohen and Klepper, 1996).

Specifications. Neither theory nor available evidence is sufficiently strong to support a tight empirical specification of

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[26] Peretto and Smulders (1998) review this emerging literature, and present a paradigm for the development and use of R&D that incorporates dilution effects, spillover networks, and technological distances relating to firm size and numbers. As populations expand, more firms enter the market and become increasingly specialized, using a decreasing portion of the nonrival technology stock.

[27] Chenery and Syrquin (1975) allow substantial flexibility in isolating population impacts, as measured by two terms: $\ln N$ and $(\ln N)^2$. Scale effects (positive or negative) are posited to decline with size (the logs), although the pace and even the direction of this pattern can vary (the squared term). Thus, while scale effects (usually positive) are found to be pervasive, the quantitative size of the impacts varies widely. For example, positive scale effects in investment and saving rates rise up to populations of sizes of around 30 million (85% of the countries in their sample), but for influences like government expenditures and taxation rates, they rise only to populations of around 15 million. The inflow of foreign capital shows an inverse pattern, and school enrollments reveal no scale effects.

[28] Chenery and Syrquin (1975) demonstrated the importance of conditioning scale effects for relevant interactions.

the impacts of size and density. Thus, following Chenery and Syrquin (1975), below we evaluate both non-linearities in the variables and in functional forms to allow for diminishing (or even negative) marginal impacts.

Kelley/Schmidt Dynamics: Components Demography

The population growth variable masks important dynamics of demography associated with the components of demographic change.[29] While, in a country without international migration, population growth is by definition the difference between the crude birth and death rates (N_{gr} = CBR - CDR), in practice the impacts of demography can vary depending on: (1) the levels of these crude rates (levels imply different age distributions and/or age-specific rates); (2) the sensitivity of the economy to the separate components (deaths and births can have different impacts); and, importantly, (3) the timing of these component changes.

With respect to levels and sensitivity, a similarly low N_{gr} is observed both before and after the demographic transition. Importantly, however, that low rate is attained in different ways with distinctly different demographic and economic implications. The high birth and death rates during pre-transition imply a younger population than do the low rates during the post-transition. To the extent that age distribution exerts impacts on economic growth, the similar N_{gr}'s will mask the true role of demographic change.

With respect to timing, consider the impacts of current births (the CBR) over time. In the short run, the effect of a birth on economic growth is likely to be negative (i.e., children are net “resource users”). At later stages of the life cycle, the effect of prior births is likely to be positive (working adults are net “resource creators”). Even later, retired adults may again be net resource users. Moreover, within the “youth-dependency” cohort (say ages 0-15), the economic impacts can vary notably since caring for babies is exceptionally time-intensive (a negative impact), and older children perform many useful economic functions (a positive impact). Specifying and measuring these various demographic impacts explicitly is potentially important since, given the strong correlation of births across time, exploring only the impacts of current births results in a difficult-to-interpret “net” rendering across time. Put differently, countries with rapid current population growth rates are likely to be those with high past population growth rates.

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[29] This section draws on Kelley and Schmidt (1995). These ideas have been explored by others: Simon and Gobin (1980), Coale (1986), Bloom and Freeman (1988), Blanchet (1991), Barlow (1994), and Brander and Dowrick (1994). This microeconomic framework underlies the recent BW models as well.

Cross-sectional evidence using contemporaneous data on births alone therefore measures *de facto* both the negative impacts of current births and the positive impacts of past births. As a result, the commonly found empirical result showing little or no measured impact of population growth (which is the contemporaneous CBR - CDR) does not necessarily mean that demographic processes are unimportant: it may simply imply that strong intertemporal demographic effects are offsetting.

There are various ways of capturing these dynamics. KS (1994, 1995) focus on the underlying demographic components of births and deaths since this rendering exposes potentially important effects within the youth-dependency cohort.[30] Moreover, from a policy perspective, analysts are typically interested in assessing the impacts of changes in births or deaths, as opposed, say, to policies that target an “age distribution” *per se*.

Operationally, there are several ways of modeling these dynamics. In KS (1994, 1995), the empirical models measure the differential impacts of CBRs, contemporaneous and lagged 15 years (to capture labor force entry). While this approach was fairly successful, the estimates are plagued by multicollinarity and as a result are less precise than desired. In the present paper we advance an alternative specification, posed by Barlow (1992), that postulates an explicit functional form of birth-rate impacts over time. This provides highly interesting estimates of the differential impacts of the components of the youth-cohort.

Bloom/Williamson Dynamics: Transitions Demography

An alternative methodology for exposing these dynamic relationships has been advanced by Bloom and Williamson (1998, BW hereafter), a demographic framework which is taken up by Radelet, Sachs and Lee (1997; RSL hereafter), and which builds upon RSL's empirical model of economic growth. Demography in these models follows neatly from a definition that translates the convergence model from one that explains productivity growth into one that explains per capita output growth, the focus of most convergence-patterns studies.

Starting with the definition of output per labor hour,

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[30] An infant death occurring in the same year of birth shows up in both the CBR and CDR but is netted out of Ngr. Furthermore, a surviving birth has different resource implications. For both of these reasons, we believe the appropriate modeling is to net infant deaths out of both CBR and CDR and to include a Crude Infant Death Rate (CIDR) as a separate variable. We experimented with that formulation in KS (1995) but found the impact of the CIDR to be trivial and insignificant. The result implies that the pregnancy, delivery, and recovery for these infants has negligible macroeconomic growth effects.

$$Y/L = (Y/N)(N/L), \qquad (6)$$

it can be shown that the basic model of equation (5) can be transformed into per-capita terms:

$$(Y/N)_{gr} = a'' + bZ - c''\ln(Y/N) + d\ln(L/N) + L_{gr} - N_{gr}.[31] \qquad (7)$$

The impacts of working-hour growth (L_{gr}) and population growth (N_{gr}) cancel each other out when they change at the same rate. This certainly occurs in steady-state growth and is imposed by assumption in most empirical studies. BW note that the 1960s, 1970s, and 1980s were periods of demographic transition for most developing countries. As a result, neither condition holds and differential growth rates will impact observed economic growth. (In an accounting sense, $d = c''$ in this formulation. BW assume that $d = 0$, an apparent oversight in the translation of the lnY/L term of equation (5) into the ln(Y/N) and ln(L/N) terms of equation (7). Thus, in the BW setup, the workforce share has no impact on output growth.[32]

BW replace L_{gr} with a pure demographic proxy, the growth rate of the working-age population (WA_{gr}).[33] That is, <u>if</u> the only determinant of hours worked were the age-distribution of the population, then the relative growth of the working-age versus full population constitutes the sole impact of demography in their model.[34] Sometimes the impact of demography will be positive, sometimes negative, and sometimes zero. This model highlights the reality that demographic impacts vary during the <u>transition</u> to a steady state. The BW theoretical model is silent about any possible impacts of demography on long-run labor productivity; i.e., demography does not affect the Z's in

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[31] As noted in equation (5) and its footnote, the estimated coefficients from this equation are not the same coefficients as in equations (3) and (4). Each of these coefficients is a function of the corresponding parameter and the convergence parameter. Furthermore, the coefficients a and c estimated here will decline as the estimation period is extended. See RSL, page 5, equation (4).

[32] This was pointed out to us by David Canning; the derivation is based on Bloom, Canning, and Malaney (BCM, 1998, p. 8). Interestingly, RSL employ the original ln(Y/L) term; BW employ the ln(Y/N) term but not the ln(L/N) term; while BCM employ both the ln(Y/N) and ln(L/N) terms.

[33] Alternatively, one might argue that Lgr is endogenous within this equation. Contemporaneous WAgr could then be viewed as an exogenous instrument for Lgr.

[34] This implies that two countries with quite different constant age-specific fertility and mortality rates--say one country with a rapid Ngr of 3%, and another with a slow Ngr of .5%--will arrive at the <u>same</u> level of $(Y/L)^*$ in the long run.

equation (5), and, as noted above, their model omits ln(L/N).[35] As a result, the BW model has a narrower interpretation than most renderings in the literature, which admit both short- and long-run impacts of demographic change as a part of the theoretical structure. On the other hand, it has the desirable attribute of clarity in interpretation. It stands, moreover, in the post 1985 "revisionist tradition," described above, which highlights the possibility of both positive and negative impacts of demographic change.

To understand the model's implications, it is useful to elaborate on the impacts of demography, and to assess, in particular, the model's predictions of (1, -1) on L_{gr} and N_{gr}, respectively. Note first that the model's theoretical predictions are not in terms of the growth of the working-age population (WA), but rather in terms of the growth of total hours worked (L). This measure is affected by age-specific labor force participation rates (LFPR), the working-age population (WA), and employment rates (ER, hours worked per labor force participant). Thus, by definition,

$$L = (WA)(LF/WA)(L/LF) = (WA)(LFPR)(ER). \qquad (8)$$

With manipulation it can be shown that the revised model is

$$Y/N_{gr} = a'' + b'Z - c''\ln(Y/N) + d\ln(L/N) + ER_{gr} + LFPR_{gr} + WA_{gr} - N_{gr}. \qquad (9)$$

This formulation reveals that the direct impact of demography is ln(L/N) plus the last two terms, and that two additional variables, the growth in employment (hours worked per laborer per period) and the growth of labor force participation rates, influence per capita output growth as well. Note finally that the predicted parameters on <u>each</u> of these last two terms is unity, and that c" = d. (This follows from the definitional feature of the modeling.) Indeed, if the basic "core model" (i.e., the convergence-pattern framework and the choice of Z's) is correct, it is not even necessary to estimate the sensitivity of output growth to the components of demography: the "parameters" are pre-determined by definition. In practice, however, these parameters in estimation can differ from unity and d can differ from c" if (1) the variables are mismeasured; (2) omitted terms, say ER_{gr} and/or $LFPR_{gr}$, are correlated (causally or not) with WA_{gr} and/or N_{gr}; (3) the Core model and framework is incorrect; and/or (4) the demographic variables affect $(Y/L)^*$ directly (as distinct from their posited sole role in the

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[35] The omission of long-run impacts is recognized by BW (1998) and is taken as a possible explanation of empirical estimates on Ngr and WAgr that may deviate from theoretical expectations. Moreover, while not a formal part of their growth-theoretic modeling structure, their empirical explorations do attempt to isolate demography (age-distributional changes) from other sources of labor force growth.

transition).[36]

These qualifications identify several directions in which the model might be refined to reveal demography's role more fully. Consider two. First, consider interrelationships among the growth of the working-age population, the labor force participation rates, and employment rates. In the short- to intermediate-run, an increase in the growth of the working-aged population will exert downward pressures on wages and employment rates, other things equal.[37] These negative impacts will be attenuated in the longer-run by demand-side feedbacks, but will not likely be overturned. Moreover, fertility may be influenced by labor-market conditions (e.g., employment rates), causing a change in the age structure (WA_{gr}).

Second, consider the focus of the BW model on the transitional impacts of demographic change. The postulated coefficients of 1 and -1 for WA_{gr} and N_{gr}, respectively, provide a clear interpretation of the role of demography: relatively rapid growth of the working-age population will speed the transition to long-run economic prosperity, $(Y/L)^*$. However, two countries with the same Z's will ultimately arrive at the same $(Y/L)^*$, irrespective of their demography.[38] BW (1998) acknowledge the possibility that WA_{gr} and/or N_{gr} might impact $(Y/L)^*$, but they do not model this explicitly. Nor do they include other demographic variables among the Z's.[39] Rather, they note that long-run influences could result in coefficient estimates which deviate from unity.

Such an inquiry into the BW model is instructive. It reveals that both theoretically [e.g., N_{gr} and LA_{gr} should be

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[36] Bloom, Canning, and Malaney (1998) have modified the RSL and BW models to include ln(WA/N), a variable that may represent both transition and longer-run impacts on output growth.

[37] The opposite appears to be occurring in countries like the United States where the relative size of "traditional" labor force participants (working-age males) is projected to decline. Businesses are preparing for much more diversity in the workplace through, among other things, training programs for females and minorities. Female labor force participation rates and minority employment rates have risen as a consequence.

[38] This implies, for example, that two countries with similar Z's, but each with stable but quite different long-run rates of population growth (e.g., 1% versus 3%), will arrive at the <u>same</u> level of economic prosperity (Y/L) in the long run.

[39] For example, we have discussed at length the possible impact of population size and density on (Y/L)*. Additionally, dependency rates (D1, D2), determined by earlier WAgr's vs Ngr's, have been widely studied for their impacts on saving and investment GDP shares. Saving and investment shares, in turn, impact (Y/L)*.

included in the Z vector, and $\ln(L/N)$ should be included as a separate variable], and empirically (the determinants of L_{gr} are correlated with WA_{gr} and N_{gr}), the resulting estimates of the impacts of demography are hard to interpret. However, highlighting the difference between transition and possible long-run impacts of demographic change is useful.

Bloom/Canning/Malaney Dynamics

David Bloom, David Canning and Pia Malaney (1998; hereafter BCM) have recently augmented the BW model to include additional demographic impacts [$\ln(L/N)$ and density]. The $\ln(L/N)$ term is included because of equation (7)’s specification in per-capita rather than per-worker terms. The effects of density on output growth are divided between coastal and inland densities as proxies of transportation costs. The impacts of inland (coastal) transport costs on growth are found to be negative (positive). Overall, the BCM model augments the demography of the BW framework. Given our goal of focusing on demographics, the BCM framework will be included below in our empirical assessments.

Empirical Specifications

Our empirical formulations below utilize either of two convergence renderings, ten-year growth periods, and a single set of “core variables” (the Barro model) to which eight demographic variants have been appended. The first six represent an evolution of the recent literature; the last two are denoted as “Expanded Dynamics” Models.

Convergence Renderings

Two quite different empirical renderings of the convergence model coexist in the literature. The first, following Barro and Sala-i-Martin (1995), phrases the basic convergence assumption [equation (3) above] in per-capita terms. The second, which we have highlighted in this paper, follows Radelet, Sachs, and Lee (RSL, 1997) and phrases that growth equation in per-worker terms. In a mechanical translation into per-capita terms, the RSL framework appends three additional terms [$\ln(L/N)$, N_{gr}, and L_{gr} per BW and BCM] to the single convergence term [$\ln(Y/N)$] of the Barro framework.

Which convergence rendering is appropriate for our estimation? On the one hand, the Barro rendering might be criticized for its implicit assumption of a constant labor force share in the population. On the other hand, the RSL rendering implies very specific, tautological predictions for the additional terms. As noted previously, the predictions of 1 and -1 for L_{gr} and N_{gr} suggest that the impact of the demographic transition on economic growth could be calculated without estimating the model.[40] Acknowledging this, the theoretically interesting question of how demography impacts long-run, steady-state levels of per capita income can be addressed in either paradigm.

We remain agnostic in choosing the "appropriate" convergence rendering. Our first six demographic variants are based on published studies. The last variants extend the two most promising and representative of the dynamic demographic renderings. In each of these, we employ the convergence rendering of the original study.

Growth-Period Length

RSL cast their theoretical model at a point in time. Consequently, growth rates are instantaneous and depend upon the values of Y/L and the Z variables at that instant. Correspondingly, the long-run, steady-state productivity level changes as the Z vector values change. This has two important implications for empirical renderings of the model.

First, what is the appropriate length for empirical growth periods? Some studies employ a single cross-section covering the entire period under study (commonly, 1965-1990) while others utilize five- or ten-year panels. We have chosen to use ten-year growth periods in a panel setting. Although most of the information is in the cross-sectional dimension, there is information within the time-series dimension as well. While there is a great deal of persistence in many of the variables, some, including several of the demographic variables, do change notably over time. Additionally, several of our demographic renderings focus on transitional impacts which we believe to be modeled better in a panel setting. We have chosen ten-year periods (1960-70, 1970-80, 1980-90, 1990-95) to mute complications of business cycles and other short-run phenomena as well as to maximize the use of "real" demographic information. (Many annual and five-year values are interpolations, albeit sophisticated ones, of information collected once a decade.) We include period binaries in the model to capture the global economic environment and/or shocks specific to the decade.[41]

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[40] This is an oversimplification. For example, working-age population is used in place of the actual labor force. BW (1998, p. 22) illustrate an approach for translating working-age growth into labor growth and, with its unitary coefficient, economic growth.

[41] For additional discussion of the choice of period length, see Barro (1997, pp. 12-13) and Pritchett (1998). Canning (1999) delves into this issue theoretically and empirically. Although his particular emphasis is on human and physical capital, his conclusions are general to any endogenous variable. He concludes that estimated coefficients in cross-country growth regressions are hybrids of parameters from the reduced-form and structural models. Estimates

Second, what changes are wrought when moving from a theoretical model of instantaneous growth to one with growth over ten or twenty-five years? RSL (1997, pp. 4-5) integrate the model over years 0 through T and note the following.

(1) The estimated convergence coefficient, c", is a function of T and the instantaneous convergence coefficient, c. Specifically, $c'' = (1 - e^{-cT})/T$.

(2) Z-vector variables should be calculated as period averages.

(3) The estimated intercept, a", is a function of a, c, and T. Specifically, a" = ac".

One can retrieve c from c" and must do so before determining the estimated coefficients for the Z vector. Recall from equation (6) that the estimated Z-vector coefficient is b′ = bc. Strangely, these calculations are seldom undertaken in the literature. As a result, and given our interest in providing findings that are comparable with that literature, we will not evaluate the recovered coefficients at this stage. However, we will explore these issues in our ongoing analysis that assesses the robustness of our results.

The Core

Variables in the Barro (1997) Core model have been defended in several publications (Barro 1991, 1997). While one can easily imagine additional variables for inclusion, suffice it to say that Barro's empirical inquiries have been lengthy and expansive. His latest model represents a reasonable framework on which to graft demographic augmentations.[42] Moreover, from our perspective, it is methodologically appropriate to use Barro's model without modification since our goal is to assess the impacts and merits of alternative demographic specifications. These are plausibly influenced by the Core. As a first pass, we therefore maintain an arm’s length in specifying that Core so as not to inadvertently bias our demographic assessments. We will then evaluate the sensitivity of our conclusions to reasonable

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from annual observations will approximate the structural coefficients while those from, say 25- or 35-year periods, replicate the reduced form. Coefficients from our ten-year periods must consequently be interpreted with some care.

[42] Most of the Barro variables are continuous. By contrast, many of RSL’s Z variables are binaries. These binaries have two disadvantages. They do not capture the full range of experience across countries. More importantly, many of the binaries are time-invariant (e.g., location in the tropics, access to the sea) which substantially weakens inferences from the time-series dimension of the panel; time-varying aspects of the Core are not being held constant.

embellishments of the Barro framework.

In Barro's model the growth rate of output per capita is positively related to:

1) a lower level of per capita income, i.e., the convergence hypothesis (with more rapid convergence in countries with higher schooling levels as measured by an interaction term between Y/N and schooling attainment);

2) more schooling (as measured by male secondary attainment), especially at higher secondary levels which facilitate the absorption of new technologies;

3) higher life expectancy, a proxy for better health and human capital in general;

4) terms of trade improvement, posited to generate added employment and income;

5) a lower rate of inflation, leading to better decisions with predictable price expectations;

6) a lower government consumption share, which is posited to release resources for more productive private investment;

7) stronger democratic institutions which promote public, and especially private investments, although at high levels of democracy, growth can be dampened by governments exerting an increasingly active role in redistributing income;

8) a stronger rule of law, which stimulates investment by promoting sanctity of contracts, security of property rights, etc.; and

9) a lower total fertility rate, which attenuates capital-shallowing and adverse saving-rate impacts of high youth dependency (Barro’s demography measure).

Variable definitions and sources are compiled in appendix table A.1.

The Demography

Table 1 presents eight demographic specifications which we append to the Core. The models are grouped by increasing detail and complexity. Models 1 and 2 are base-line renderings that incorporate the two most popular summary measures of demography: fertility [$\ln$(TFR)], and the population growth rate (N_{gr}). Model

3 adds density (Dns) and population size (ln(N)).

Table 1

Demographic Specifications

Model	Variables
1 Barro	ln(TFR)
2 Early KS	Ngr
3 Augmented KS	Ngr, Dns, ln(N)
4 KS Components	CBR, CBR-15, CDR, Dns, ln(N)
5 BW Trns	Ngr, WAgr
6 BCM Trns	Ngr, WAgr, ln(WA/N), Dns
Expanded Dynamics	
7 BCM TrnsExp	Ngr, WAgr, ln(WA/N), Dns, lnN
8 KS CompExp	CBR, CBR-5, CBR-10, CBR-15, CDR, Dns, lnN

Definitions & expected signs: TFR^{-} = Total Fertility Rate; $Ngr^{-?}$ = Population Growth; $Dns^{?}$ = Density; N^{+} = Population Size; CBR^{-} = Crude Birth Rate ls CIDR; CBR_{-5}^{-}, (lagged 5 years), $CBR_{-10}^{?}$, CBR_{-15}^{+}; WA/N^{+} = Working Age/ Population; CDR^{-} = Crude Death Rate ls CIDR; $WAgr^{+}$ = Working Age Growth.

Models 4-6 present three dynamic formulations that highlight the timing of demographic impacts. In Model 4, KS isolate the separate impacts of contemporaneous and lagged crude birth rates. This permits separating the negative dependency impacts of births (CBR_t) from the positive impacts on labor force entry of those births that occurred fifteen years earlier (CBR_{t-15}). In Model 5 BW explore a variant of this framework which isolates (or “factors out”) the positive impacts of working-age growth (WAgr) from the (mainly negative) impacts of population growth, leaving Ngr to measure primarily the negative costs of dependency. In Model 6 BCM append the working age share ln(WA/N) and density to the basic BW framework.[43]

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[43] In their 25-year period cross-section estimation, BCM account separately for the impacts of inland and coastal density; in their 5-year panel estimation, BCM use total land area. In both measures density is expressed in terms of working-aged population. Separate calculations using the Barro core indicate that the impacts of density are largely invariant to using WA versus N.

The remaining two models, denoted “Expanded Dynamics,” extend the dynamic specifications. Model 7 reformulates the BCM formulation to include population size [$\ln(N)$]. Model 8 allows for greater flexibility in exposing birth rate impacts over time. It is hypothesized that children exert differential impacts by age (CBR_t, CBR_{t-5}, CBR_{t-10}, and CBR_{t-15}) with relatively high negative impacts at early ages, and smaller negative or even positive impacts at later ages as they increasingly contribute to productive household and labor force activities.

To accommodate problems due to temporally correlated CBRs, the estimated parameters on each CBR term are constrained by a logarithmic functional form, found to have the best statistical fit compared to linear or quadratic. Operationally, the coefficient for the i^{th} lag is defined as: $\beta_i = \alpha_0 + \alpha_1 \ln(i)$ where $i > 0$. α_0 and α_1 can be estimated directly from variables created as transformations on the CBRs:

$\text{Alpha0} = CBR_t + CBR_{t-5} + CBR_{t-10} + CBR_{t-15}$; and

$\text{Alpha1} = \ln(5)CBR_{t-5} + \ln(10)CBR_{t-10} + \ln(15)CBR_{t-15}$.

Endogeneity

An issue arises with respect to possible reverse causation both in terms of several of the variables in the Barro Core (e.g. inflation, Gcons/Y, democracy) and the demographic variables appended to this framework. Barro elects to attenuate possible endogeneity through instrumentation. While the resulting parameter estimates may be sensitive to his choice of instruments and procedures, we have chosen to adopt his methodology without modification[44] given our strategy of maintaining an arm’s length in specifying the Core. Our goal is to minimize possible unintended biases in our demographic assessments.

Problems of reverse causation may plague demographic variables as well, although here the case is less clear. On the

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[44] Barro employs three-stage least-squares estimation, with the third-stage correcting for possible serial correlation. Since he found little evidence of serial correlation, we opted for two-stage estimation instead. Within the Core, we followed Barro in treating the following variables as endogenous: government consumption’s share in GDP, democracy and its squared term, and inflation. Because of perceived measurement error, Barro also instruments ln(Y/N) and its interaction with education. The first-stage equations use the following 5-year lags as instruments: ln(Y/N), ln(Y/N)’s interaction with contemporaneous education, government consumption’s GDP share, and democracy and its squared term. The following exogenous variables from the Core are also used as instruments: education, ln(e0), rule of law, and terms-of-trade change. Finally, binaries for former colonies of Spain and Portugal and former colonies of Great Britain and France are included as instruments for inflation. The first-stage equations are run separately for each period. The second-stage equation is pooled but includes period-specific binaries. The Wu-Hausman test was significant at the 0.1% level in all eight demographic variants, indicating that ordinary least-squares will not provide consistent estimates for the indicated Core variables.

one hand, fertility rates are likely to be more sensitive to the level than to the growth of income. On the other hand, the length of the observations used in the analysis ranges from 5 to 25 years, resulting in periods sufficiently long that the levels can change notably through growth. Interestingly, both BW and BCM fail to uncover any problems of endogeneity in their long, 25-year periods, yet BCM do encounter reverse-causation with their 5-year panels. Our analysis below uses an intermediate period (10 years). Consequently, we assessed the need to instrument the demographic change variables through the Wu-Hausman test. In no demographic variant was that test significant at the 5% level.[45] As a result, we do not instrument any of the demographic variables in the results presented below.

Results

Appendix table A.2.1 presents the two-stage least-squares results for the eight models.

The Core

The Core performs well: all of the estimated parameters are of the expected sign; almost all (71 of 80) are significant at the 5% level, and most at the 1% level. The parameter estimates are reasonably robust with respect to alternative demographic specifications. The coefficient that changes the most is ln(e0), not surprising given its linkages to the demographic variables. Finally, the period effects are plausible and significant: events like OPEC shocks, financial crises, and debt overhang have adversely affected economic growth *vis-à-vis* the 1960s.

Demography: A First-Pass Assessment

The demographic augmentations yield strong and consistent results. All 24 parameter estimates have the anticipated sign, and most are statistically significant at the 5% level or better. Overall, demography contributes notably to accounting for economic growth: R^2 increases from 48% in the Core model without the TFR and e0 (not shown in the table) to 54-60% in the various

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[45] Again, to maintain an arm's length from the modeling specification, we assessed reverse causation in the demographic variables by utilizing the instruments proposed by BCM. BCM treat both Ngr and WAgr as endogenous, using as instruments 5-year lags for Ngr and Wgr as well as beginning-of-period TFR (total fertility rate) and IMR (infant mortality rate). Within that spirit, we included as instruments a lag for the demographic change variable(s) specific to the model as well as TFR and IMR. For the eight demographic variants, the Wu-Hausman test was performed on the following: (1) ln(TFR), (2 & 3) Ngr, (4 & 8) CBR_t, and (5-7) Ngr and WAgr. *p-values* from these tests are provided in the last line of Table A.2.1.

models where demography is included.

Population density and size typically reveal significant positive impacts on economic growth. Apparently the stimulus of density on technical change and on reducing the costs of transport/communications, as well as the various positive effects of scale, offset the negative forces of diminishing returns and crowding.[46]

Several of the remaining measures of population change exert negative impacts on economic growth. This is true, for example, of the TFR and N_{gr} alone. Of course, the combined effects of N_{gr}, WA_{gr}, and $\ln(WA/N)$ in the "Transition" Models, and the combined effects of the CBR and CDR in the "Components" Models, can only be assessed by taking into account realistic changes in the demographic variables, a calculation that is undertaken below.

Transition Dynamics: Models 5-7. The estimates give mixed support to the interpretation that the impacts of demography are solely transitional. Recall the predictions of 1 and -1 for WA_{gr} and N_{gr}, respectively, indicate that the effects of demographic change are offset in long-run steady state. There will be transitional effects on the path to steady state, however. Indeed, BW found substantial transitional effects in East Asia since the mid-1960s. Deviations from 1 and -1 could indicate impacts beyond transitional, and our own estimates are as high as 1.41 and as low as -1.47. However, these coefficients are not statistically different from unity. Statistically, the effects of N_{gr} and WA_{gr} cannot be said to extend beyond the demographic transition.

On the other hand, additional demographic variables do appear to have long-run impacts. Population size has a significant positive impact in model 7; density has a positive, but insignificant, impact in models 6 and 7. More substantively, $\ln(WA/N)$ appears to have a strong, positive impact on growth in both Models 6 and 7. Recall that BCM include this variable as part of an algebraic translation from per-worker to per-capita

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[46] These conclusions are invariant to the removal of observations that are statistically identified as strongly "influential" on these two coefficient estimates. SAS's DFBETAS (scaled measures of changes in each parameter estimate from deleting an observation) were used for making assessments of influential observations within the "KS Components Extended" model. DFBETAS identified 5 of 344 observations as being influential in estimating the Dns coefficient (one observation each for Chile, Hong Kong, India, Malaysia, and Singapore). By comparison, 24 observations were influential in determining the coefficient on ln(N). India is represented in each of the four decades with the effect of lowering the parameter estimate in three decades but raising it in the 1980s. Paraguay (one negative, two positive) is noted three times; Nicaragua (both positive), Panama and Togo (one positive, one negative) are identified twice; and the remaining are scattered across mainly developing countries.

terms. As such, its coefficient should be the same as that on ln(Y/N). It is not. In fact at 9.52, it is 7.5 times that of ln(Y/N), a difference significant at the 0.1% level. This disparity indicates that ln(WA/N) may have a long-run impact on steady-state productivity as well as the immediate impact on growth modeled by BCM. As the complement of dependency, the working-age share in the population can play a quite different role from Ngr and WAgr in the convergence model. The empirical savings literature reveals that dependency can influence both saving and investment. WA/N might be argued to affect labor force quality as well. Both, in turn, plausibly influence Y/N^*.

KS Components Dynamics: Model 8. The complexity of reckoning dependency impacts in a dynamic setting is further illustrated by the Expanded KS Components framework (KS CompEx, Model 8). Here the estimated birth-rate impacts differ notably depending upon the lag. Computing these impacts from the estimated alphas, the parameters on CBR_t, CBR_{t-5}, CBR_{t-10}, and CBR_{t-15} turn out to be -1.26, -.35, .04, and .27, respectively. The overall impact of reducing the birth rate over the youth-dependency period is therefore positive, and most of this benefit to growth occurs right away. (Very young children are relatively costly, presumably on the mother's time.) After around 10 years, the net impact of a child is estimated to be positive, although up to age 15 (and even abstracting from discounting), this positive impact is not enough to offset the earlier negative costs of dependency. A bottom-line assessment would be that youth dependents have notable costs only for the first few years; thereafter, their net impacts, positive or negative, are a wash.[47]

It is interesting that the benefits to economic growth of death-rate reductions are substantial, indeed considerably larger than those of birth rate reductions in the early years. Clearly the source of population change matters, as well as its timing; and accounting for these dynamics is critical to understanding the impacts of Ngr on Y/Ngr.

Demography: A Second-Pass; A Fuller Reckoning

What are the overall quantitative impacts of the various components of demographic change on the pace of economic growth? To answer this question one must account both for the coefficient size and the magnitude of “relevant” changes in the demographic variables. For the latter, and as one experiment, we examine the

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[47] This assessment, which finds a rather modest resource cost of children during the educational years (ages 5-15), is also consistent with several recent empirical studies [(Schultz (1987, 1996), Tan and Mingat (1992), Kelley (1996), and Ahlburg and Jensen (1997)] that downplay the quantitative importance of demography on education costs.

impacts of actual average changes in demography in our country sample over the 1960s, 1970s, and 1980s. Appendix table A.2.2 provides these calculations, obtained by multiplying each estimated parameter by the corresponding average change in the demographic variable over each decade.[48] Since most of the parameters carry signs identical to the trends in the variables, the impacts on per capita output growth are positive (the product of these two factors). Thus, for example, both the decline in the TFR, and an increase in density and size, contribute positively to economic growth.

A question arises on whether or not to include mortality changes [ln(e0) or CDR] in these calculations. On the one hand, Barro primarily treats life expectancy as a proxy for health, although he recognizes its demographic component. This argues for excluding mortality from our list of “demographic” variables. On the other hand, ignoring mortality downplays an element of demographic change that merits consideration and reckoning. As a compromise, table A.2.2 presents renderings with, and without mortality change. Our analysis focuses on the total column (Demog w/ Mort) that includes the impacts of mortality declines.

Several interesting results emerge.

(1) Demographic trends (declining population growth, fertility, mortality; changing age distributions; and rising density and population sizes) have had a sizeable impact on economic growth. Across all eight models the average combined impact (including mortality changes) over 30 years on Y/N_{gr} is .64. Declines in fertility and mortality have each contributed around half of this combined impact. Such a figure for each component corresponds to 21% of 1.50%, the average annual Y/N_{gr}, or, alternatively, 22% of combined impacts of changes in non-demographic influences on Y/N_{gr}.[49]
The consistency of the results across models provides some confidence in this overall assessment.

(2) While the overall impact of population growth (N_{gr}) is negative (per models 2 and 3), this derives from the offsetting

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[48] For variables measured as period averages, decade changes are calculated as differences between averages of the first five years’ experience. Thus, for example, the 1960s are calculated from 1960-64 to 1970-74.

[49] Y/Ngr declined at an average rate of -.80 per decade. Without the positive influence of demographic change, this decline would have been faster (-1.44 = -.80 - .64). Demography's impact on economic growth is, then, 44% (.64/1.44) of the impact of changes in non-demographic influences. Note also that for expositional simplicity, we use "mortality" to refer to life expectancy or CDR and "fertility" to refer to all other demographic variables in the models (TFR, CBR and its lags, population and working-age growth rates, age structure, size, and density).

forces of fertility and mortality change. The observed declines in fertility/mortality reinforce each other in encouraging economic growth, but offset each other in their impact on decreasing/increasing N_{gr}. These results underscore the reality that changes in N_{gr}, *per se*, conceal the size and even the direction of the impacts of N_{gr}. Increases in N_{gr} based on mortality declines can stimulate growth while increases in N_{gr} based on fertility change can attenuate growth. Exposing these differences is important to assessing the impacts of demographic trends.

(3) Increasing densities and population sizes contribute a positive but relatively small boost to economic growth, with scale effects dominating density. The lack of importance of density merits qualification given our inability at this stage to compile more appropriate measures of arable land.[50]

(4) In most of the models the impact of demography has declined over time. The exceptions are the KS Early and Augmented Models where the average impact in the 1960s, 1970s, and 1980s was .60, .64 and .66, respectively. By contrast, the respective averages for the other six models were .77, .63, and .52. (The contrast is even more stark for the column which excludes mortality.) These disparities highlight the importance of more sophisticated demographic modeling. (For example, many empirical studies have found negligible and insignificant demographic impacts for the 1960s and 1970s, and several have found significant impacts for the 1980s.)

(5) Demographic impacts are virtually identical in the "KS Comp" and "KS CompEx" models. The extended variant is useful in that it details the lag structure for fertility's impact on economic growth. Nevertheless, the impact for the contemporaneous birth rate in KS Comp turns out to be the sum of the impacts from the contemporaneous, and the specified lags. This is consistent with our earlier argument that the current birth rate, entered alone in a model, will capture the net effects of past fertility because of high levels of persistence in the crude birth rate.

(6) Perhaps the most striking aspect of our results is how similar are the combined demographic impacts across the eight models. The simpler Barro and early KS models reveal a combined demographic impact comparable in magnitude to the more sophisticated later models. Of course, the Transition and

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[50] The FAO estimates of "potential arable land" are unfortunately available for only a subset of our sample. BCM (1998) find a substantive impact of density when they separate inland from coastal density. Unfortunately, such regional measures are not available in time series.

Components models provide a richer understanding of the underlying processes, even if the bottom-line assessment is little changed.

Demography: Bottom-Line Assessments

Empirical assessments using cross-country data of the impacts of demographic change on the pace of economic growth are presently in a state of flux. This represents a notable change in the literature on this topic which, until the last few years, found only weak or inconclusive empirical relationships. Several factors have changed this situation. (1) Five studies using data for the 1980s appear to reveal reasonably strong negative impacts of rapid population growth and related demographic components on per capita economic growth. (2) Convergence-type frameworks are enlarging the analytical perspectives beyond the simple-correlations and production-functions frameworks. (3) Data have continued to improve and expand in scope. (4) Dynamic specifications that probe the patterns of demographic change are emerging. (5) Applications of appropriate econometric techniques standard in other literatures are increasingly being transferred to demographic studies. (6) Population debates, in the past heated and contentious, are giving way to “revisionist”[51] renderings that assess these dimensions in a more even-handed and balanced manner. These renderings recognize both positive and negative, and short- and long-run, impacts of demography.

The present paper is an installment in this research program. Building upon a state-of-the-art Core economic and political model of economic growth, we evaluate the merits of alternative specifications to expose the impacts of demographic change. We arrive at the <u>qualified</u> judgment that, given the demographic trends (mainly declining mortality and fertility) over the period 1960-1995, economic growth has been favorably impacted by demography. For example, fertility and mortality changes have each contributed around 22% to changes in output growth, a figure that corresponds to around 21% of 1.50%, the average growth of per capita output over the period. More broadly, declining population growth, fertility, and mortality as well as larger populations and higher densities have all spurred growth. The sole growth-inhibiting trend is a decline in the growth of the working-age population. However this trend is not universal. The many emerging economies that are now passing through the beginning stages of the demographic transition can look forward to increases in working-age growth for some time to come. Whether they possess the political and economic conditions to effectively capture the benefits of these favorable

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[51] For an elaboration of the revisionist methodology and results, see above, chapter **X**.

demographic trends remains an open issue.

We consider these results to be “qualified” at this stage since our robustness tests reveal that the Core Model findings are sensitive to the periods of aggregation (5 versus 10 versus 25 or 35 years), although demography much less so, for reasons not fully understood. On the other hand, our conclusions are robust with respect to many modeling variants including alternative instrumenting procedures, estimating by OLS, compiling White-corrected standard errors, utilizing a LDC sample alone, and assessing results absent observations with exceptional statistical impact. (See Appendix B for details.)

In addition to the above assessments of the aggregate macroeconomic paradigms, there is also a significant need to draw upon results of (largely absent) microeconomic analyses. Do poor (mainly rural) households in fact behave according to the life-cycle hypothesis embedded in many of the macro paradigms? Do governments and economies in fact significantly divert resources from productive investments toward relatively unproductive “demographic spending” in response to population pressures? What are the impacts of demographic changes at the firm and farm levels on the form and pace of technical change? And, what is the quantitative importance of the various determinants of fertility and mortality, and are these determinants exogenous or endogenous with respect to the main arguments in the economic-growth Core?

Happily, the macroeconometrics literature is making steady progress in exposing relationships of long-standing interest. Complementary to maintaining this progress will be an increasing availability of relevant microeconometric studies. This healthy symbiotic relationship between these research programs will predictably bear significant dividends.

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Appendix

A. Data and Procedures

Data Sample

The data set consists of 86 countries with populations exceeding 1 million in 1960, which Summers and Heston (1994) classify as market-oriented and for which they provide data on gross domestic product in constant purchasing power. We exclude countries with missing data, extensive resource dependency, and problems with data definitions. For details and a country listing, see Kelley and Schmidt (1994). From that list we exclude Chad, Mauritania, and Somalia due to missing data on educational attainment; and add Taiwan due to its importance in recent studies attempting to explain the "Asian Tigers."

Regressions use three decadal (1960-70, 1970-80, 1980-90) and one quinquennial (1990-95) growth period for each country. A panel of 344 observations result.

Variable Definitions and Sources

Table A.1 describes the variables used in this study. Within that table, "Source" uses the following key:

BL93	Barro and Lee's data set used in Barro and Lee (1993).
BL96	Barro and Lee (1996) update of their educational attainment series.
G	Gastil (1991).
ICRG	International Country Risk Guide.
SH	Summers and Heston Penn World Tables, version 5.6.
Trans	Transformation of variable described elsewhere in table.
UN	United Nations (1996).
WB	World Bank's 1997 *World Development Indicators* CD-ROM in conjunction with earlier versions for backfilling.

"When?" uses the following codes:

Avg	Period average of the annual observations.
BOP	Beginning-of-period value calculated as three-year average centered on the first year of the period.
Chg	Rate of change expressed as a percent and calculated using the continuous growth formula.

Table A.1

Variables used in the Study

Var	Source*	When?	Description
Y/N	SH	BOP	Per Capita GDP: Purchase-Power Parity, 1985 International Currency Units (approximately scaled to US$), chained index.
Y/N_{gr}	Trans	Chg	Per Capita GDP percentage growth rate.
TT %chg	WB	Chg	Percentage change in the terms of trade (P_X / P_M).
Gcons/Y	WB, BL93	Avg	Government consumption's (defined as G - education - defense) percentage share in GDP.
Inflatn	WB	Chg	Inflation rate based on the CPI if available, otherwise on the GDP Deflator.
e0	WB	BOP	Life expectancy at birth.
MaleEduc	BL96	Avg	Number of years of secondary plus higher education per adult male, aged 25 and above.
Rule Law	ICRG	Avg	Index of overall maintenance of the rule of law; seven possible rankings rescaled from 0 (low) to 1 (high).
Democrcy	G	Avg	Index of level of democratization; seven possible rankings rescaled from 0 (low) to 1 (high).
TFR	WB	Avg	Total Fertility Rate.
Ngr	Trans	Chg	Percentage change in population size.
WAgr	UN	Chg	Percentage change in population ages 15-64.
CBR (net)	WB	Avg	Crude Birth Rate (per 100 population) netted of infant deaths.
Alpha 0	Trans	Avg	See discussion and footnote in "Demography" under "Theory and Modeling."
Alpha 1	Trans	Avg	See discussion and footnote in "Demography" under "Theory and Modeling."
CDR (net)	WB	Avg	Crude Death Rate (per 100 population) netted of infant deaths.
D1	UN	Avg	Youth dependency ratio: ratio of population ages 0-14 to population ages 15-64.
D2	UN	Avg	Elderly dependency ratio: ratio of population ages 65+ to population ages 15-64.
Dns	WB	BOP	Thousands of population per square kilometer.
N	WB	BOP	Thousands of population.

* Data fills and extrapolations were made by imposing rates of change from an alternative data set with more complete series. For SH, WB was the primary filling source with UN and IMF as alternatives. WB was generally filled from earlier versions, UN sources, or SH. Fills for ICRG and G are too complicated to describe here; a description is available upon request.

A.2 Tables of Results

Table A.2.1

Impacts of Demography in Core Convergence Model: Full Sample, 1960-1995

	Early Models			Exploratory Dynamics			Expanded Dynamics		
	Barro (1997)	KS Early (1994)	Augmntd (1994)	KS Comp (1995)	BW Trns (1997)	BCM Trns (1998)	BCM TrnsEx (1999)	KS CompEx (1999)	Mean & StdDev
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	
The Model Core									
ln(Y/N)	-1.50**	-1.27**	-1.35**	-1.20**	-1.06**	-1.27**	-1.28**	-1.21**	0.85
	(6.01)	(5.00)	(5.50)	(5.02)	(4.13)	(5.08)	(5.18)	(5.07)	(1.03)
TT %chg	0.16**	0.16**	0.16**	0.15**	0.15**	0.15**	0.15**	0.15**	-0.45
	(5.34)	(5.21)	(5.55)	(5.31)	(4.95)	(5.35)	(5.45)	(5.33)	(3.35)
Gcons/Y	-0.10*	-0.12**	-0.05	-0.04	-0.12**	-0.08*	-0.05	-0.04	7.26
	(2.19)	(2.64)	(1.01)	(0.86)	(2.64)	(1.77)	(0.98)	(0.82)	(3.61)
Inflatn	-0.03**	-0.04**	-0.03**	-0.03**	-0.04**	-0.03**	-0.03**	-0.03**	14.95
	(4.12)	(4.43)	(4.09)	(4.18)	(4.58)	(4.05)	(3.94)	(4.13)	(27.82)
ln(e0)	4.61**	6.44**	6.39**		5.52**	5.01**	5.17**		4.07
	(4.04)	(5.63)	(5.81)		(4.79)	(4.58)	(4.77)		(0.21)
MaleEduc	0.59**	0.65**	0.64**	0.46*	0.52**	0.34	0.36*	0.47*	1.29
	(2.82)	(2.96)	(3.06)	(2.19)	(2.37)	(1.60)	(1.76)	(2.23)	(1.19)
ln(y)*Ed	-0.28*	-0.22*	-0.27*	-0.20	-0.13	-0.11	-0.14	-0.21*	0.95
	(2.30)	(1.71)	(2.14)	(1.62)	(1.01)	(0.88)	(1.16)	(1.69)	(1.48)
Rule Law	1.92*	2.58**	2.42**	1.92*	2.42**	1.80*	2.04**	1.94*	0.56
	(2.27)	(2.96)	(2.83)	(2.31)	(2.86)	(2.16)	(2.49)	(2.33)	(0.24)
Democrcy	6.82**	7.88**	6.64**	4.95**	6.60**	5.79**	5.51**	4.91**	0.58
	(3.30)	(3.58)	(3.08)	(2.34)	(3.04)	(2.75)	(2.68)	(2.35)	(0.33)
Democ ^2	-7.57**	-8.46**	-7.00**	-5.48**	-7.39**	-6.35**	-6.19**	-5.43**	0.44
	(4.04)	(4.21)	(3.41)	(2.75)	(3.73)	(3.19)	(3.16)	(2.75)	(0.38)
The Demography									
ln(TFR)	-2.52**								1.39
	(6.02)								(0.52)
Ngr		-0.53**	-0.41**		-1.47**	-1.37**	-1.27**		1.92
		(3.64)	(2.85)		(4.61)	(4.49)	(4.14)		(0.99)
WAgr					0.95**	1.41**	1.31**		2.10
					(3.31)	(4.79)	(4.46)		(1.02)
ln(WA/N)						9.52**	8.54**		-0.57
						(4.42)	(3.94)		(0.10)
BR (net)				-1.54**					2.97
				(4.53)					(1.09)
BR lag15				0.23					3.26
				(0.69)					(1.03)
Alpha 0								-1.26**	12.51
								(3.54)	(4.21)
Alpha 1								0.57**	21.14
								(2.68)	(6.92)
Implied BR coefficients									
Current								-1.26	
Lag 5								-0.35	
Lag 10								0.04	
Lag 15								0.27	
DR (net)				-1.71**				-1.75**	0.93
				(3.62)				(3.70)	(0.33)

Table A.2.1 (continued)

Impacts of Demography in Core Convergence Model: Full Sample, 1960-1995

	Early Models			Exploratory Dynamics			Expanded Dynamics		
	Barro (1997)	KS Early (1994)	Augmntd (1994)	KS Comp (1995)	BW Trns (1997)	BCM Trns (1998)	BCM TrnsEx (1999)	KS CompEx (1999)	Mean & StdDev
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	
Dns			0.57**	0.36		0.21	0.31	0.37*	0.17
			(3.04)	(1.93)		(1.15)	(1.70)	(1.97)	(0.61)
ln(N)			0.27**	0.18*			0.18*	0.18*	9.37
			(3.20)	(2.13)			(2.22)	(2.19)	(1.26)
Pd:70-80	-0.83**	-0.60	-0.70*	-0.87**	-1.02**	-0.96**	-1.03**	-0.87**	0.25
	(2.67)	(1.87)	(2.28)	(2.79)	(3.02)	(3.01)	(3.28)	(2.81)	(0.43)
Pd:80-90	-2.46**	-2.07**	-2.26**	-2.40**	-2.47**	-2.54**	-2.64**	-2.41**	0.25
	(7.27)	(5.92)	(6.79)	(7.17)	(6.85)	(7.50)	(7.91)	(7.24)	(0.43)
Pd:90-95	-3.28**	-3.10**	-3.24**	-3.10**	-3.36**	-3.24**	-3.35**	-3.11**	0.25
	(9.55)	(8.65)	(9.46)	(9.34)	(9.40)	(9.56)	(9.99)	(9.37)	(0.43)
Constant	-11.65*	-22.47**	-25.29**	6.76**	-18.42**	-11.72*	-14.89**	6.73**	
	(2.38)	(4.85)	(5.50)	(4.45)	(3.92)	(2.53)	(3.09)	(4.45)	
R Squared	0.57	0.54	0.57	0.60	0.56	0.60	0.61	0.60	
Adj R-Sq.	0.55	0.52	0.55	0.58	0.54	0.58	0.59	0.58	
Std Error	1.67	1.74	1.67	1.63	1.71	1.61	1.60	1.63	
# of Obs	344	344	344	344	344	344	344	344	
t-values	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	

p-values from Tests of Joint Significance

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
DEMOG_GR				0.000**	0.000**	0.000**	0.000**	0.000**
DNS_LNN			0.001**	0.042*			0.052	0.036*
EDUC	0.021*	0.008**	0.010*	0.095	0.024*	0.248	0.220	0.088
DEMOCRCY	0.000**	0.000**	0.003**	0.016*	0.000**	0.005**	0.005**	0.016*
PERIOD	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**

p-values from Tests that Ngr = -1 and WAgr = 1: Significance indicates different from -1 or 1.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
NGR_NEG1					0.137	0.232	0.388	
WAGR_ONE					0.850	0.172	0.302	

p-values from Tests that ln(Y/N) = - ln(WA/N): Significance indicates they differ in absolute value.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
YCAP_WAN						0.000**	0.001**	

p-values from Durbin-Wu-Hausman Test on Demographic Variables: ln(TFR), Ngr, WAgr, and/or BR.
Significance indicates OLS estimates are inconsistent & variable(s) should be instrumented.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
DWT Test	0.091	0.081	0.122	0.891	0.087	0.981	0.967	0.356

Notes: The dependent variable is Y/Ngr. The full sample includes 86 countries and three decennial periods (1960-70, 1970-80, 1980-90) and one quinquennial period (1990-95). Pooled regressions have been estimated using Two-Stage Least-Squares. Variable definitions are presented in table A.1. Pd:70-80, Pd:80-90, and Pd:90-95 are binaries; their coefficients are relative to the 1960s.

Table A.2.2

Demographic Impacts on Changes in Y/Ngr from Decadal Changes

Model	Year	Demog w/ Mort	Demog w/o Mrt	ln(TFR)	ln(e0)	Ngr	WAgr	ln(WA/N)	CBR	CBR05	CBR10	CBR15	CDR	Dns	ln(N)
Part 1: Period Means															
	1960s			1.65	3.97	2.28	2.04	-0.59	3.39	3.42	3.41	3.41	1.12	0.13	9.06
	1970s			1.52	4.04	2.13	2.37	-0.60	3.14	3.27	3.39	3.42	0.99	0.16	9.27
	1980s			1.34	4.10	2.00	2.34	-0.57	2.92	3.02	3.14	3.27	0.88	0.19	9.48
	1990s			1.18	4.16	1.40	1.64	-0.54	2.62	2.77	2.92	3.02	0.81	0.22	9.68
Part 2: Inter-Period Changes in Means															
	1960s			-0.13	0.07	-0.14	0.33	-0.01	-0.25	-0.15	-0.02	0.02	-0.13	0.03	0.21
	1970s			-0.18	0.07	-0.13	-0.03	0.03	-0.22	-0.25	-0.25	-0.15	-0.11	0.04	0.21
	1980s			-0.16	0.05	-0.60	-0.70	0.03	-0.30	-0.25	-0.22	-0.25	-0.07	0.03	0.20
Part 3: Impact of Inter-Period Changes in Demography															
Barro	1960s	0.66	0.33	0.33	0.32	.	.	.	.	.	.	.	.	.	.
	1970s	0.76	0.45	0.45	0.31	.	.	.	.	.	.	.	.	.	.
	1980s	0.64	0.40	0.40	0.25	.	.	.	.	.	.	.	.	.	.
	Average	**0.68**	**0.39**												
KS Early	1960s	0.53	0.08	.	0.45	0.08	.	.	.	.	.	.	.	.	.
	1970s	0.51	0.07	.	0.44	0.07	.	.	.	.	.	.	.	.	.
	1980s	0.67	0.32	.	0.34	0.32	.	.	.	.	.	.	.	.	.
	Average	**0.57**	**0.16**												
Augmentd	1960s	0.58	0.13	.	0.44	0.06	.	.	.	.	.	.	.	0.02	0.06
	1970s	0.56	0.13	.	0.43	0.05	.	.	.	.	.	.	.	0.02	0.06
	1980s	0.66	0.32	.	0.34	0.25	.	.	.	.	.	.	.	0.02	0.05
	Average	**0.60**	**0.19**												
KS Comp	1960s	0.66	0.43	.	.	.	.	.	0.38	.	.	0.00	0.23	0.01	0.04
	1970s	0.55	0.36	.	.	.	.	.	0.34	.	.	-0.03	0.19	0.01	0.04
	1980s	0.57	0.45	.	.	.	.	.	0.46	.	.	-0.06	0.12	0.01	0.04
	Average	**0.59**	**0.41**												
BW Trns	1960s	0.91	0.52	.	0.38	0.21	0.31	.	.	.	.	.	.	.	.
	1970s	0.54	0.17	.	0.37	0.19	-0.02	.	.	.	.	.	.	.	.
	1980s	0.52	0.22	.	0.30	0.88	-0.66	.	.	.	.	.	.	.	.
	Average	**0.66**	**0.31**												
BCM Trns	1960s	0.91	0.56	.	0.35	0.20	0.46	-0.11	.	.	.	.	.	0.01	.
	1970s	0.76	0.42	.	0.34	0.18	-0.04	0.27	.	.	.	.	.	0.01	.
	1980s	0.40	0.13	.	0.27	0.82	-0.98	0.29	.	.	.	.	.	0.01	.
	Average	**0.69**	**0.37**												
BCM TrnsEx	1960s	0.92	0.56	.	0.36	0.18	0.43	-0.10	.	.	.	.	.	0.01	0.04
	1970s	0.77	0.42	.	0.35	0.17	-0.03	0.24	.	.	.	.	.	0.01	0.04
	1980s	0.43	0.15	.	0.28	0.76	-0.92	0.26	.	.	.	.	.	0.01	0.04
	Average	**0.71**	**0.38**												
KS CompEx	1960s	0.65	0.42	.	.	.	.	.	0.31	0.05	-0.00	0.00	0.23	0.01	0.04
	1970s	0.57	0.37	.	.	.	.	.	0.28	0.09	-0.01	-0.04	0.20	0.01	0.04
	1980s	0.56	0.44	.	.	.	.	.	0.38	0.09	-0.01	-0.07	0.12	0.01	0.04
	Average	**0.59**	**0.41**												
AVG EIGHT MODELS		**0.64**	**0.33**												

Demog w/ Mort: Total of the line's demographic impacts, including ln(e0) and CDR.
Demog w/o Mrt: Total, excluding ln(e0) and CDR.
Notes: Coefficient estimates used to calculate these impacts are shown in Table A.2.1.
1960s refers to changes between the 1960s and 1970s; 1970s between the 1970s and 1980s; and 1980s between the 1980s and 1990-95. Average is the unweighted average of the indicated column.
(1) ln(TFR), CBR (net of infant deaths), BR15 (net of infant deaths), CDR (net of infant deaths), Alpha0, Alpha1 represent the impacts of changes in decadal averages.
(2) Ngr and WAgr represent the impacts of changes in annual growth rates for the decade.
(3) Dns and ln(N) represent the impacts of changes in beginning of decade levels.
(4) Average annual Y/Ngr for the 1960-65, 1970-75, 1980-85, & 1990-95 are 2.96, 2.51, -0.04, and 0.55, respectively. Consequently, the inter-decade changes in Y/Ngr are -0.45, -2.55, and 0.59, respectively; or an average of -0.80.

B. Robustness of the Results

To assess the robustness of our results, tables A.2.1 and A.2.2 have been re-estimated with alternative data sets, time periods, aggregation periods, and statistical procedures. Our goal is not to ascertain whether a few parameters (or their precision) change, but rather to determine whether any changes observed are sufficiently large to modify our conclusions. Such an assessment represents a judgment call that can be evaluated by consulting the 21 re-estimated tables (in preparation) available at our web site URL www.econ.duke.edu/~kelley/Research/Synthesis/synthesis.html.

Our primary conclusions, to be evaluated with respect to alternative specifications, are:

1) The Core economic/social/political model reveals conditional convergence and performs well, with most explanatory variables statistically significant at usual standards.
2) The Core model results are broadly insensitive to the demographic specifications.
3) Declines in fertility and mortality each have a positive impact on Y/N_{gr}.
4) This total demographic impact is about equally divided between separate impacts deriving from changes in fertility (including associated age, size, and density changes) and changes in mortality.
5) Each separate demographic impact is approximately 22% of the combined impacts on Y/N_{gr} of changes in Core model influences over the period 1960-1995, or, alternatively, around 21% of the average decadal Y/N_{gr}.
6) Population size and density commonly exert a positive but small impact on Y/N_{gr}.

Five sets of tables are initially generated to examine the impacts of:

1) including instrumented demographic variables,
2) estimating by ordinary least squares,
3) compiling White-corrected standard errors,
4) utilizing the LDC sample alone, and
5) assessing the impacts of observations having exceptional statistical impact.

Examining the results reveals that the six conclusions above are generally invariant to these modeling alternatives. Three qualifications merit noting. First, the rate of adjustment in the model Core is somewhat slower in the LDCs. Second, while the absolute size of the assessed impacts of demography in the LDCs are similar to those in the full sample, the relative importance of demography is greater in the LDCs given the slower overall growth rate there.[52] Third, among the Core model variables, government consumption appears to be the least stable across the tables.

We next re-estimated the basic model to assess the impacts of:

1) three data aggregations (5, 10, and 25/35 years), and
2) two periods (1960-1995, 1965-1990).

Examining these tables reveals some results that are sensitive to modeling variations. Specifically,

1) the impact of demography, as measured by the size of the estimated parameter, increases with the length of data aggregations. However, calculations that show the quantitative size of the impacts, accounting for changes in the variables over time, is not much affected on a per-year basis (i.e., when one controls for the difference in period length);
2) the Core model deteriorates substantially with data aggregations of 25 and 35 years.

The latter result is in contrast to findings in the literature that use the Radelet-Sachs-Lee Core, which is fairly insensitive to data aggregation. This is plausibly explained by the limited temporal variation of many of the RSL variables. Still, even with the weak Core performance of the Barro framework for the 25- and 35-year aggregations, the main conclusions with respect to demography (when transformed to account for period-length scaling) are broadly preserved.

Table B illustrates the above conclusions. The first two columns present results comparable to those in table A.2.2 for two of the eight models, while column three presents a simple average of all eight models (see table 1). The last three columns present the percentage of the total demographic impacts accounted for by "fertility" which, technically, represents non-mortality impacts. These include, for example, age-structure impacts and the small impacts of population size and density.

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[52] This result merits exploration, including an assessment of the LDC model with respect to the several variants examined in this section. This project is outside our present objectives which focus on comparisons with comparable empirical models in the literature. These focus almost exclusively on a wider country coverage.

Table B

Summary of Demographic Impacts

Model	Dynamic Models		8-Model	% Due to "Fertility"		
	BCMTex	KSCex	Average	BCMTex	KSCex	Avg
1960 - 1995						
Basic	71/38	59/41	64/33	54	69	52
InstDem	71/39	42/23	62/32	55	55	52
OLS	66/38	55/40	59/32	58	73	54
LDC	79/45	66/44	70/37	57	67	53
DfFits	66/33	55/36	61/28	50	65	46
Basic 5yr	68/32	59/43	64/32	47	73	50
Basic 10yr	71/38	59/41	64/33	54	69	52
Basic 35yr	89/65	62/50	69/43	73	81	62
1965-1990						
Basic 5yr	77/35	64/46	72/35	45	72	49
Basic 10yr	72/39	57/45	66/38	54	79	58
Basic 25yr	80/49	58/45	66/35	61	78	53

Notes: (1) Columns present demographic impacts for the two most detailed demographic models (BCM TransEx and KS CompEx) as well as for the average of the eight demographic variants. (2) Entries in the first three columns represent impacts on Ngr change of demographic change: Total/"Fertility" (i.e., without e0 and/or CDR). For example, the first entry, 71/38 is listed in table A.2.2 under BCM TrnsEx as 0.71 and 0.38. The last three columns present "Fertility" as a percentage of Total. (3) The "Basic" model is estimated by two-stage least squares; uses 10-year data aggregations; and instruments selected core, but not demographic, variables (see pp. 22-24 above). "InstDem" instruments demography as well (see pp. 25-26 above); "OLS" has been estimated by ordinary least squares using standard as well as White-corrected t-values; "LDC" uses the LDC sample; "DfFits" eliminates observations of unusual influence; and the "Basic" model has been estimated over 5-year, 10-year, and full-period growth periods for the 1960-95 as well as 1965-90 time frames. (4) Full tabular outputs are posted on the WWW as referenced in the text.